COURSE BINDER

MCEG 4472 SENIOR DESIGN AND PROFESSIONALISM I

FALL 2020

Prepared by Drs. Xiaobo Peng, Paul Biney, and Chang Duan

DEPARTMENT OF MECHANICAL ENGINEERING

COLLEGE OF ENGINEERING

PRAIRIE VIEW A&M UNIVERSITY

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ROY G. PERRY COLLEGE OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING
MCEG 4472 SENIOR DESIGN AND PROFESSIONALISM I
FALL 2020

I. COURSE DESCRIPTION IN ABET FORMAT

II. ASSESSMENT RESULTS FOR CURRENT AND PAST THREE PERIODS
Program Outcomes Assessed in Course
Assessment Summary of Class Semester Averages for Outcomes

End of Semester Course Outcomes Assessment Reports

III. PRESENTATIONS
Original presentation grading scheme used
(Summary of topics can be a separate page or include on the assignment itself)
Above Average (Graded original work)
Average (Graded original work)
Below Average (Graded original work

IV. REPORTS
Original report grading scheme used
Above Average (Graded original work)
Average (Graded original work)
Below Average (Graded original work)

V. STATUS REPORTS AND QUIZS
Summary of Topics covered by Homework
Original Homework Questions & Master Solution/grading scheme used
Above Average (Graded original work)
Average (Graded original work)
Below Average (Graded original work)

VI. MEETING MINUTES
Summary of Topics covered by Homework
Original Homework Questions & Master Solution/grading scheme used
Above Average (Graded original work)
Average (Graded original work)
Below Average (Graded original work)

One or Two Page Course Description in ABET Format (Format provided below)

MCEG 4472 Course Description in ABET Format

Please use the following format for the course syllabi (2 pages maximum in Times New Roman 12 point font)

1.	**Course number and name:**	MCEG 4472 Senior Design and Professionalism I
2.	**Credits and contact hours:**	3 credit hours; 5 contact hours
3.	**Instructor's or course coordinator's name:**	Dr. Paul O. Biney Dr. Xiaobo Peng Dr. Chang Duan
4.	**Text book**: Title:	Senior Project Manual
	Author:	Prairie View A & M University College of Engineering Committee
	Publisher, Year & Edition:	College of Engineering
	a. Other Supplemental material	Fundamentals of Engineering Design ", by Barry Hyman, Second Edition, 2003, Pearson Education, Inc. (Prentice Hall)
5.	**Specific course information**	
	a. Brief description of the content of the course (catalog description)	This is the first course of a two-semester capstone experience (MCEG 4482 must immediately follow MCEG 4472 or sequence must restart with MCEG 4472) involving engineering design of an industrial or advanced team project. Elements of ethics and professionalism in engineering practice are integrated into the project experience. The project will include application of relevant engineering codes and standards, as well as realistic constraints. Design achievements are demonstrated with written reports, and oral presentation, and professional standards and ethics examinations.
	b. Prerequisites or Co-requisites	MCEG 3023 Thermodynamics II, MCEG 3043 Machine Design I, MCEG 3011 Measurement Laboratory MATH 2043 Differential Equations I MCEG 3013 Heat Transfer
	c. *Indicate whether a required, elective, or selected elective (as per definition provided) course in the program	Required

6.	**a. Specific goals for the course** specific outcomes of instruction (e.g. The student will be able to explain the significance of current research about a particular topic.) *Students will be able to :*	**b. Explicitly indicate which of the student outcomes listed in Criterion 3** or any other outcomes are addressed by the course. *The specific goals for the course specific outcomes listed on the left column will address the following student learning outcomes:*
	1. Recognize ethical and professional responsibilities in engineering situations involving global, and societal contexts. (Students will be able to demonstrate the knowledge of professional code of ethics by reviewing code of ethics from your specific professional society and from the State board of professional Engineers. Case studies will be provided and discussed. Students will be tested on these).	**Outcome 4** An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
	2. Make informed judgements on ethical and professional responsibilities in engineering while considering the impact of engineering solutions in global, economic, environmental, and societal contexts. (Students will study several ethics case studies and make informed judgements on them with regard to the impact of engineering solutions on (a) global, (b) economic, (c) environmental, and (d) societal contexts. There will be enough case studies to cover all the four areas of global, economic, environmental and societal context)	
	1. Plan and keep good record of team meetings including documentation of individual contributions 2. Share ideas, complete assigned task on time, help others, and be professional to each other (through peer evaluation of team members on these characteristics). 3. Resolve conflicts professionally within the group with the view of creating an inclusive and collaborative environment	**Outcome 5** An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
	1. Identify and break down work into tasks and subtasks and identify the personnel and deliverables for each. 2. Develop a Gantt chart and critical path analysis for managing the project. 3. Establish major milestones for tracking progress and define performance metrics to measure success. 4. Track progress of team members to ensure project is on schedule and meets objectives (through submission of progress reports).	
7	**Brief list of topics to be covered**	
	Course Overview, Introduction to Design, Team Dynamics	5 hrs
	Engineering Design Process- Process Formulation and it Application to Project	5 hrs
	Project Planning and its Application to Project	5 hrs
	Literature review and Lifelong Learning and application to project	10 hrs
	Preliminary Design- concept generation and Application to Project	5 hrs
	Evaluation of alternative Concepts and Application to Project	5 hrs
	Detailed Design- Form refinement and application to design	5 hrs
	Detailed Design – Analysis and Refinement and application to project	5 hrs
	Detailed Design –Sizing of components	15 hrs
	Contemporary issues	2 hrs
	Engineering Ethics and Professionalism	3 hrs
	Codes and Standard	3 hrs
	Application of Modern Tools	2 hrs

***Required** courses are required of all students in the program, **elective** courses (often referred to as open or free electives) are optional for students, and **selected elective** courses are those for which students must take one or more courses from a specified group. Please hide all of the row and column lines when done.

II ASSESSMENT RESULTS FOR CURRENT AND PAST THREE PERIODS

Program Outcomes Assessed in this course

Outcome 4: An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts an ability to function on multi-disciplinary teams.

Outcome 5: An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.

Assessment Summary of Class Semester Averages for Outcomes: Fall 2018-Fall 2020

Outcomes	4	5
Semester	Semester Class Average (%)	Semester Class Average (%)
Fall 20	79.1	84.4
Fall 19	79.2	81.3
Fall 18	75.6	85.3
Comments on Data	The trend has been improved student performance over the last 3 years	The average has been between 80 and 86 % for the last three years.

*Expected Semester Class Average = 70% (or as defined by the program)
Ideal Semester Class Average =75% (or as defined by the program)

End of Semester
Course Assessment Report

This summary contains the following Information

1. Performance Statistics

- **Total number of students in class**
- **The class average performance (stated as %) in each course outcome assessed in this class and the two previous times course was assessed.**
- **The acceptable class average for the class in each outcome area as set by your Department.**
- **Percentage of students who scored below the expected average in each outcome.**

2. Implementation Summary

- **Brief summary of plans implemented during the semester based on last assessment report**

3. Perceived Problems

- **Instructor's critical evaluation of perceived problems that affected students' performance.**

4. New Plans for Addressing Problems

- **Instructor's plans for addressing the perceived problems the next time the class is taught.**

5. Overall Trend over last three assessment periods

- **Instructors summary of overall performance trend for each outcome measured over the last three periods.**

END OF SEMESTER COURSE OUTCOME ASSESSMENT REPORT
MCEG 4472-P01, P02, & P03 SENIOR DESIGN PROJECT I
FALL 2020 SEMESTER

Report Prepared by: Dr. Paul O. Biney
Report Date: December 20, 2020

Semester	Analysis Type	Number of Students	**Outcome 4** An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts				**Outcome 5** An ability to (1) function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, (2) establish goals, plan tasks, and meet objectives.			
			Expected Class Average/	Expected Percent of students at or above average	Class Average	% Students meeting Expected Average	Expected Class Average/	Expected Percent of students at or above average	Class Average	% Students meeting Expected Average
Fall 2020	**Direct**	**60**	**70**	**70**	**79.1**	**70**	**70**	**70**	**84.4**	**91.7**
Fall 2019	**Direct**	**63**	**70**	**70**	**79.2**	**71**	**70**	**70**	**81.3**	**88.7**
Fall 2018	**Direct**	**69**	**70**	**70**	**75.6**	**54**	**70**	**70**	**85.3**	**69**
Fall 2017	**Direct**	**65**	**75**	**70**	**68.1**	**32**	**70**	**70**	**84.7**	**60**
Implementation Summary	**Items implemented from previous report or after meeting previous instructor**		The notes and information were provided to the students very early give them more time to study and prepare for the ethics test. And this appears to have improved performance				The assignment on group meeting, group management, role assignment and group agreement was given in the beginning of the semester which helped the teams to be better organized.			
Perceived Problems	**Perceived problems are directly related to the PC and the sub items under them**		Some few students did not devote enough time to study the material well enough to answer some of the tricky questions correctly.				Some of the group leaders were not firm in penalizing members who did not do their fair share of the work. Need to remind students of the need to perforn so they get good reviews during the peer evaluation.			
Plans for Addressing Problems	**Plans for address specific measures to address PC and their sub areas**		The NSPE code of ethics should be given to students section by section throughout the semester and mini quizzes should be given to prepare the students for the main ethics tests. Spend a little bit more time discussing how the NSPE code of ethics can be formed into questions and ask students within a group to make questions themselves and practice answering their own questions within a group.				Instructors should give some basic guidelines on how the groups should account for member participation . Meeting attendance, assignment submission, and tasks completion log spreadsheet should be developed and provided to the groups to assist them in managing and getting full participation from team members.			
Overall Trend over Periods	Ascertain if there were improvements over previous semesters		The trend has been improved student performance over the last 3 years				The average has been between 80 and 86 % for the last three years.			
Were Expectations Met?	Class Average ≥75% and ≥70% of Students Performed at or Above Expected Average.		**YES**				**YES**			

SENIOR DESIGN AND PREFESIONALISM I
FALL 2020

Title of Assignment: Mid-term Presentation

List of Topics of Presentation

1. Enhancing Thermal Resistance of Building
2. Design, Fabricate and Test a Condenser Train for Condensing Biogas to Bio-Oil During Pyrolysis of Biomass
3. Experimental Design to Measure Heat Transfer Coefficient and Effective Thermal Conductivity in Nanofluids Under Different Boundary Conditions
4. Design of Exoskeleton-based Hybrid Human Rehabilitation Robot
5. Optimized Design of Satellite Thermal Radiator for Space-Based Applications
6. Low Shock Restraint and Deployment Device for Deployable Satellite Appendages
7. Design, Fabrication, and Testing of an Automated Oil Recovering Skimmer
8. Design and Analysis of Steering and Suspension System
9. Design of a Multi-Heat Exchanger Bed Laboratory

Group 7

ORAL COMMUNICATION EVALUATION Performance Criteria	Evaluator 1 Biney	Evaluator 2 Peng	Evaluator 3 Duan	Average for all Evaluators
1. Ability to Organize, Plan, Design/Prepare and Use Appropriate Visual Aids for communication/Presentation				
Presentation is organized in well structured logical sequence making it easy for audience to follow the content with clear understanding.	85	95	90	90.0
Slides are well prepared and are effective in helping audience to understand. (*adequate and relevant technical content and viewgraphs that are legible, completely labeled, annotated, dimensioned to illustrate important features of the work being presented*)	85	90	90	88.3
Modern presentation techniques are used (*may include visually enhanced transitions, animations, video, and sound clips*).		85	85	85.0
Average for this Performance Criteria (%)	**85.0**	**90.0**	**88.3**	**87.8**
2. Ability to Articulate Subject Knowledge (Technical Content)				
Demonstration of knowledge and understanding of the technical subject. (*This may be demonstrated by presenting literature review, originality, creativity, required standards, constraints, and other appropriate considerations such as economics, environmental, and societal impac* t)	78	90	85	84.3
Prototypes or models are prepared and displayed when they are necessary to support the presentation.		90		
Questions are responded to in a clear professional manner after restating questions to audience	85	90	90	88.3
Average for this Performance Criteria (%)	**81.5**	**90.0**	**87.5**	**86.3**
3. Appearance and Ability to Provide Good Oral Delivery				
Correct grammatical English and technical terms appropriate to technical area and audience are used; and presenters speak with clarity and confidence	90	90	90	90.0
Good posture and eye contact with the audience are maintained (*should not read from prepared notes*) and elicits the attention of the audience	92	90	95	92.3
Presenters dress appropriately for the occasion.	95	95	95	95.0
Average for this Performance Criteria (%)	**92.3**	**91.7**	**93.3**	**92.4**
GRAND AVERAGE FOR OUTCOME (%)	87.1	90.6	90.0	**89.2**

Group 3

ORAL COMMUNICATION EVALUATION Performance Criteria	Evaluator 1 Biney	Evaluator 2 Peng	Evaluator 3 Duan	Average for all Evaluators
1. Ability to Organize, Plan, Design/Prepare and Use Appropriate Visual Aids for communication/Presentation				
Presentation is organized in well structured logical sequence making it easy for audience to follow the content with clear understanding.	75	80	85	80.0
Slides are well prepared and are effective in helping audience to understand. (*adequate and relevant technical content and viewgraphs that are legible, completely labeled, annotated, dimensioned to illustrate important features of the work being presented*)	75	80	85	80.0
Modern presentation techniques are used (*may include visually enhanced transitions, animations, video, and sound clips*).		80	85	82.5
Average for this Performance Criteria (%)	**75.0**	**80.0**	**85.0**	**80.8**
2. Ability to Articulate Subject Knowledge (Technical Content)				
Demonstration of knowledge and understanding of the technical subject. (*This may be demonstrated by presenting literature review, originality, creativity, required standards, constraints, and other appropriate considerations such as economics, environmental, and societal impac* t)	70	85	80	78.3
Prototypes or models are prepared and displayed when they are necessary to support the presentation.		80		
Questions are responded to in a clear professional manner after restating questions to audience	70	80	85	78.3
Average for this Performance Criteria (%)	**70.0**	**81.7**	**82.5**	**78.3**
3. Appearance and Ability to Provide Good Oral Delivery				
Correct grammatical English and technical terms appropriate to technical area and audience are used; and presenters speak with clarity and confidence	85	85	85	85.0
Good posture and eye contact with the audience are maintained (*should not read from prepared notes*) and elicits the attention of the audience	85	85	80	83.3
Presenters dress appropriately for the occasion.	90	95	85	90.0
Average for this Performance Criteria (%)	**86.7**	**88.3**	**83.3**	**86.1**
GRAND AVERAGE FOR OUTCOME (%)	78.6	83.3	83.8	**82.2**

Group 2

ORAL COMMUNICATION EVALUATION Performance Criteria	Evaluator 1 Biney	Evaluator 2 Peng	Evaluator 3 Duan	Average for all Evaluators
1. Ability to Organize, Plan, Design/Prepare and Use Appropriate Visual Aids for communication/Presentation				
Presentation is organized in well structured logical sequence making it easy for audience to follow the content with clear understanding.	72	80	85	79.0
Slides are well prepared and are effective in helping audience to understand. (*adequate and relevant technical content and viewgraphs that are legible, completely labeled, annotated, dimensioned to illustrate important features of the work being presented*)	72	70	85	75.7
Modern presentation techniques are used (*may include visually enhanced transitions, animations, video, and sound clips*).		75	80	77.5
Average for this Performance Criteria (%)	**72.0**	**75.0**	**83.3**	**77.4**
2. Ability to Articulate Subject Knowledge (Technical Content)				
Demonstration of knowledge and understanding of the technical subject. (*This may be demonstrated by presenting literature review, originality, creativity, required standards, constraints, and other appropriate considerations such as economics, environmental, and societal impac* t)	65	60	80	68.3
Prototypes or models are prepared and displayed when they are necessary to support the presentation.		40		
Questions are responded to in a clear professional manner after restating questions to audience	75	75	90	80.0
Average for this Performance Criteria (%)	**70.0**	**58.3**	**85.0**	**74.2**
3. Appearance and Ability to Provide Good Oral Delivery				
Correct grammatical English and technical terms appropriate to technical area and audience are used; and presenters speak with clarity and confidence	80	80	70	76.7
Good posture and eye contact with the audience are maintained (*should not read from prepared notes*) and elicits the attention of the audience	80	85	75	80.0
Presenters dress appropriately for the occasion.	80	90	85	85.0
Average for this Performance Criteria (%)	**80.0**	**85.0**	**76.7**	**80.6**
GRAND AVERAGE FOR OUTCOME (%)	74.9	72.8	81.3	**77.8**

ABOVE AVERAGE

Design, Fabrication, and Testing of an Automated Oil Recovering Skimmer

By: Ximena C., Caleb R., Demetrious S.,
Amna A., Amna J., Daniel A., David T.

Presentation outline

1. Project Scope
2. Project Planning and Task Identification
3. Literature Review
4. Preliminary Design
5. Results and Discussion
6. Conclusions and Recommendations

1. Project Scope

1.1 Problem Statement

- The purpose of this project is to design, fabricate, and test a fully functional automated oil skimmer for companies to use during oil spill cleanups and containment.

1.2 Recognition of Need

- Current oil skimmers recovery efficiencies are too low to combat the rate of oil spills that are damaging the environment

1.3 Client Identification

- Bureau of Safety and Environmental Enforcement
- Environmental Protection Agency
- Marine Spill Response Corporation
- Marine Preservation Association
- Occidental Petroleum Corporation

1. Project Scope

1.4 Project Goal and Objectives

- The project goal is to design an improved oil skimmer system with a refined process that will increase the recovery rate and oil containment capacity of current oil skimmers.
- Objectives were categorized between low-level and high-level objectives and their most relevant criteria category



1.5 Initial Project Constraints and operating environment

- Cannot exceed an operating domain of 5 ft by 5 ft
- Needs to be an easily portable design.

2. Project Planning

2.1 Task Identification

1. Identified major tasks and their respective subtasks
   - Problem Formulation
   - Project Planning
   - Literature Review
   - Concepts Generation
   - Concept Evaluation
   - Preliminary Design
   - Detailed Design
   - Detailed Parts Specifications
   - Budget & and Project Cost (Economic Analysis)
   - Purchasing
   - Fabrication & and Testing
   - Final Report & and Presentation

2. Project Planning

2.2 Timeline

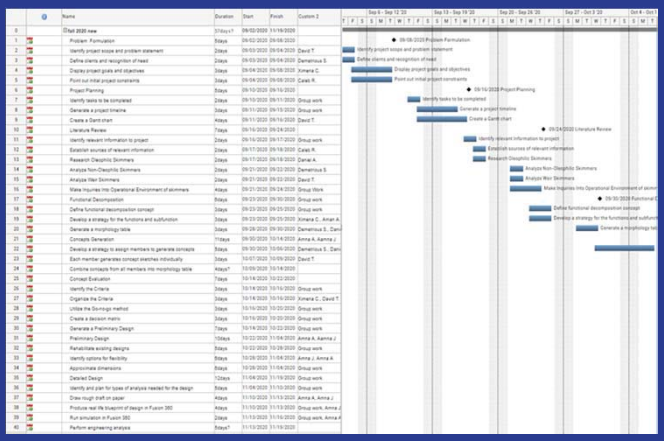
1. Major task description
2. Sub-task descriptions
3. Task objectives
4. Task deliverables
5. Estimated task duration
6. Start and end dates
7. Primary responsible person

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
Problem Formulation	1.1 Problem statement	To formulate the current problem and identify the current need for product optimization	Full description of the current unsatisfactory conditions that will be approached by the proposed design	2	9/3	9/5	David T.
	1.2 Client Identification and recognition of need	To find who will be a potential end user of the product and to determine the reason why the client needs the product	A list of 5 potential clients and structured statement that defines the overall project goal and the scope of the goal	2	9/3	9/5	Demetrious S.
	1.3 Project goals and objectives	To develop a goal statement and define measurable performance characteristics of design	A labelled objective tree showing hierarchical relationships between objectives based on their performance characteristics.	4	9/4	9/8	Ximena C.
	1.4 initial project constraints and operating environment	To identify the different permissible ranges of the product design and recognizing the product working environment	A list of permissible range for the design parameters, description of the environment in which the design will operate.	2	9/4	9/6	Caleb R.

2. Project Planning

2.3 Gantt Chart

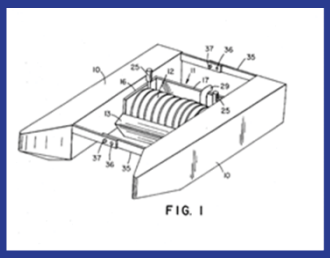
- Project task tracking
  - Projected important milestones with Google Gantter



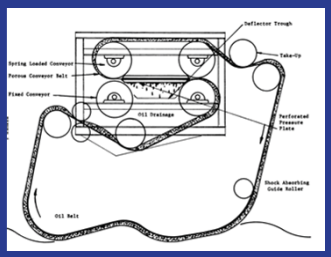
3. Literature Review

3.1 Oleophilic Skimmers

1. Disc Skimmers:
Operate by mounting to the top of the tank and running a large diameter disk into the coolant surface. (Oleophilic)



2. Belt Skimmer:
Utilize a corrosive resistant steel belt that passes through resilient wiper blades where the oil is removed from both sides of the medium. (Oleophilic)



3. Literature Review

3.1 Oleophilic Skimmers (Cont)

3. Drum Skimmers:
Incorporates rotating drums to collect oil from shallow waters. (Oleophilic)



4. Rope-Mop Skimmer:
Rope mop skimmer can be used in a variety of configurations. (Oleophilic)



3. Literature Review

3.2 Non-Oleophilic Skimmers

1. Vacuum Skimmers:
Oil is recovered directly from the water surface by air suction systems.



Source: Ambar

2. Belt Mop Oil Skimmer
Mechanism employed to skim oil from coolant and wastewater.



Source: Nauticexpo.com

3. Literature Review

3.3 Weir Skimmers

1. Uses the difference in specific gravity of oil and water for effective draining of spilled oil from the surface water.

1. Heavily dependant on stable operational environment.

1. Commonly used due to portability and easy assembly.



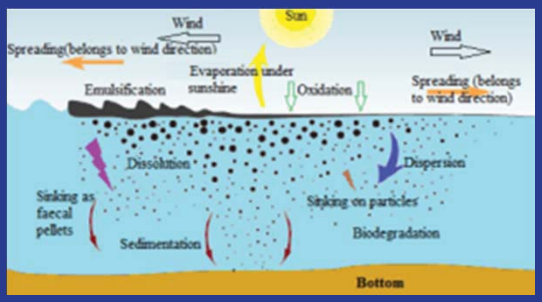
Source: SpillPro

3. Literature Review

3.4 Operational Environment of Weir Skimmers

Weathering affects the productivity and efficiency of the oil recovering process.

1. Various ways of weathering:
   - High Currents
   - Evaporation
   - Dispersion
   - Dissolution
   - Emulsification



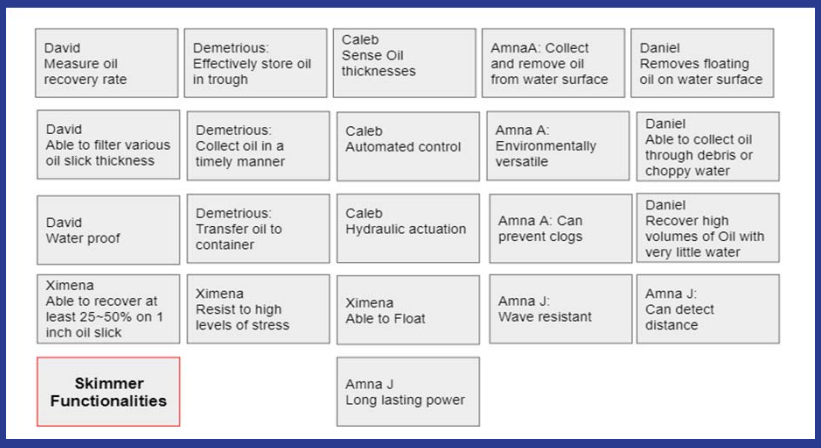
3. Literature Review

3.5 Major Components

1. **Pump/hose:** Used to extract collected oil to be relocated to an outside container source.
2. **Container:** Used to store the collected oil from the skimmer.
3. **Draining system:** A system designed to drain the collected oil from the container after it is separated from the water.
4. **Filter system:** Oil and water separator that detects the density of collected liquids and also catches small particles to keep oil purified for reuse.
5. **Power supply:** A power supply would be needed for skimmer mobility. (DC battery)
6. **Sensors:** These sensors will also manage the START and STOP control for the skimmer during skimming operations.
7. **Actuators:** Hydraulic actuators are components used to control the intake of a system.

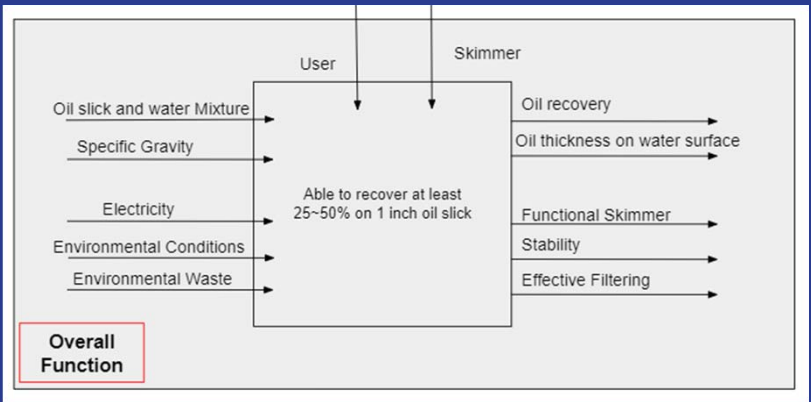
4. Preliminary Design

4.1 Functional Decomposition



4. Preliminary Design

4.1 Functional Decomposition



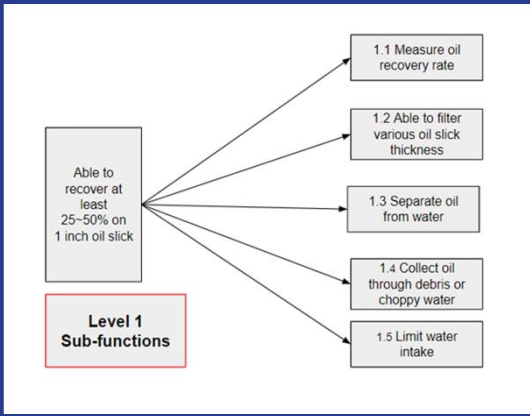
4. Preliminary Design

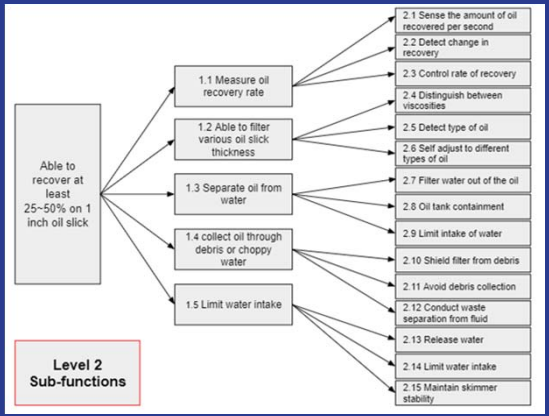
4.1 Functional Decomposition

David Generate clean oil	Demetrious: Limit water intake	Caleb Gauge oil viscosity	Amna A: Efficient filtering	Daniel Absorbs oil from water
David Orient skimmer	Demetrious: Sense oil thickness	Caleb Pre - programmed operating system	Amna A: Collect oil waste	Daniel Efficiently works through debris
David Limit waste entering skimmer	Demetrious: Direct oil to storage tank	Caleb Shield filter	Amna A: Encountered oil and recovered oil	Daniel Effective filtration system
Ximena Pumping efficiently	Ximena Absorb water and oil	Ximena Store oil	Amna J Store oil effectively	Amna J: Avoid water intake
Level 1 Sub-functions		Amna J Absorb wave and wind stress effectively		

4. Preliminary Design

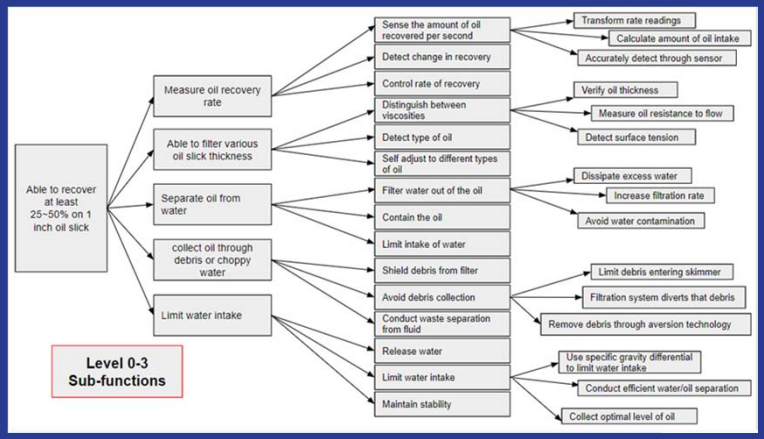
4.1 Functional Decomposition





4. Preliminary Design

4.1 Functional Decomposition



5. Results and Discussion

Summary of Goals and Objectives

- A Need for a design of an automated oil recovering system that is at least comparable to current skimmers
- The skimmer should target to address current significant drawbacks
- Oleophilic skimmers are the most favored topics of interest
- Create a new control algorithm for system recovery

Discussion of Completed Work

- Fundamental analysis of skimmer designs and focus on initial constraints
- Schedule development and time constraints

Summary of Constraints and Codes Identified for Project

- Specifications given by The Bureau of Environmental Enforcement (BSEE)
- ASTM-2709-08 test methods give a requirement of a maximum ORR at a 70% performance

6. Conclusions and Recommendations

Key Points:

The lack of consistency of oil recovery response has led to environmental damage as well as unnecessary costs to the environment and oil industries

Testing optimization within BSEE requires operations of oil skimmer efficiencies to be .25-.50 for oil thicknesses of 1 inch

Moving forward, we seek to advance a current oleophilic skimmer design.

Questions?

AVERAGE

Experimental Design to Measure Heat Transfer Coefficient and Effective Thermal Conductivity in Nanofluids Under Different Boundary Conditions

By: Diana Morales, Fanta Kaba, Christian White, Yemboado Brayan Yonli,

Abdullah EL Aker, Marcelo Epam Ona

Presentation Outline

- Problem Statement
- Client Identification & Need
- Objective Tree
- Project Constraints/Operating Environment
- Project Planning
- Gantt Chart
- Literature Review
- Major Components of Designs & Functions
- Functional Decomposition
- Summary of Literature Review
- Conclusion



Problem Statement

Measurement of heat transfer coefficient and thermal conductivity of nanofluids do not accommodate under different boundary conditions; therefore, an effective measurement technique will be selected to adapt to the change of properties of the nanofluids.

Client Identification & Need

Potential Clients:

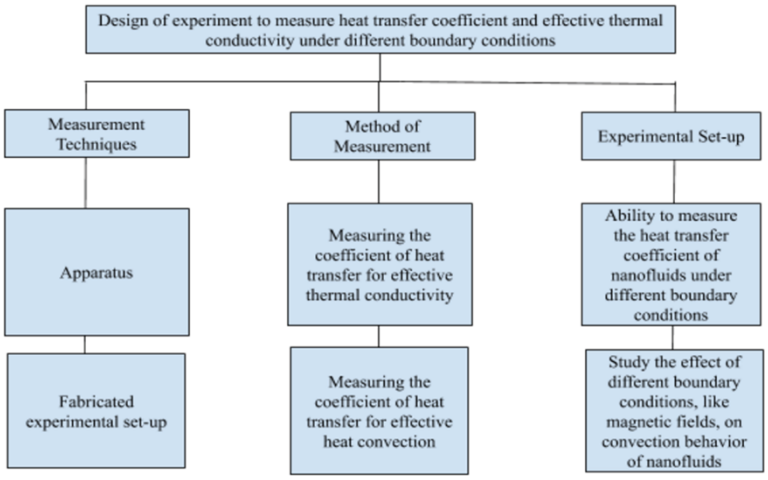
- Engineers
- Professors
- Scientist
- Engineering Firms (Koch Heat Transfer Company)



Understanding the Need:

- Anomalous behavior
- Nanofluids vs. Base Fluid
- Current methods
- Finding the right ratio
- Unstranding true function of nanofluids
- Learning effective manipulation for desired outcomes.

Objective Tree



Project Constraints

- Flexible boundary conditions
- Technique applicable to nanofluids
- Material selection
- Ability to withstand high pressures
- Apparatus size



Project Planning

To successfully undertake the design of this experiment in its entirety, it is important that the framework for this project is clearly outlined and defined.

2. Project Planning

2.1 Identify the tasks.

-Objective: Clear understanding of task.

-Deliverable: List of tasks.

-Members: Diana Morales

-Timeline: 2 days

2.2 Develop objectives for each task.

-Objective: Develop objectives.

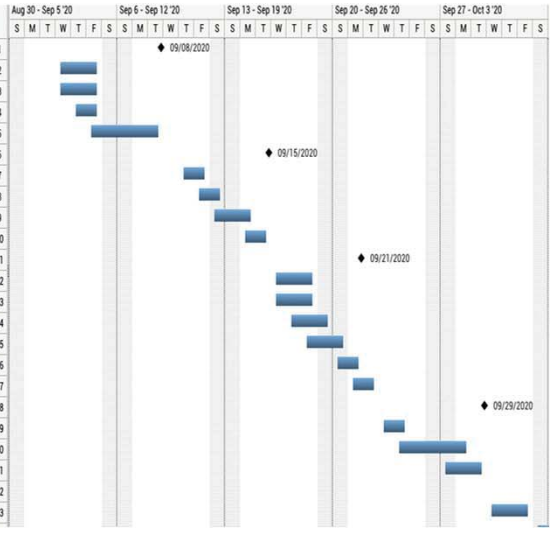
-Deliverable: Specify all requirements to complete the task.

-Members: Fanta Kaba

-Timeline: 2 days

Gantt Chart

	Name	Duration	Start	Finish
1	1. Problem formulation	7days	09/02/2020	09/08/2020
2	1.1 Identify the consumer that may need the product and understar	3days	09/02/2020	09/04/2020
3	1.2 Have a clear understanding of the output that is needed	3days	09/02/2020	09/04/2020
4	1.3 Have clear cut objectives while designing the product	2days	09/03/2020	09/04/2020
5	1.4 Understand the limitation of the design and the product	5days	09/04/2020	09/08/2020
6	2. Project planning	6days	09/10/2020	09/15/2020
7	2.1 Have a schematic and a clear idea about what the project and i	2days	09/10/2020	09/11/2020
8	2.2 Develop objectives (actions needed) for each task.	2days	09/11/2020	09/12/2020
9	2.3 Set up estimate dates in which each task might be completed.	3days	09/12/2020	09/14/2020
10	2.4 Give a visual representaation of the timelime	2days	09/14/2020	09/15/2020
11	3 Literature Review	6days	09/16/2020	09/21/2020
12	3.1 Understand the background of the project and I have a clear ic	3days	09/16/2020	09/18/2020
13	3.2 Understand the mechanism behind convection heat transfer for	3days	09/16/2020	09/18/2020
14	3.3 Understand how a change of boundary condition like magnetic	3days	09/17/2020	09/19/2020
15	3.4 Identify different measurement technique for convection and so	3days	09/18/2020	09/20/2020
16	3.5 Obtain a range of results that will help make sure that experim	2days	09/20/2020	09/21/2020
17	3.6 Conclusion of the literature review	2days	09/21/2020	09/22/2020
18	4. Functional Decomposition	7days	09/23/2020	09/29/2020
19	4.1 Define the general function and what is to be accomplished by	2days	09/23/2020	09/24/2020
20	4.2 Define the main functions aof what is to be accomplished	5days	09/24/2020	09/28/2020
21	4.3 Break each second level function into sub function until the poi	3days	09/27/2020	09/29/2020
22	5. Concept Generation	6days	09/30/2020	10/05/2020
23	5.1 Generating concepts using concept generation techniques	3days	09/30/2020	10/02/2020



Literature Review

- Identify potential sources of information (books journals research papers)
- Study of nanofluids
- Study of nanofluids under different boundary conditions
- Study of different measurement techniques for convection and their advantages
- Collection of comparable results



Major Components of Designs & Functions

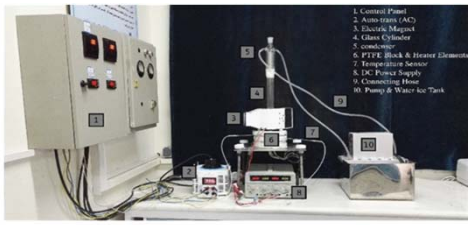


Fig. 1 Boiling device Overview

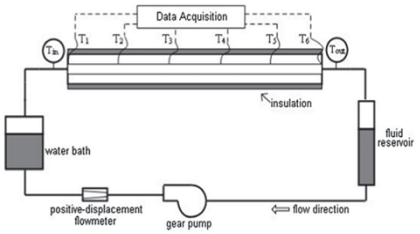


Fig. 3 Schematic of heat transfer Test rig

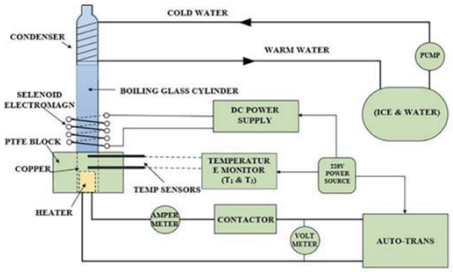


Fig. 2 The operational diagram of the boiling device

Equations and Formulas

General Equation

$E_{tot} = E_{in} - E_{out} + E_{Storage}$

Thermal Fluid Heater

$Q = M \times C_p \times \Delta T$

Flow Rate

$M = Q / (C_p \times \Delta T)$

Heat Loss

$L_{Conduction}$ = Thermal Conductivity of Material Accepting Heat x Area of Contact x ΔT x 1 Hour Per Thickness of Material Accepting Heat

Convection Loss

$L_{Convection}$ = Surface Loss (W/in2) x Area x 1 hr

Radiation Loss

$L_{Radiation}$ = Radiation Loss (W/in2) x Area x Emissivity x 1 hr

Resistance Temperature Detectors (Sensors)

For Temperature: -200°C ≤ t ≤ 0°C,

$R_T = R_o[1 + AT + BT^2 + (t - 100)CT^3]$

For Temperature: 0°C ≤ t ≤ 661°C

$R_T = R_o(1 + AT + BT^2)$

Callendar - Van Dusen constants

$A = \alpha + (\alpha\delta)/100$

$B = -(\alpha\delta)/100^2$

$C = -(\alpha\beta)/100^4$

$\alpha = (R_{100} - R_o)/(100 + R_o)$

β = constant if t < 0 °C, else zero

$\delta = (R_o[1 + \alpha(260)] - R_{200})/(4.16\, R_o\alpha)$

Heat Loads and Condensers

$h = c_p \rho\, q\, dt$

Evaporator water flow rate

$q_{evap} = 24\, h_{evap}/dt$

Condenser water flow rate

$q_{cond} = 30\, h_{cond}/dt$

Summary of Literature Review

This experiment is to assign the proper measurement method for convection transfer coefficient for nanofluids under different boundary conditions. In order to completely understand the scope of this experiment, the identification of relevant information is necessary to ensure the functionality in the measurement technique selected. Relevant sources are reviewed to establish a well planned literature review, which focuses on examining existing similar designs and its components, relevant design analysis methods, fabrication and testing, as well as, relevant codes and standards.

Functional Decomposition

Morphology (Functional Decomposition and Concepts) Table

Overall Function	Level 1 Sub-functions	Level 2 Sub-functions	Level 3 Sub-functions	Concept 1		Concept 2		Concept 3	
				Description	Sketch	Description	Sketch	Description	Sketc
Measure the heat transfer coefficient and the thermal conductivity of nanofluid under different boundary conditions	Create a setup for the experiment	Choose appropriate measurement techniques for convection	find the appropriate measurement techniques						
			evaluate the measurement techniques						
			choose the appropriate technique						
		Design the experimental setup based on the chosen technique	create the CAD design for the apparatus						
			Evaluate the Design for the experiment						
		Assemble the experimental setup of the experiment	manufacture the parts of the apparatus						
			assemble the parts of the apparatus						

Conclusion

In conclusion, this project will address an issue that professors, scientists, engineers, and engineering students face when it comes to understanding nanofluids and their behaviours under different boundary conditions. The group is undergoing research on how to better measure heat transfer coefficient and effective thermal conductivity in nanofluids under those different boundary conditions by creating a system designed to conduct an experiment that will measure different nanofluids and their behaviors. The constraints that we face deal with inflexible boundary conditions, applicable techniques for such nanofluids, selecting the appropriate material, ensuring the nanofluid(s) has an ability to withstand high pressure, and the apparatus size. The conclusion drawn from this result is that there are more effective ways in measuring the behavior of different nanofluids that will help those who are under the study of heat transfer use to gain a better understanding of the overall function of nanofluids when placed in different boundary conditions.

BELOW AVERAGE

Design, Fabricate and Test a Condenser Train for Condensing Biogas to Bio-oil During Pyrolysis of Biomass

Group 2

Sultan Khalid
Shikhar Desai
Dacory Harris
Clarence Reed
Kennedy Simmons
Mohammed Suliman

Outline

- **Project Scope**
- **Project Planning and Task Identification**
- **Literature Review**
- **Preliminary Design(Functional Decomposition)**
- **Summary**
- **Conclusion**
- **Suggestions from the audience**

Project Scope

1. Problem Statement
   - The current double pipe heat exchanger configuration is not effective in condensing biogas to bio-oil. Furthermore, final condensate collection vessel is made from glass which is not a suitable material under high pressure conditions.
1. Client recognition and need:
   - Companies/industries/private parties or firms?
   - Need and requirement? - Effectiveness, easy to use, produce oil efficiently*
1. Goals and objectives: To redesign the condenser that can condense all vapor into biogas during pyrolysis.
2. Impact on Society: Energy efficient, User-friendly, Provides clean energy.
3. Initial Constraints:
   - The condenser should fit in given container
   - Gases will be in form of a mist which is difficult to condense
   - There are unwanted gases produced such as Nitrogen
   - Accumulation of oil that covers the surface of the tube

Project Planning and Task Identification

1. **Task Identification**
   - **Problem Formulation**: This part of the project enabled the group to set a goal which was elaborated in goal statement earlier by group members.
   - **Project Planning**: To plan the project by giving detailed description of the tasks assigned and will be assigned in future. Key goal to come up with gantt chart.
   - **Literature Review**: Identify relevant project information and there potential sources. The information will help in making Table of Contents.
   - **Functional Decomposition**: To put together all the information gathered by group members and make flow chart as a breakdown of all steps. To create overall function of the project and break it down into sublevels.

Project Planning and Task Identification

Timeline:

The time line was created based on major tasks and following their subtask descriptions.

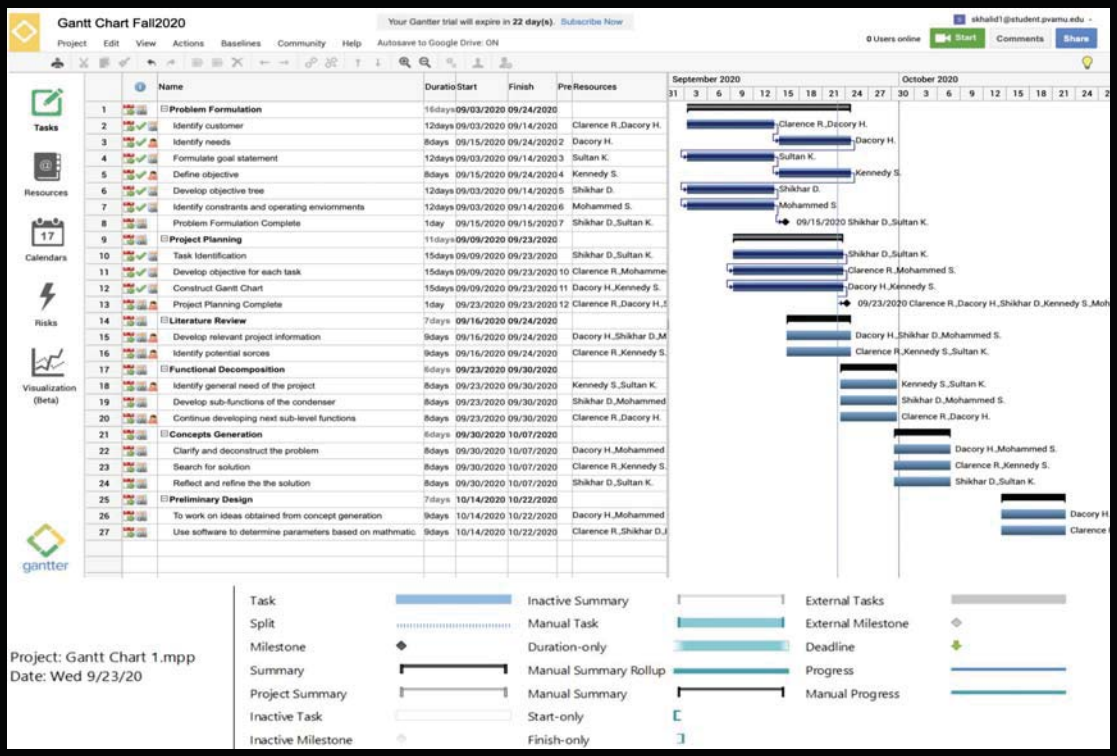
The objectives were identified for each task and their respective deliverables to be submitted.

Duration of each task and the start and end date was recorded/planned in this section

The sequence of this timeline with respect to the task were arranged as in the order they needed to be performed.

Project Planning (contd.)

Gantt Chart



Literature Review

What is Literature review?

- The Literature review is used to understand relevant information related to the project.
- Research information on the major components listed were researched and a list of references, cited by members of the group, is produced.

Major Components

This section contains information identified with the process of pyrolysis, its reactions and products.

- Fundamentals of the Fluidized Bed Reactor
- Functions of Biomass Reactor
- Condensable Gases
- Heat Exchanger
- Electrostatic Precipitator
- Engineering Economic Analysis
- Codes/Standard

Potential sources of Information

- Potential sources are identified through research conducted using Google scholars, online encyclopedias, library databases, and textbooks. Following research, the references were listed, representing the source of information for each topic.

Literature Review

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8. **Codes/Standards…… 25**

6. References

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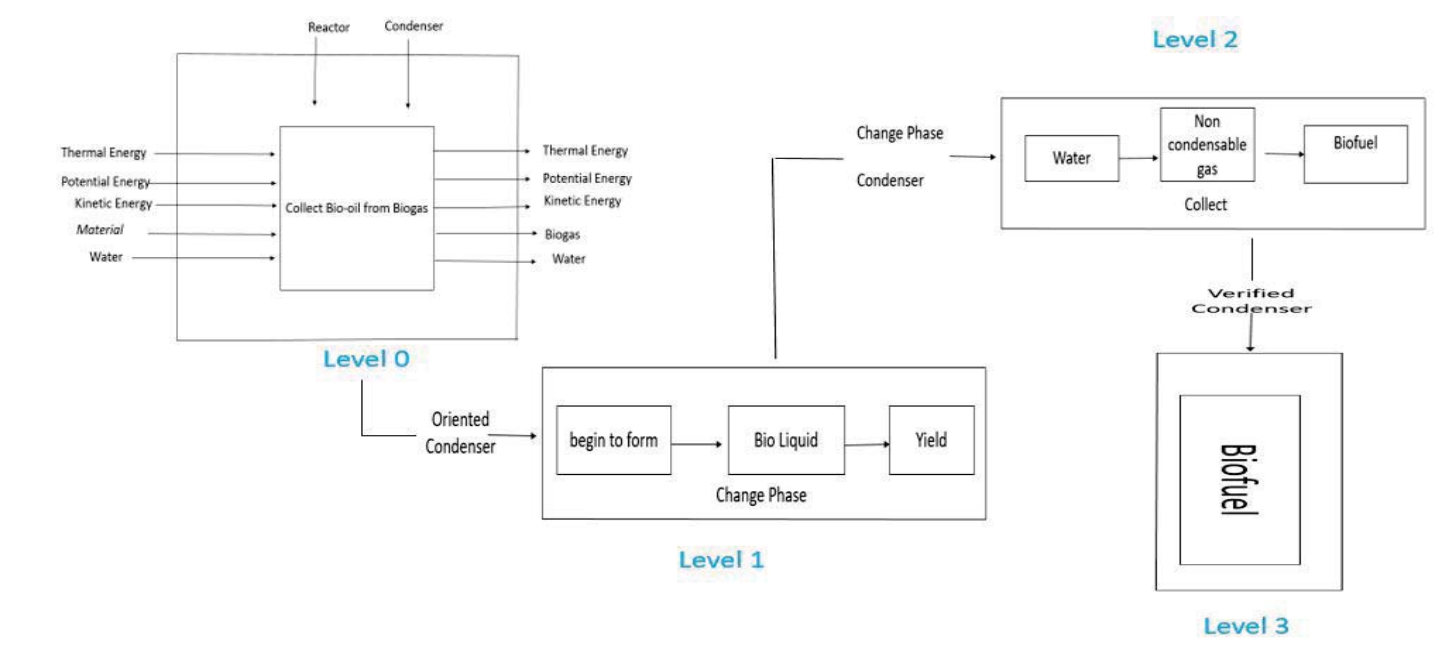
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Preliminary Design

Functional Decomposition



Results & Discussion

Goals & Objectives

- Redesigned condenser train
- Improved efficiency

Completed Work

- Project statements & Timeline
- Research & Partial Development

Constraints & Codes

- Constraints based on previous design

Conclusion

- Project scope
- Project Planning & Task Identification
  - Task Identifications
  - Timeline
  - Gantt Chart
- Literature Review
  - Major Components
    - Fundamentals of the Fluidized Bed reactor
    - Functions of biomass reactor
    - Condensable Gases
    - Heat Exchanger (condenser)
    - Electrostatic Precipitator
    - Thermochemical Conversion of Biomass
    - Engineering Economic Analysis
    - Codes/Standards
- Preliminary Design
  - Functional Decomposition
- Results

SENIOR DESIGN AND PREFESIONALISM I
FALL 2020

Title of Assignment: Final Presentation

List of Topics of Presentation

1. Enhancing Thermal Resistance of Building
2. Design, Fabricate and Test a Condenser Train for Condensing Biogas to Bio-Oil During Pyrolysis of Biomass
3. Experimental Design to Measure Heat Transfer Coefficient and Effective Thermal Conductivity in Nanofluids Under Different Boundary Conditions
4. Design of Exoskeleton-based Hybrid Human Rehabilitation Robot
5. Optimized Design of Satellite Thermal Radiator for Space-Based Applications
6. Low Shock Restraint and Deployment Device for Deployable Satellite Appendages
7. Design, Fabrication, and Testing of an Automated Oil Recovering Skimmer
8. Design and Analysis of Steering and Suspension System
9. Design of a Multi-Heat Exchanger Bed Laboratory

Group 7

OUTCOME G ORAL COMMUNICATION

ORAL COMMUNICATION EVALUATION Performance Criteria	Evaluator 1 Biney	Evaluator 2 Peng	Evaluator 3 Duan	Average for all Evaluators
1. Ability to Organize, Plan, Design/Prepare and Use Appropriate Visual Aids for communication/Presentation				
Presentation is organized in well structured logical sequence making it easy for audience to follow the content with clear understanding.	90	95	95	93.3
Slides are well prepared and are effective in helping audience to understand. (*adequate and relevant technical content and viewgraphs that are legible, completely labeled, annotated, dimensioned to illustrate important features of the work being presented*)	90	90	90	90.0
Modern presentation techniques are used (*may include visually enhanced transitions, animations, video, and sound clips*).	85	90	90	88.3
Average for this Performance Criteria (%)	**88.3**	**91.7**	**91.7**	**90.6**
2. Ability to Articulate Subject Knowledge (Technical Content)				
Demonstration of knowledge and understanding of the technical subject. (*This may be demonstrated by presenting literature review, originality, creativity, required standards, constraints, and other appropriate considerations such as economics, environmental, and societal impact*)	94	95	90	93.0
Prototypes or models are prepared and displayed when they are necessary to support the presentation.	95	95	90	93.3
Questions are responded to in a clear professional manner after restating questions to audience		95	90	92.5
Average for this Performance Criteria (%)	**94.5**	**95.0**	**90.0**	**92.9**
3. Appearance and Ability to Provide Good Oral Delivery				
Correct grammatical English and technical terms appropriate to technical area and audience are used; and presenters speak with clarity and confidence	92	95	90	92.3
Good posture and eye contact with the audience are maintained (*should not read from prepared notes*) and elicits the attention of the audience	95	95	95	95.0
Presenters dress appropriately for the occasion.		95	95	95.0
Average for this Performance Criteria (%)	**93.5**	**95.0**	**93.3**	**94.1**
GRAND AVERAGE FOR OUTCOME (%)	91.6	93.9	91.7	**92.5**

Group 6

OUTCOME G ORAL COMMUNICATION

	ORAL COMMUNICATION EVALUATION Performance Criteria	Evaluator 1 Biney	Evaluator 2 Peng	Evaluator 3 Duan	Average for all Evaluators
	1. Ability to Organize, Plan, Design/Prepare and Use Appropriate Visual Aids for communication/Presentation				
	Presentation is organized in well structured logical sequence making it easy for audience to follow the content with clear understanding.	85	90	90	88.3
	Slides are well prepared and are effective in helping audience to understand. (*adequate and relevant technical content and viewgraphs that are legible, completely labeled, annotated, dimensioned to illustrate important features of the work being presented*)	78	90	90	86.0
	Modern presentation techniques are used (*may include visually enhanced transitions, animations, video, and sound clips*).	76	90	90	85.3
3	**Average for this Performance Criteria (%)**	**79.7**	**90.0**	**90.0**	**86.6**
3	**2. Ability to Articulate Subject Knowledge (Technical Content)**				
	Demonstration of knowledge and understanding of the technical subject. (*This may be demonstrated by presenting literature review, originality, creativity, required standards, constraints, and other appropriate considerations such as economics, environmental, and societal impact*)	80	90	85	85.0
	Prototypes or models are prepared and displayed when they are necessary to support the presentation.	78	90	80	82.7
	Questions are responded to in a clear professional manner after restating questions to audience	79	85	80	81.3
3	**Average for this Performance Criteria (%)**	**79.0**	**88.3**	**81.7**	**83.0**
3	**3. Appearance and Ability to Provide Good Oral Delivery**				
	Correct grammatical English and technical terms appropriate to technical area and audience are used; and presenters speak with clarity and confidence	85	95	90	90.0
	Good posture and eye contact with the audience are maintained (*should not read from prepared notes*) and elicits the attention of the audience	80	95	90	88.3
	Presenters dress appropriately for the occasion.	90	85	90	88.3
2	**Average for this Performance Criteria (%)**	**85.0**	**91.7**	**90.0**	**88.9**
2	**GRAND AVERAGE FOR OUTCOME (%)**	81.2	90.0	87.2	**86.1**

Group 3

OUTCOME G ORAL COMMUNICATION

ORAL COMMUNICATION EVALUATION Performance Criteria	Evaluator 1 Biney	Evaluator 2 Peng	Evaluator 3 Duan	Average for all Evaluators
1. Ability to Organize, Plan, Design/Prepare and Use Appropriate Visual Aids for communication/Presentation				
Presentation is organized in well structured logical sequence making it easy for audience to follow the content with clear understanding.	70	85	85	80.0
Slides are well prepared and are effective in helping audience to understand. (*adequate and relevant technical content and viewgraphs that are legible, completely labeled, annotated, dimensioned to illustrate important features of the work being presented*)	75	80	85	80.0
Modern presentation techniques are used (*may include visually enhanced transitions, animations, video, and sound clips*).	65	80	85	76.7
Average for this Performance Criteria (%)	**70.0**	**81.7**	**85.0**	**78.9**
2. Ability to Articulate Subject Knowledge (Technical Content)				
Demonstration of knowledge and understanding of the technical subject. (*This may be demonstrated by presenting literature review, originality, creativity, required standards, constraints, and other appropriate considerations such as economics, environmental, and societal impact*)	70	80	75	75.0
Prototypes or models are prepared and displayed when they are necessary to support the presentation.	65	70	70	68.3
Questions are responded to in a clear professional manner after restating questions to audience	75	80	80	78.3
Average for this Performance Criteria (%)	**70.0**	**76.7**	**75.0**	**73.9**
3. Appearance and Ability to Provide Good Oral Delivery				
Correct grammatical English and technical terms appropriate to technical area and audience are used; and presenters speak with clarity and confidence	80	90	85	85.0
Good posture and eye contact with the audience are maintained (*should not read from prepared notes*) and elicits the attention of the audience	85	90	85	86.7
Presenters dress appropriately for the occasion.	85	95	90	92.5
Average for this Performance Criteria (%)	**83.3**	**91.7**	**86.7**	**88.1**
GRAND AVERAGE FOR OUTCOME (%)	74.4	83.3	82.2	**80.3**

ABOVE AVERAGE

Design, Fabrication, and Testing of an Automated Oil Recovering Skimmer

By: Ximena C., Caleb R., Demetrious S.,
Amna A., Aamna J., Daniel A., David T.

Presentation outline

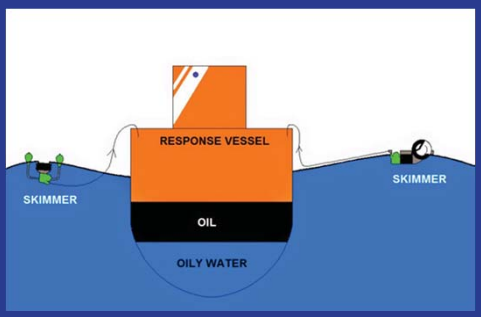
1. Project Scope
2. Project Planning and Task Identification
3. Literature Review
4. Preliminary Design
5. Detailed System Design
6. Results and Discussion
7. Conclusions and Recommendations
8. Q&A



1. Project Scope

1.1 Problem Statement

The purpose of this project is to design, fabricate, and test a fully functional automated oil skimmer for companies to use during oil spill cleanups and containment.



Sedosr Inc

1. Project Scope

Fact: According to the American Petroleum Institute approximately 706 million gallons of waste oil enter the ocean every year.

1.2 Recognition of Need

- Current oil skimmers recovery efficiencies are too low to combat the rate of oil spills that are damaging the environment
  - Marine life and ecosystem



Guanabara Bay, January 24, 2000

1. Project Scope

1.3 Client Identification

- Bureau of Safety and Environmental Enforcement
- Environmental Protection Agency

1.4 Project Goal and Objectives

- To design an improved oil skimmer system with a refined process that will increase the recovery rate and oil containment capacity of current oil skimmers.



1. Project Scope

1.5 Initial Project Constraints & Operating Environment

- Cannot exceed size constraint of 5 ft by 5 ft
- Recovery rate constraint of at least 0.25%-0.50% for 1 inch oil thicknesses

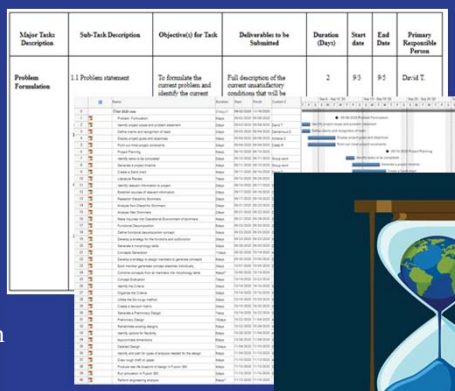


2. Project Planning

2.1 Task Identification
- Major tasks
- Subtasks

2.2 Timeline
- Major task description
- Sub-task descriptions
- Task objectives
- Task deliverables
- Estimated task duration
- Start and end dates
- Primary responsible person

2.3 Gantt Chart
- Project task tracking
- Projected important milestones with Google Gantter

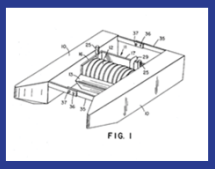


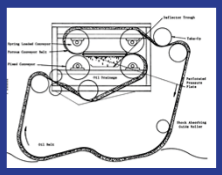


3. Literature Review

3.1 Oleophilic Skimmer

1. Disc Skimmers
2. Belt Skimmers
3. Drum Skimmers
4. Rope-Mop Skimmer









3. Literature Review

3.2 Non-Oleophilic Skimmers

1. Vacuum Skimmer
2. Belt Mop Oil Skimmer

3.3 Weir Skimmers



Source: Ambar



Source: SpillPro



Source: Nauticexpo.com

3. Literature Review

3.4 Operational Environment

3.5 Major

- Pump/hose
- Container
- Draining system
- Filter system
- Power supply
- Sensors
- Actuators

3.6 Relevant Analysis

- Equations
- Materials

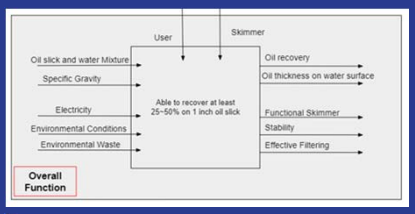
3.7 Codes and Standards

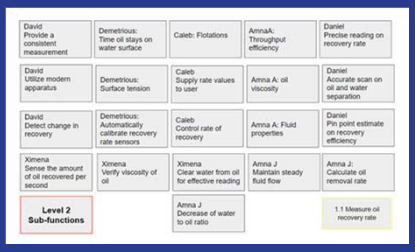


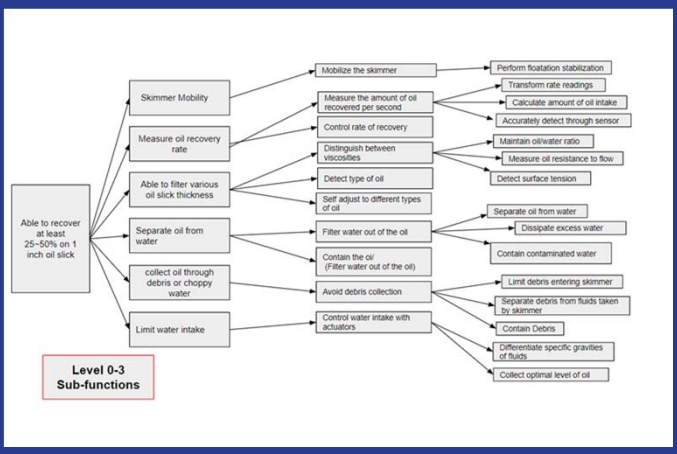
Balikpapan Bay, Borneo 2018

4. Preliminary Design

4.1 Functional Decomposition



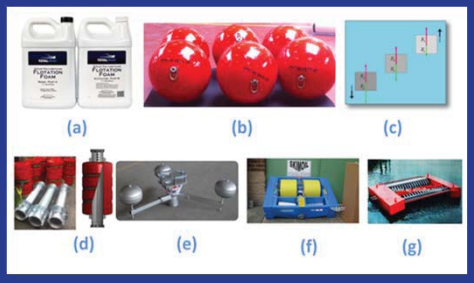




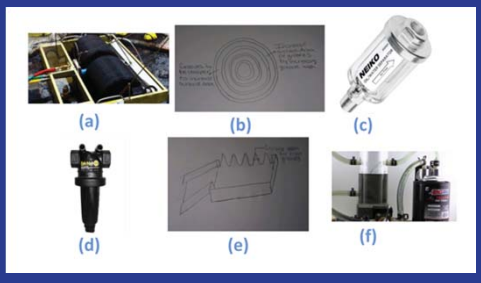
4. Preliminary Design

4.3 Concepts Generation

Concepts generated for certain functions



Concept Sketches for "Perform floatation stabilization"



Concept Sketches for "Separate oil from water"

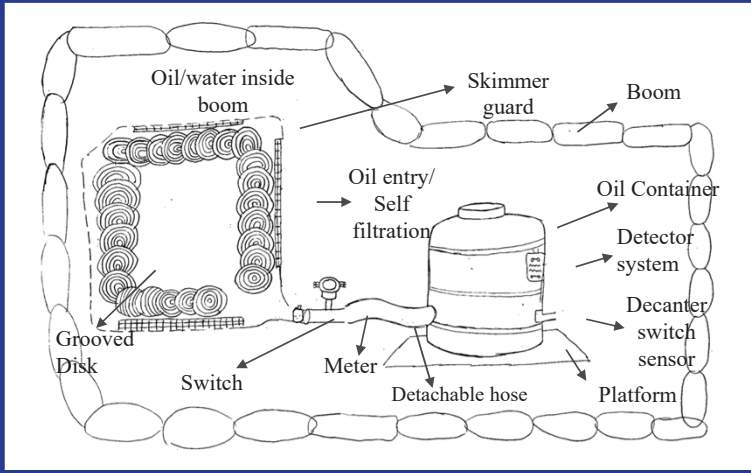
4.3 Concepts Evaluation and Selection

Methods used for evaluation for each concept

1. **GO-NO-GO** Evaluation of the function
2. **Decision Matrix** Evaluation of the function

4. Preliminary Design

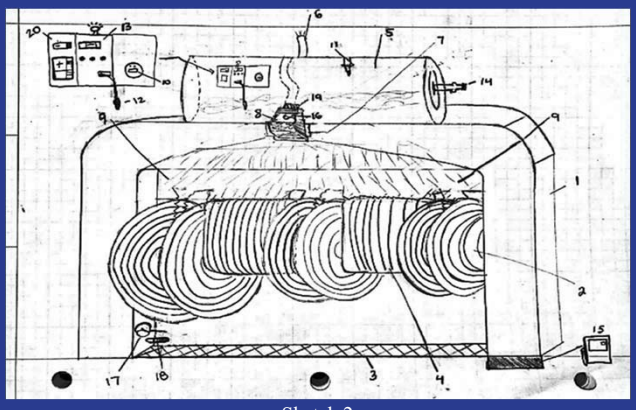
4.4 System Sketches and Description for Two final Designs



Sketch 1

4. Preliminary Design

4.4 System Sketches and Description for Two final Designs



Sketch 2

Sketch 2 Legend
1. U-shaped body
2. Grooved disk
3. Debris shield
4. Floating Drum skimmer
5. Oil retainer
6. Hose
7. Waste Basket
8. Commercial screen shield
9. Oil ramp
10. Magmeter
11. Point level sensor
12. Submersible level transmitter
13. Detector array
14. Pressure Transducer
15. Line transducer
16. Oval gear flow meter
17. Tensiometer
18. Density meter
19. Fixed Orifice system
20. Moisture oil transmitter

4. Preliminary Design

4.5 Design Constraints and Applicable Codes and Standards Used in the Design

Environmental Learning Center

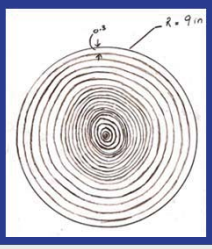
ASTM standards were used in the manufacturing of our design.

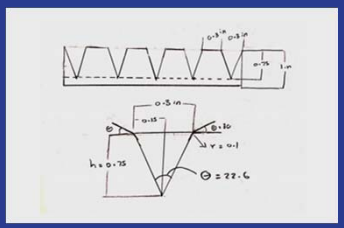
- E2986 - 18: Standard Guide for Evaluation of Environmental Aspects of Sustainability of Manufacturing Processes
- D1129 - 13: Standard Terminology Relating to Water
- E1739 - 95(2015): Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites.

5. Detailed System Design

5.1 Identifications and Plans for Types of Analysis Needed for the Design

- Identify Type of Analysis needed
  - Process/FBD Diagram
  - Equations Required for Analysis
  - Identify Known Variables
  - Computational Method
  - Specifications of Part Selected





5. Detailed System Design

5.2 Detailed Engineering Analysis and Simulation for Designing, Sizing, Specifying and Selecting Parts for the Design

Analysis performed:

5.2.1 ORR (Oil recovery rate) & RE (Recovery efficiency) through different oil slick

5.2.2 Pump flow rate and efficiency

5.2.3. Shaft rotational speed and most effective material

5.2.4 Appropriate motor

5.2.5 Appropriate dimensions for skimmer design

5.2.6 Floating mechanism for the skimmer design



5. Detailed System Design

5.2.1 ORR (Oil recovery rate) & RE (Recovery efficiency) Analysis

ORR=Voil/T

Voil = Volume of oil recovered, liter or gallon

T= Elapsed time of recovery, minutes

RE = (Voil/Vtotal fluid) * 100

Fluid = Oil and Water

Vtotal fluid = Volume of total fluid recovered

Slick Thickness (mm)	DISC Speed (rpm)	Collection Time (s)	Oil Recovery Rate (L/min)/(gpm)	Recovery Efficiency (%)
75-50	36	69	284/75	77
75-50	36	63	322/85	85
75-50	34	70	307/81	87
			307/81	**83**
50	25	60	242/64	85
50	25	60	227/60	84
50	25	60	238/63	84
			235/62	**85**
25	10	60	68/18	72
25	10	60	76/20	75
25	10	60	72/19	80
			72/19	**76**
12	6	60	38/10	84
12	6	60	42/11	68
12	6	60	30/8	75
			38/10	**76**
6	6	60	26/7	62
6	5.5	60	19/5	68
6	5.5	60	23/6	65
			23/6	**65**

5. Detailed System Design

5.2.3 Dimensional Analysis

- The analysis for various skimmer part dimensions is being proposed

Groove angle for the drums:
Tan(theta) = (opposite) /(adjacent)
Tan(theta) = ((drum groove width / 2) /(groove depth)

Number of grooves per drum:
#Grooves=drum length/(grooves width * (2))

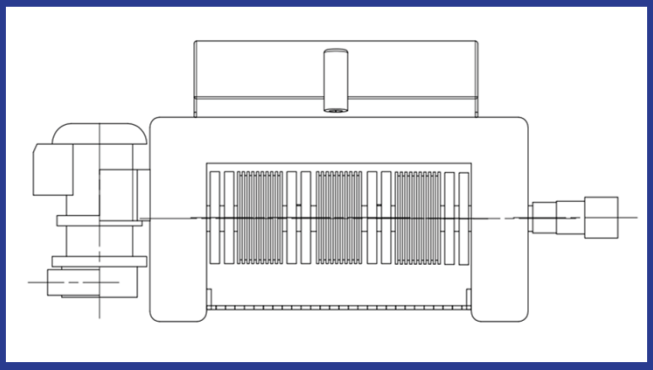
Space between discs, drums, and skimmer shell:
S= (disc T * # of discs) + (# of drums * drum L)
- L of removed area)/(# of spacing)

	Skimmer Part	Dimension Specification
1	U shaped Body	Skimmer body = 40 x 20 x 5 (in) area removed = 28 x 14 x 5 (in)
2	Grooved disk	Disk diameter = 9 (in) Disk thickness = 1 (in) Number of Disks = 8 disks Groove depth = 0.75 (in) number of grooves = 15 Space between disk = 0.5 (in) Space between skimmer and first/last disk =0.375 (in)
3	Debris Shield	Length x Width = 28 x 5 (in) Thickness =0.25 (in) Squares = 1 x 1 (in)
4	Floating Drum Skimmer	4.75 (in) D=9 (in) Number of Drums = 3 drums
5	Oil container	Diameter = 15 (in) L = 30 (in)
6	Shaft	L = 44 (in) D = 2.5 (in)

5. Detailed System Design

5.2.3 Dimensional Analysis (contd)

- Top view of the Completed assembly of the oleophilic oil skimmer



- **Size constraints:**
  - 5 ft by 5 ft
  - 60 x 60 (in)
- **Final dimensions:**
  - 58.392 x 39 x 15 (in)

5. Detailed System Design

5.3. CAD Models, Detailed Drawings, Sub-assemblies, System Assembly and Equipment specifications and selection

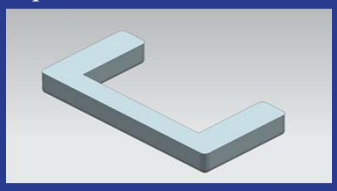


Figure 5.1 Skimmer Frame

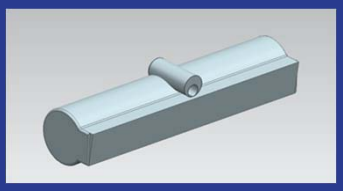


Figure 5.2 Vertical Oval Oil Storage Tank

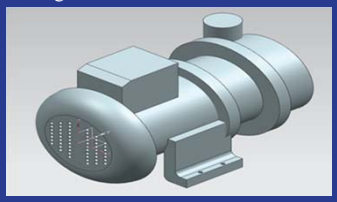


Figure 5.3 Pump



Figure 5.4 115V 7RPM Motor

5. Detailed System Design

5.3. CAD Models, Detailed Drawings, Sub-assemblies, System Assembly and Equipment specifications and selection

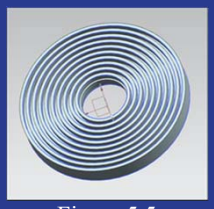


Figure 5.5
Grooved Disk

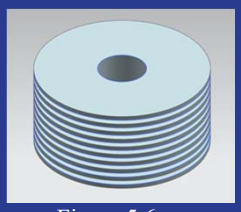


Figure 5.6
Rotating Drum



Figure 5.7
Rotating Shaft

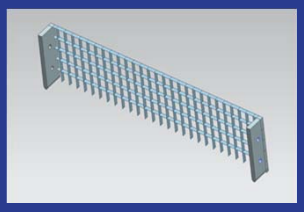


Figure 5.8
Debris Shield

5. Detailed System Design

5.3. CAD Models, Detailed Drawings, Sub-assemblies, System Assembly and Equipment specifications and selection

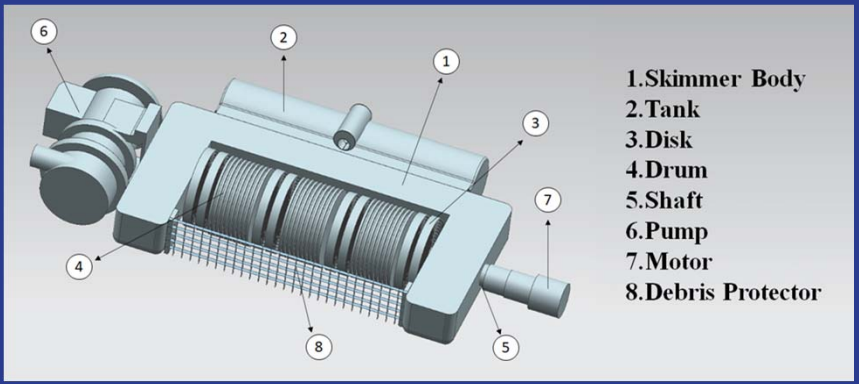


Figure 5.17 Assembled Oil Skimmer

5. Detailed System Design

5.3. CAD Models, Detailed Drawings, Sub-assemblies, System Assembly and Equipment specifications and selection

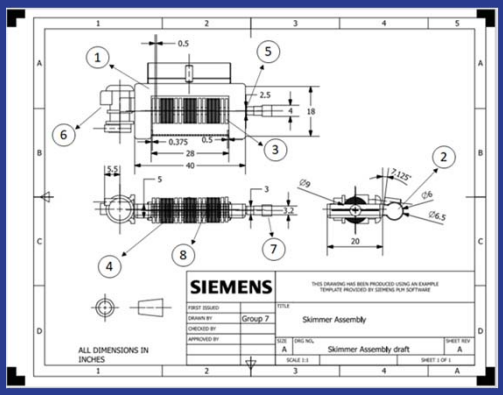


Figure 5.18 Assembled Oil Skimmer

5. Detailed System Design

5.5 Economic Analysis

The following table summarizes some of the data obtained from different suppliers:

Part #	Part Name	Part Specification/Description	Quantity Needed	Unit Price	Extended Price	Vendor Name	Vendor Phone #	Web-address
1	Skimmer Body	The skimmer frame is manufactured in Polyethylene HD, making it resistant to many chemicals found in industrial pits, sumps, separators, and tanks.	1	$1332.00	$1332.0	Elastec	(618)382-2525	https://www.elastec.com/products/oil-spill-skimmers/drum-oil-skimmers/minimax/
2	Tank	Vertical oval oil storage tank that features heavy-duty steel construction and can hold up to 275 Gal. The tank includes a vent-fill cap and a tank gauge.	1	$1,370	$1,370.0	Liquidynamics	(281)239-2777	https://www.homedepot.com/p/Liquidynamics-275-Gal-Vertical-Oval-Oil-Storage-Tank-with-Vent-Fill-Cap-and-Tank-Gauge-90100503/305613847
3	Disk	Rustlick - 4" Reach 12" Wheel Diam Oil Skimmer Disk - For Use with Disk Oil Skimmers	8	$57.72	$461.76	Strong Tooling	($88)-988-8820	https://strongtooling.com/products/90045775?variant=45664191304&currency=USD&utm_source=google&utm_medium=cpc&utm_campaign=google+shopping&gclid=CjwKCAiAzLr-BRBnEiwAPuCVk7TPPRHeQOVnbZvF9m_T8tPmFL3bX0TFeRiOhfFkVOn-4eZnBaAaAEALw_wcB



Total Skimmer Cost = $11,045.05 + Shipping and Handling

6. Results and Discussion

DISCUSSION OF COMPLETED WORK

- Fundamental analysis of skimmer designs and focus on initial constraints
- Schedule development and time constraints
- Development of a detailed system design

CODES AND STANDARDS

- Risk management
- Dimensioning and Tolerancing
- ASME standards on water waste separation
- Specifications given by The Bureau of Environmental Enforcement (BSEE)
- ASTM-2709-08 test methods give a requirement of a maximum ORR at a 70% performance

7. Conclusions and Recommendations

Key Points:

- 1.8 million gallons of petroleum are spilled in U.S. waters every year
- Current skimmer designs lack efficiency and consistency
- Only a small percentage of oil is ever recovered
- Beneficial for the environment
- Less is more



Questions?



AVERAGE

LOW SHOCK RESTRAINT AND DEPLOYMENT DEVICE FOR DEPLOYABLE SATELLITE APPENDAGES

Bryce Boyd
Asher Carson
Alexander Deshields
Kapiduach Echarry
Jeremy Hunter
David Otinwa
Kendall Lemons

PRESENTATION OUTLINE

1. Project Scope
2. Problem Statement
3. Client Identification
4. Recognition of Need
5. Goal Statement
6. Objectives
7. Potential Impact of Project
8. Task Identification
9. Timeline
10. Gantt Chart
11. Literature Review
12. Shape Memory Alloy
13. Permanent Magnets with Mechanical Mechanism
14. High Output Paraffin Actuators
15. Deltoid Toggle Linkage
16. Burn Wire Release Mechanism
17. Release through Mechanical Friction
18. Functional Decomposition
19. Concept Generation
20. Requirements List
21. Concept Evaluation
22. System Sketches
23. ID and Plans for Analysis
24. Detailed System Design
25. Summary of Goals and Objectives
26. Completed Work
27. Standards and Codes
28. Conclusion and Recommendations

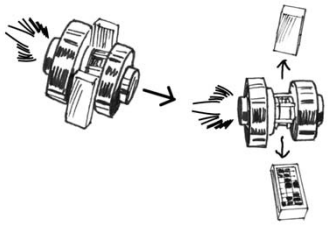
PROJECT SCOPE

- The project for "Low Shock Restraint and deployment Device for Deployable Satellite Appendages" will be **focusing on the design and implementation of a system to reduce shock and vibration upon deployment**.

2

PROBLEM STATEMENT

- Satellites include one-time deployable appendages.
  - These deployable components require mechanical restraint devices for launch ascent, subjecting the internal mechanisms to inertial, vibration, acoustic, and thermal loading.
- Current satellite appendage system uses pyrotechnics but due to the high vibration shock the satellite mechanism needs to be redesigned to reduce shock to the system's internal components during the required satellite separation process.



3

CLIENT IDENTIFICATION

- Ball Aerospace
  - Similar companies, such as, SpaceX and Lockheed Martin.
- Other industries where shock or heavy vibrations can cause damage to internal integrities.

4

RECOGNITION OF NEED



Reduction of the space footprint



Size



Lower cost applications



Increased opportunities for potential missions

5

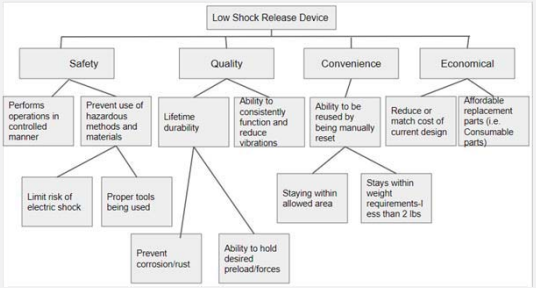
GOAL STATEMENT

- Formulate a solution and design a release mechanism that will reduce shock on electronic components upon release by developing or implementing existing technology.

6

OBJECTIVES

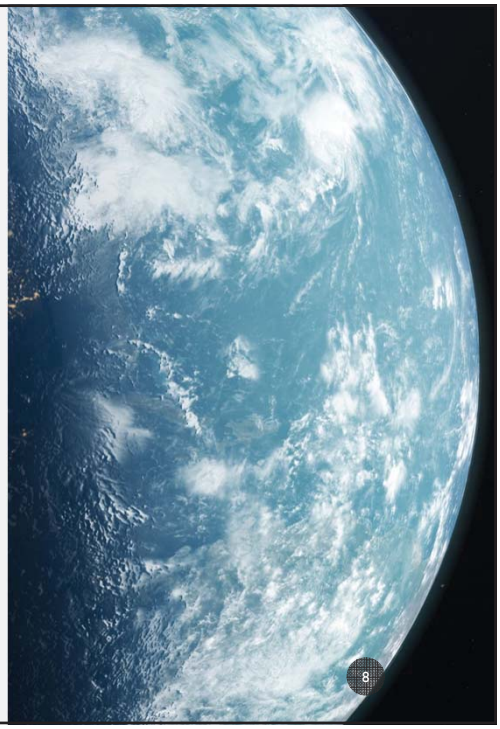
- Reduce vibration
- Ability to be reused/ manually reset
- Ability to last a lifetime
- prevent corrosion/rust
- Stays under weight- Reduce weight
- Stays within given area
- Performs operation in a controlled manner
- Prevent use of hazardous materials
- Reduce or match cost of current design
- Ability to consistently function-Reliability
- Simple design for demonstration purposes
- Affordable replacement parts (IE: Consumable parts)
- Precision
- Ability to hold any preloads/forces
- Modify with minimal economic effort



7

POTENTIAL IMPACT OF PROJECT

- Impact of Space Pollution
  - Due to the rate of speed and volume of debris in low Earth orbit, current and future space-based services, explorations, and operations pose a safety risk to people and property in space and on Earth.



8

INITIAL CONSTRAINTS

The team has established several constraints with the client:

- The device must be less than 2 lbs.
- The envelope size must be 3.5" in diameter and 3" long
- The allowable shock load must be less than 100 G's
- It must not require power to hold the load during ascension
- Should only require power when ready to be deployed
- Able to fully function in thermal conditions ranging from -60℃ to 80 ℃

9

PROJECT PLANNING AND TASK DEFINITION

10

TASK IDENTIFICATION

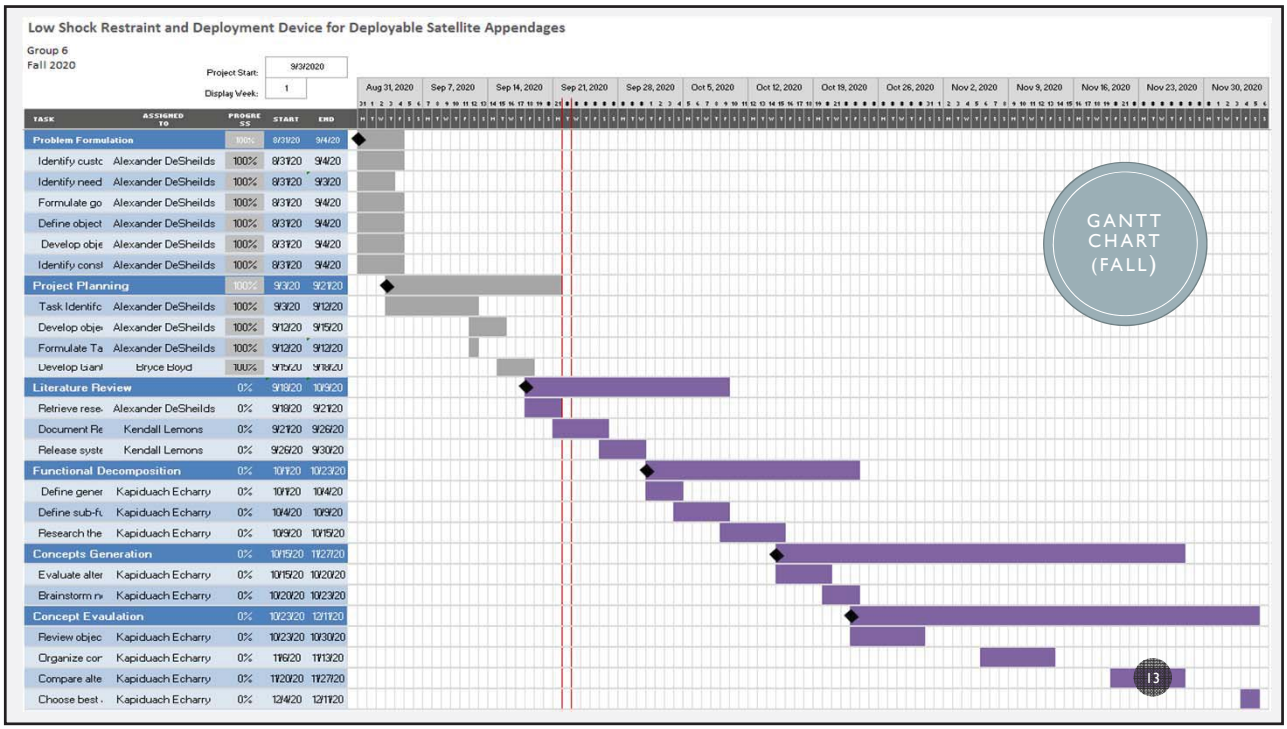
- Referring to class syllabus, senior design manual and the project sample document.
- The group strategically categorized the entire project's deliverables into categories and subcategories.
- Educated assumptions were made to the duration and deadlines formulated for each task.

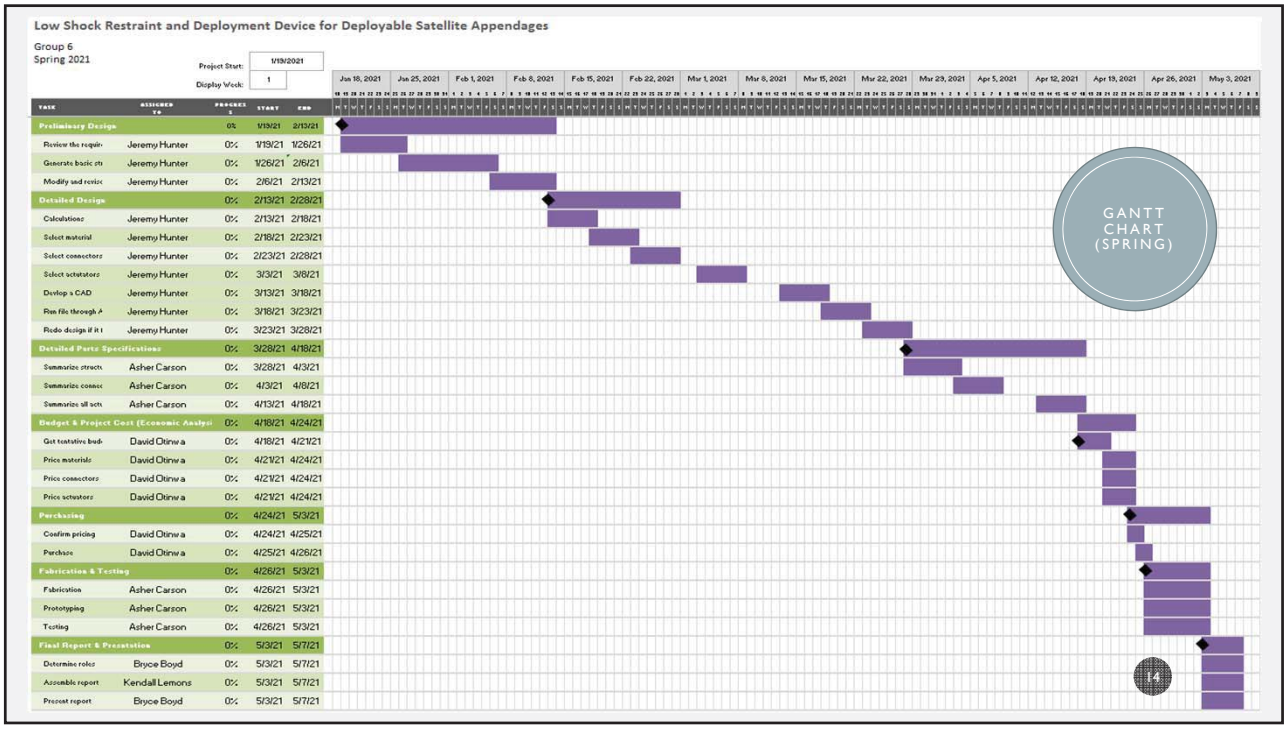
11

TIMELINE

Problem Formulation	Project Planning 9/3/2020-9/18/2020	Literature Review 9/18/2020-9/29/2020	Functional Decomposition 10/1/2020-10/15/2020	Concepts Generation 10/15/2020-10/22/2020	Concepts Evaluation 10/22/2020-12/11/2020
31 Aug. – 9 Apr. 2020	9 Mar. – 18 Sep. 2020	18 Sep. –29 Sep. 2020	10 Jan. – 15 Oct. 2020	15 Oct. –22 Oct. 2020	22 Oct. – 12 Nov. 2020

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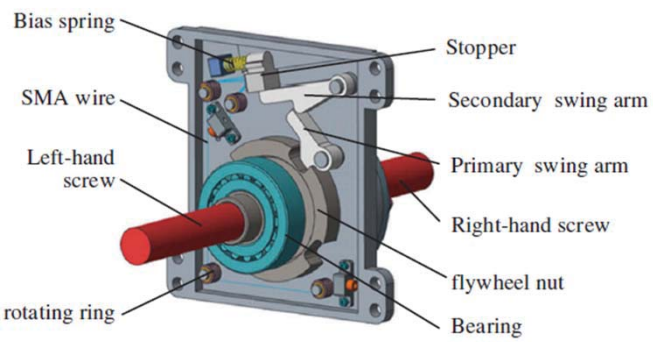
LITERATURE REVIEW

Provide the foundational knowledge required to properly understand the different mechanisms that can be used to solve the vibrational shock issue with the current design that is being utilized.

Identifying areas of prior scholarship to prevent duplication and give credit to other researchers.

Identify inconsistencies in research, conflicts in previous studies, and open questions left from other research.

15



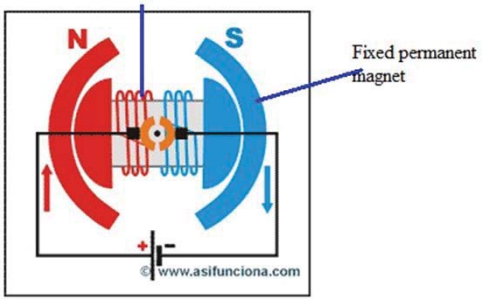
SHAPE MEMORY ALLOY

- Shape memory alloy holds down release mechanisms that use the alloy as a focal point, given its unique properties.
- They can be used in various applications and is a top-rated solution for low shock satellite appendages.

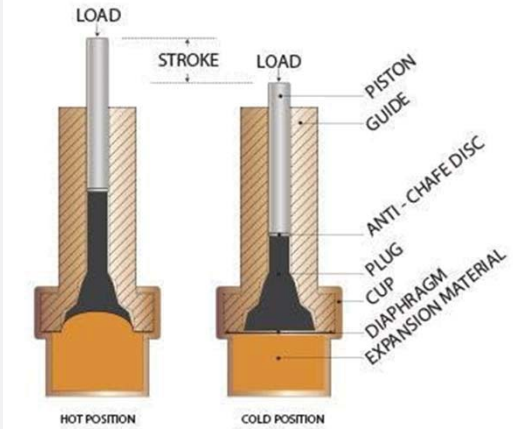
16

PERMANENT MAGNETS WITH MECHANICAL MECHANISM

- Permanent Magnets have an indefinite number of uses.
- From kid's toys to heavy machinery, permanent magnets are incredibly useful with different chemistries.



17



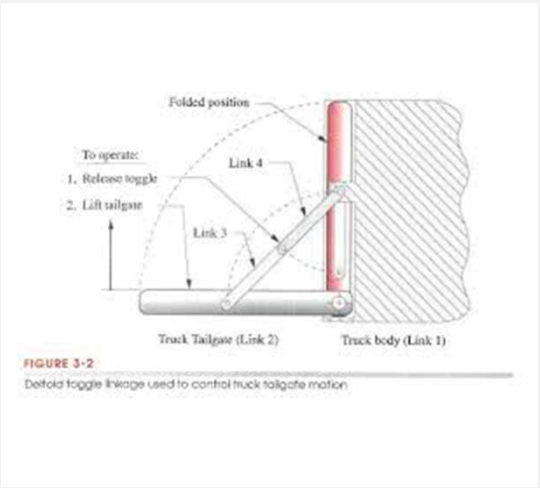
HIGH OUTPUT PARAFFIN ACTUATORS

- Used as linear motors in spacecraft mechanical systems.
- Heat energy to drive the devices is provided by either environmental temperature changes or electrically powered resistance heaters.

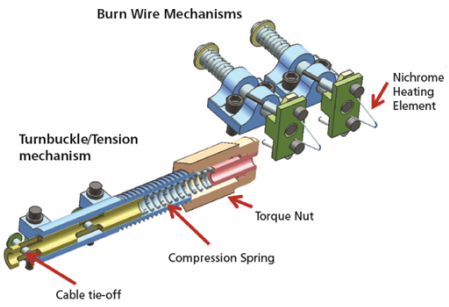
18

DELTOID TOGGLE LINKAGE

- Four-bar mechanism which consists of two pairs of equal and adjacent links.
- It is a Grashof Linkage for which the sum of the lengths of the shortest link and the longest link is equal to the sum of the lengths of the other two links.



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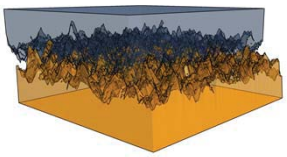
BURN WIRE RELEASE MECHANISM

- For a spacecraft or other system having two masses initially held together by a pretensioned loop, with a spring configured to push the masses apart.
- When an electrical current flows through the burn wire, the wire heats up and severs the pretensioned loop, and the masses are pushed apart by the spring

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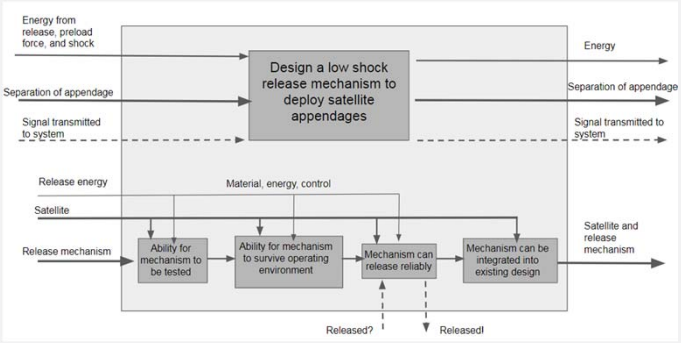
RELEASE THROUGH MECHANICAL FRICTION

- To prevent or slow down the movement of an item and is a concept that can be applied to this project.
- It has its own challenges that will be discussed in further detail.



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FUNCTIONAL DECOMPOSITION



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CONCEPT EVALUATION AND SELECTION

CONCEPT GENERATION

Overall Function	Level 1 Sub-functions	Level 2 Sub-functions	Level 3 Sub-functions	Concept 1		Concept 2		Concept 3		Concept 4	
				Description	Sketch	Description	Sketch	Description	Sketch	Description	Sketch
Deploy satellite appendages with minimal shock	Accommodates features that make it testable	Tests well with shock measuring testing devices	Tests well with specialized shock measuring testbeds- 1.1.1	Successful shock-test on testbed	Figure 4.9	Test Model and Removable Model	Figure 4.10	Release Concept That Can Test Shock	Figure 4.11	Release mechanism testable with shock	Figure 4.12
			Tests well with FEA software 1.1.2	Small Release Component, Low Potential Errors	Figure 4.13	FEA tested side release buckle	Figure 4.14	Folding table clamp release mechanism	Figure 4.15	Virtually no moving parts, releases via redirection of mechanical energy	Figure 4.16
		Resets once appendage is release.	Provides access to positions to be reset. 1.2.1	Easily Resettable Release.	Figure 4.17	Easily Accessible Mechanism	Figure 4.18	Release Mechanism Which is Easily Accessible	Figure 4.19	Release Mechanism Which is Easily Accessible	Figure 4.20
			Resets to locked position with minimal cost. 1.2.2	Durable Release, made for 40 Cycle Uses	Figure 4.21	Trunk lock reset to lock position	Figure 4.22	Efficeinlty resets to locked position	Figure 4.23	Concept Which Resets with Minimal Cost	Figure 4.24
	Endures operating environments without being damaged	Maintains functionality through launch.	Secures preload through launch- 2.1.1	HDRM securely holding release mechanism	Figure 4.25	Secure Holding by Release Mechanism	Figure 4.26	Mechanism holds preload through both launch and space	Figure 4.27	Aluminum Insulated and Thermal Insulated Envelopes	Figure 4.28
			Prevents damage to other components - 2.1.2	Protect internal mechanism	Figure 4.29	System is Enclosed with No Possibility of Releasing Space Debris	Figure 4.30	Concept That Protects Satellite Release System from Damaging Other Components	Figure 4.31	Concept That Protects Satellite Release System from Damaging Other Components	Figure 4.32

Overall Function	Level 1 Sub-functions	Level 2 Sub-functions	Level 3 Sub-functions	Concept 1		Concept 2		Concept 3		Concept 4	
				Description	Sketch	Description	Sketch	Description	Sketch	Description	Sketch
			Withstands temperature variation during launch-2.1.3	Protective Shell/Housing Allows System to Withstand Both Launch and Space Temperatures.	Figure 4.33	Frangibolt System can Withstand Both Launch and Space Temperatures Because Of High Strength Systems.	Figure 4.34	Shock is Easily Testable by Creating the Housing to Fit Around the Sensors	Figure 4.35	Concept that Survives Temperature Variation During Launch	Figure 4.36
		Maintains functionality in space.	Functions in given range of temperatures- 2.2.1	Concept that Survives Temperature Variation	Figure 4.37	AVCOAT Protects Against Temperature Ranges	Figure 4.38	Temperature resistant with magnetic release	Figure 4.39	Release through quicknut.	Figure 4.40
			Functions in vacuum environments. 2.2.2	Releases via actuator separation, designed to function in deep sea environments.	Figure 4.41	Kapton Tape Keeps the Satellite Vacuum Sealed and the Connectors Secure the Vacuum Seal	Figure 4.42	Concept Design Which Functions in Vacuum Environments	Figure 4.43	Choice of Clamp for Vacuum Environments	Figure 4.44
			Functions in environments that lack gravity. 2.2.3	Using Gears Allows the System to Not Need Gravity to Function	Figure 4.45	Using Magnetic Forces Allows the System to Not Need Gravity to Function	Figure 4.46	Concept That Functions in Environments That Lack Gravity	Figure 4.47	Concept That Functions in Environments That Lack Gravity	Figure 4.48

Overall Function	Level 1 Sub-functions	Level 2 Sub-functions	Level 3 Sub-functions	Concept 1		Concept 2		Concept 3		Concept 4	
				Description	Sketch	Description	Sketch	Description	Sketch	Description	Sketch
		Releases appendages autonomously. 2.2.4	Latch Release the Appendage Autonomously	Figure 4.49	Using Magnetic Forces Allows the System to Remain Locked and Idle Without Power	Figure 4.50	Releases autonomously in sliding motion	Figure 4.51	Release is signaled by sound signal	Figure 4.52
		Resists radiation environment 2.2.5	Burn wired composed of lead composite shielding.	Figure 4.53	Pin puller composed of polyethylene to reduce radiation	Figure 4.54	Kelvar is radiation resistant	Figure 4.55	Kapton tape is radiation resistant	Figure 4.56
	Maintains functionality while be stored for prolonged periods.	Holds continuous loading without failing. 2.3.1	Allows for appendages to be Held Without Failing	Figure 4.57	Allows for appendages to be Held Without Failing	Figure 4.58	Holds Continuous Loading Without Power	Figure 4.59	Using magnetic forces allows the system to remain locked and idle without power	Figure 4.60
		Resists corrosion during storage- 2.3.2	Protective Coating Prevents Corrosion During Storage	Figure 4.61	System Resists Chemical Corrosion Through the Use of a Protective	Figure 4.62	Protects from Corrosion	Figure 4.63	Concept Which Resists Corrosion During Storage	Figure 4.64
	Release appendages reliably	Release appendages properly (no jam)	Releases appendage without complexity. – 3.1.1	Simple release, release of cylindrical notch acts as the catalyst	Figure 4.65	Simple Clamp Style Release	Figure 4.66	Uses Simple Systems Such as Gear Trains to Release Appendage	Figure 4.67	Uses simple system like the Frangibolt to release appendage	Figure 4.68

Overall Function	Level 1 Sub-functions	Level 2 Sub-functions	Level 3 Sub-functions	Concept 1		Concept 2		Concept 3		Concept 4	
				Description	Sketch	Description	Sketch	Description	Sketch	Description	Sketch
			Uses predictable concepts -3.1.2	Uses Reliable Components Such as Gears to Release	Figure 4.69	Uses Well Researched Frangibolt System That is Known as Being a Reliable System	Figure 4.70	Concept Which Releases predictably	Figure 4.71	Concept Which Releases predictably	Figure 4.72
			Use reliable components- 3.1.3	Fracture of Nut Causes Release and Separation Causes Ejection, Causing Release	Figure 4.73	Reliable Latch Release System	Figure 4.74	Trusted Low Shock Device, Relies on Cables to Release Components and Does Not Rely on Pyrotechnics to Release Components , Redirects Energy.	Figure 4.75	Reliable release latch	Figure 4.76
		Releasing appendage does not damage system	Dampens amount of shock to systems- 3.2.1	Design Concept Meant to Dampens Amount of Shock	Figure 4.77	Oil Pump Absorbs Shock	Figure 4.78	Reduces Overall Shock	Figure 4.79	Dampens Amount of Shock to System	Figure 4.80
			Isolates any free moving parts- 3.2.2	Very Small Component, Moving Part Is Sealed and Narrowed for Direct Opening and Virtually No Moving Parts, Releases Via Redirection of ME.	Figure 4.81	Easily Isolated Parts from Flangybolt	Figure 4.82	Concept Which Isolates Any Free Moving Parts	Figure 4.83	Concept Which Isolates Any Free Moving Parts	Figure 4.84

Overall Function	Level 1 Sub-functions	Level 2 Sub-functions	Level 3 Sub-functions	Concept 1		Concept 2		Concept 3		Concept 4	
				Description	Sketch	Description	Sketch	Description	Sketch	Description	Sketch
		Release of appendage is timely		The Simple Latch Makes it Timely	Figure 4.85	Concept Design for a Timely Release	Figure 4.86	Quick dependable release	Figure 4.87	Timely release mechanism	Figure 4.88
	Integrates into existing satellite design	Materials used for mechanism will be compatible.	Attaches to satellite securely 4.1.1	Modified Material to Secure on Satellite and Modified Burn Wires to Fit Securely Around Satellite	Figure 4.89	Easy to Secure Release Mechanism	Figure 4.90	Attaches to Satellite Securely	Figure 4.91	Securely attaching release mechanism	Figure 4.92
			Resists galvanic corrosion in the system 4.1.2	Protective Coating Prevents Corrosion	Figure 4.93	Low Shock Band Resisting Corrosion	Figure 4.94	Design Which Resists Galvanic Corrosion in the System	Figure 4.95	Design Which Resists Galvanic Corrosion in the System	Figure 4.96
		Meets weight and load constrains	Causes minimum strain on other components 4.2.1	Tension release with low strain	Figure 4.97	Low strain release mechanism	Figure 4.98	HDRM Made to Resist Corrosion	Figure 4.99	Causes minimum strain on other components	Figure 4.100
			Weighs less than two pounds- 4.2.2	Lightweight release mechanism	Figure 4.101	Through the Use of Selective Materials and Shape Optimizatio n the System Can Be Limited to 2 Pounds	Figure 4.102	Release Concept That Weighs Less Than Two Pounds	Figure 4.103	Release Concept That Weighs Less Than Two Pounds	Figure 4.104

Overall Function	Level 1 Sub-functions	Level 2 Sub-functions	Level 3 Sub-functions	Concept 1		Concept 2		Concept 3		Concept 4	
				Description	Sketch	Description	Sketch	Description	Sketch	Description	Sketch
		Meets size constraints	Avoids displacing other components- 4.3.1	Pin Puller's Only Moving Part is Pin, Reducing Room for Error and Similar to Pin Puller, Redirects Mechanical Energy (No Moving Parts.)	Figure 4.105	Locks to Not Displace Other Components	Figure 4.106	Prevents Unwanted Contact	Figure 4.107	Low/no interference release	Figure 4.108
			Has high strength to weight ratio- 4.3.2	Pin Puller Composed of Aluminum, Functions Like Normal.	Figure 4.109	HDRM with High Strength to Weight Ratio	Figure 4.110	System is Strong Yet Light by Using Shape Optimizatio n and Alloys	Figure 4.111	Design Concept Which Has High Strength to Weight Ratio	Figure 4.112

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REQUIREMENTS LIST

1. Does not corrode
2. Resists radiation in space
3. Does not compress easily
4. Does not expand easily
5. Frequencies doesn't interfere w/ other mechanisms
6. Withstands obsoleting vibrations during launch
7. Withstands self-generated shock
8. Minimal free moving parts
9. Housed
10. Operates at -60 C
11. Operates at 80 C
12. Shock under 100G's
13. Material availability
14. Part manufacturable
15. Technology exists
16. No servicing while in operation
17. Minimal servicing to reuse
18. No servicing while in storage
19. Requires no additional support
20. Can not be further simplified
21. Easy to assemble
22. Easy to operate
23. Small production cost
24. Small maintenance cost
25. Small operational cost
26. Supports 50lbs of deployable mass
27. Bears 5000lbf axial preload
28. Bears small radial load
29. Maintains functionality w/o gravity
30. Doesn't interfere with launch aerodynamics
31. Testable / Repeatable
32. Accurate
33. Persistent
34. Can transmit accurate signal
35. Uses no power during ascent
36. Uses low power to deploy
37. Scalable
38. Releases in deployment window
39. Can be simulated
40. Less than 3.5 inches in diameter
41. Less than 3 inches in length
42. Less than 2 pounds
43. Remotely resettable
44. Electrically redundant actuators

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CONCEPT EVALUATION

Overall Function	Level 1 Sub-functions	Level 2 Sub-functions	Level 3 Sub-functions	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Deploy satellite append-ages with minimal shock	Accommo-dates features that make it testable	Tests well with shock measuring testing devices	Tests well with specialized shock measuring testbeds- 1.1.1	15	6	31	7	37	43	12	14	32	39	34	25				
			Tests well with FEA software 1.1.2	39	13	14	22	15	31	20	21	37	33	32	12	8	25	19	
		Resets once appendage is release.	Provides access to positions to be reset. 1.2.1	43	9	8	21	25	31	30	22	15	34	7	38	36	6	32	
			Resets to locked position with minimal cost. 1.2.2	25	23	24	15	13	9	31	14	22	43	37	44	21	29	36	17
	Endures operating environ-ments without being damaged	Maintains functionality through launch.	Secures preload through launch-2.1.1	7	8	13	14	15	6	26	27	28	31	32	33	36	43	38	30
			Prevents damage to other components - 2.1.2	8	5	1	36	12	31	16	40	41	42	35	26	7	18	30	20
			Withstands temperature variation during launch-2.1.3	9	10	11	2	13	14	16	26	34	35	3	4	12	37		
			Functions in given range of	9	10	11	2	13	14	16	26	34	35	3	4	12	37		

1.1.1 Tests well with specialized shock measuring testbeds	Concept 1		Concept 2		Concept 3		Concept 4	
	Hold and Lock Mechanism		SMA quick release		Clip friction release		Nonexplosive HDRM	
Criteria/ Requirements	Score	Weighted score	Score	Weighted score	Score	Weighted score	Score	Weighted score
Requirement 15		Go		Go		No-Go		Go
Requirement 31		Go		Go		Go		Go
Requirement 39		Go		Go		Go		Go
Requirement 7		Go		Go		Go		Go
Requirement 37		Go		Go		Go		No-Go
Overall Decision		Go		Go		Go		Go

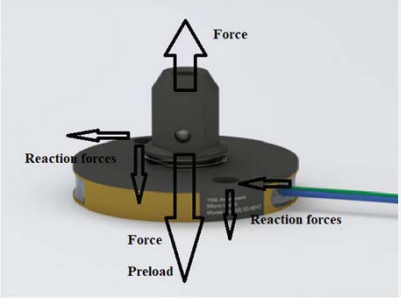
28

Tests well with FEA software 1.1.2		Concept 1		Concept 2		Concept 3		Concept 4	
		Tension Releases		Buckle release		Table clamp		Pin puller	
Criteria/ Requirements	Concept Weight	Score	Weighted score	Score	Weighted score	Score	Weighted score	Score	Weighted score
Requirement 15	2	10	20	10	20	6	12	10	20
Requirement 31	9	10	90	9	81	9	81	10	90
Requirement 39	10	10	100	10	100	9	90	10	100
Requirement 7	4	8	32	5	20	4	16	6	24
Requirement 37	5	5	25	7	35	2	10	10	50
Requirement 13	1	10	10	9	9	1	1	10	10
Requirement 14	3	10	30	10	30	1	3	10	30
Requirement 20	7	10	70	9	63	8	56	10	70
Requirement 32	6	7	42	3	18	3	18	10	60
Requirement 21	8	10	80	9	72	5	40	10	80
Overall Decision			499		448		327		534

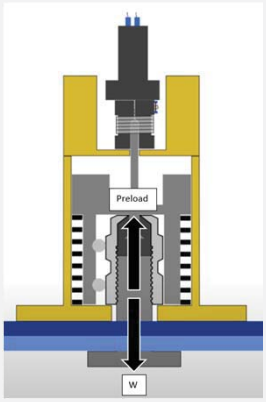
29

SYSTEM SKETCHES AND DESCRIPTION FOR TWO FINAL DESIGNS

SEPERATION NUT



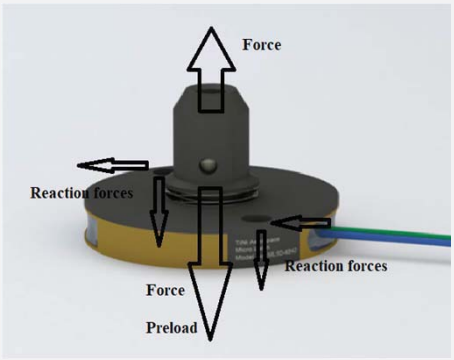
HOLDING BOLT



30

IDENTIFICATION AND PLANS FOR TYPES OF ANALYSIS NEEDED

ANALYSIS FOR FINDING THE FORCE REQUIRED FOR HOUSING SEPARATION



The free body diagram illustrates the separation nut's housing, and the forces required for actuation

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ANALYSIS EQUATIONS

Through FEA some of the analysis will not be provided at this time, these analyses will include Deformation and fatigue. These analyses can be provided for later designs.

$$F = m * a$$
$$m = mass$$
$$a = acceleration$$

To calculate the force created the assumption for accelerations will be set to $9.8\frac{m}{s^2}$, this assumption is made based on the fact that the device will be assembled on earth.

To determine the amount of weight/ bending force that the face of the housing device will be able to support before bending can be illustrated with the equation blow will be used.

$$F_b = \frac{K * T * W * t^2}{D}$$
$$F_b = Bending\ force$$
$$K = Constant\ for\ V - shape\ bending$$
$$T = Tensile\ strength$$
$$t = thickness$$
$$D = Diameter$$

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VALUES OF KNOWN VARIABLES

- Required preload will be P=5000lbf of axial preload, this value may vary but at a minimum must meet the 5000lbf requirement.
- The release device must be able to support/restrain at least a 50lbs mass, $m_{restraint}$=50lbs.
- The estimated dimensions of the release device are 3.5 inches in diameter, 3 inches in length and under 2 lbs.

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VALUES OF COMPUTED VARIABLES

- Force determined by mass of appendage

$$m = 50lbs = 22.68\ kg$$
$$222.26N = F = 22.68kg * 9.8\frac{m}{s^2}$$

- Relating force of mass to spring constant formula

$$F = -k * x \rightarrow -\frac{F}{x} = k$$

- Assumed spring displacement of 0.3 inches

$$0.3in = 0.0076m$$
$$-\frac{222.26N}{0.00762m} = -29.167.9\frac{N}{m} = k$$

- Calculating allowable weight/bending force that can be supported by the housing of release device.

$$240MPa = 34{,}809.06\frac{lb}{in^2}$$
$$t^2 = 0.1^2in = 0.01in^2$$
$$462.96\ lb = F_b = \frac{1.33 * 34{,}809.06 * 2 * 0.1^2}{2}$$

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VALUES OF COMPUTED VARIABLES CONTINUED

- Force that can be supported by a Ti-6Al-4V (Grade 5) titanium plate should not reach yielding, while also keeping a reasonable thickness for the plate.

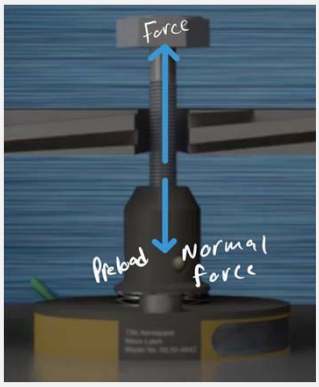
$$70\ MPa = 10152.6\ \frac{lb}{in^2}$$
$$t^2 = 0.25^2 in = 0.0625 in^2$$
$$135.03\ lb = F_b = \frac{1.33 * 10152.6 * 2 * 0.1^2}{2}$$
$$m = 462.96\ lbs = 210\ kg$$
$$2058N = F_2 = 210\ kg * 9.8\frac{m}{s^2}$$
$$F_1 < F_2$$
$$222.26N < 2058N$$

- Calculations got acrylic (PMMA) have also been provided as an alternative option, this may be due to environmental conditions or material properties. $m = 135.03\ lbs = 61.25\ kg$

$$600.25\ N = F_3 = 61.25\ kg * 9.8\frac{m}{s^2}$$
$$222.26N < 600.25N$$

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ANALYSIS FOR SIZING AND PARAMETERS OF THE CONSTRAINING BOLT



The free body diagram shows the forces acting on the constraint bolt that is required to secure the appendage.

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ANALYSIS EQUATIONS

- To analysis this system we will be calculating the minimum amount of torque required to reach our desired preload using the equation below.

$$T = K * D * P$$
$$T = Torque$$
$$K = Bolt\ Constant\ dependent\ on\ conditions$$
$$D = Crest\ Diameter\ of\ bolt/pin$$
$$P = Preload(desired)$$

- The following equations will be used to determine the stress that will need to be supported by the bolt. This will then help us determine the material needed to support the stress.

$$P = 0.75 * FP$$
$$P = 0.9 * FP$$

- Typically, the aim is to have total preload on the bolt to be equal to 75% of the proof load, or 90% if the bolt will not be reused.

$$FP = \sigma_p * A_t$$
$$FP = Proof\ load$$
$$\sigma = stress$$
$$A_t = Area\ of\ threads$$

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VALUES OF KNOWN VARIABLES

- Required preload will be P=5000lbf of axial preload, this value may vary but at a minimum must meet the 5000lbf requirement.
- The release device must be able to support/restrain at least a 50lbs mass, $m_{restraint}$=50lbs.
- The estimated dimensions of the release device are 3.5 inches in diameter, 3 inches in length and under 2 lbs.

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VALUES OF COMPUTED VARIABLES

$$T = K * D * P$$

Lubricated and Coarse 0.75-inch crest diameter

$$46.275\ lbf * ft = T_3 = 0.15 * 0.0625\ ft * 5000 lbf$$

Lubricated and Coarse 1.2-inch crest diameter

$$75\ lbf * ft = T_4 = 0.15 * 0.1\ ft * 5000 lbf$$

Reusable Bolt

$$\frac{5000}{.75} = FP_1 = 6667\ lbf$$

Will Not Reuse Bolt

$$\frac{5000}{.90} = FP_2 = 5556\ lbf$$

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COMPUTED VARIABLES CONTINUED

Clear and Dry Bolt Thread Areas

$0.75\ in$: $A_t = 0.373\ in^2 = 0.03108\ ft^2$

$1.2\ in$: $A_t = 0.663\ in^2 = 0.05525\ ft^2$

Light and Coarse Bolt Thread Areas

$0.75\ in$: $A_t = 0.334\ in^2 = 0.0283\ ft^2$

$1.2\ in$: $A_t = 0.606\ in^2 = 0.0505\ ft^2$

$$FP = \sigma_p * A_t$$

Reusable- Lubricated and Coarse 0.75 in

$$\frac{6667\ lbf}{0.0283\ ft^2} = \sigma_p = 235583.1 \frac{lbf}{ft^2}$$

Reusable- Lubricated and Coarse 1.2 in

$$\frac{6667\ lbf}{0.0505\ ft^2} = \sigma_p = 132019.8 \frac{lbf}{ft^2}$$

Non-Reusable- Lubricated and Coarse 0.75 in

$$\frac{5556\ lbf}{0.0283\ ft^2} = \sigma_p = 196325.1 \frac{lbf}{ft^2}$$

Non-Reusable- Lubricated and Coarse 1.2 in

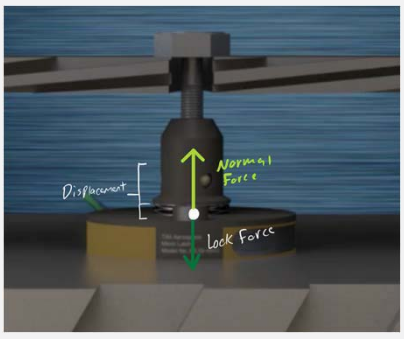
$$\frac{5556\ lbf}{0.0505\ ft^2} = \sigma_p = 110019.8 \frac{lbf}{ft^2}$$

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		Thread Area (A_t)	Proof load (FP)	K constant	Required Torque (T)	Stress (σ)
Reusable	Clean and Dry 0.75 in	$0.03108\ ft^2$	$6667\ lbf$	0.20	$62.5\ lbf * ft$	$1489.65\ psi$
	Lubricated and Coarse 0.75 in	$0.0283\ ft^2$	$6667\ lbf$	0.15	$100\ lbf * ft$	$837.98\ psi$
	Clean and Dry 1.2 in	$0.05525\ ft^2$	$6667\ lbf$	0.2	$46.275\ lbf * ft$	$1635.99\ psi$
	Lubricated and Coarse 1.2 in	$0.0505\ ft^2$	$6667\ lbf$	0.15	$75\ lbf * ft$	$916.8\ psi$
Nonreusable	Clean and Dry 0.75 in	$0.03108\ ft^2$	$5556\ lbf$	0.2	$62.5\ lbf * ft$	$1241.42\ psi$
	Lubricated and Coarse 0.75 in	$0.0283\ ft^2$	$5556\ lbf$	0.15	$100\ lbf * ft$	$1363.37\ psi$
	Clean and Dry 1.2 in	$0.05525\ ft^2$	$5556\ lbf$	0.2	$46.275\ lbf * ft$	$698.24\ psi$
	Lubricated and Coarse 1.2 in	$0.0505\ ft^2$	$5556\ lbf$	0.15	$75\ lbf * ft$	$764.02\ psi$

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ANALYSIS FOR FINDING THE FORCE REQUIRED FOR SPRING SEPARATION



The free body diagram is showing the springs and the forces required for separation. As the mechanism is locked the spring undergoes minor compression. Once released the spring force pushes the released housing that connects the lock mechanism to the satellite to achieve complete separation.

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ANALYSIS EQUATIONS

$$G = E/(2(1+v)$$

$$k = \frac{Gd^4}{[8nD^3]}$$

$$F = -k * x$$

$F = Force$

$k = spring\ constant$

$x = spring\ displacement$

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VALUES OF KNOWN VARIABLES

- Required preload will be P=5000lbf of axial preload, this value may vary but at a minimum must meet the 5000lbf requirement.
- The release device must be able to support/restrain at least a 50lbs mass, $m_{restraint}$=50lbs.
- The estimated dimensions of the release device are 3.5 inches in diameter, 3 inches in length and under 2 lbs.
- Modulus of elasticity of Titanium Ti-6Al-4V (Grade 5), Annealed, E, is 16500 ksi
- Poisons ratio for titanium is .342

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VALUES OF COMPUTED VARIABLES

$G = 16500ksi/(2(1 + .342)$= 6,147.54 ksi

$k = 6{,}147.54ksi(.125^4)/[8(5)1.125^3]$ = 181,676.855N/m^2

$F = -k * x$

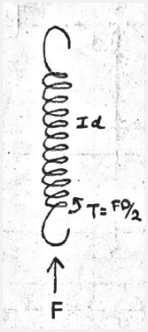
$x = .5in = 0.013m$

$-181676.855855\text{N/m}^2 * .013m = -2{,}361.79912\ N/m$



ANALYSIS FOR SMA COMPONENTS

ANALYSIS FOR FINDING THE TORQUE AREA AND SPRING STRESS IN THE DRIVE SPRING



The free body diagram displays the forces acting on the drive spring. The spring will support some of the weight and the preload as seen in the free body diagram.

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ANALYSIS EQUATIONS

- The first equation is to calculate the spring force:

$$F = -k \times x$$

- The following equation allows us to use find the spring constant, based on the properties of the material used.

$$G = \frac{E}{2(1+\nu)}$$

49

VALUES OF KNOWN VARIABLES

- The assumed values for the Young's modulus, E, is 120 GPa.
- The assumed Poisson's ratio, ν, is 0.31.
- The mass of the deployable load is, F, is given to be 50 lb.
- The assumed acceleration of gravity is 9.81 $\frac{m}{s^2}$.

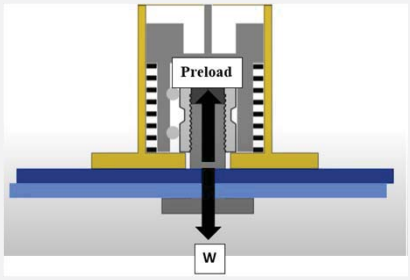
50

COMPUTED VARIABLES

$$F = -k \times x$$
$$F\ (force) = 50\ lbs$$
$$W\ (weight) = Force * gravity = 50\ lbs * 9.81\frac{m}{s} = 490.5\ NF\ (force) = 50\ lbs$$
$$490.5\ N = -k * 65\ mm$$
$$k = 7.54\ N/m$$
$$G = \frac{E}{2(1+v)}$$
$$E\ (elasric\ modulus\ or\ Young's\ modulus) = 120\ GPA$$
$$v\ (Poisson's\ ratio) = 0.31$$
$$G = \frac{120}{2(1+0.31)} = 45.8\ GPA$$

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ANALYSIS FOR FINDING MULTIPLE PARAMETERS OF THE HOLDING BOLT



The free body diagram displays the forces acting on the holding bolt. The holding bolt must hold the weight and the preload and is held. The preloaded force, indicated by P, is the force the bolt will need to hold as well as the weight of the deployable mass, W. These forces cause a tensile stress on to the bolt, and we can calculate the maximum preload allowable for the bolt.

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ANALYSIS EQUATIONS

To find the tensile stress for a bolt, the equation is required. This calculation gives us the stress acting on the bolt given the area.

$$\sigma_T = \frac{F}{A}$$

The force, *F*, is the preload of the bolt. The area of a bolt, *A*, is calculated by using this equation:

$$A = \frac{\pi}{4}(D - 0.9743p)^2$$

This equation is necessary for finding the overall force acting on the bolt.

$$F_T = \frac{\pi}{4} d_i^2 * \sigma_T * n$$

Lastly, the equation to calculate the overall preload of the bolt is given using this equation.

$$F_{Pl} = \%_{yld} * S_{yt} * A$$

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COMPUTED VARIABLES

Area of the bolt

$$A = \frac{\pi}{4}(D - 0.9743p)^2$$

$$A = \frac{\pi}{4}\left(1.2\ in - 0.9743(0.6in)\right)^2$$

$$A = 0.45\ in^2$$

Tensile Stress

$$\sigma_T = \frac{F}{A}$$

$$\sigma_T = \frac{5000\ lbf}{0.45\ in^2}$$

$$\sigma_T = 7464.06\ psi$$

Total Force

$$F_T = \frac{\pi}{4} d_i^2 * \sigma_T * n$$

$$F_T = \frac{\pi}{4}(1.2\ in)^2 * 7464.06\ psi * 16$$

$$F_T = 135066.44\ lbs$$

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COMPUTED VARIABLES CONTINUED

Preload of the bolt

$$F_{pl} = \%_{yld} * S_{yt} * A$$

$$135066.44\ lbs = 60\% * S_{yt} * 0.46\ in$$

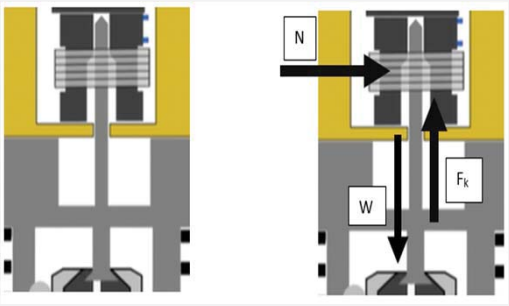
$$S_{yt} = \frac{135066.44\ lbs}{60\% * 0.46\ in}$$

$$S_{yt} = 103592.56\ psi$$

$$S_{yt} = 103.59\ kpsi$$

55

ANALYSIS OF THE FORCE REQUIRED TO ACT ON THE SLIDING NAIL



The component that is the focus of this analysis is the wires holding the sliding nail in place. Because of the nature of the mechanism, the wires will be subjected to forces in both the x and y direction. The weight of the mechanism will influence the wires as well as the pre-loaded force of 5000 pounds acting in the x direction

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ANALYSIS EQUATIONS

- The force of the actuator will push the sliding nail upward, causing the component to apply force on the latch/release component resulting in a release. This force can be denoted as a force of kinetic friction or F_k. To calculate the forces of the kinetic friction the equation is

$$F_k = \mu_k N$$

- We will have to two major forces acting on the spring, we will use the force equilibrium equation to compute all the forces acting on the sliding nail.

$$+\uparrow \Sigma F_y = F_k - W$$

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VALUES OF KNOWN VARIABLES

- The given axial preload, P, required would be like the weight pulling down on the bolt, P=5000 lbs.
- We are given that the mass of the preload is 50 lbs.
- The acceleration of gravity is 32 ft/s^2.
- We can assume that the materials needed for the bulk of the component will be clean, and dry aluminum, making the coefficient of kinetic friction, μ_k, 1.4

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VALUES OF COMPUTED VARIABLES

$$F_k = (1.4)(5000\ lbs) = 7000\ lbs - force$$

- The above equation represents the calculation of the kinetic friction acting on the sliding nail, with 1.4 representing the coefficient of kinetic friction and 5000 representing the weight of the pre-load itself.

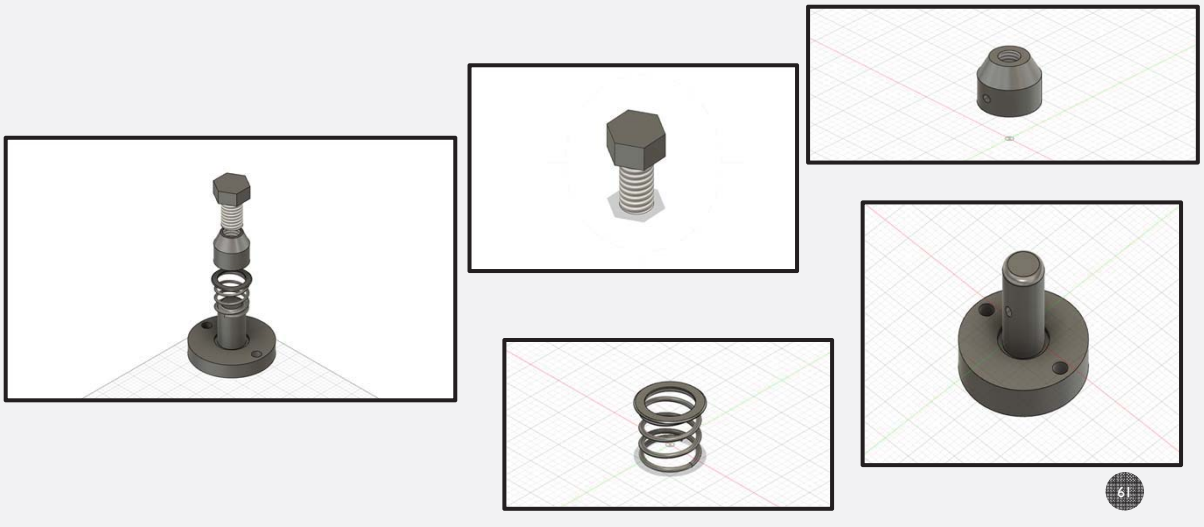
$$+\uparrow \Sigma F_y = 7000 - 50(32\frac{ft}{s^2}) = 5400\ lbs - force$$

- The above equation represents the summation of the forces acting on the sliding nail. The major forces that will be acting on the component are the force of kinetic friction and the weight of the entire mechanism.

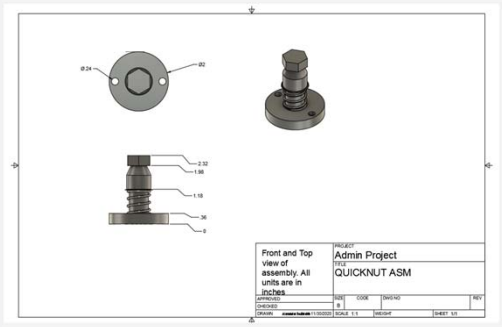
59

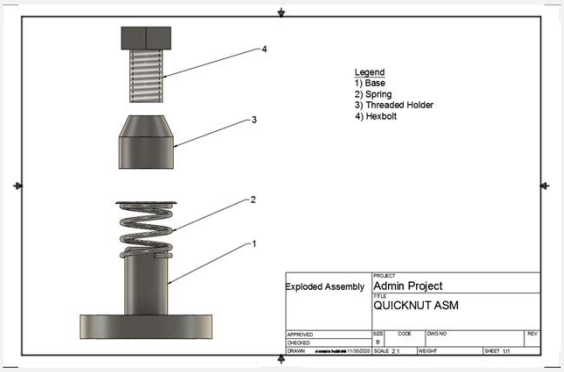
DETAILED SYSTEM DESIGN CONTINUED

CAD MODELS



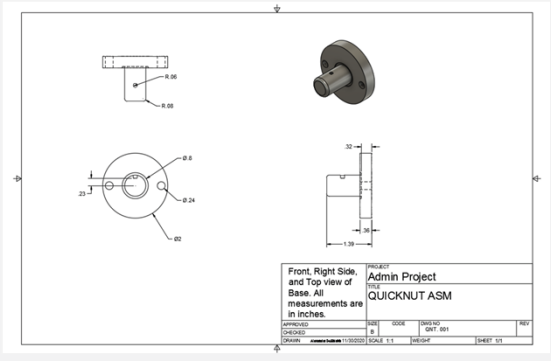
ENGINEERING DRAWINGS

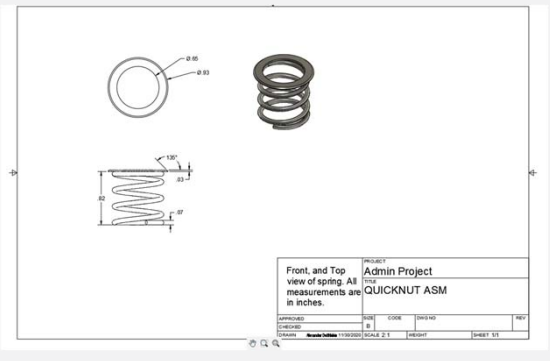




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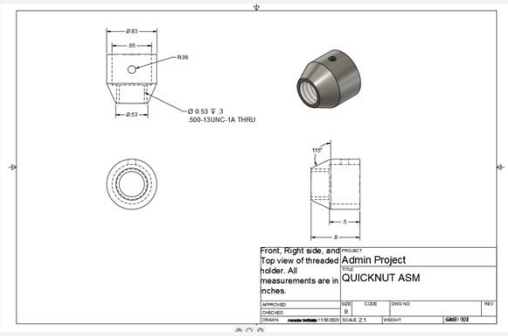
ENGINEERING DRAWINGS

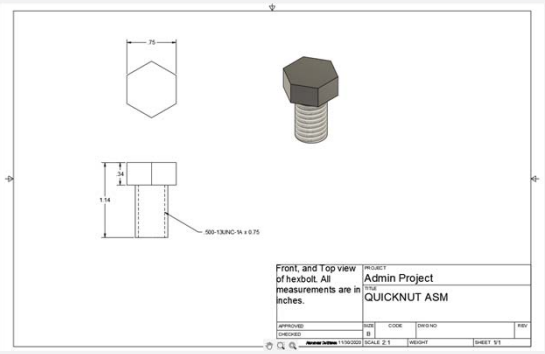




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ENGINEERING DRAWINGS





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ECONOMIC ANALYSIS

Part #	Part Name	Part Specification/Description	Quantity Needed	Unit Price	Extended Price	Vendor Name	Vendor Phone #	Web-address
1	Quicknut Base	Titanium base, 2 inches diameter and 1.25 inches in height. Fixed object.	1	285	285	Tiger titanium	5627770999	www.tigertitanium.com
2	Threaded Holder	Titanium Holder, 1 Piece design. Will release with bolt & appendage.	1	96	96	Tiger titanium	5627770999	www.tigertitanium.com
3	Spring	Stainless Steel spring with a unsprang height of .8 inches.	1	20.00	200.00	Acxess Spring	951-276-2777	acxesspring.com
4	Bolt	A-286 High temperature Fasteners Minimum of 10 units	2	9.95	99.50	Extreme Bolt & Fastener	888-393-4517	Sales@extreme-bolt.com
5								
6								
7								
8								
9								
				Total	680.5			

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SUMMARY OF GOALS AND OBJECTIVES

- Tasked with determining an appropriate design that is functional in a variety of elements and conditions.
- Reduce shock to system's internal components

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COMPLETED WORK

Following in accordance with the requirements and deadlines of Ball Aerospace

- ✓ Concept Generation and Evaluation
- ✓ Design Selection
- ✓ Design Analysis and Completion

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- EN9100:2018 — also called AS9100D or AS9100- standardizes quality management system requirements for companies involved with the aerospace industry and supply chain.
- AS9100- This standard is intended for use by organizations whose primary business is providing maintenance or continuing airworthiness management services for civil or military aviation articles and products.
- Standard ES44 Which outlines the best drafting practices to have a properly drawn part drawing
- ES3 Fabricating Tolerances, to allow for consistent parts during fabrication
- General ASME standards for design development and fabrication
- AMS5643T Steel, corrosion resistant, bars, wires, ... standard

These standards were chosen to make our part both structurally sound and universally compatible

STANDARDS AND CODES IDENTIFIED

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CONCLUSIONS AND RECOMMENDATIONS

- Based on the team's current findings, it has been determined that the market for this product includes aerospace companies, automotive, and possibly implementation into civil design. The primary need for such design in these fields is to prevent shock through the structure to avoid damages and protect sensitive electronics onboard.
- Based on current design needs, team 6 has researched mechanical systems that require low maintenance and resources. However, our literature review and functional decomposition discussed various other methods involving magmatism and fluid mechanics that can be further developed for alternative purposes and achieve similar goals.
- Based on our analysis, and between further discussion with our project owner, team 6 has decided to go with the separation nut for our final design

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QUESTIONS?
COMMENTS?

BELOW AVERAGE

Experimental Design to Measure Heat Transfer Coefficient and Effective Thermal Conductivity in Nanofluids Under Different Boundary Conditions

By: Diana Morales, Fanta Kaba, Christian White, Yemboado Brayan Yonli,

Abdullah EL Aker, Marcelo Epam Ona

Presentation Outline

- Motivations
- Problem Statement
- Client Identification & Need
- Objective Tree
- Project Constraints/Operating Environment
- Project Planning
- Gantt Chart
- Literature Review
- Major Components of Designs & Functions
- Equations and Formulas
- Summary of Literature Review
- Functional Decomposition
- Concept Evaluation Selection
- Detailed Analysis
- Detail Design CAD Models & Drawings
- Conclusion

Motivation and Reasoning

- Creation of simpler inexpensive set up that will allow the measurement of the thermal properties of a nanofluid
- Nanofluid are used in multiple industries and multiple devices such as CPU's or GPU's for their cooling properties
- Fast accurate method will make the choice of a cooling fluid faster and will greatly simplify the choice of a cooling fluids

Problem Statement

Measurement of heat transfer coefficient and thermal conductivity of nanofluids do not accommodate under different boundary conditions; therefore, an effective measurement technique will be selected to adapt to the change of properties of the nanofluids.

Client Identification & Need

Potential Clients:

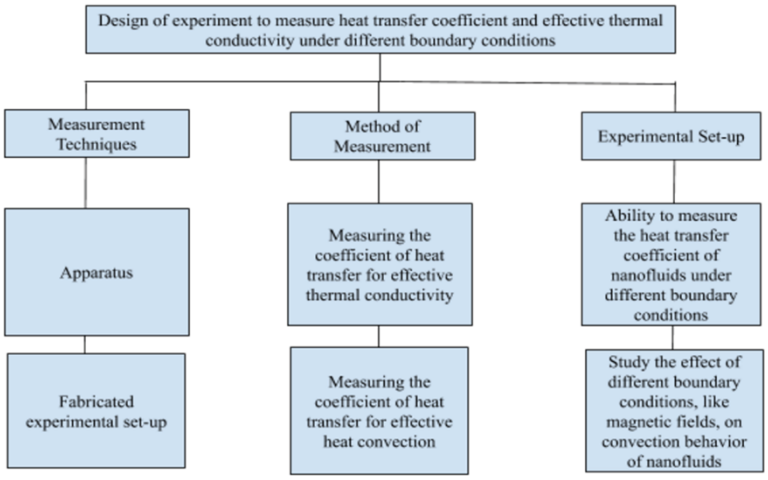
- Engineers
- Professors
- Scientist
- Engineering Firms (Koch Heat Transfer Company)



Understanding the Need:

- Due to their anomalous thermal behavior, current methods do not adequately predict the order of magnitude of thermal conductivity.
  - Reason: nanofluids carry an enhanced thermal conductivity, relative to the base fluid.
- A proper measurement technique will help form an educated hypothesis on understanding how to manipulate the nanofluid and the environment to gain accurate readings in order to effectively manipulate them to achieve the desired outcomes.
- Cool down CPU's

Objective Tree



Project Constraints



- Design should withstand flexible boundary conditions.
  - adding or removing magnetic fields
- Technique must be applicable to nanofluids.
- Material selection for high temperatures.
  - Material chosen for this experiment must be able to sustain high level temperatures. Ex: Borosilicate glass up to 400 °C.
- Ability to withstand high pressures
  - Maximum pressure for glass is 25 to 30 Psi.
- A strong magnetic field (1000 Gauss or more)

Project Planning

To successfully undertake the design of this experiment in its entirety, it is important that the framework for this project is clearly outlined and defined.

2. Project Planning

2.1 Identify the tasks.

-Objective: Clear understanding of task.

-Deliverable: List of tasks.

-Members: Diana Morales

-Timeline: 2 days

2.2 Develop objectives for each task.

-Objective: Develop objectives.

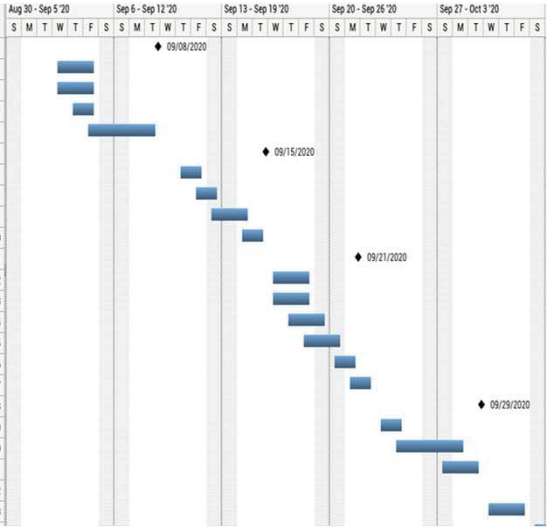
-Deliverable: Specify all requirements to complete the task.

-Members: Fanta Kaba

-Timeline: 2 days

Gantt Chart

	Name	Duration	Start	Finish
1	1. Problem formulation	7days	09/02/2020	09/08/2020
2	1.1 Identify the consumer that may need the product and understar	3days	09/02/2020	09/04/2020
3	1.2 Have a clear understanding of the output that is needed	3days	09/02/2020	09/04/2020
4	1.3 Have clear cut objectives while designing the product	2days	09/03/2020	09/04/2020
5	1.4 Understand the limitation of the design and the product	5days	09/04/2020	09/08/2020
6	2. Project planning	6days	09/10/2020	09/15/2020
7	2.1 Have a schematic and a clear idea about what the project and i	2days	09/10/2020	09/11/2020
8	2.2 Develop objectives (actions needed) for each task.	2days	09/11/2020	09/12/2020
9	2.3 Set up estimate dates in which each task might be completed.	3days	09/12/2020	09/14/2020
10	2.4 Give a visual representaation of the timelime	2days	09/14/2020	09/15/2020
11	3 Literature Review	6days	09/16/2020	09/21/2020
12	3.1 Understand the background of the project and I have a clear ic	3days	09/16/2020	09/18/2020
13	3.2 Understand the mechanism behind convection heat transfer for	3days	09/16/2020	09/18/2020
14	3.3 Understand how a change of boundary condition like magnetic	3days	09/17/2020	09/19/2020
15	3.4 Identify different measurement technique for convection and so	3days	09/18/2020	09/20/2020
16	3.5 Obtain a range of results that will help make sure that experim	2days	09/20/2020	09/21/2020
17	3.6 Conclusion of the literature review	2days	09/21/2020	09/22/2020
18	4. Functional Decomposition	7days	09/23/2020	09/29/2020
19	4.1 Define the general function and what is to be accomplished by	2days	09/23/2020	09/24/2020
20	4.2 Define the main functions aof what is to be accomplished	5days	09/24/2020	09/28/2020
21	4.3 Break each second level function into sub function until the poi	3days	09/27/2020	09/29/2020
22	5. Concept Generation	6days	09/30/2020	10/05/2020
23	5.1 Generating concepts using concept generation techniques	3days	09/30/2020	10/02/2020



Literature Review

- Identify potential sources of information (books journals research papers)
- Study of nanofluids
- Study of nanofluids under different boundary conditions
- Study of different measurement techniques for convection and their advantages
- Collection of comparable results



Major Components of Designs & Functions

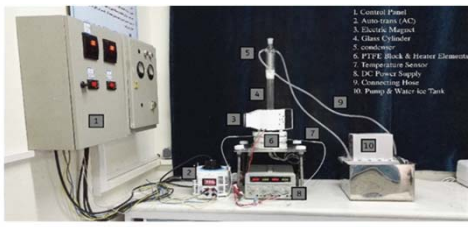


Fig. 1 Boiling device Overview

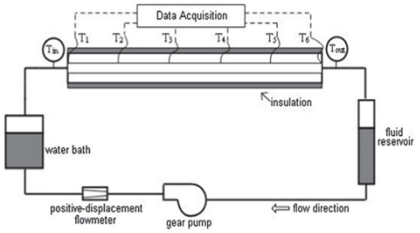


Fig. 3 Schematic of heat transfer Test rig

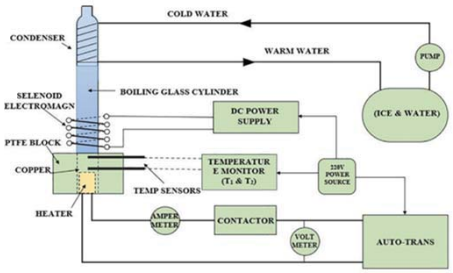


Fig. 2 The operational diagram of the boiling device

Equations and Formulas

General Equation

$E_{tot} = E_{in} - E_{out} + E_{Storage}$

Thermal Fluid Heater

$Q = M \times C_p \times \Delta T$

Flow Rate

$M = Q / (C_p \times \Delta T)$

Heat Loss

$L_{Conduction}$ = Thermal Conductivity of Material Accepting Heat x Area of Contact x ΔT x 1 Hour Per Thickness of Material Accepting Heat

Convection Loss

$L_{Convection}$ = Surface Loss (W/in2) x Area x 1 hr

Radiation Loss

$L_{Radiation}$ = Radiation Loss (W/in2) x Area x Emissivity x 1 hr

Resistance Temperature Detectors (Sensors)

For Temperature: $-200^{\circ}C \le t \le 0^{\circ}C$,

$R_T = R_o[1 + AT + BT^2 + (t - 100)CT^3]$

For Temperature: $0^{\circ}C \le t \le 661^{\circ}C$

$R_T = R_o(1 + AT + BT^2)$

Callendar - Van Dusen constants

$A = \alpha + (\alpha\delta)/100$

$B = -(\alpha\delta)/100^2$

$C = -(\alpha\beta)/100^4$

$\alpha = (R_{100} - R_o)/(100 + R_o)$

β = constant if $t < 0$ °C, else zero

$\delta = (R_o[1 + \alpha(260)] - R_{200})/(4.16\, R_o\alpha)$

Heat Loads and Condensers

$h = c_p \rho\, q\, dt$

Evaporator water flow rate

$q_{evap} = 24\, h_{evap}/dt$

Condenser water flow rate

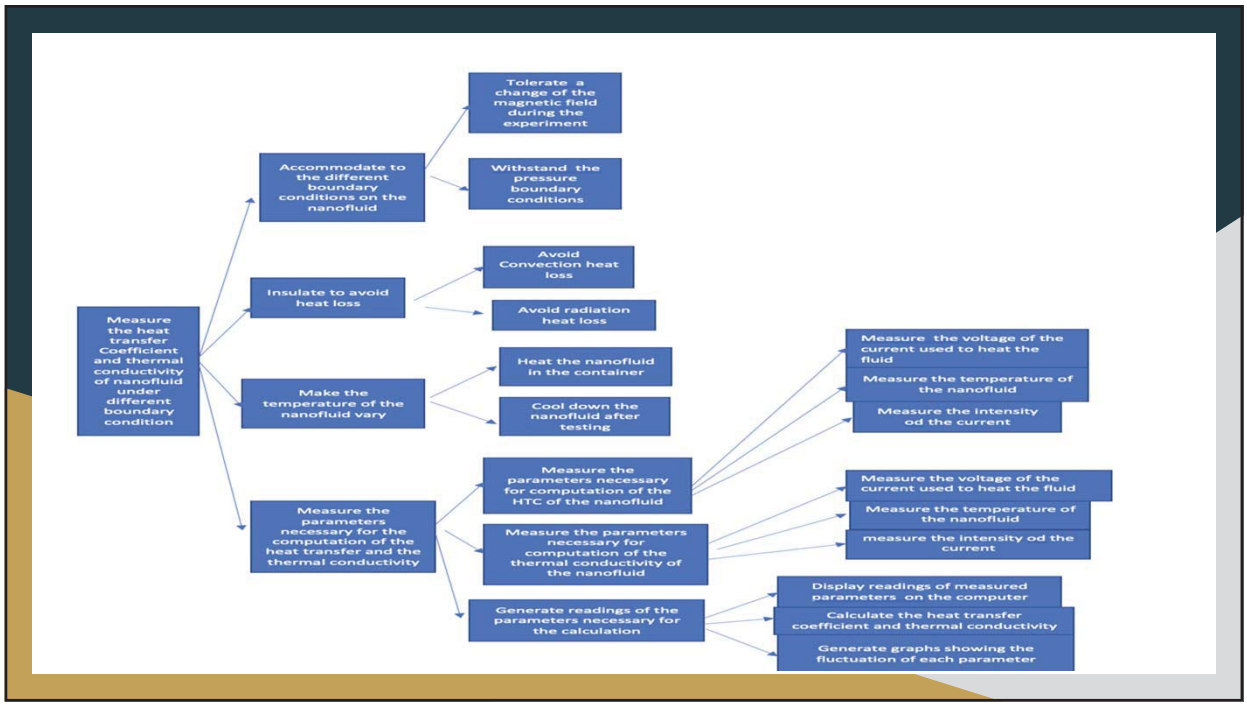
$q_{cond} = 30\, h_{cond}/dt$

Summary of Literature Review

This experiment is to assign the proper measurement method for convection transfer coefficient for nanofluids under different boundary conditions, which are the **direct method** and **transient method**. In order to completely understand the scope of this experiment, the identification of relevant information is necessary to ensure the functionality in the measurement technique selected. Relevant sources are reviewed to establish a well planned literature review, which focuses on examining existing similar designs and its components, relevant design analysis methods, fabrication and testing, as well as, relevant codes and standards.

Functional Decomposition

- Functions based on the what the group desire the apparatus to be capable of
- Functions are going from level 0 to level 3. Each level being a sublevel of the level above
- Function decomposition chart represented below
- Then followed by the function decomposition table



Functional Decomposition Table

Table 4.1|Morphology table

Overall Function	Level 2 Sub-functions	Level 3 Sub-functions	Concept 2		Concept 3		Concept 4		
			Sketch	Description	Sketch	Description	Sketch	Description	Sketch
Measure the heat transfer coefficient and the thermal conductivity of nanofluid under different boundary conditions	Make the temperature of the nanofluid vary	Heat up the nanofluid before pumping							
		cool down the nanofluid after the measurements are made							
	Insulate to avoid heat loss	Avoid convection heat loss							
		Avoid radiation heat loss							

Concept Generation

Overall Function	Level 1 Sub-functions	Level 2 Sub-functions	Level 3 Sub-functions	Concept 1		Concept 2		Concept 3		Concept 4	
				Description	Sketch	Description	Sketch	Description	Sketch		
Measure the heat transfer coefficient and the thermal conductivity of nanofluid under different boundary conditions	Create a temperature variation in the nanofluid	Heat up the nanofluid before pumping		Ban heater	Figure 4.21	Heat exchanger	Figure 4.22	Boilers	Figure 4.23	Hot plate	Figure 4.24
		Cool down the nanofluid after measurements		A condenser	Figure 4.25	cold plates	Figure 4.26	"Open feedwater cooler"	Figure 4.27	a liquid cooling heat exchanger	Figure 4.28
	Accommodate to different type of boundary conditions for the experiment	Accommodate to the magnetic field change		Stainless steel	Figure 4.29	The permeability	Figure 4.30	Crystals pipes	Figure 4.31	Magnetic field stabilizer	Figure 4.32
		Accommodate to the pressure boundary condition change		A pressure sensor	Figure 4.33	The pressure sensor	Figure 4.34	pressure Sensor	Figure 4.35	a control valves.	Figure 4.36
	Measure the heat transfer coefficient and the thermal conductivity of the nanofluid	Measure the heat transfer coefficient of the nanofluid in the experiment	Measure the voltage(V) drop in the boiler	Analog voltmeters	Figure 4.37	The control	Figure 4.38	An analog multimeter	Figure 4.39	A digital voltmeter	Figure 4.40
			Measure the temperature of the nanofluid (Tin and Tout)	Multipoint temperature sensors"	Figure 4.41	A temperature gauge"	Figure 4.42	"Thermistors"	Figure 4.43	"The KD2 Pro"	Figure 4.44

Concept Evaluation and Selection

List of criterias:

What customer requirements are related to the project?

1) safety
2) cost effectiveness
3) Ease to operate

What operating environments are related to the project?

1) Applicable to lab settings
5) Eliminate radiation
6) Eliminate convection

GO-NO-GO

Function: Cool down the Nanofluid after the measurement are made

Concepts	Concept 1	Concept 2	Concept 3	Concept 4
Concepts title	Condenser	Cold plate	Heat sink	Liquid cooling heat exchanger
Criteria/Requirement	GO-NO-GO	GO-NO-GO	GO-NO-GO	GO-NO-GO
Safety	GO	NO	GO	GO
Feasibility	GO	NO	GO	GO
ease assembly	GO	NO	GO	GO
Overall Decision	GO	NO-GO	GO	GO

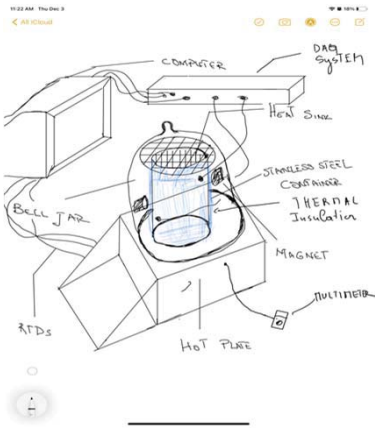
Decision Matrix Table

Function: Cool down the Nanofluid after the measurement are made

Concepts		Concept 1		Concept 2		Concept 3	
Concepts title		Heat sink		Liquid cooling heat exchanger		condenser	
Criteria/Requirement	Weights	Scores	Weighted Score	Scores	Weighted Score	Scores	Weighted Score
Safety	9	10	90	7	63	6	54
Cost effectiveness	7	7	49	6	42	5	35
weight	5	8	40	7	35	6	30
Ease to assembly	6	6	36	5	30	7	42
Speed	7	8	56	5	35	7	49
Ease to operate	8	5	40	7	56	6	48
Overall Decision			311		261		258

Representation of the Primary Apparatus

A representation of the primary apparatus based on the grades obtained by the concepts in the matrix evaluation.



Detailed Analysis

Analysis Equations for Aluminum Foil Tape

$$L \times W = A \qquad (21)$$

Where,
A=Area of the tube
L=Length of foil to cover tube
W= width of the foil wrap around tube

Values of known variables

It can be assumed that the surface area to be covered would be about 5 inches.
The length of the foil could be 6 inches to cover the tube.
The width could be about 1 inch.

Values of computed variables

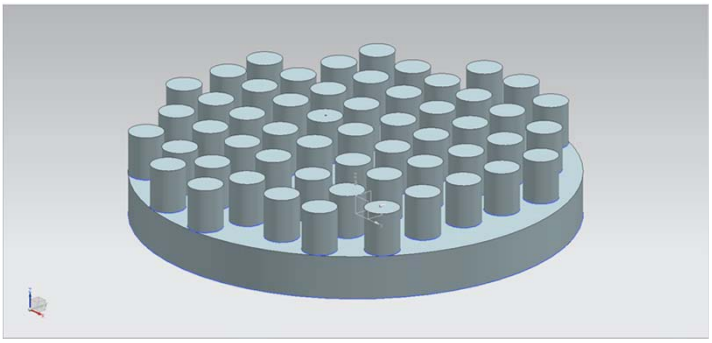
To calculate the surface area needed, the known and estimated variables can be substituted to get an idea of how much foil is needed. This is done by using equation 3.

$6 \text{ in.} \times 1 \text{ in.} = 6 \text{ in}^2$



Tape Width	Tape Length	Tape Thickness	Tape Shape	Max. Tape Performance Temp.	Min. Tape Performance Temp.	Item #	Price
Series 433L Silicone Adhesive Foil Tape with Aluminum Tape Backing Material							
1/2 in	5 yd	3.5 mil	Continuous Roll	600 Degrees F	-65 Degrees F	45K241	$28.00 / each

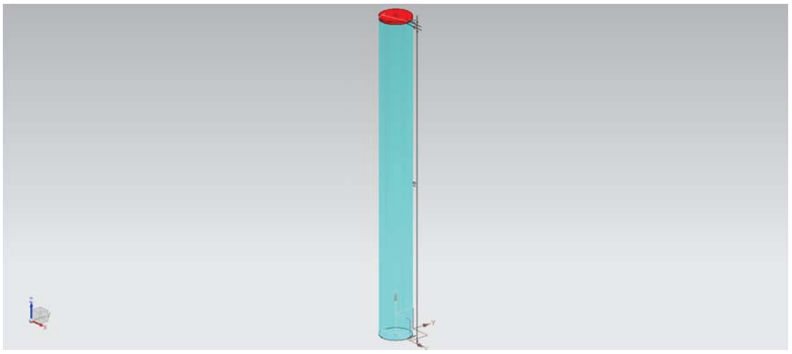
Detailed Design CAD Models & Drawings



Heat Sink

This figure is the designated heat sink which will be used in the systematic to increase the heat flow within the nanofluid as it travels throughout the system. It will increase the working surface area of the system to which the nanofluids cooling particles will pass and allow the nanofluid to stay within a state of harmony.

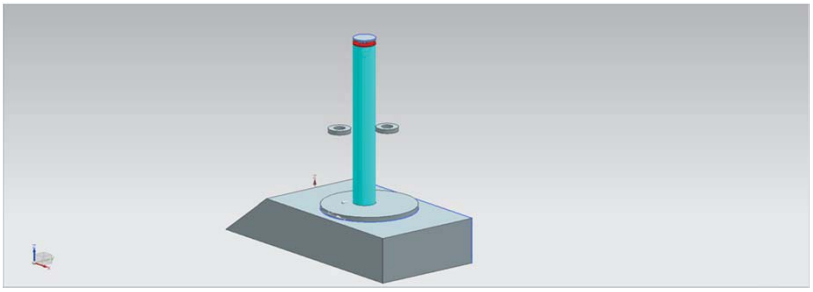
Detailed Design CAD Models & Drawings



Tube Container

This figure represents the tube container tube that each sample will be placed in. There will be a hole on the top (red) for the nanofluid to go in and out of the tube. Multiple tubes will be added for different tests under different boundary conditions. Figure 5.34 represents the dimensions of the container tube from top, side, and front views to provide a better view of the component. all the dimensions used are in inches.

A Model Assembly of the Design Party



Model will be covered by a bell jar
2 RTD will be placed on the top and bottom and 4 others at various heights in the set up. A heat sink will be placed on the te to allow heat dissipation.

Parts Specifications, Vendor Information and Cost Summary Table

Table 5.1 Parts Specifications, Vendor Information and Cost Summary Table

Part #	Part Name	Part Specification/Description	Quantity Needed	Unit Price	Extended Price	Vendor Name	Vendor Phone #	Web-address
1	hot plate	Scilogex 81112102 MS-H-S Analog Magnetic Hotplate Stirrer, Porcelain Plate, 110V/60Hz, 5-2/7" Diameter	1	$295	$295	Amazon	(888) 280-4331	https://www.amazon.com/Scilogex-MS-H-S-Analog-Magnetic-Stirrers/dp/B0079NOMX2/?tag=geometryofmolecules-20
2	heat sink	3.5x1.2inch Round Spiral Aluminum Alloy Heat Sink for 1W-10W LED Silver White	1	$8.90	10	Amazon	(888) 280-4331	https://www.amazon.com/3-5x1-2inch-Spiral-Aluminum-1W-10W-Silver/dp/B00N2HGWMS

Conclusion

In conclusion, this project will address an issue that professors, scientists, engineers, and engineering students face when it comes to understanding nanofluids and their behaviours under different boundary conditions. The constraints that we face with inflexible boundary conditions, applicable techniques for such nanofluids, selecting the appropriate material, ensuring the nanofluid(s) has an ability to withstand high pressure, and the apparatus size. A thorough analysis on concept evaluation helps to design the primary apparatus, where the design CAD models and drawings can be produced. With the results drawn a concept has been fabricated to measure the behavior of different nanofluids.

Questions?

SENIOR DESIGN AND PREFESIONALISM I
FALL 2020

Title of Assignment: Mid-term Report

Group Mid Term Report

Outcome 3
Outcome 3 Written Communication

	Relevant to ABET Criterion	Points Assigned	GROUP 3
1. Ability to organize, plan and properly format a written technical report		**40**	**23.3**
(i) Students are able to organize report by categorizing ideas for the report into well and logically organized chapters, major sections, subsections and paragraphs blended within the larger units.		10	9.5
(ii) Students provide Title Page, Abstract, and Table of Contents, list of Figures, and List of Tables properly formatted.	(g)	6	3
(iii) Students provide figure number and title for each figure in the report, reference each figure, and completely discuss each figure in the report in accord with standards in the project manual.	(g)	6	2
(iv) Students provide table number and title for each table in the report in accord with standards in the project manual, reference each table, and completely discuss each table in the report.	(g)	6	1
(v) Students properly cite references in the report and provide well formatted reference list at the end.	(g)	**6**	**3.6**
(vi) Students prepare the written report in accord with standard report formatting provided in the Senior Projects Report Manual.		**6**	**4.2**
Total for PC1			
2. Ability to compose original texts and properly apply the conventions of written language.	(i)	40	33
(i) properly apply capitalization, punctuation, and penmanship, to communicate clearly		10	8
(ii) Spell proficiently		10	9
(iii) Apply standard grammar and usage to communicate clearly and effectively in writing including • **using complete sentences**, varying the types such as compound and complex to match meanings and purposes • properly employing standard English usage in writing for audiences, including subject-verb agreement, pronoun referents, and parts of speech • properly using adjectives (comparative and superlative forms) and adverbs appropriately to make writing vivid or precise • properly using prepositional phrases to elaborate written ideas • properly using conjunctions to connect ideas meaningfully		15	12
(iv) Use available technology to support aspects of creating, revising, editing, spell checking, and publishing the report.		5	4
Total for PC2			
3. Ability to provide appropriate discussion, conclusions and recommendations	0	20	17
(i) Summarize the goals, objectives, and indicate whether they were met.		5	4.5
(ii) Summarize the results.		5	4
(iii) Summarize constraints and codes and indicate whether they were met.		5	4
(iv) Provide logical conclusions and recommendations (including strengths and		5	4.5
Total for PC3			
TOTAL FOR REPORT		100	73.3

ESD		Max	
PC1		40	23.3
PC2		40.00	33.00
PC3		20.00	17.00
TOTAL		100.00	73.30
Did not make correctoins			-15
Adjusted Total			**58.30**

Mid-term report
Group

Outcome 2
Ability to Design

	Relevant to ABET Criterion	Points Assigned	GROUP 3
1. Ability to Define/Understand the Problem and then Plan the Project		**40**	**32**
(i) Identify the customer and the needs.	(g)	5	4
(ii) Identify and list the design objectives.	(g)	10	6
(i) Identify the design constraints.	(g)	5	4
(ii) Define the design strategy and methodology.	(g)	0	
(iii) Identify and break down work into tasks and subtasks and identify the personnel and deliverables for each.	(g)	10	9
(iv) Develop a Gantt chart and critical path analysis for managing the project.	(g)	**5**	**4**
(v) Establish major milestones for tracking progress and define performance metrics to measure		**5**	**5**
Total for PC1			
2. Ability to Conduct a Review of the Literature, Generate Ideas and Apply Creativity	(i)	60	43
(i) Identify the types of information needed for a complete understanding of all aspects of the project (Based on task described in the project planning).	(c)	10	8
(ii) Gather information on relevant fundamentals, theory / concept (demonstrate technical competence) and relate them to the design.	(c)	25	20
(iii) Provide the sources in a list of references properly cited in the literature review section and relevant sections of the report.		10	6
(iv) Functional Decomposition: Define functional requirements for design (Specific required actions needed to be performed for the design to be achieved).		15	9
(v) Concepts Generation: Transform functional requirements into candidate solutions / mathematical modeling.			
(vi) Evaluate candidate solutions to arrive at feasible designs.			
Total for PC2			
3. Ability to Perform Preliminary and Detailed Design	(c)	0	0
(i) Identify applicable codes and standards for the design	(c)	0	
(ii) Perform relevant detailed analysis (engineering, mathematical, economic) in accord with applicable codes and standards.		0	
(iii) Develop final design specifications		**0**	
(iv) Do the design within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	(i)	0	
(v) Select materials/components/software/test equipment.		0	
(vi) Fabricate a prototype or a model (physical, software, hardware) of the design.		0	
(vii) Test or simulate the design and make necessary changes to obtain optimum design.			
Total for PC3			
Outcome Maximum			
TOTAL FOR REPORT		100	75

ESD	Max	Score	
PC1		40	32
PC2		60.00	43.00
PC3		0.00	0.00
TOTAL		100.00	75.00

Group Mid Term Report

Outcome 3
Outcome 3 Written Communication

	Relevant to ABET Criterion	Points Assigned	GROUP 7
1. Ability to organize, plan and properly format a written technical report		**40**	**36.1**
(i) Students are able to organize report by categorizing ideas for the report into well and logically organized chapters, major sections, subsections and paragraphs blended within the larger units.		10	10
(ii) Students provide Title Page, Abstract, and Table of Contents, list of Figures, and List of Tables properly formatted.	(g)	6	4.2
(iii) Students provide figure number and title for each figure in the report, reference each figure, and completely discuss each figure in the report in accord with standards in the project manual.	(g)	6	5.1
(iv) Students provide table number and title for each table in the report in accord with standards in the project manual, reference each table, and completely discuss each table in the report.	(g)	6	6
(v) Students properly cite references in the report and provide well formatted reference list at the end.	(g)	**6**	**5.4**
(vi) Students prepare the written report in accord with standard report formatting provided in the Senior Projects Report Manual.		**6**	**5.4**
Total for PC1			
2. Ability to compose original texts and properly apply the conventions of written language.	(i)	40	38.5
(i) properly apply capitalization, punctuation, and penmanship, to communicate clearly		10	9.5
(ii) Spell proficiently		10	10
(iii) Apply standard grammar and usage to communicate clearly and effectively in writing including • **using complete sentences**, varying the types such as compound and complex to match meanings and purposes • properly employing standard English usage in writing for audiences, including subject-verb agreement, pronoun referents, and parts of speech • properly using adjectives (comparative and superlative forms) and adverbs appropriately to make writing vivid or precise • properly using prepositional phrases to elaborate written ideas • properly using conjunctions to connect ideas meaningfully		15	14
(iv) Use available technology to support aspects of creating, revising, editing, spell checking, and publishing the report.		5	5
Total for PC2			
3. Ability to provide appropriate discussion, conclusions and recommendations	0	20	19.5
(i) Summarize the goals, objectives, and indicate whether they were met.		5	4.75
(ii) Summarize the results.		5	5
(iii) Summarize constraints and codes and indicate whether they were met.		5	5
(iv) Provide logical conclusions and recommendations (including strengths and		5	4.75
Total for PC3			
TOTAL FOR REPORT		100	94.1

ESD		Max	
PC1		40	36.1
PC2		40.00	38.50
PC3		20.00	19.50
TOTAL		100.00	94.10
Did not make correctoins			-4
Adjusted Total			**90.10**

Mid-term report
Group

Outcome 2
Ability to Design

	Relevant to ABET Criterion	Points Assigned	GROUP 7
1. Ability to Define/Understand the Problem and then Plan the Project		**40**	**39.25**
(i) Identify the customer and the needs.	(g)	5	5
(ii) Identify and list the design objectives.	(g)	10	10
(i) Identify the design constraints.	(g)	5	4.75
(ii) Define the design strategy and methodology.	(g)	0	
(iii) Identify and break down work into tasks and subtasks and identify the personnel and deliverables for each.	(g)	10	9.75
(iv) Develop a Gantt chart and critical path analysis for managing the project.	(g)	**5**	**4.75**
(v) Establish major milestones for tracking progress and define performance metrics to measure		**5**	**5**
Total for PC1			
2. Ability to Conduct a Review of the Literature, Generate Ideas and Apply Creativity	(i)	60	54.25
(i) Identify the types of information needed for a complete understanding of all aspects of the project (Based on task described in the project planning).	(c)	10	9.5
(ii) Gather information on relevant fundamentals, theory / concept (demonstrate technical competence) and relate them to the design.	(c)	25	22.5
(iii) Provide the sources in a list of references properly cited in the literature review section and relevant sections of the report.		10	8
(iv) Functional Decomposition: Define functional requirements for design (Specific required actions needed to be performed for the design to be achieved).		15	14.25
(v) Concepts Generation: Transform functional requirements into candidate solutions / mathematical modeling.			
(vi) Evaluate candidate solutions to arrive at feasible designs.			
Total for PC2			
3. Ability to Perform Preliminary and Detailed Design	(c)	0	0
(i) Identify applicable codes and standards for the design	(c)	0	
(ii) Perform relevant detailed analysis (engineering, mathematical, economic) in accord with applicable codes and standards.		0	
(iii) Develop final design specifications		**0**	
(iv) Do the design within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	(i)	0	
(v) Select materials/components/software/test equipment.		0	
(vi) Fabricate a prototype or a model (physical, software, hardware) of the design.		0	
(vii) Test or simulate the design and make necessary changes to obtain optimum design.			
Total for PC3			
Outcome Maximum			
TOTAL FOR REPORT		100	93.5

ESD	Max	Score	
PC1		40	39.25
PC2		60.00	54.25
PC3		0.00	0.00
TOTAL		100.00	93.50

Outcome 3

Group Mid Term Report

Outcome 3 Written Communication

	Relevant to ABET Criterion	Points Assigned	GROUP 8
1. Ability to organize, plan and properly format a written technical report		**40**	**34.3**
(i) Students are able to organize report by categorizing ideas for the report into well and logically organized chapters, major sections, subsections and paragraphs blended within the larger units.		10	10
(ii) Students provide Title Page, Abstract, and Table of Contents, list of Figures, and List of Tables properly formatted.	(g)	6	3
(iii) Students provide figure number and title for each figure in the report, reference each figure, and completely discuss each figure in the report in accord with standards in the project manual.	(g)	6	6
(iv) Students provide table number and title for each table in the report in accord with standards in the project manual, reference each table, and completely discuss each table in the report.	(g)	6	6
(v) Students properly cite references in the report and provide well formatted reference list at the end.	(g)	**6**	**5.1**
(vi) Students prepare the written report in accord with standard report formatting provided in the Senior Projects Report Manual.		**6**	**4.2**
Total for PC1			
2. Ability to compose original texts and properly apply the conventions of written language.	(i)	40	37
(i) properly apply capitalization, punctuation, and penmanship, to communicate clearly		10	9
(ii) Spell proficiently		10	9.5
(iii) Apply standard grammar and usage to communicate clearly and effectively in writing including • **using complete sentences**, varying the types such as compound and complex to match meanings and purposes • properly employing standard English usage in writing for audiences, including subject-verb agreement, pronoun referents, and parts of speech • properly using adjectives (comparative and superlative forms) and adverbs appropriately to make writing vivid or precise • properly using prepositional phrases to elaborate written ideas • properly using conjunctions to connect ideas meaningfully		15	13.5
(iv) Use available technology to support aspects of creating, revising, editing, spell checking, and publishing the report.		5	5
Total for PC2			
3. Ability to provide appropriate discussion, conclusions and recommendations	0	20	15.5
(i) Summarize the goals, objectives, and indicate whether they were met.		5	4
(ii) Summarize the results.		5	3.5
(iii) Summarize constraints and codes and indicate whether they were met.		5	4
(iv) Provide logical conclusions and recommendations (including strengths and		5	4
Total for PC3			
TOTAL FOR REPORT		100	86.8

ESD		Max	
PC1		40	34.3
PC2		40.00	37.00
PC3		20.00	15.50
TOTAL		100.00	86.80
Did not make correctoins			**-4**
Adjusted Total			**82.80**

Mid-term report
Group

Outcome 2
Ability to Design

	Relevant to ABET Criterion	Points Assigned	GROUP 8
1. Ability to Define/Understand the Problem and then Plan the Project		**40**	**33**
(i) Identify the customer and the needs.	(g)	5	5
(ii) Identify and list the design objectives.	(g)	10	9.5
(i) Identify the design constraints.	(g)	5	4
(ii) Define the design strategy and methodology.	(g)	0	
(iii) Identify and break down work into tasks and subtasks and identify the personnel and deliverables for each.	(g)	10	8.5
(iv) Develop a Gantt chart and critical path analysis for managing the project.	(g)	**5**	**3.5**
(v) Establish major milestones for tracking progress and define performance metrics to measure		**5**	**2.5**
Total for PC1			
2. Ability to Conduct a Review of the Literature, Generate Ideas and Apply Creativity	(i)	60	52.5
(i) Identify the types of information needed for a complete understanding of all aspects of the project (Based on task described in the project planning).	(c)	10	8.5
(ii) Gather information on relevant fundamentals, theory / concept (demonstrate technical competence) and relate them to the design.	(c)	25	21.25
(iii) Provide the sources in a list of references properly cited in the literature review section and relevant sections of the report.		10	8.5
(iv) Functional Decomposition: Define functional requirements for design (Specific required actions needed to be performed for the design to be achieved).		15	14.25
(v) Concepts Generation: Transform functional requirements into candidate solutions / mathematical modeling.			
(vi) Evaluate candidate solutions to arrive at feasible designs.			
Total for PC2			
3. Ability to Perform Preliminary and Detailed Design	(c)	0	0
(i) Identify applicable codes and standards for the design	(c)	0	
(ii) Perform relevant detailed analysis (engineering, mathematical, economic) in accord with applicable codes and standards.		0	
(iii) Develop final design specifications		**0**	
(iv) Do the design within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	(i)	0	
(v) Select materials/components/software/test equipment.		0	
(vi) Fabricate a prototype or a model (physical, software, hardware) of the design.		0	
(vii) Test or simulate the design and make necessary changes to obtain optimum design.			
Total for PC3			
Outcome Maximum			
TOTAL FOR REPORT		100	85.5

ESD	Max	Score	
PC1		40	33
PC2		60.00	52.50
PC3		0.00	0.00
TOTAL		100.00	85.50

ABOVE AVERAGE

"Design, Fabrication, and Testing of an Automated Oil Recovering Skimmer"

Senior Design & Professionalism I

Midterm Report

Submitted by

Ximena Cifuentes
Caleb Riggins
Demetrious Sanford
Amna Ansari
Aamna Jangda
Daniel Akpan
David Trevino

To

Dr. Xiaobo Peng
Senior Design Instructor

Department of Mechanical Engineering
College of Engineering
Prairie View A&M University

October 10, 2020

SENIOR DESIGN & PROFESSIONALISM I
FALL 2020
PROJECT PROGRESS REPORT COVER SHEET

PROJECT TITLE: _Design, Fabrication, and Testing of an Automated Oil Recovering Skimmer

GROUP NUMBER: ___7___

Progress Report Title: Midterm Report

Due Date: 10/10/2020

No	Group Member Name Group Member signature	Brief Description of Work Assigned to Member	% Completed by Member	Your Score
1	**Daniel Akpan** DocuSigned by: D752FAC3D5EC429...	**Section work:** Revise: Project scope, project planning, literature review Assist: formatting and tables **Attendance:** attend meetings. **Participation:** participate in meetings.	**84%**	
2	**David Trevino** DocuSigned by: David Trevino 70629F9F1296489...	**Section work:** Revise: Project scope, project planning, literature review Assist: formatting and tables **Attendance:** attend meetings. **Participation:** participate in meetings.	**98%**	
3	**Amna Ansari** DocuSigned by: Amna Ansari E25E51620421451...	**Section work:** Revise: Project scope, project planning, literature review Assist: formatting and tables **Formatting**: indenting sections, font type and size consistency, page numbers. **Minutes:** Record meeting minutes for each meeting and record of attendance. **Attendance:** attend meetings. **Participation:** participate in meetings	**99%**	
4	**Demetrious Sandford** DocuSigned by: Demetrious Sandford C7D32FE84B0A419...	**Section work:** Revise: Project scope, project planning, literature review Assist: formatting and tables **Proofreading:** Full report **Formatting:** indenting sections, font type and size consistency. **Meeting:** Organize meeting times. **Attendance:** attend meetings. **Participation:** participate in meetings.	**94%**	
5	**Caleb Riggins** DocuSigned by: Caleb Riggins 41AFA23858EE4BC...	**Section work:** Revise: Project scope, project planning, literature review Assist: formatting and tables Complete: Chapter 5 and 6 **Technical writing review:** Full report **Formatting:** indenting sections, font type and size consistency, page numbers. **Attendance:** attend meetings. **Participation:** participate in meetings.	**99%**	
6	**Ximena Cifuentes** DocuSigned by: Ximena Cifuentes BD1F416D20884F6...	**Section work:** Revise: Project scope, project planning, literature review Assist: formatting and tables **Formatting:** Cover page, empty report sheet, indenting sections, font consistency. **Communication:** Send report to Dr. Park for feedback, assign tasks. **Attendance:** attend meetings. **Participation:** participate in meetings.	**99%**	
7	**Aamna Jangda** DocuSigned by: Aamna Jangda 781C4B4D2C9D46D...	**Section work:** Revise: Project scope, project planning, literature review Assist: formatting and tables **Formatting:** Font consistency within certain parts, page numbers, table formatting **Attendance:** Attend meetings **Participation:** Participate in meetings	**99 %**	

*100% means the member completed his/her assigned work

By signing this assignment cover sheet, I agree that the percentages stated in the % completed column reflect the contribution made by me and the other members of the group.

Letter of Transmittal

October 8, 2020
Mechanical Engineering Students
100 University Dr.
Prairie View, Texas 77446

Dr. Peng Xiaobo
Senior Design and Professionalism I Instructor
Prairie View A&M University
CL Wilson 102A
October 10, 2020

Dear Dr. Peng:

This detailed Mid-term report of Senior Design and Professionalism I, MCEG 4472, entitles project 7, which is "Automated Oil Skimmer." This report addresses educational findings on potential preliminary methods to design an automated oil skimmer that offers greater than or equal to the industrial skimmers today. The team utilized many different techniques to establish foundations for the project. The group advisors, Dr. Park and Dr. Zhou, assisted and guided the students with questions, group research, and analysis of various components functions.

If you have any questions or concerns, please call or email the group Leader, Ximena Cifuentes at (832) 755-0117 or xcifuentes@student.pvamu.edu

Sincerely,

Ximena Cifuentes
DocuSigned by:
Ximena Cifuentes
BD1F416D20884F6...
Caleb Riggins
DocuSigned by:
Caleb Riggins
41AFA23858EE4BC...
Demetrious Sandford
DocuSigned by:
Demetrious Sandford
C7D32FE84B0A419...
David Trevino
DocuSigned by:
David Trevino
70629F9F1296489...
Amna Ansari
DocuSigned by:
Amna Ansari
E25E51620421451...
Daniel Akpan
DocuSigned by:
D752FAC3D5EC429...
Aamna Jangda
DocuSigned by:
Aamna Jangda
781C4B4D2C9D46D...

Enclosure: Mid-term Report

Acknowledgement

This manual was prepared using input from Demetrious Sandford, Caleb Riggins, Amna Ansari, Daniel Akpan, Aamna Jangda, David Trevino, and Ximena Cifuentes.

We would like to express our gratitude to Dr. Jaejong Park and Dr. Jianren Zhou for providing guidance and commitment to our project.

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1. PROJECT SCOPE

In this chapter, the problem at hand will be introduced in a greater detail including the potential clients, their need, project goals, objectives, and project restraints.

1.1 Problem Statement

Today, the main form of energy source comes from crude oil and other liquids produced from fossil fuels in which they are refined into petroleum. With the advancement of technology, we can extract oil from wells through offshore drilling. However, this mode of extraction can cause harm to the environment during oil spill incidents. With the increase of incidents every year, we need to combat this using improved designs for oil skimmers which are used to ultimately recover crude oil slicks. Oil skimmers are devices that are used to remove floating oil from the surface of a body of water. With the different and unpredictable changes in the world, the current oil recovering skimmers have a lot of room for optimization. When an oil spill occurs, the skimmers need to be able to combat the situation while maintaining the safety of the environment quickly and effectively. The skimmers need to be able to retain durability and functionality. Meaning, if a situation occurs where the skimmer takes sufficient damage, it should be able to protect the oil already stored without allowing another spill.

The purpose of this project is to design, fabricate and test a fully functional automated oil skimmer for companies to use during oil spill cleanups and containment. This will be accomplished by improving upon existing oil skimmer designs and overall increase the efficiency through various constraints and innovations.

1.2 Client Identification and Recognition of Need

In this section we identified the potential clients for the automated oil skimmer. While this technology is still in development, there are dozens of companies who have created oil skimmers. The main companies our design is intended for are oil companies that operate in coastal regions. In addition, the section discusses the clients' needs. The clients' needs will open the doors to the identification of the project goal.

1.2.1 ~~Identifying the project's client~~

- Bureau of Safety and Environmental Enforcement: This client was chosen due to its leading division in oil recovery. Within this organization, there is a division called Oil Spill Preparedness Division (OSPD) where specialized improving spill responses are taken to help develop decision making strategies for oil spill response. The organization has developed a scientific program that seeks to improve oil spill response and oil behavior understandings. In addition, the organization focuses on detecting effective methods by using alternative solutions.

- Environmental Protection Agency: This client was chosen due to their mission in ensuring that all Americans have clean air and water. EPA is dedicated to

reducing environmental risks by using the best scientific resources. One of EPA's top priorities is management of their (SPCC) Spill Prevention, Control, Countermeasure methods program.

- Marine Spill Response Corporation: This client was chosen as a potential contact due the recognition of the company. The Marine Spill Response Corporation is the largest oil response organization in the United States. In addition, if our product were to succeed, they have a robust network of qualified Spill Team Area Responders (STARs) in which we can apply and become a part of.

- Marine Preservation Association: This client was chosen due to its large influence in funding companies in the petroleum, energy, and related transportation industries. They are a leading organization in supporting the development and maintenance of effective spill response capability in the United States. They are the parent company of Marine Spill Response Corporation and include over 600 corporate members who utilize their technology in oil recovery.

- Occidental Petroleum Corporation: This client was chosen due to being an international energy company that operates in multiple regions such as the United States, Middle East, Africa, and Latin America. They are a leading producer of oil and gas and are looking into new innovations for oil skimmers to minimize damage to the environment and maximize oil recovery.

1.2.2 Identifying the client's need

A clear-cut problem for current Automated Oil skimmers is that their efficiency could be improved to where they can handle large amounts of oil in a timely manner, which in turn negatively affects marine life and potentially becomes an environmental pollutant. The Use of innovative materials like Super absorbent materials paired with nanotechnology, incorporated into an existing automated skimmer by replacing a disc or a drum would significantly increase its efficiency. The overall goal for this project is to combat oil spill situations and effectively while maintaining the safety of the environment.

Current skimmer capabilities can easily adapt to oil thicknesses that are greater than or equal to about 1-3 inches generally. If the thickness of the oil is lower than half of an inch, skimmers may ingest large amounts of water which makes the process inefficient. BSEE suggests that in actual oil spills, skimmers cannot be assumed to encounter enough oil to continuously conduct recovery operations to 50-75 mm. This is about 2-3 inches. So, it is important to understand how a skimmer's performance will vary based on oil thicknesses. Results from testing conclude that reduced oil thicknesses have a significant impact on the measured recovery capabilities.

1.3 Project Goal and Objectives

To break down the scope of the project, the team followed a series of steps. In this section, the goal statement is presented. In addition, the objectives were clearly defined and categorized to allow the team to experience the design thinking process. Finally, the purpose of this section is to ensure that the goal allowed room for different approaches to fulfill the clients' needs.

1.3.1 Goal Statement

The project goal is to design an improved oil skimmer system with a refined process that will increase the recovery rate and oil containment capacity of current oil skimmers. The team will begin by researching and observing current oil skimmers in order to address current deficiencies/limitations as well as current successes. The scope of this goal is to design a system that offers greater efficiencies of recovery rates for oil slicks that are less than 1/2-inch thickness. During the development of the design process, the team will prioritize the responder safety, portability of technology, simplicity of use, and reduction of waste during recovery operations.

1.3.2 Design Objectives

In this subsection a variety of objectives were generated as the team collaborated about the different ways to access the clients' needs. In addition, the listed objectives were categorized between low-level and high-level objectives and their most relevant criteria category. Finally, the section demonstrates the hierarchical relationship between the objectives and their measurements units.

1. List of objectives

    - Cost effectiveness
    - Product safety
    - Durability
    - User friendly
    - Compact design
    - Eco friendly
    - Efficient recovery rate
    - Waterproof
    - Improved filtration
    - High pump capacity
    - Design should meet all federal and state regulations
    - Detachable parts
    - Oil containment capacity
    - Universal usage
    - Marketable

- Oil removal concentration

2. Objectives in sets of higher and lower level

In Table 1.1 the objectives are organized based upon their roles within the completion of the skimmer design. All categories allow for a structured and complete analysis of possible skimmer design motives and desirables that may be considered for client needs.

Table 1.1 Categories of objectives

Safety	**Quality**	**Environment**	**Economic**	**Workability**	**Conveniences**
Product safety	Durability Compact design Oil removal concentration Oil Containment capacity Waterproof High pump capacity Improved filtration Detachable parts Marketable	Eco friendly	Cost effectiveness Design should meet all federal and state regulations	Efficient recovery rate Universal usage	User friendly

3. Objective Tree

Figure 1.1 is an organized assembly of the design objectives for the automated oil skimmer. Categories are presented to establish a hierarchy of requirements needed for the successful implementation of the project design process. These objectives are the major aspects of the design formulation.

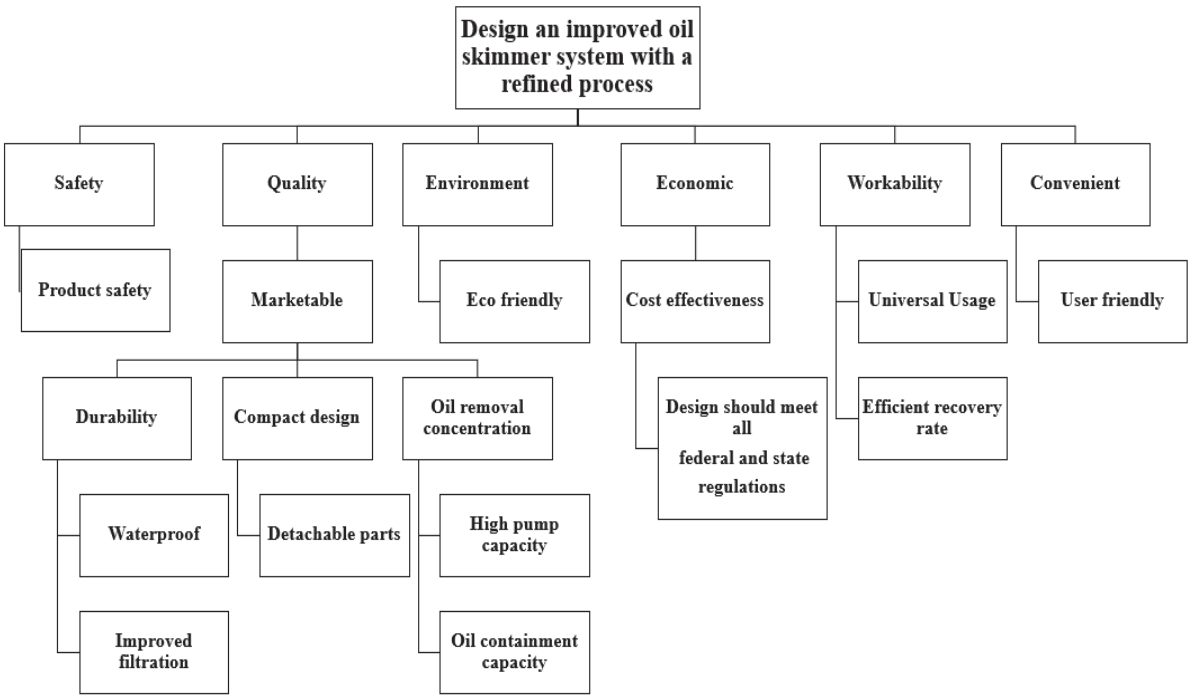


Figure 1.1 Objective tree

4. Table of measured objectives

Table 1.2 presents measured objectives that can be quantified based upon developed criteria. The basis of criteria allows for the design to offer a quantity of success within each objective that will in turn reflect the success of the design.

Table 1.2 Measured objectives

Objective	Measurement Basis	Criteria	Units
Cost effectiveness	Fabrication cost to not exceed 5000	Economic	Currency
Product safety	Product to achieve lower incident rate of current oleophilic skimmers.	Safety	Incidents/Product life cycle
Durability	Toughness of design	Quality	in·lbf·in
Compact design	To not exceed 5ft X 5ft	Quality	ft
Eco friendly	Energy efficiency	Environment	%
Efficient recovery rate	Fast recover	Workability	recovery/min
User friendly	Completion rate	Convenient	start machine/min
Waterproof	150 fr	Quality	ft
Improved filtration	Design effective innovative filtering system	Quality	Micron
High pump capacity	High pump capacity	Quality	m3/h
Marketable	Sales performance	Quality	Number of sales
Universal usage	Product attractiveness	Workability	Number of sales
Design should meet all federal and state regulations	Compliance measurement	Economic	satisfaction rating/dollars
Detachable parts	Easy setup	Quality	Weight & quantity
Oil containment capacity	Increase in efficiency	Quality	Gallons
Oil removal concentration	Quality of pure oil removed	Quality	Grams/Gallo ns

1.4 Initial Project constraints and Operating Environment

All engineering designs require physical limitations to ensure that they are acceptable and functional. The design must be upheld to some initial constraints as well as be constructed within permissible parameters. The selection of these parameters and constraints were selected based on research as well as the mode of the operating environment. These selections are largely affected by the roles the design must perform within the given operating environment. This section will provide the generated lists of appropriate initial project constraints and the operating environment.

1. Initial Project Constraints

    -Must be buoyant.

    -Must be autonomous.

    -Needs to be an easily portable design.

    -Must rely upon a custom computer algorithm for tracking and movement (PROJECT 1037) (BSEE).

    -Cannot exceed an operating domain of 5 ft by 5 ft.

    -Must operate in and be accustomed to thick layers of oil, up to 3 inches.

    -Design requires an oil storage containment device.

    -Skimmer must be adapted to recover different temperatures of oil.

    -Skimmer design must be climate resistive or adaptable.

    -Design needs a heat system to counteract ambient temperatures.

    -Skimmer must include an oil capacity sensor for measuring oil thickness (Development of an Oil Thickness Sensor, PROJECT 1072). (BSEE)

    -Design must be Oleophilic (An affinity to oil rather than water/be able to distinguish the difference).

    -Must have a velocity between 3-5 knots or 3.5- 6 mph (Recent research has led to boom systems that can be towed at speeds up to 3-5 knots and have automated inflation and deployment capabilities. (BSEE)

    -Must at least operate at an efficiency of 25%-50% in 1-inch oil thickness.

-Must have an acceptable nameplate capacity number (number which defines skimmer efficiency). (BSEE)

-ASTM F2709 calls for testing stationary oil skimmers in either pure oil, or in a threeinch layer of oil on water. However, in an actual oil spill it is likely that a skimmer will be operating in a thinner range of oil thicknesses. BSEE is conducting testing on various skimming systems in varying slick thicknesses to better understand the relationship between Oil Recovery Rates (ORR) and Recovery efficiencies (RE) and decreasing oil slick. thicknesses. (https://www.bsee.gov/research-record/evaluation-of-skimmer-performance-indiminishing-oilslick-thicknesses) TESTED ON OLEOPHILIC SKIMMERS. (BSEE)

2. Operating environment

- Various water conditions including wavy and calm.
- Operational in different types of waters (Salt or freshwater).
- Houses in various types of marine life environments.

2. PROJECT PLANNING AND TASK DEFINITION

In this chapter, the planning of the Automated Skimmer Project will be discussed in detail. In addition, the chapter will reveal the key project tasks and subtasks that were vital to the execution of the project. The tasks will be delegated evenly depending on everyone's strengths. Finally, the chapter includes a visual representation of the fully developed project plan created by the team. The representation includes a timeline table and its interpretation in a Gantt chart form.

2.1 Task identification

In this section, the different project tasks are identified based on the hierarchy of needs for the design process. Analysis of these needs were driven through brainstorming and identifying which problems needed to be assessed to fulfill future design process requirements. In addition, each task is divided into subsections that detail the different stages required to successfully complete the tasks. In the subsection below, the tasks identified are listed with their respective sub-tasks. The combination of research and reference to the course syllabus, the team was able to successfully identify all the tasks needed to effectively complete the project.

- Problem Formulation
  - Identify project scope and problem statement
  - Define clients and recognition of need
  - Display project goals and objectives
  - Point out initial project constraints

- Project Planning
  - Identify tasks to be completed
  - Generate a project timeline
  - Create a Gantt chart

- Literature Review
  - Identify relevant Information to project
  - Establish sources of relevant information
  - Research Oleophilic Skimmers
  - Analyze Non-Oleophilic Skimmers
  - Analyze Weir Skimmers
  - Make Inquiries into Operational Environment of skimmers

- Functional Decomposition
  - Define functional decomposition concept
  - Develop a strategy for the functions and subfunction
  - Generate a morphology table

- Concepts Generation
  - Develop a strategy to assign members to generate concepts
  - Each member generates concept sketches individually

    - Combine concepts from all members into morphology table

- Concept Evaluation
    - Identify the Criteria
    - Organize the Criteria
    - Utilize the Go-no-go method
    - Create a decision matrix
    - Generate a Preliminary Design

- Preliminary Design
    - Rehabilitate existing designs
    - Identify options for flexibility
    - Approximate dimensions

- Detailed Design
    - Identify and plan for types of analysis needed for the design
    - Draw rough draft on paper
    - Produce real life blueprint of design in Fusion 360
    - Run simulation in Fusion 360
    - Perform engineering analysis

- Detailed Parts Specifications
    - Create specifications of each component
    - Identify constraints of design
    - Design Evaluation/Modifications

- Budget & Project Cost (Economic Analysis)
    - Organize a list of suppliers
    - Generate a Budget Generation
    - Evaluate the Approval of the Budget agreement

- Purchasing
    - Generate a technical report that identifies all the parts.
    - Purchase parts

- Fabrication & Testing
    - Devise plan for manufacturing and assembly of Automated Skimmer
    - Create a detailed schedule for monitoring machine shop work
    - Conduct final testing and inspection for the Automated Skimmer

- Final Report & Presentation
    - Finalize report
    - Prepare presentation

2.2 Timeline

This section provides an overview of the active objectives' timeline for this project. The timeline serves to organize and present the objectives that will guide the accomplishment of deliverables through Fall 2020 and Spring 2021 in order for the construction of the automated oil skimmer to be completed. Selected tasks were created and communicated to be organized and arranged into an appropriate chronological sequence. Persons responsible for a given task were determined through examining previous experiences and expertise that correspond to the given tasks to know who was best fit. An assessment of workload and priority was taken to quantify the amount of time needed for each task to be completed.

- Identify project scope and problem statement
    - To formulate the current problem and identify the current need for product optimization
        - A statement of current unsatisfactory conditions that will be approached by the proposed design
        - Person(s) Responsible: (David T.)
        - Estimated Time: 2 day
- Define clients and recognition of need
    - To find who will be a potential end user of the product and to determine the reason why the client needs the product
        - A list of 5 potential clients and structured statement that defines the overall project goal and the scope of the goal
        - Person(s) Responsible: (Demetrious S.)
        - Estimated Time: 2 days
- Display project goals and objectives
    - To develop a goal statement and define measurable performance characteristics of design
        - A labelled objective tree showing hierarchical relationships between objectives based on their performance characteristics.
        - Person(s) Responsible:(Ximena C.)
        - Estimated Time: 4 days
- Point out initial project constraints
    - To identify the different permissible ranges of the product design and recognizing the product working environment
        - A list of permissible range for the design parameters, description of the environment in which the design will operate

        - Person(s) Responsible: (Caleb R.)
        - Estimated Time: 2 days

- Identify tasks to be completed

    - To identify the different tasks that will need to be completed during the project
        - A list of all the tasks that need to be completed for the project and their main subtasks
        - Person(s) Responsible: (Group work) ▪ Estimated Time: 2 days

- Generate a project timeline

    - To develop a detailed timeline for each one of the tasks listed in the task identification section
        - An effective timeline table
        - Person(s) Responsible:(Group work) ▪ Estimated Time: 4 days

- Create a Gantt chart

    - Effectively organize the tasks and subtasks in a Gantt chart for timely completion.
        - A Gantt chart that has multiple features for project tracking.
        - Person(s) Responsible: (David T.)
        - Estimated Time: 5 days

- Identify relevant Information to project

    - To identify information relevant to project
        - A comprehensive list of relevant information
        - Responsible: (Group work)
        - Estimated Time: 1 day

- Establish sources of relevant information

    - To establish a list of credible sources for the Information provided
        - A list of credible cited sources
        - Person(s) Responsible: (Daniel)
        - Estimated Time: 1 day

- Research Oleophilic Skimmers

    - To study relevant information on Oleophilic skimmers
        - A thorough research paper on oleophilic skimmers
        - Person(s) Responsible: (Caleb R)

        - Estimated Time: 1 day

- Analyze Non-Oleophilic Skimmers

    - To create a detailed research on Non-oleophilic skimmers
        - A thorough research paper on Non-oleophilic skimmers
        - Person(s) Responsible: (Ximena)
        - Estimated Time: 1 day

- Analyze Weir Skimmers

    - To Review information on Weir skimmers
        - A thorough research paper done on Weir Skimmers
        - Person(s) Responsible: (Amna)
        - Estimated Time: 2 days

- Make Inquiries into Operational Environment of skimmers

    - To Inquire into operational environment of skimmers
        - A list of inquiries made into operational environment of skimmers
        - Person(s) Responsible: (Daniel)
        - Estimated Time: 2 days

- Define functional decomposition concept

    - To study functional decomposition and generate concepts
        - An overall function statements
        - Responsible group member (Group work) ▪ Estimated time: 2 days

- Develop a strategy for the functions and subfunction

    - To establish a strategy that define functions and subfunctions
        - A list of overall functions, a level 1 subfunction, a level 2 subfunction, a level 3 subfunction
        - Responsible group member (Ximena C, Amna A, Amna J, Caleb R) ▪ Estimated time: 3 days

- Generate a morphology table

    - To create a morphology table that identifies functional analysis
        - A morphology table for the functional decompositions, and a report that summarizes all the functions
        - Responsible group member (Demetrious S, Daniel A)
        - Estimated time: 2 days

- Develop a strategy to assign members to generate concepts

- Generate concepts using well established concepts generation techniques for each of the functions.
    - A list of generated concepts
    - Person(s) Responsible: (Group Work) ▪ Estimated time: 2 days

- Each member generates concepts sketches individually

    - Generate sketches into team concepts for each function
        - Sketches that present concept of function
        - Person(s) Responsible: (Group Work)
        - Estimated time: 3 days

- Combine concepts from all members into morphology table

    - Assimilate individual concepts into a morphology
        - A morphology tables
        - Person(s) Responsible: (Group Work)
        - Estimated time: 3 days

- Identify the Criteria

    - To develop a list of generated criteria to begin the design analysis
        - A list of criteria that will be used to determine the preliminary concept design
        - Person(s) Responsible: (Group)
        - Estimated Time: 3 days

- Organize the Criteria

    - Reorganize the created list into a manageable table
        - A Criteria Table
        - Person(s) Responsible: (Ximena, David)
        - Estimated time: 4 days

- Utilize the Go-no-go method

    - Utilize the Go-no-go method and decision matrix to evaluate the list
        - The final result of the Go-No-Go method of the given criteria
        - Person(s) Responsible: (Group)
        - Estimated time: 4 days

- Create a decision matrix

    - Utilize the Go-no-go method and decision matrix to evaluate the list
        - Final result of the decision matrix determined
        - Person(s) Responsible: (Group)

        - Estimated time: 4 day

- Generate a Preliminary Design

    - Develop a final preliminary concept for the design
        - The evaluation of the preliminary design
        - Person(s) Responsible:(Group)
        - Estimated time: 4 days

- Rehabilitate existing designs

    - To Explore the advantages and disadvantages of existing designs
        - The most effective outcomes to improve the design process
        - Person(s) Responsible: (Group)
        - Estimated Time: 7 days

- Identify options for flexibility

    - To Prepare for the design to be subject to change if applicable
        - To allow the preliminary design construct to be flexible
        - Person(s) Responsible: (Amna J, Amna A)
        - Estimated Time: 7 days

- Approximate dimensions

    - To Meet the initial constraints requirements
        - Final preliminary design adheres to the constraint guidelines
        - Person(s) Responsible: (Group)
        - Estimated time: 7 days

- Identify and plan for types of analysis needed for the design

    - To get a realistic idea of the type of functional skimmer to create
        - An idea for skimmer design
        - Person(s) Responsible: (Group)
        - Estimated Time: 3 days

- Draw rough draft on paper

    - To have a finalized image of skimmer design
        - A drawing on paper
        - Person(s) Responsible: (Aamna J)
        - Estimated Time: 6 days
- Produce real life blueprint of design in Fusion 360

    - To make design come to life virtually in Fusion 360 software

        - Blueprint of skimmer in Fusion 360
        - Person(s) Responsible: (Aamna J)
        - Estimated Time: 4-5 days

- Perform engineering analysis

    - To run experimental testing of skimmer
        - Simulations on design, record all data overtime
        - Person(s) Responsible: (Aamna J)
        - Estimated time: 6-7 days

- Identify constraints of design

    - To apply standards and design constraints to generate realistic models.
        - A model in Fusion 360 that shows the correct correct measurements of each component while assuring all components are scaled properly
        - Person(s) Responsible: (Aamna J and Amna A) ▪ Estimated time: 6 days

- Generate specifications of each component

    - To identify the permissible range of the design and performance parameters
        - List of permissible ranges for the design parameters, and applying it to the model
        - Person(s) Responsible: (Aamna J) ▪ Estimated Time: 4 days

- Design evaluation/modifications

    - To ensure all parts meet parameter criteria.
        - A final drawing with all labels and dimensions
        - Person(s) Responsible: (Group) ▪ Estimated Time: 4-5 days

- Final CAD drawing

    - To create design with all separate parts merged together for one finalized skimmer
        - A finalized Fusion 360 drawing that is realistic, meets industry needs, and will function when fabricated.
        - Person(s) Responsible: (Group)
        - Estimated Time: 7 days

- List of Suppliers
    - To compare prices and quality with those from different suppliers
        - A list of parts necessary for purchase
        - Person(s) Responsible: (Demetrious S, David T, Daniel A)
        - Estimated time: 2 days
- Budget Generation
    - Generate a budget for all of the listed parts
        - A budget that is reasonable
        - Person(s) Responsible: (Demetrious S, David T, Daniel A)
        - Estimated time: 3 days
- Approval of Budget Agreement
    - Get approval of budget from the Mechanical Engineering Department
        - A cost comparison
- Technical Report
    - Generate a report that identifies all the parts that need to be purchased
        - A detailed technical report that identifies all the necessary parts
        - Responsible person (Group work)
        - Estimated time: 4 days (2/05 - 2/09)
- Purchases/Manufacture and Assembly
    - Purchase parts
        - A detailed technical report that identifies all the parts that have been purchased
        - Responsible person (Group work)
        - Estimated time: 8 days (2/8 - 2/19)
- Manufacture and Assembly
    - Create a plan for manufacturing and assembly of automated oil skimmer
        - A detailed plan on how to go about the production of the skimmer
        - Responsible Person(s): (Group Work)
        - Estimated Time: 1 day (2/12 - 02/15)

- Machine Shop Work

    - Create a detailed schedule for machine shop work rotation
        - A finalized schedule for workshop rotations
        - Responsible Person(s): (Group Work)
        - Estimated Time: 7 days (2/15 - 2/22)

- Product Testing

    - To conduct final testing and inspections for the automated oil skimmer
        - A fully functional Automated Skimmer
        - Responsible Person(s): (Group Work)
        - Estimated Time: 7 days (2/22 - 03/02)

- Finalize report

    - To construct a final report that reveals the entire design process of the project.
        - A compilation of revised reports
        - Person(s) Responsible: (Group work)
        - Estimated Time: 7 days (TBD)

- Prepare Presentation

    - To organize all project elements into a presentation
        - A well-developed PowerPoint presentation
        - Person(s) Responsible: (Group work)
        - Estimated Time: 2 days (TBD)

The list below includes the estimated times for each one of the tasks to be performed during the project. The estimated time for each task was determined based on the reflection of the current time spent on the previous reports. In addition, the list includes the approximated start and end dates for the task.

1. Problem Formulation

    - Identify project scope and problem statement
        - Start/End Dates: 9/3 to 9/5
        - Estimated Duration: 3 hrs
    - Define clients and recognition of need
        - Start/End Dates: 9/3 to 9/5
        - Estimated Duration: 2 hrs
    - Display project goals and objectives
        - Start/End Dates: 9/4 to 9/8
        - Estimated Duration: 6 hrs

- Point out initial project constraints
    - Start/End Dates: 9/4 to 9/6
    - Estimated Duration: 2 hrs

2. Project Planning

- Identify tasks to be completed
    - Start/End Dates: 9/10 to 9/12
    - Estimated Duration:2 hrs
- Generate a project timeline
    - Start/End Dates: 9/11 to 9/15
    - Estimated Duration:4 hrs
- Create a Gantt chart
    - Start/End Dates: 9/11 to 9/16
    - Estimated Duration:7 hrs

3. Literature Review

- Identify relevant Information to project
    - Start/End Dates: 9/16 to 9/17
    - Estimated Duration: 2 hours
- Establish sources of relevant information
    - Start/End Dates: 9/17 to 9/18
    - Estimated Duration: 4 hrs
- Research Oleophilic Skimmers
    - Start/End Dates: 9/18 to 9/19
    - Estimated Duration: 4 hrs
- Analyze Non-Oleophilic Skimmers
    - Start/End Dates: 9/20 to 9/21
    - Estimated Duration: 4 hrs
- Analyze Weir Skimmers
    - Start/End Dates: 9/20 to 9/22
    - Estimated Duration: 4 hrs
- Make Inquiries into Operational Environment of skimmers
    - Start/End Dates: 9/22 to 9/24
    - Estimated Duration: 2 hrs

4. Functional Decomposition

- Define functional decomposition concept
    - Start/End Dates: 9/23 to 9/25
    - Estimated Duration: 4hrs
- Develop a strategy for the functions and subfunction
    - Start/End Dates: 9/23 to 9/26
    - Estimated Duration: 6hrs

- Generate a morphology table
  - Start/End Dates: 9/28 to 9/30
  - Estimated Duration: 4hrs

5. Concepts Generation

- To review the Concepts
  - Start/End Dates: 9/30 - 10/2
  - Estimated time: 8 hrs
- To Modify the Concepts
  - Start/End Dates: 10/7 - 10/9
  - Estimated time: 4 hrs

6. Concept Evaluation

- Identifying criteria
  - Start/End Dates: 10/14 to 10/17
  - Estimated Duration:4hrs
- Organizing Criteria
  - Start/End Dates: 10/14 to 10/17
  - Estimated Duration: 4hrs
- Go-no-go method
  - Start/End Dates: 10/16 to 10/20
  - Estimated Duration: 8hrs hrs
- Decision matrix
  - Start/End Dates: 10/16 to 10/20
  - Estimated Duration: 8-10 hrs
- Preliminary Design
  - Start/End Dates: 10/14 to 10/22
  - Estimated Duration: 8-10 hrs

7. Preliminary Design

- Rehabilitate existing design
  - Start/End Dates:10/22 to 10/28
  - Estimated Duration: 10-12hrs
- Identify options for flexibility
  - Start/End Dates: 10/28 to 11/04
  - Estimated Duration: 10-12hrs
- Approximate dimensions
  - Start/End Dates: 10/28 to 11/04
  - Estimated Duration: 4-6 hrs

8. Detailed Design

- Identify and plan for types of analysis needed for the design
  - Start/End Dates: 11/04 to 11/07

        - Estimated Duration: 6 hrs
    - Draw rough draft on paper
        - Start/End Dates: 11/04 to 11/10
        - Estimated Duration: 4 hrs
    - Produce real life blueprint of design in Fusion 360
        - Start/End Dates: 11/10 to 11/14
        - Estimated Duration: 15-20 hrs
    - Run simulation in Fusion 360
        - Start/End Dates: 11/14 to 11/19
        - Estimated Duration: 10-15 hrs

9. Detailed Parts Specifications

    - Create specifications of each component
        - Start/End Dates: 11/04 to 11/08
        - Estimated Duration: 12 hrs
    - Identify constraints of design
        - Start/End Dates: 11/08 to 11/12
        - Estimated Duration: 4 hrs
    - Design Evaluations/Modifications
        - Start/End Dates: 11/13 to 11/19\
        - Estimated Duration: 15-20 hrs

10. Budget & Project Cost (Economic Analysis)

    - List of suppliers
        - Start/End Dates: 1/15 to 1/20
        - Estimated Duration: 7 hrs
    - Budget Generation
        - Start/End Dates: 1/20 to 1/25
        - Estimated Duration: 2 hrs
    - Approval of Budget Agreement
        - Start/End Dates: 1/25 to 2/02
        - Estimated Duration: 3 hrs

11. Purchasing

    - Technical report
        - Start/End Dates: 2/05 to 2/09
        - Estimated Duration: 6hrs
    - Purchases
        - Start/End Dates: 2/11 to 2/19
        - Estimated Duration: 8hrs

12. Fabrication & Testing

- Manufacture and Assembly
  - Start/End Dates: 2/26 to 2/28
  - Estimated Duration: 12 hrs
- Machine Shop Work
  - Start/End Dates: 2/28 to 3/02
  - Estimated Duration: 10-15 hrs
- Product Testing
  - Start/End Dates: 3/03 to 3/05
  - Estimated Duration: 8-10 hrs

13. Final Report & Presentation

- Finalize report
  - Start/End Dates: 4/22 to 4/29
  - Estimated Duration: 10 hrs
- Prepare presentation
  - Start/End Dates: TBA
  - Estimated Duration: 3 hrs

The arrangement of the timeline was determined appropriately and accurately in order to effectively and efficiently complete the different tasks and objectives in a timely manner. To accomplish this, a step by step analysis was performed to prioritize which tasks needed to be completed before others. This allows for smooth transitions between tasks and provides certainties for objectives to be completed to reach deliverables. To regulate the time constraints for each task, the project manual and syllabus was observed in order to settle suitable time frames for every objective and piece of work needed to be achieved.

Table 2.1 includes the arrangement of the developed project tasks, objectives, and deliverables for the automated oil skimmer. Task durations are presented through start and end dates that serve to create time constraints for effective production. Responsibility of personnel is also presented to establish accountability and work effectiveness.

Table 2.1 Detailed Project Tasks, Objectives, Deliverables, Task Duration & Responsible Personnel

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
Problem Formulation	1.1 Problem statement	To formulate the current problem and identify the current need for product optimization	Full description of the current unsatisfactory conditions that will be approached by the proposed design	2	9/3	9/5	David T.
	1.2 Client Identification and recognition of need	To find who will be a potential end user of the product and to determine the reason why the client needs the product	A list of 5 potential clients and structured statement that defines the overall project goal and the scope of the goal	2	9/3	9/5	Demetrious S.
	1.3 Project goals and objectives	To develop a goal statement and define measurable performance characteristics of design To identify the different permissible ranges of the product design and recognizing the product working environment	A labelled objective tree showing hierarchical relationships between objectives based on their performance characteristics. A list of permissible range for the design parameters, description of the environment in which the design will operate.	4 2	9/4	9/8	Ximena C.
	1.4 initial project constraints and operating environment				9/4	9/6	Caleb R.
Project Planning	2.1 Task identification	To identify the different tasks that will need to be completed during the project	A list of all the tasks that need to be completed for the project and their main subtasks	2	9/10	9/12	Group Work
	2.2 Timeline	To develop a detailed timeline for each one of the tasks listed in the task identification section	An effective timeline tables	4	9/11	9/15	Group Work
	2.3 Gantt Chart	Effectively organize the tasks and subtasks in a Gantt chart for timely completion.	A Gantt chart that has multiple features for project tracking.	5	9/11	9/16	David T.

1.

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
Literature Review	3.1 Identify relevant information to project	To identify information relevant to the project	A list of relevant Information for the project	1	9/16	9/17	Group Work
	3.2 Establish sources of relevant information	To establish a list of credible sources for the information provided	A list of credible cited sources	1	9/17	9/18	Caleb R.
	3.3 Research Oleophilic skimmers	To study relevant information on Oleophilic skimmers	A thorough research paper done on Oleophilic skimmers	1	9/18	9/19	DanielA.
	3.4 Analyze Non-Oleophilic skimmers	Detailed research on Non-oleophilic skimmers	A thorough research paper done on Non-oleophilic skimmers	1	9/19	9/20	Demetrious S.
	3.5 000Analyze Weir Skimmers	Review information on weir skimmers	A thorough research paper done on Weir Skimmers	2	9/20	9/22	David T.
	3.6 Make Inquiries into operational environment of skimmers	Inquire into operational environment of skimmers	list of inquiries made into operations environment of skimmers	2	9/22	9/24	Group Work
Functional Decomposition	4.1. Define functional decomposition concept	To study functional decomposition and generate concepts	Create an overall function statement	2	9/23	9/25	Group work
			A list of overall functions	3	9/23	9/26	Ximena C. Amna A.
	4.2 Develop a strategy for the functions and subfunctions.	To establish a strategy that define functions and subfunctions	A Level 1 subfunction, A Level 2 subfunction, A Level 3 subfunction				Caleb R.
	4.3 Generate a morphology table	To create a morphology table that identifies Functional analysis.	A morphology table for the functional decomposition	2	9/28	9/30	Demetrious S. Daniel A.

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
Concepts Generation	5.1 Develop a strategy to assign members to generate concepts	Generate concepts using well established concepts generation techniques for each of the functions.	A list of generated concepts Sketches that present concept of function	2	9/30	10/2	Demetrious S. Daniel A,
	5.2 Each member generates concept sketches individually	Generate sketches into team concepts for each function.		3	10/7	10/9	David T
	5.3Combine concepts from all members into morphology table	Assimilate individual concepts into a morphology	A morphology table	2	10/7	10/14	David T
Concept Evaluation	6.1 Identifying Criteria	Develop a list of generated criteria to begin the design analysis	A list of criteria that will be used to determine the preliminary concept design	3	10/14	10/17	Group work
	6.2 Organizing Criteria	Reorganize the create list into a manageable table	A criteria table	4	10/14	10/17	Ximen C. David T.
	6.3 Go-no-go method	Use the Go-No-Go and decision matrix to evaluate the list	Final result of the Go-No-Go method of the given criteria	4	10/16	10/20	Group Work
	6.4 Decision matrix	Use the Go-No-Go and decision matrix to evaluate the list	Final result of the Go-No-Go method of the given criteria	4	10/16	10/20	Group Work
	6.5 Preliminary Design	Develop a final preliminary concept for the design	Final result of the decision matrix determined The evaluation of the preliminary design	4	10/14 10/14	10/22 10/22	Group Work Group work
Preliminary Design	7.1 Rehabilitate existing designs	Explore the advantages and disadvantages of existing designs	Most effective ways to improve the design process	7	10/22	10/28	Group Work
	7.2 Identify options for flexibility	Prepare for the design to have room for changes if needed	Flexible options	7	10/28	11/04	Amna J, Amna A
	7.3 Approximate Dimensions		Final preliminary design should follow the constraint guidelines	7	10/28	11/04	Group Work

		Meet the initial constraints requirements					

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
Detailed Design	8.1 Identify and plan for types of analysis needed for the design	To get a realistic idea of the type of functional skimmer to create	A design idea created by working with all group members to produce ideas of skimmers that have never been on the market before.	4	11/04	11/07	Group Work Amna A.
	8.2 Draw rough draft on paper	To have a finalized image of skimmer design	A drawing of rough draft on paper based on group ideas.	7	11/04	11/10	Amna J.
	8.3 Produce real life blueprint of design in Fusion 360	To make design come to life virtually in Fusion 360 software.	A prototype in Fusion 360 software that has all aspects of design with correct parameters to resemble what the skimmer would look like once fabricated.	4	11/10	11/14	Group work Amna J. Amna A.
	8.4 Run Simulation in Fusion 360	To run experimental testing of skimmer.	A simulation run that replicates tests, i.e. stress analysis and skimmer capabilities before doing real time experimentation.	5	11/14	11/19	Amna J.
	8.5 Perform Detailed analysis	To perform thorough analysis of the skimmer design	A comprehensive analysis is established for the skimmer that will establish all components	5	11/14	11/19	Amna J
Detailed Parts Specifications	9.1 Identify constraints of design	To apply standards and design constraints to generate realistic models.	A model in Fusion 360 that shows the correct measurements of each component, and assuring all components are scaled properly.	4	11/04	11/08	Group work Amna J
	9.2 Generate specifications of each component	To identify the permissible range of the design and performance parameters	A list of permissible ranges for the design parameters, and applying it to the model.	4	11/08		Group Work
	9.3 Design Evaluation/Modifications	To ensure all parts meet parameter criteria.				11/12	Group work
	9.4 Final CAD drawing	To create design with all separate parts	A finalized drawing with all labels and dimensions			11/16	Group Work

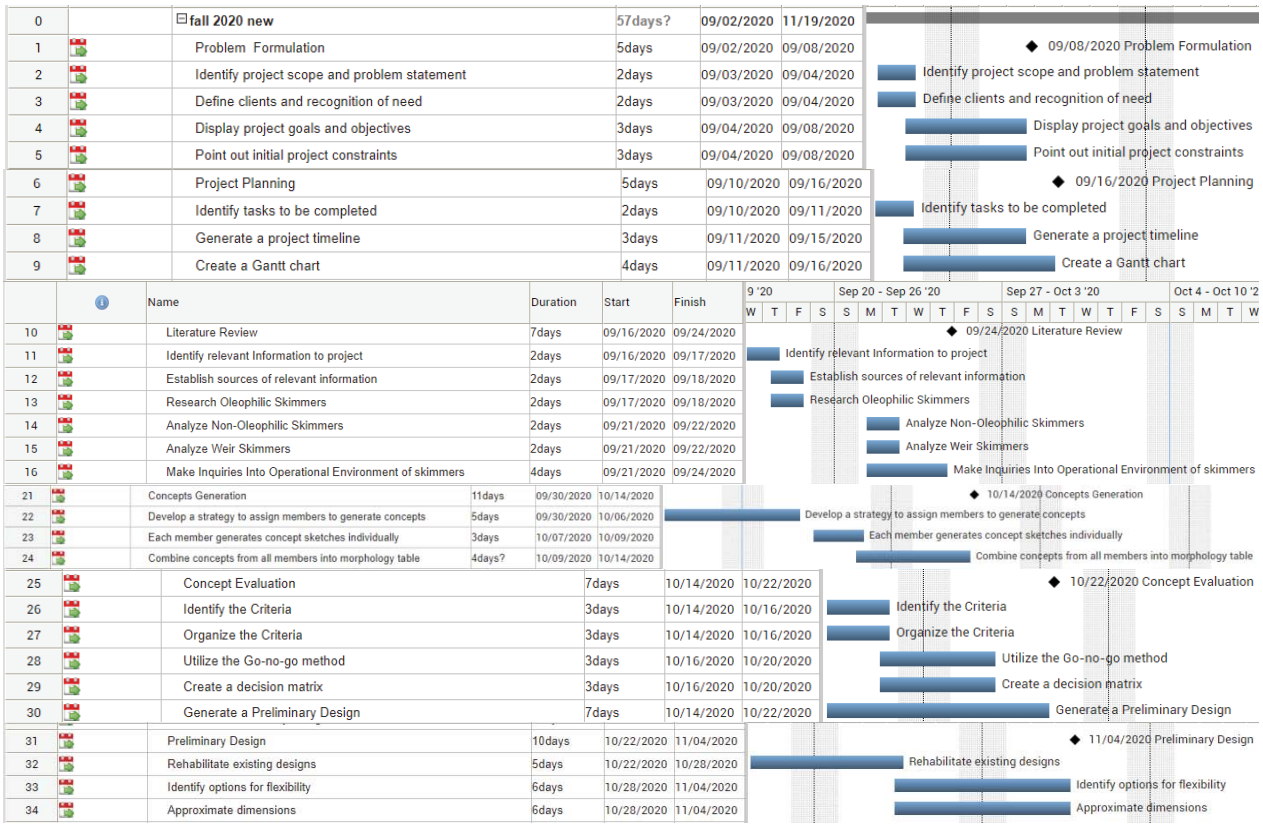
		merged for one finalized skimmer	A finalized Fusion 360 drawing that is realistic, meets industry nee needs, and will function when fabricated.	3 3	11/13 11/16	11/19	
Major Tasks Description	**Sub-Task Description**	**Objective(s) for Task**	**Deliverables to be Submitted**	**Duration (Days)**	**Start date**	**End Date**	**Primary Responsible Person**
10. Budget & Project Cost (Economic Analysis)	10.1 1 List of suppliers 10.2 Budget Generation 10.3 Approval of Budget Agreement	To Compare prices and quality with those from different suppliers To generate budgets for all the parts To get budget approval from the Mechanical Engineering department to review the budget	a list of parts that are necessary for purchase a budget that is reasonable Cost Comparison	20 5 8	11/05 1/20 1/25	11/25 1/25 2/02	David Trevino Group Work Group Work
Purchasing	11.1 Technical report 11.2 purchases	Generate a report that identifies all the parts that need to be purchased. Purchase parts.	A detailed technical report that identifies all the necessary parts. finalize purchases a final report that identifies all the parts that have been purchased.	4 8	2/05 2/11	2/09 2/19	Group work Group work
Fabrication & Testing	12.1 Manufacture & Assembly 12.2 Machine shop work 12.3 Product Testing	A plan for manufacturing and assembly of Automated Skimmer To create a detailed schedule for machine shop work rotation To conduct final testing and inspections for the automated skimmer	A detailed plan on how to go about the manufacturing of the skimmer Finalized schedule for workshop rotations Fully Functional Automated Skimmer	1 7 7	2/26 2/26 03/03	2/27 03/03 03/09	Group Work Group Work Group Work

Final Report & Presentation	13.1Finalize report	To construct a final report that reveals the entire design process of the project.	Compilation of revised reports and a table of contents and figure list A final presentation	7	4/22	4/29	Group work
	13.2 Prepare presentation	To organize all project elements into a presentation To present a well-prepared presentation of the project	A well-developed PowerPoint presentation	2	TBA	TBA	Group presentation

2.3 Gantt Chart

Gantt charts are a key tool for successful planning when executing a project. They are effective in projecting the duration of tasks and planning the order of milestone achievement. In this section, a Gantt chart was created to show a visual representation of the planning and scheduling of the tasks to be performed in Fall 2020 and Spring 2021. The program used to develop the planning of this project was Gantter Google.

In the ~~figures~~ 2.1 a visual representation of the planning for the Fall 2020 semester is displayed. In addition, the diamond shapes located above the bars indicate project milestones.



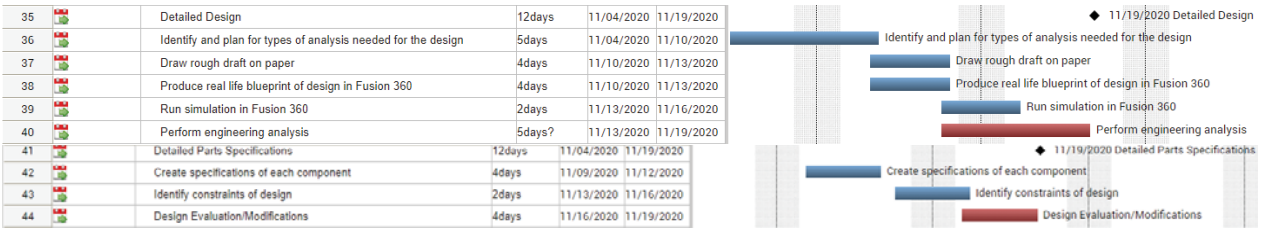


Figure 2.1 Gantt Chart Fall 2020

In Figure ~~2.1~~ a visual representation of the planning for the Spring 2021 semester is displayed. In addition, the green bar indicates the spring break week.

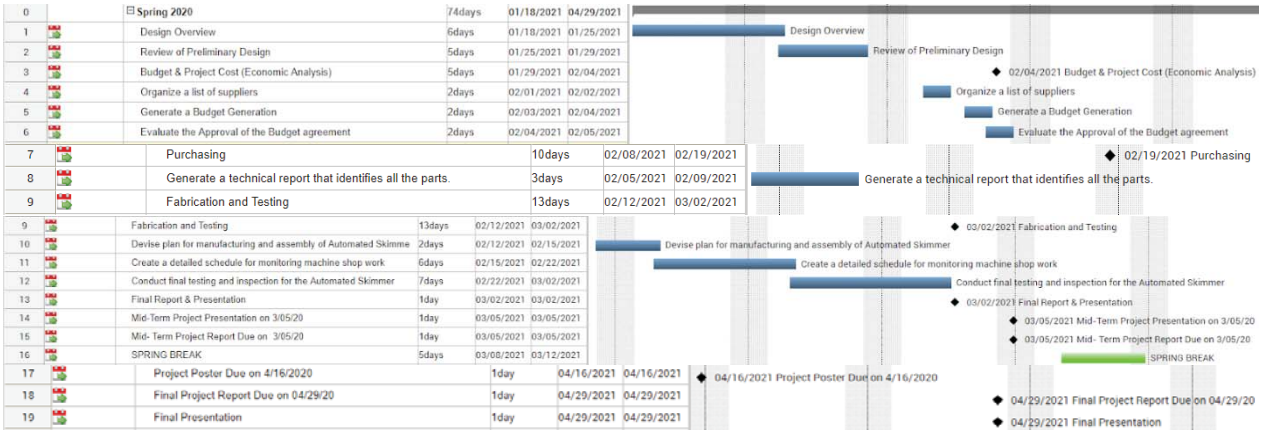


Figure 2.2. Gantt Chart Spring 2021

The use of the Gantt chart consists in strictly tracking the completion of the milestones and following the plan during the course of the school year. Strict use of the Gantt chart will ensure successful completion of the project. Currently, the team has reached the completion of the second milestone (Status Report on Project Planning) and are working on completing the third milestone (Status Report on Literature Review) of the Fall 2020 Gantt chart.

3. LITERATURE REVIEW

This chapter discusses different types of oil skimmers covered in our project. The oleophilic skimmers focused on include the disk-type, belt-type, drum-type and rope mop-type which all have different and unique ways to extract oil from water. The Non-Oleophilic skimmer types include Vacuum and Suction types, and Belt Mop-type. The topics for Weir skimmers include specific gravity and operational environment, as well as weir skimming operations. The last section covered over operational environment of skimmers include weathering and oil spill classifications.

3.1 Identification of Information Relevant to the Project

Research was done by each group member on the various types of skimmers currently in the market. Gaining a better understanding of the information needed to complete this project was carried out by identifying the relevant subject areas, and then analyzing previous skimmers that are currently in the market. The advantages and disadvantages of the existing designs were listed. Understanding the mechanics behind the different designs of existing skimmers was executed. Design analysis research was explored to aid with sizing and specifications for the current project.

Below is a list of main topics and their respective subtopics. Throughout the report every topic will be discussed in detail and the figures will give a visual representation of each topic.

- Oleophilic Skimmers
  - Disk-Type Skimmers
  - Belt-Type Skimmers
  - Drum-Type Skimmers
  - Rope Mop Skimmer

- Non-Oleophilic Skimmers
  - Vacuum and Suction Skimmers
  - Belt Mop Oil Skimmer

- Weir Skimmers
  - Specific gravity and operational environment
  - Weir skimming operation

- Operational Environment of Skimmers
  - Weathering
  - Oil Spill Classification

- Major Skimmer Components

- Relevant Analysis
  - Relevant Equations
  - Relevant Materials Skimmer

- Codes and Standards

3.2 Potential Sources of Information for Project

Sources have been gathered from using online scholarly databases such google scholars, University library, books, or any other online articles that have reliable secondary sources. Websites that allow multiple editors such as Wikipedia have been avoided to ensure information accuracy. In the list below you will find the different sources that were used in each section of the literature review.

- Oleophilic Skimmers
  - [1]Grill,P. Linde, F, Oil Skimming**,** Business Potential and Strategic Options Facing a Marginalised Business Segment at Sandvik Process Systems, Master of Science Thesis KTH School of Industrial Engineering and Management Energy Technology EGI-2013-077MSC SE-100 44 STOCKHOLM, pp 27-28

  - [2] Robert Governale, inventor; Miller Environmental Group, Inc., assignee. Oil Skimming Apparatus, United States patent US 5,685,979, 1997 Nov 11.

  - [3] Ray Ayers,Kenneth L. Bickham inventors; Shell Oil Company, assignee. Fibrous Disc Oil Skimmer, United States patent US 4,264,450, 1981 Apr 28.

  - [4] Agnew, R.W., *Free floating endless belt oil skimmer* United States Environmental and protection agency, 1972

  - [5] Philip C. Lewan, inventor; Camshaft Machine Company assignee. Belt Type Oil Skimmer with Horizontal Rotors, United States patent US 5,062,953, 1991 Nov 5.

  - [6] Philip C. Lewan, inventor; Miller Environmental Group, Inc., assignee. Belt Oil Skimmer Apparatus, United States patent US 5,015,378, 1991 May 14.

- [7] Gregory A. Ettelt, Alfred L. Cohen, inventor; Tenco Hydro/Aero ScienceS, Inc., assignee. Belt Type Oil Removal Unit, United States patent US 4,089,784, 1978 May 16.

- [8] INC., Elastec. "Drum Oil Skimmers: Oleophilic Skimmer." *Elastec*, 17 Sept. 2020, www.elastec.com/products/oil-spill-skimmers/drum-oil-skimmers/.

- [9] Donald L. Wilson, Jerry C. Trippe, inventors; Elastec Inc., assignee. Device for skimming oil from water. United States patent US 4,957,636, 1990 Sep 18.

- [10] J. S. Shum and M. Borst Mason & Hanger-Silas (*2015*) OHMSETT TESTS OF A ROPE-MOP SKIMMER IN ICE-INFESTED WATERS. International Oil Spill Conference Proceedings: February 2015, Vol. 2015, No. 1, pp. 31-34.

- [11] Alves, Tiago M et al. 2015. "Modelling of Oil Spills in Confined Maritime Basins: The Case for Early Response in the Eastern Mediterranean Sea." Environmental Pollution 206: 390–99

- Non-Oleophilic Skimmers

  - [12] Al-Majed et al., 2012 A.A. Al-Majed, A.R. Adebayo, E.M. Hossain A sustainable approach to controlling oil spills J. Environ. Manag., 113 (2012).

  - [13] Anh Tuan Hoang & Minh Quang Chau, 2018. "A Mini Review of Using Oleophilic Skimmers For Oil Spill Recovery," Journal of Mechanical Engineering Research & Developments (JMERD), Zibeline International Publishing, vol. 41(2), pages 92-96, July.

  - [14] ITOPF. (2012). The Fate of Marine Oil Spills. London, UK: The International Tanker Owners Pollution Federation.

  - [15] NOAA. (2010). Fact Sheet: Skimmers. Mobile, AL: National Oceanic and Atmospheric Administration.

  - [16] Ortega AE, Walker JT, Whitfield WW, Bostwick J (2011) Materials and methods for removing oil from bodies of water Google Patents.

- Weir Skimmers

  - [17] Grill, P., Linde, F., *Oil Skimming Business Potential and Strategic Options Facing a Marginalised Business Segment at Sandvik Process*

Systems, EGI-2013-077MS, The Royal Institute of Technology Stockholm, 2013, pp 24-90

- [18] N.O.A.A., *Fact Sheet: Skimmers*,National Oceanic and Atmospheric Administration,2010
- [19] I.T.O.P.F., *The Fate of Marine Oil Spills*, International Tanker Owners Pollution Federation, 2012
- [20] Hammoud, A.H. *Enhanced oil spill recovery rate using the weir skimmer* Mechanical Engineering Department, Beirut Arab University, pp 1
- [21] Cengel, Y.M., Cimbala, J.M., *Fluid Mechanics: Fundamentals and Applications*, McGraw-Hill, New York, 2014, pp 39,980
- [22] Kaperick, J.A., *Oil Beneath the Water Surface- and-Review of Currently Available-Literature on Group V Oils: An Annotated Bibliography Report,* HMRAD 95-8, National Oceanic and Atmospheric Administration, 1997, pp 3,9,18
- [23] SpillPro: *Oil Spill Control and Management*, https://spillpro.com.au/ 2017

- Operational Environment of Skimmers
  - [24] *Northwest National Petroleum Reserve-Alaska: Draft integrated activity plan/environmental impact statement* (Vol. 2). (2003). Anchorage, AK: U.S. Dept. of the Interior, Bureau of Land Management.
  - [25] Hoang, A., Pham, V., & Nguyen, D. (n.d.). *A Report of Oil Spill Recovery Technologies* (Vol. 13, 0973-4562, pp. 4915-4928, Rep.). Research India Publications. Retrieved 2018.
  - [26] ITOPF. (2014). Effects of oil pollution on the marine environment (Technical Information Paper 13). London, UK: ITOPF Ltd.

- Relevant Analysis
  - Grill, P., Linde, F., *Oil Skimming Business Potential and Strategic Options Facing a Marginalised Business Segment at Sandvik Process Systems,* EGI-2013-077MS, The Royal Institute of Technology Stockholm, 2013, pp 20-90

- Codes and Standards
  - Oil Spills Prevention and Preparedness Regulations. (2020, August 05). Retrieved October 01, 2020, from https://www.epa.gov/oil-spills-prevention-and-preparedness-regulations

Environment preservation is a topic often overlooked by society. throughout the years the human population has had to jeopardize the well being of the earth to be able to fulfil the population needs. therefore, the world has reached a level where immediate action to preserve the environment needs to be taken and this literature review will focus on the preservation of the earth's bodies of water using different types of skimmers.

Industries that develop and enable the population to have access to sources derived from the oil exploitation have experienced major failures in their systems. These failures have open room for multiple and critical oil spills in the ocean. As a result, the quality of these bodies of water has been negatively affected and marine life is suffering major consequences. As a consequence, immediate need for an effective oil recovery system has grown and the development of new oil recovery technologies has been requested.

To further the discussion of oil recovery, it is extremely important to recognize that the recovery operation is broken into two different categories. One of the categories is the ability to immediately and effectively contain oil spills. On the other side, the other category is based on the different types of oil recovery methods and devices. This literature report will focus on the different types of skimmers and the oil behavior on the skimmer's operational environment.

In this literature report, there are two main types of skimmers that are discussed. The first type of skimmer consists of an oleophilic skimmer that utilizes a belt, disc, drum, tube, brush, grooved disc, smooth drum, and grooved drum to safely remove oil from water. The second type is called a non-oleophilic skimmer that employs a weir, belt mop or suction components in order to separate the oil. Each variant of skimmer has its advantages, and some may contain more than one component in order to improve the efficiency of the skimmer.

3.3 Oleophilic Skimmers

In this section, the different types of oleophilic skimmers will be discussed in detail. Oleophilic skimmers are the type of skimmers that use disks, belts, drums or rob mop chains composed of oleophilic materials to catch the oil from the water surface.

3.3.1 Disk-Type Skimmers

Disk skimmers operate by mounting to the top of the tank and running a large diameter disk into the coolant surface. The disk itself is made of either plastic or stainless steel. As the disk passes through the coolant surface, oil is captured and cleaned with a set of wiper blades as the disk passes between them. The recovered oil may be stored in a container or pumped directly into a reservoir. This description can apply to the generic form of any disk skimmer, but what will be assessed are the different functionalities and flexible designs that today's oil skimmer has to offer as well as the advantages and disadvantages.

The Disk-Type oil skimmer offers flexible design options that allow versatility as well as cost efficient production options. Disk skimmers, although dependent upon the number and size of the operational discs; are most effective in medium viscosity oils. Compared to other oleophilic

skimmer types, the disk skimmers are smaller, more cost efficient and have a slightly higher pick-up rate than their counterparts. Grooved disks, studies have shown, result in higher recovery rates than of disks with smoother surfaced disks. The skimmers can also be operational in a stationary setting or float within polluted waters. Some drawbacks are that the disk skimmer requires a larger operating space due to the accommodation of the disks. Also, the skimmer typically cannot sustain efficient operation if debris is present. The skimmer may also require additional ancillaries to operate. These include separate power packs, hydraulic or discharge hoses and storage containment. ~~[1]~~ Industrial skimmers can be quite large in weight and volume due to the size and number of rotating disks. The final disadvantage is that the disk-skimmer cannot handle oil that has been emulsified, or chemically broken up into small droplets.

The designs of most disk-skimmers contain a single disk or a multiplicity of disks that rotate along a common axis. The tops of the disks rotate away from the skimmer enclosure while the bottom of the disk(s) rotates towards the skimmer. Materials for these disks are usually smooth unmalleable and rigid metals or plastic and plate like structures. Some designs also include disks that have sorbent materials that provide extra efficiency to oil recovery rate. Figure 3.1, A United States patent [2] developed in 1981 incorporated fibrous bristles that can attach to the disks. The design features 32 disks with absorbent fibers attached that provide a large surface area to which oil can adhere. The bristles have a thickness of .005-.100 inches and a length of .25-2 inches. Possible bristle materials were nylon, polyesters, and polyamides. An experiment conducted through this patent included a test of two types of oil with and without the presence of the oil absorbent bristles. Figure 3.2 is a side profile of US patent 5,685,979 that demonstrates the process of how the oil processes through the skimmer design using the fibrous disks. Results concluded that the presence of the fibrous bristles substantially increased the oil recovery for both oil types due to the increased surface area they provided. This patent experiment expresses that simple disk design can be easily altered to increase the overall recovery efficiency of the skimmer.

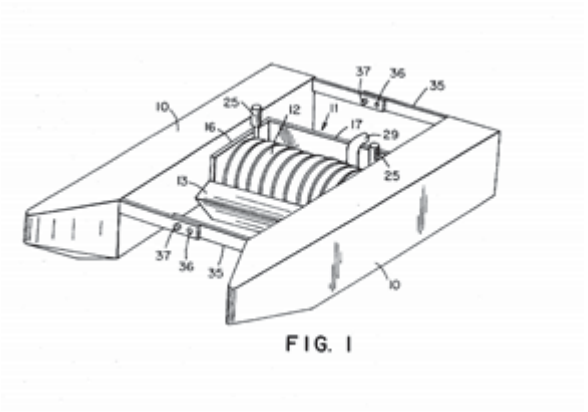


FIG. 1

Figure 3.1 US Patent 5,685,979

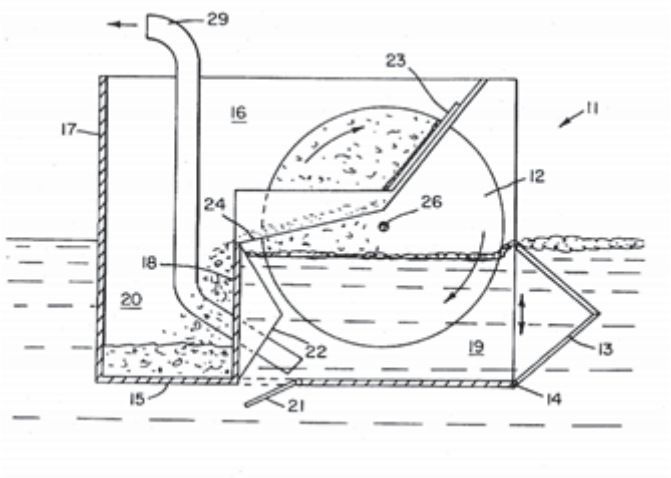


Figure 3.2 US Patent 5,685,979

Another United States Patent presented in ~~figure 3.1~~ is a [3] design that was developed in 1997 that features a detachable skimmer system that is suspended within two hulls. The open U-shaped design allows for water to flow inwards to a plurality of oleophilic disks along the same shaft. Like the previous mentioned patent, disks rotate away from the skimmer and alternatively collect oil while rubber scrapers are then used to remove the oil into a drainage area and into the hulls for storage. In many disk-designs like this one, hydraulic actuators can be used to compensate for the weight of the collected oil to maintain deployment of the skimmer device on the surface of the water. Keels and bows were also used to allow directional stability. The patent claims also express that the design was not limited to just the two hulls included. This helps to expand the design options for future oil skimmer developments.

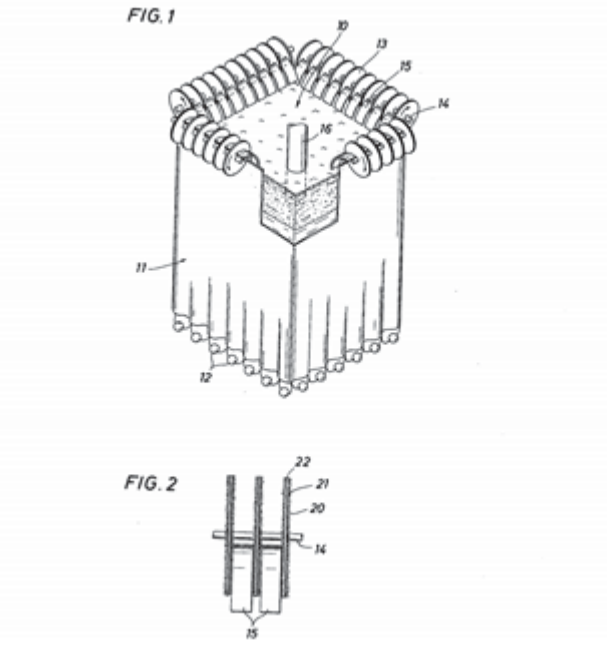


Figure 3.3 US Patent 4,264,450,

Automation within design serves as a key advantage to disk skimmers. Power packs are utilized for disk designs to allow the disk to rotate which can serve as a motor for the disk shaft. These can be hydro- electric or possibly just a standard industrial DC volt battery.

3.3.2 Belt-Type Skimmer

In this section, we will discuss an oleophilic oil skimmer which utilizes a belt system. This type of apparatus is commonly used in the oil recovery field alongside disc, drum, tube, brush, grooved disc, smooth drum, and grooved drum. A belt-type oil skimmer uses an endless belt of corrosion resistant steel or synthetic medium, which is lowered into the tank or vessel to be skimmed. The belt passes through resilient wiper blades where the oil is removed from both sides of the medium. The advantage of a belt type skimmer is that it is the most reliable and economical type of skimmer design that is able to remove various thickness of oil layers.

In the research paper "A free floating endless belt skimmer" an experiment was conducted using a free-floating endless belt skimmer. Another patent explored was developed in 1990 in which "The belt is threaded over the upper portion of a primary drive roller having a horizontal axis and pressure rollers mounted upon linkage sets are biased towards opposite sides of the primary roller in engagement with the belt to squeeze the collected oil from the belt permitting the oil to flow to a collector located below the rollers"[5]. "The skimmer utilized a unique high efficiency conveyor wringer to power and wring the belt. The belt is designed to float on the water surface and responds rapidly to the shape of the waves, thereby maximizing oil-sorbent contact time" [4]. This experiment was conducted in a 60-foot diameter annular test tank and demonstrated the effectiveness of a belt type oil skimmer. The results of this experiment showed that the oil pick up rates would vary depending on the belt speed, oil slick thickness and porosities. In addition, "oil pick-up rates of 8.3 and 3.7 gpm per foot of belt width were obtained for #2 Fuel Oil and Bunker C oil respectively at a slick thickness of 0.10 inches. The recovered liquid contained approximately 50-70% oil at 0.10-inch slick thickness."[4] This research was conducted in 1972, however it demonstrates the effectiveness of a belt type skimmer and provides experimental data and a design that can be improved upon. Another similar design explored was developed in 1990 in which "The belt is threaded over the upper portion of a primary drive roller having a horizontal axis and pressure rollers mounted upon linkage sets are biased towards opposite sides of the primary roller in engagement with the belt to squeeze the collected oil from the belt permitting the oil to flow to a collector located below the rollers"[5].

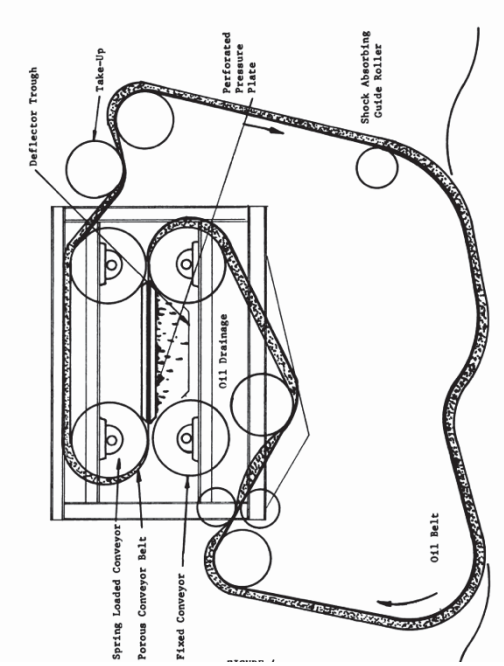


Figure 3.4 Free Floating Endless Belt Skimmer

In the patent 5,015,378, it illustrates an "apparatus for removing oil from the surface of a liquid using an endless belt partially submerged in the liquid, the belt passes over a primary roller having a vertical axis and pressure rollers squeeze the belt which flows by gravity to a collection receptacle mounted upon the frame supporting the primary roller and its driven structure. The belt twists whereby its lower portion submerged in the liquid defines a reversing loop whose configuration is maintained by a weight roller having a horizontal axis of rotation."[4] Using a combination of belt and rollers, this design is able to produce high efficiency oil removal and requires minimum maintenance and servicing.

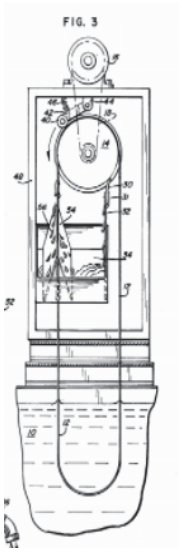


Figure 3.5 U.S Patent 5,017,378

In Figure 3.5 the patent 5,062,953 depicts an oil skimmer where "The belt is threaded over the upper portion of a primary drive roller having a horizontal axis and pressure rollers mounted upon linkage sets are biased towards opposite sides of the primary roller in engagement with the belt to squeeze the collected oil from the belt permitting the oil to flow to a collector located below the rollers. The linkage sets include reversing rollers, and the apparatus is constructed to readily permit belt replacement" [5]. Similarly, to the last patent, it uses a combination of belt and rollers in order to successfully remove oil from water. These patents exhibit similar goals and objectives, however, take various steps into achieving them. In Figure 3.6 the patent 4,089,784 portrays a design where "An endless belt for carrying oil is partially submerged in the basin and is driven and supported by a rotary drum. The rotary drum has an irregular surface for frictional cooperation with the belt and a spring biased roller urges the belt against the irregular surface. The oil is scraped from the belt and directed away from the belt and basin" [6].

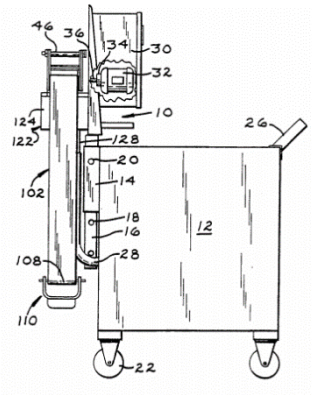


Figure 3.6 U.S Patent 4,089,784

Unlike these last two patents, this one utilizes a rotary drum in addition to a belt and roller system. The addition of a drum indicates that most oil skimmers will utilize a combination of designs in order to maximize efficiency of oil removal.

3.3.3 Drum Skimmers

The oleophilic drum skimmer shown in Figure 3.7 was pioneered in 1990 by Elastec and was regarded as one of the most efficient oil recovery skimmers for shallow waters [8]. This type of skimmer uses materials like aluminum, steel, or general-use plastics since these materials attract oil and repel water. This allows for oleophilic skimmers to be very efficient in not picking up substantial amounts of water even when there is little to no oil present. This is one of the most crucial elements of its design because this is what determines its rate of efficiency of oil recovery.



Figure 3.7 Elastec Drum oil Skimmer

Drum skimmers typically have one or more large drums that rotate while slightly submerged in water. The oil attaches to the surface of the drum while the drum rotates in the oil-water interface. The oil is then squeezed or scraped off the drums into the recovery tank. The oil is passed to a reservoir trough, which forms the back of the frame, through channels between the two drums and at the drum ends. The reservoir trough and the drums are sized to provide all of the buoyancy necessary to float the device and are proportioned so as to position the skimmer in an effective, oil gathering attitude.

The drum skimmer consists of three main items in the development stage, a smooth or grooved drum skimmer, a pump, and a power unit. Just as there are also many factors to consider during configuration. For starters, the location of the oil must be known in order to choose the sizing of the model. Knowing if the oil is very light, light, moderate, or heavy as well as knowing what condition the oil is in due to the weather will affect the viscosity of the oil. For example, cold weather will cause more viscous oil which will be harder to pump. The volume of the oil is a big factor as well as the timeframe. When time is a factor, skimmers with a larger trough are not ideal since the large trough skimmers are used for a more paced scenario. Lastly, being aware of the surrounding area and resources will help depict the best power source (pneumatic skimmer system, electric power pack, or a diesel hydraulic power unit). Figure 3.8 and Figure 3.9 show the patient's design features; "polyolefins including polyethylene and polypropylene since they are among the preferred plastics due to the fact that they have desirable properties including light weight, oil wettability, and corrosion resistance [9].

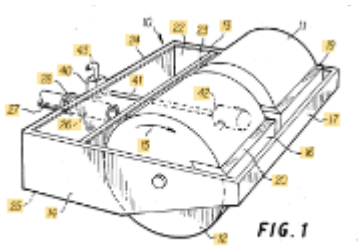


Figure 3.8 US Patent 4,957,636

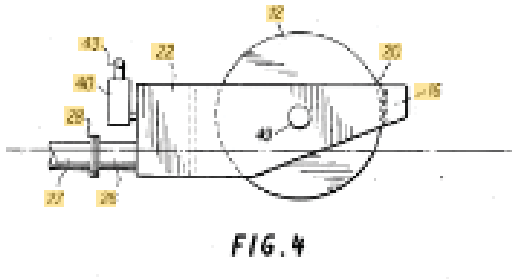


Figure 3.9 US Patent 4,957,636

The collection trough is open-topped, has two rear wall portions, each adjacent to and extending along the length of one of the drums and topped with scraper or doctor blades which bear against the cylindrical wall surface of the drums respectively. The total power required to drive the drums is modest; less than 1 horsepower, so a very light weight air motor is adequate" [9].

3.3.4 Rope Mop Skimmer

The rope mop oil skimmers or rope mop wringers are about the oldest technology out there for oil skimming or getting oil off water. Like all hard-mounted oil skimmers, the Rope Mop Oil Skimmer can be set to run continuously and run unattended. These rope mops run an endless or looped rope or belted material (looks like a squirrel tail) with oil attracting (oleophilic) fibers woven or sewn into it, out across the water or down vertically (as in a pit). The oil sticks to the outside of the fibers and the rope goes back into the wringer machine where either 2 or 3 rubber coated rollers squeeze the oil out and off of the rope and gravity drains it into a tank [10]. For higher viscosity oils, this medium tends to mat down and lose effectiveness. Generally, a decantation system must be used with these Units, as water pickup can be quite high. Also, replacement mops tend to be more expensive than its counterpart (Belt type skimmer).



Figure 3.10 Rope Mop Skimmer

Rope mop skimmer can be used in a variety of configurations and they are listed as follows. Vertical mop skimmers can be deployed down boreholes, drains, separators and sumps. Horizontal mop skimmers can be deployed across lakes and rivers, settlement bonds, balancing tanks or fat traps. They can also be Retrofitted to existing industrial water treatment facilities. Rope mop skimmers are efficient during early responses to oil spills while offering long durations of operations. 'Rope mop skimmer systems typically incorporate an oil/water separator which allows any free water pick up to be returned to the effluent water allowing only oil to be gravity drained or pumped to the waste oil storage tanks nearby. This means the system can effectively operate 24 hours per day 7 days per week without any manual assistance ensuring peace of mind clearing all visible surface oil contamination'[11].

The skimmers can be powered either by an electric drive, air, hydraulic or diesel options are available if required.

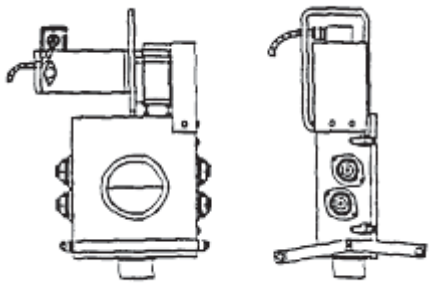


Figure 3.11 Rope Mop Skimmer Apparatus

The mops are manufactured from a special polypropylene fabric which is stitched to form a continuous loop. Oil skim ropes are made from fibrillated polypropylene which has a large surface area and ensures excellent oil recovery rates. The mops are available in varying widths in black (For heavy sticky oils) and white (for light oils). They are available in lengths form 2m long to 120m long depending on the application. In addition to that, they recover up to 2000L an hour of floating oil.

The Rope Mop recovery rate is dependent on the number and velocity of the ropes, it is generally low throughput. It can be used in both medium to high oil spills, but it is most effective when used on medium spills. The design of the mop skimmer makes it operable in choppy waters, and it is also able to tolerate significant debris, ice and other obstructions.

3.4 Non-Oleophilic Skimmers

Non-oleophilic skimmers carry out the same function as other skimmers, to separate oil from water. The distinguishing component between non-oleophilic vs. oleophilic is that the latter uses oleophilic material. Oleophilic material is oil attracting, by adding oleophilic material onto the skimmer, oil adheres to the surface. In certain situations, such as hot alkaline aqueous parts washer, oleophilic material is inappropriate [12]. In such cases, non-oleophilic skimmers are necessary. Non-oleophilic techniques include weir skimmers, suction systems, and mechanical skimmers. Non-oleophilic skimmers are not as prevalent due to the many restrictions they have. They are usually only used in environments where oleophilic skimmers are inappropriate. They are not as efficient in differentiating between oil and water and aren't as versatile in the types of water they can be used in [13].

3.4.1 Suction Skimmers

Suction skimmers include vacuum skimmers, whereby oil is recovered directly from the water surface by air suction systems. Other vacuum skimmers use a hose directly connected to a vacuum truck, which can easily be carried out in rivers. Vacuum trucks are generally self-contained with necessary power supply, pump and storage [14]. Due to the sensitivity to waves, vacuum skimmers are often restricted for use in calm waters. Furthermore, suction skimmers are ideally suited for recovery of oil on or near the shoreline [15]. Another disadvantage of suction mechanisms are the unchanging capabilities of a suction device which can result in high proportions of water being collected and are easily clogged by large debris.

3.4.2 Belt Mop Oil Skimmer

A belt mop oil skimmer is a non-oleophilic mechanism employed to skim oil from coolant and wastewater. The belt is used in applications where an oleophilic material, such as a rope, drum, or disc, is inappropriate. The skimmer works on the difference in surface tension of oil and water allowing the rotating continuous belt to attract waste oil and reject water. Since belt mop oil skimmers are used in harsh conditions, the skimmer is generally turned off whenever there is no oil to skim to minimize the amount of water collected. It is most effective in heavy oils and is capable of removing a high volume of oil [16].

3.5 Weir Skimmers

Weir skimmers are used for effective oil recovery all around the globe. This type of skimmer uses the difference in specific gravity from the oil and water to their advantage for effective draining of spilled oil from the surface of a body of water. The skimmers are usually released using a crane from a moving vessel into an oil containment area to proceed with the recovery of the oil.

The weir skimmers are either remote controlled by compressed air or by self-adjusting. [17][18][19]Moreover, according to a study of the enhanced oil spill recovery rate using the weir skimmers made by A.H. Hammoud from the Mechanical Engineering Department of the Beirut Arab University, "Weir skimmers play an important role in oil spill recovery." [20] In addition, the study emphasized that improving the performance of weir skimmers will allow spilled oil to be recovered more efficiently, which will result in the reduction of environmental harm [20]. However, weir skimmers' recovery effectiveness lies on several factors that will be discussed in detail in the following paragraphs

3.5.1 Specific gravity and operational environment

In order to start developing a fundamental understanding of how the weir skimmer works, it is necessary to understand the role that specific gravity plays in the overall effectiveness of the skimmer. According to the book "Fluid Mechanics Fundamentals and Applications," specific gravity is defined to be the ratio of the density of a liquid to the density of a standard liquid such as water at a specific temperature. Therefore, for many applications the specific gravity of a liquid is calculated based on the specific gravity of water at 4°C, 1000 kg/m3 [21]. As mentioned in the beginning of this section, the difference in specific gravity between the oil and water allows the oil to create layers on top of the surface of the water. The higher the difference in specific gravity between them, the higher chance for effective containment and recovery of the oil.

When an oil spill is experienced, one of the most important operations that leads to effective oil recovery, is the effective containment of the oil. Therefore, most of the oil recovery operations begin by using oil containment booms. Although the booms difference in size and form, what affects their effectiveness is the operational environment and the specific gravity difference between the oil and the water. These two factors go hand by hand and directly affect each other. For example, if the difference in specific gravity of the oil and the water is significant, then the oil will be more accessible in the recovery process as it will form a thick layer on top of the water surface. In addition, the thick layer of oil will be more likely to withstand higher wave pressure and increased wind. On the other hand, if the specific gravity of the oil is very close or equal to the specific gravity of the water, then the waves and higher winds are likely to easily move the oil. Harsh movement of the oil whose specific gravity is close to the water's specific gravity, causes the oil to sink under the boom and resurface around 100 ft away from where it sank. As a consequence, the weir skimmer will not be able to recover the amount of oil when it experiences that level of turbulence and buoyancy [22].

3.5.2 Weir skimming operation

Weir skimmers drain are known to be floating devices. The edges of the weir skimmers are positioned at the interface between water and the oil layer on top of it or right below the upper oil slick surface. This allows the oil to successfully flow right over the weir edges into the containment area within the skimmer. Once the oil is recovered and placed in the containment area the Oil is then pumped into external storage tanks. The weird skimmers are the skimmers most used due to their portability and easy assembly [18][19]. Conclusively, these skimmers effectiveness increases when there is effective containment of the oil by using a boom like the one shown in Figure 3.12 and again depending on the specific gravity of the oil over the water as

stated in the specific gravity and environment subsection. In addition, weir skimming operations can be improved by developing a mechanism that will increase oil recovery rate with less amount of water recovered and becoming independent of the oil-water gravitational force effects.

Figure 3.12 displays an oil recovery operation by using a weir skimmer and a boom containment unit.

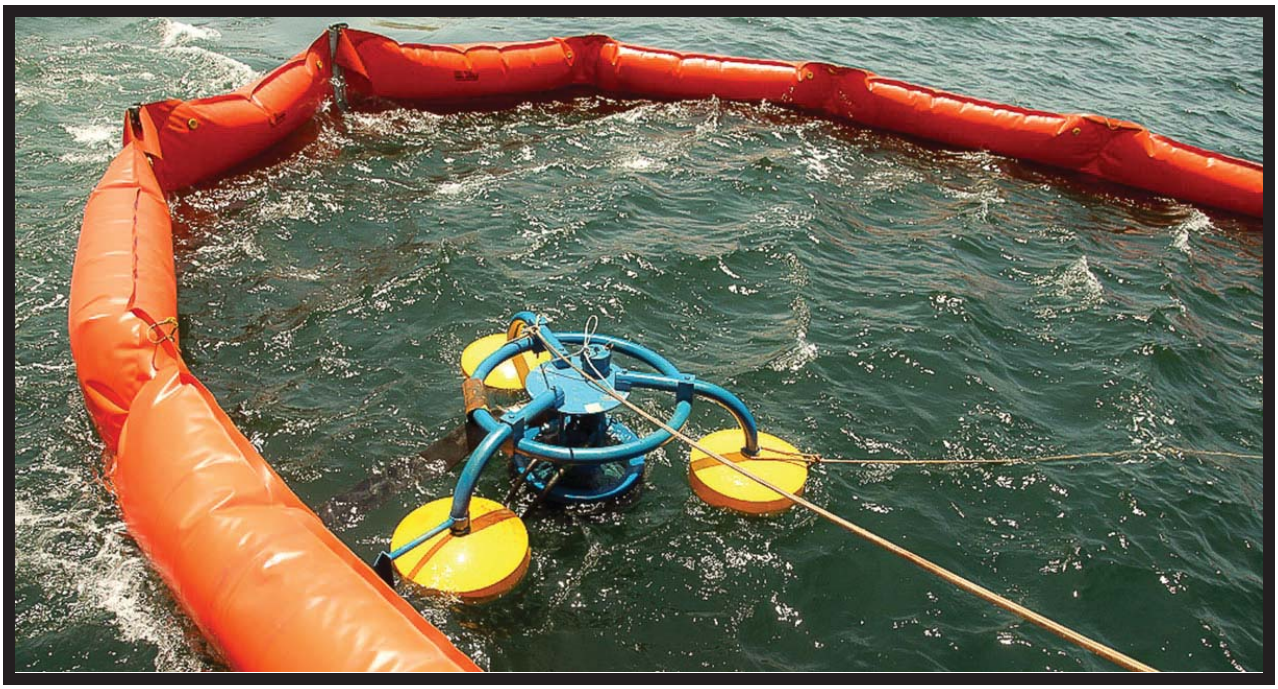


Figure 3.12 SpillPro on 1 November 2017

3.6 Operational Environment of Skimmers

Operational environment can be described as a condition that influences the behavior and efficiency of an object to do a certain function. Operational environment on booms, skimmers, absorbent materials or any other physical oil recovery method is the primary process that affects the nature of an oil spill. Boom is a barrier used to prevent oil spill or slick from spreading, however the efficiency of this operation can heavily depend on the characteristics of the current, wind, or wave behavior [24]. When the wind or current velocity is at a certain point or the height of the wave is above 1 meter then the oil will spill underneath the barrier. This will limit the booms efficiency recovery which leads to using a skimmer as the next step of the water cleanup process. An oil skimmer is a device used to remove oil from a body of water, however an operational environment can heavily influence the productivity of this product. These negative consequences can happen because of weathering, which is the case of spreading, evaporating, dispersion, dissolution, and emulsification of an oil [25]. The final step of water rehabilitation is using adsorbent materials, which is the use of sorbent materials to clean oil spills.

3.6.1 Weathering

The effect of weathering on the productivity and efficiency of the oil recovering process can occur in various ways. one of the weathering aspects is spreading, which can be described as the reduction of bulk quantity of oil and increasing spatial area [24]. Thus, oil in a high current system can be less concentrated as opposed to a well contained system. Evaporation is another characteristic of weathering that can affect the recovery of an oil spill. Evaporation is the mechanism of losing the light molecules into the air which leaves the oil to be denser, heavier, and more viscous. Dispersion can be described as the action of distributing the oil into the water which can damage the skimmer or booms physical impact on oil recovering. Dispersion can be a result of having a high-water turbulence. Dissolution of oil occurs when the water-soluble component of oil may dissolve into the water surrounding. This type of weather characteristics is one of the primary toxic reasons of an oil spill. The process of dissolution may occur frequently when temperature rises, molecular weight decreases, salinity decreases, and when there is an increase in the dissolved concentrations of organic matter [25]. Lastly, emulsification is opposite to dispersion, it is when water dissolves and incorporates oil. This is a product of the wave behavior into the oil and water, the high energy of the wave emulsifies the oil. Heavier oil is more likely to emulsify rapidly as opposed to lighter oil. This condition is often referred to as "mousse". Figure 3.13 showcases some of the different alteration processes that an oil spill faces on water [26].

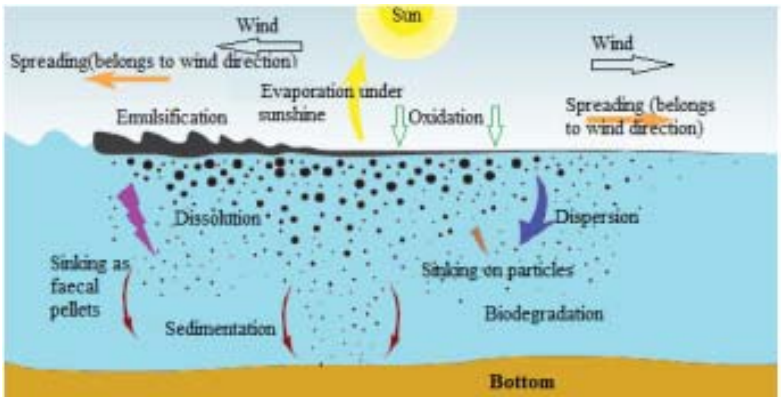


Figure 3.13: Various Weathering Conversations of Oil Spills

3.6.2 Oil Spill Classification

Oil spills unquestionably damages marine environments and causes severe impact to the water. Therefore, oil spills have been classified into three categories.

- First class: The following classification is for small oil spills that are related to machinery discharge of oil water mixture. It can also be a result of operational vessels/ships in port, or berth line [25].
- Second class: The following classification is for oil spills that are related to ship incidents such as fires, collisions, or any other damages that are associated with ships. This can result in contaminating large water areas and can result in damaging the ocean environment [25].

- Third class: The following oil spill classification is for any intentional oil spill, someone who jeopardizes the water quality and marine life just to save money. This can be classified as a criminal act [25].

3.7 Major Components of Skimmers

This section focuses on the main and vital components of many different skimmer designs. Through extensive research the team was able to accumulate a list of major components that current skimmer designs have. Below, a list of some of the different components identified is provided with their respective functions.

- Pump/hose: Extension of skimmer design used to extract collected oil to be relocated to an outside container source.
- Container - Used to store the collected oil from the skimmer. This prevents the oil from mixing with the water after it is collected.
- Draining system - A system designed to drain the collected oil from the container after it is separated from the water. The collected oil is then removed and stored to keep the container empty to restart the skimming process.
- Filter system - Oil and water separator that detects the density of collected liquids and also catches small particles to keep oil purified for reuse. After liquid is filtered, it is then moved to the container.
- Power supply - A power supply would be needed for skimmer mobility. Examples consist of an Electric motor, Diesel hydraulic power unit, or a DC volt battery.
- Sensor: A sensor will be needed to determine the distances the skimmer will fluctuate within. These sensors will also manage the START and STOP control for the skimmer during skimming operations. Finally, the sensor will be able to detect oil thicknesses.
- Actuators: Hydraulic actuators are components used to control the intake of a system. Since the skimmer is mechanically driven by water, the actuator can “control” how the system reacts to the environment using a control signal, usually a valve.

3.8 Relevant Analysis

This section covers the relevant analysis needed to understand the methods and mathematics for proper fabrication of a working skimmer. The skimmer will need to have realistic rates of recovery to meet general standards. The materials will need to be cost effective, meet the specifications for mechanical properties, have corrosion resistance, and the ability to withstand various types of weathering. Using the proper materials is vital to the lifetime of the skimmer. Below, a list of chemical properties, calculations, and material standards can be observed.

- Oil and grease always on the water surface. They do not mix with water. Separation of it is based on the surface tension, specific gravity and viscosity of them

- properties determining if oil can skim surfaces involve floatation, viscosity and the time the oil stays on the surface of the water.
- Specific gravity can be calculated to determine if oil will float on water, if the specific gravity is lower than the surrounding water is(which depends on if it's pure or sea water) then it will float. API equation can be used to measure specific gravity of oil

$$^{\circ}API = \frac{141.5}{specific\ gravity\ at\ 15.6\ ^{\circ}C} - 131.5 \qquad \text{(Equation 3.8)}$$

- Besides specific gravity, pour point, is another method used to categorize oils. The pour point is the temperature below which an oil can no longer float [17].
- The speed of oil spreading depends on the viscosity of the oil as well as external factors like wind. Low viscosity oil spreads easily while high viscosity oils do not
- The rate of evaporation depends on the ambient temperature as well as the wind speed, but in temperate climates all hydrocarbons with a boiling point below 200°C will evaporate within 24 hours [17].
- Oil dispersions mainly occur at sea, at the location of breaking waves. Dispersion usually affects low viscosity oils as high viscosity oils are more protected of dispersion as the particles are more tightly attached to each other thus requiring more force to break the oil particles apart.
- Various factors need to be taken into account during the selection skimmers but the most important aspects to consider are the viscosity and the adhesive properties of the oil within the skimming process
- The second most important factor to assess is the skimmer's intended use and expected operational conditions.
- Recovery rate (RR): The rate at which pure oil is recovered
- Recovery efficiency (RE): The relation between recovered oil and recovered fluids (oil-water mixture)
- Throughput efficiency: The relation between encountered oil and recovered oil

3.8.1 Relevant Equations

Theoretical calculation that can potentially be used to identify the amount of oil that can be recovered using disc type oil skimmer:

$$Amount\ of\ recovered\ oil\ spill = A\ x\ \mathrm{R}\ x\ \mathrm{Ti}\ x\ \mathrm{T} \qquad \text{(Equation 3.8.1)}$$

where A is the area of the dipped disc(m2). R is the disc rotation speed (RPM).
Ti is the time/duration taken(s). T is the oil thickness (cm).

When oil spill is recovered by a rotating drum skimmer, the following variables are involved:

$$f_1(Q, d, L, \omega, h, t, \rho, \mu, \sigma) = 0$$

(Equation 3.8.2)

where Q is the oil recovery rate (m3/s), d is drum outer diameter (m), L is drum length (m), o is rotational speed (rad/s), h is height of the drum centre above the oil/water interface surface (m), t is oil film thickness (m), r is oil density (kg/m3), m is dynamic viscosity of oil (Pas), and s is oil surface tension (N/m).

The volume rate of oil recovered per turn when shaft is rotating for the belt type skimmer:

$$V=T \times W \times \pi \times d \times N \qquad \text{(Equation 3.8.3)}$$

where T is the thickness of film on the belt in (mm). W is the width of the belt in (m). D is the diameter of the shaft in (m). N is the speed of rotation of the shaft in (rpm).

3.8.2 Relevant Materials

The proper selection of material for different parts of a machine will depend on the following factors:

1. The cost of materials.
    1. The cost of the materials used will need to be within means to appeal to buyers.
2. Physical and chemical properties of materials.
    1. Weather, water, and corrosion resistant materials such as stainless steel, rubber, aluminum and polypropylene.
3. Mechanical property of material.
    1. Factors include: Strength, Stress, Stiffness, Elasticity, Plasticity, Brittleness, and Hardness.

3.9 Codes and Standards

This section covers some of the acts, programs, and testing regulations that are relevant to Oil skimmers and oil recovery.

The oil pollution act was passed in 1990. This act was an amendment to the Clear Water Act in which some oil storage facilities were required to develop facility response plans for spills. The lead federal response agency EPA is the agency for oil spills occurring in inland waters. Some of EPA's top priorities are to prevent, prepare for, and respond to oil spills that occur in and around inland waters of the United States. EPA's oil spill prevention program includes the Spill Prevention, Control, and Countermeasure (SPCC) and the Facility Response Plan (FRP) rules [17].

On the other hand, the Bureau of Safety and Environmental Enforcement, the Oil Spill Preparedness Division, and the Response Research Branch manages the OSRR Program. This research program has focused on improving the spill response countermeasures. The program

opens a path that helps develop decision making strategies for oil spill responses in the offshore environment.

In addition, testing optimization from ASTM-2709-08 requires performance data to be the result of three measurements that produce results within 20% of the arithmetic mean. The skimmer optimization process requires that a skimmer should operate to provide the maximum ORR while also meeting 70%.

Discussion:

The supporting articles and references above help to establish the credibility and procurement of today's advances within the efforts of efficiently conducting oil removal from open water sources. The abundance of resources pertaining to these advances allow for comparisons of the advantages and disadvantages that the industrial oil skimmers have to offer today. By examining the many key differences between oleophilic, non-oleophilic, and weir skimmers, an analysis can be conducted to determine which design can be further altered to increase the efficiency of today's oil recovery. Key aspects of understanding the efforts of increasing the efficiency include the characterization of each skimmer type as well as their operational environments. Patterns and characteristics of oil behavior are also examined to comprehend the "oil life" during its duration on the water's surface. This guides the sense of urgency for the effectiveness of the oil removal process. All references gathered guided for a general understanding of the oil skimmer industry.

4. PRELIMINARY DESIGN

This chapter discusses the process in which the skimmer main functions were identified. Throughout the chapter descriptions and images related to the functional decomposition of prospective skimmer design can be found. Note that as some of the figures in the chapters are perceived as repetitive it is important to observe closely and effectively real the descriptions to better understand the process.

4.1 Functional Decomposition

In this section, the team worked both individually and in conjunction to come up with the best overall skimmer function for the prospective design. In addition, the team further decomposed the overall function in level 1, level 2, and level 3 sub-functions. This section allowed each team member to freely express their individual ideas and it encouraged each team member to research and get familiar with existing skimmer designs.

Identifying the most important function that the prospective skimmer design should achieve, was not an easy task. The process of narrowing down from the many functions available for skimmers to one overall function was found to be interesting and it will be considered for future project assignments.

To begin the identification of the overall function, each team member individually came up with 3 main functionalities that the prospective design should be able to perform. Once each member was ready to share their ideas, a sticky note splashguard was made available on a Google slides document. Team members were given approximately 4 minutes to input their ideas on the google sticky note splashguard as shown in Figure 4.1. After all the team members' ideas were posted, the team joined a Zoom meeting to discuss each one of the functionalities provided by the team and make an effective decision on an overall function. As shown in Figure 4.2, it was determined that the overall function of the prospective skimmer design was identified to be the ability to recover at least 25~50% of oil in 1-inch oil slick. In addition, the Figure 4.2 indicates the appropriate inputs related to the overall function and its expected outcomes.

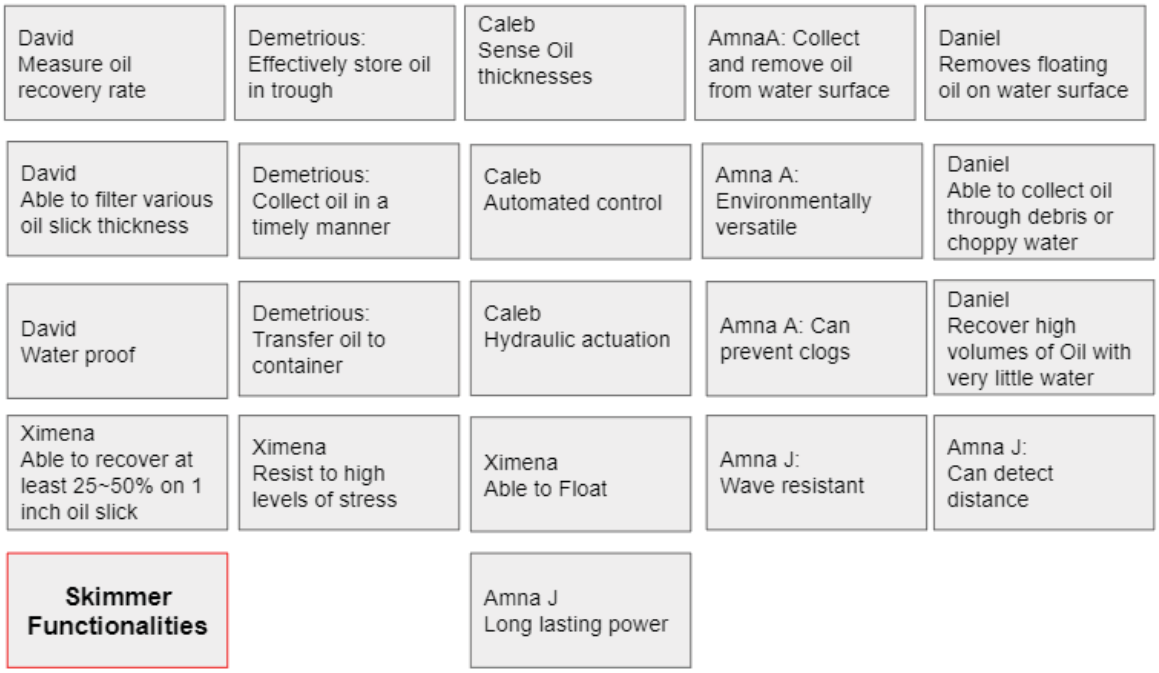


Figure 4.1 Skimmer Function Splashguard - Level 0

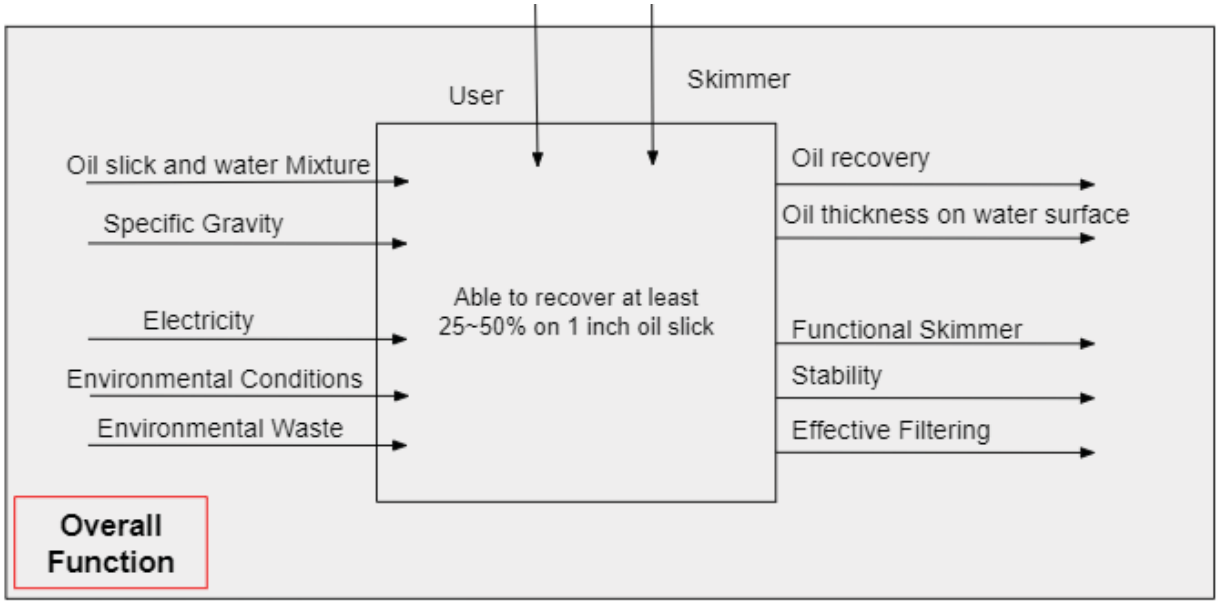


Figure 4.2 Overall Function Inputs and Outputs

In this section, each team member was asked to come up with three different level 1 sub-functions based on the identified overall function of the prospective skimmer. Once each Team member was ready to share their level 1 sub-function ideas, a sticky note splashguard was made available to each member on another Google slides document. Then, each team member was given another 4

minutes to input their ideas on the new google sticky note splashguard as shown on Figure 4.3. After all the group members shared their ideas, the team joined a Zoom meeting to further discuss each sub-function. Subsequently to the analysis, the team selected five main level one sub-functions. As expressed in Figure 4.4, the team concluded that in order for the prospective skimmer design to be able to recover at least 25~50% of oil in 1 inch oil slick, the skimmer should be able to measure oil recovery rate, filter various oil slick thickness, separate oil from water, collect oil through debris or choppy water, and limit water intake.

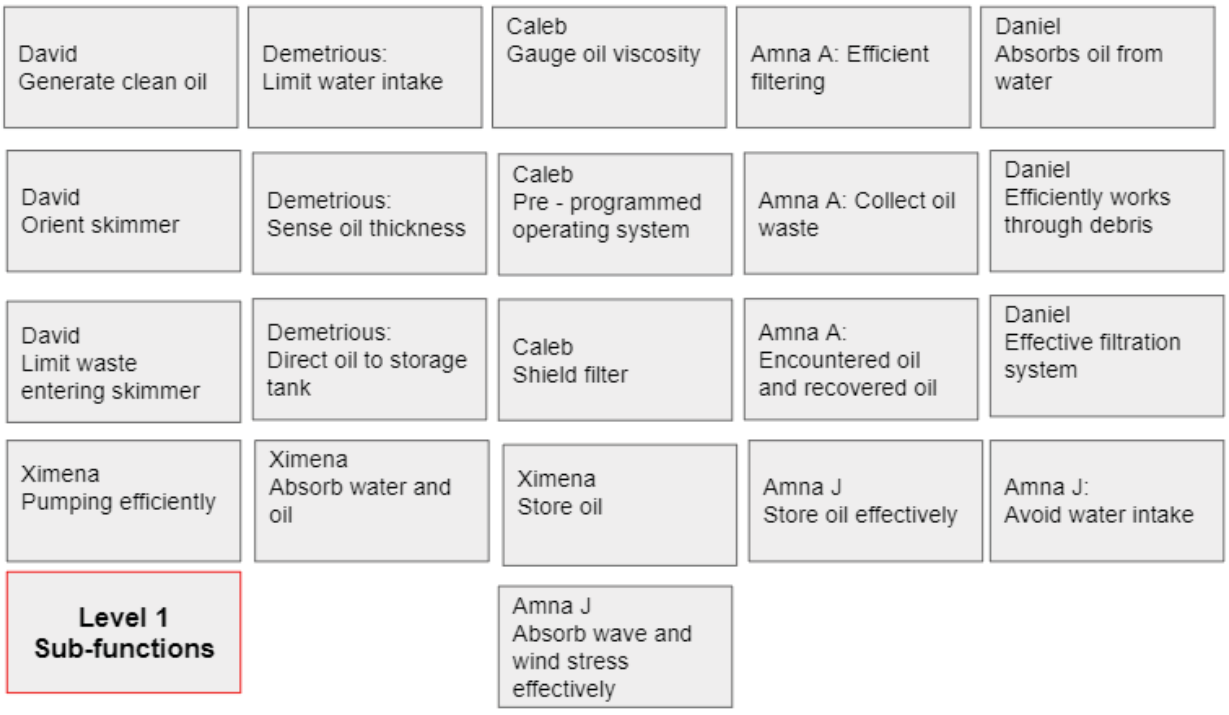


Figure 4.3 Skimmer Idea Splash Guard - Level 1 Sub-functions

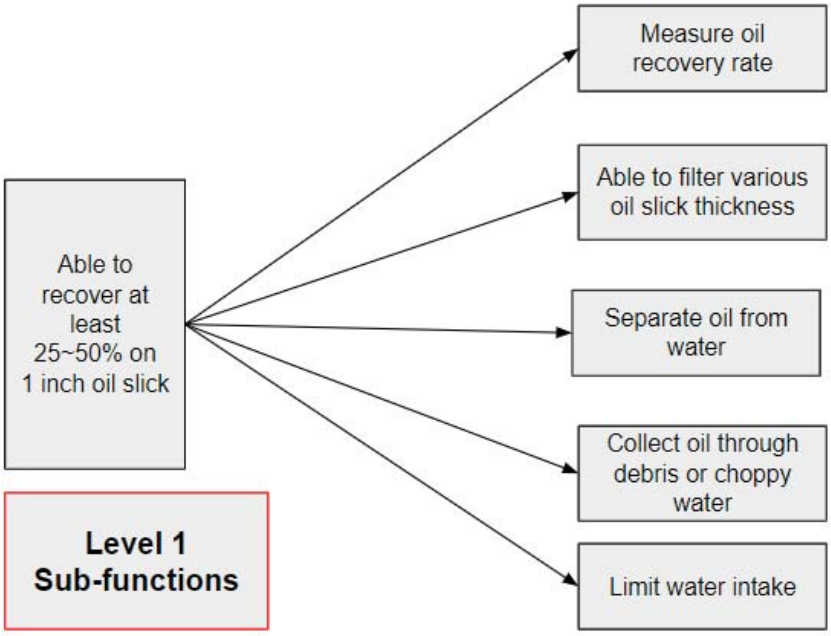


Figure 4.4 Level 1 Sub-functions Tree

In this section, each team member was asked to generate three different level 2 sub-functions for each one of the five level 1 sub-functions selected in the previous section. Once each team member was ready to share their 15 level 2 sub-function ideas, a sticky note splashguard was made available to each member for each one of the level 1 subfunctions.
Then, each team member was given 12 minutes to input their ideas on the google sticky note splashguards as shown on Figures 4.5 - 4.9. After all the group members shared their ideas, the team joined another Zoom meeting to further discuss each level 2 sub-function. Next, the team selected 15 out of 105 level 2 sub-function ideas provided based on the level 1 sub-functions. In figure 4.10 a display of the 15 level 2 sub-functions selected was made available.

During the analysis of the level 2 functions, the team concluded that for the prospective skimmer design to be able to measure oil recovery rate, the skimmer should be able to sense the amount of oil recovered per second, effectively detect change in recovery of oil, and efficiently control the rate of recovery. It was also concluded that for the skimmer to be able to filter various oil slick thickness, the skimmer must be able to distinguish between viscosities, detect type of oil, and self-adjust to different types of oil. In addition, the team decided that to successfully separate the oil from the water, the prospective skimmer must be able to filter water out of the oil, to contain the oil, and limit the intake of water. Moreover, it was determined that for the skimmer to be able to collect oil through debris or choppy water, the design must successfully shield debris from the filter, avoid debris collection, and conduct waste separation from fluid. Finally, the team agreed that to limit the water intake, the skimmer design should be able to maintain stability, release the water it takes in and control water intake with the help of actuators.

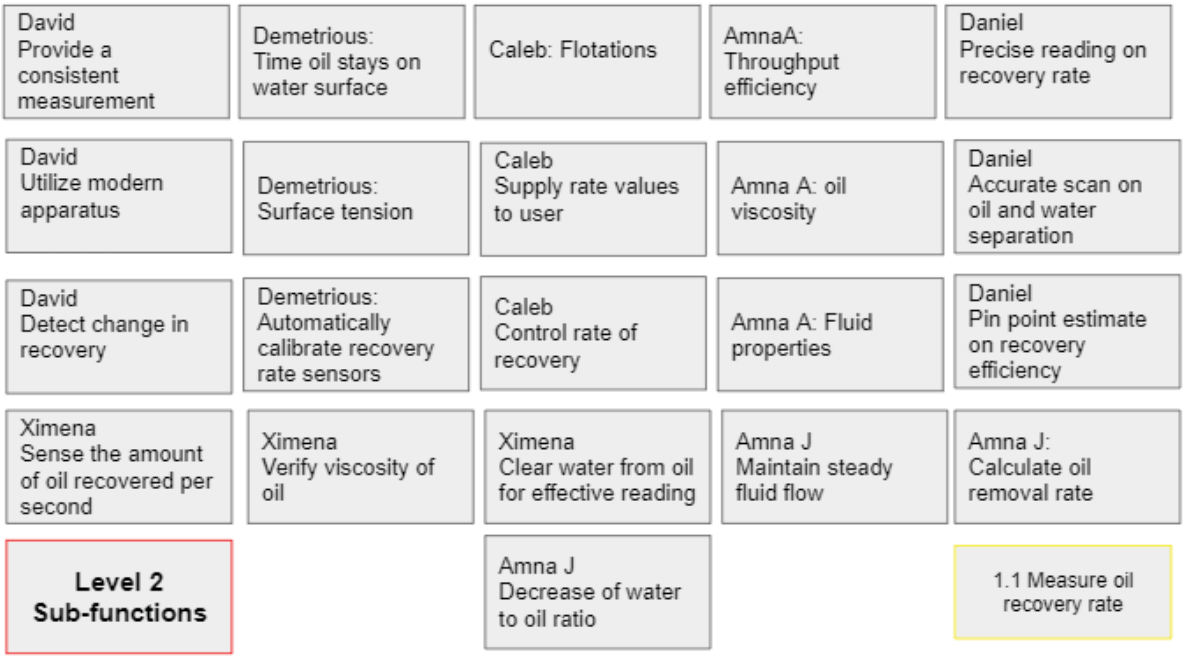


Figure 4.5 Measure Oil Recovery Rate - Level 2 Sub-functions Splashguard

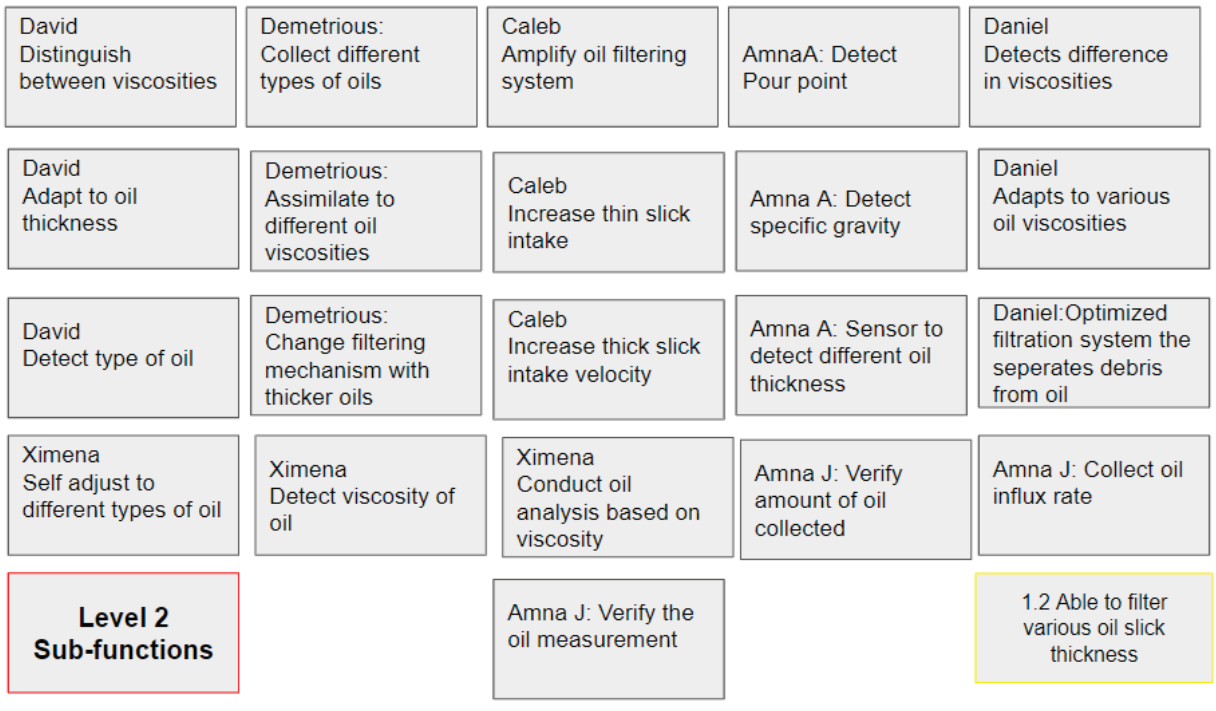


Figure 4.6 Filter various oil slick thickness - Level 2 Sub-functions Splashguard

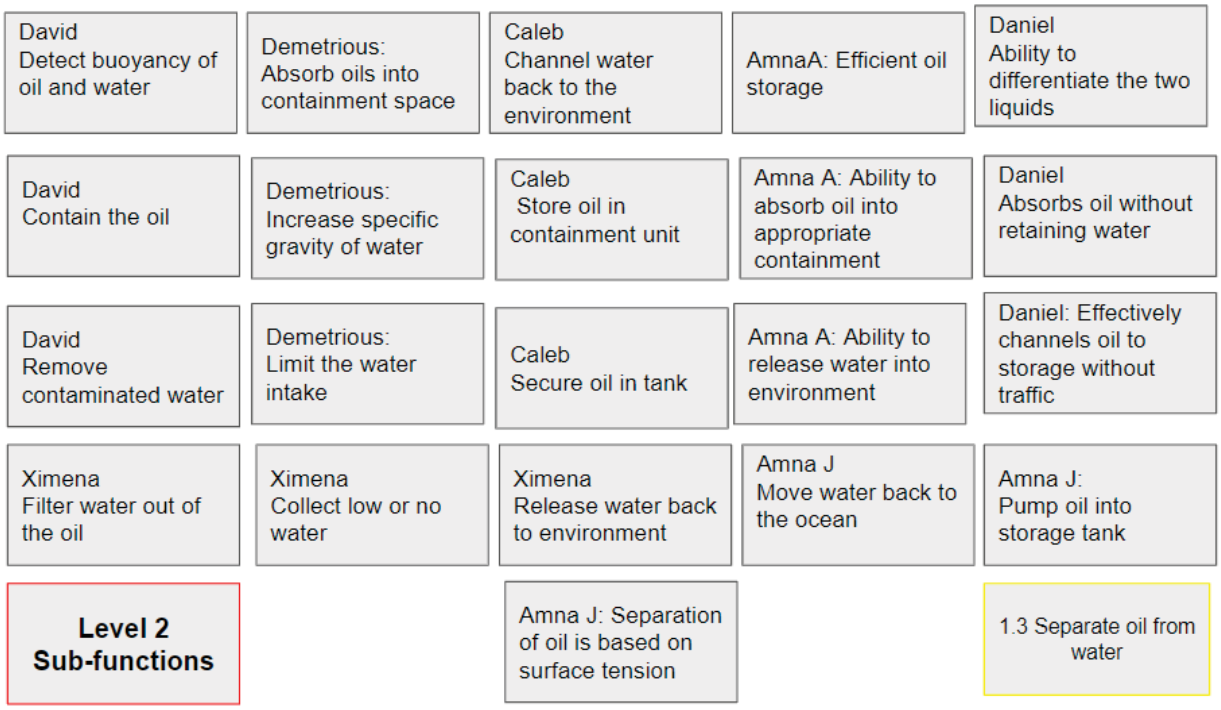


Figure 4.7 Separate Oil from Water - Level 2 Sub-functions Splashguard

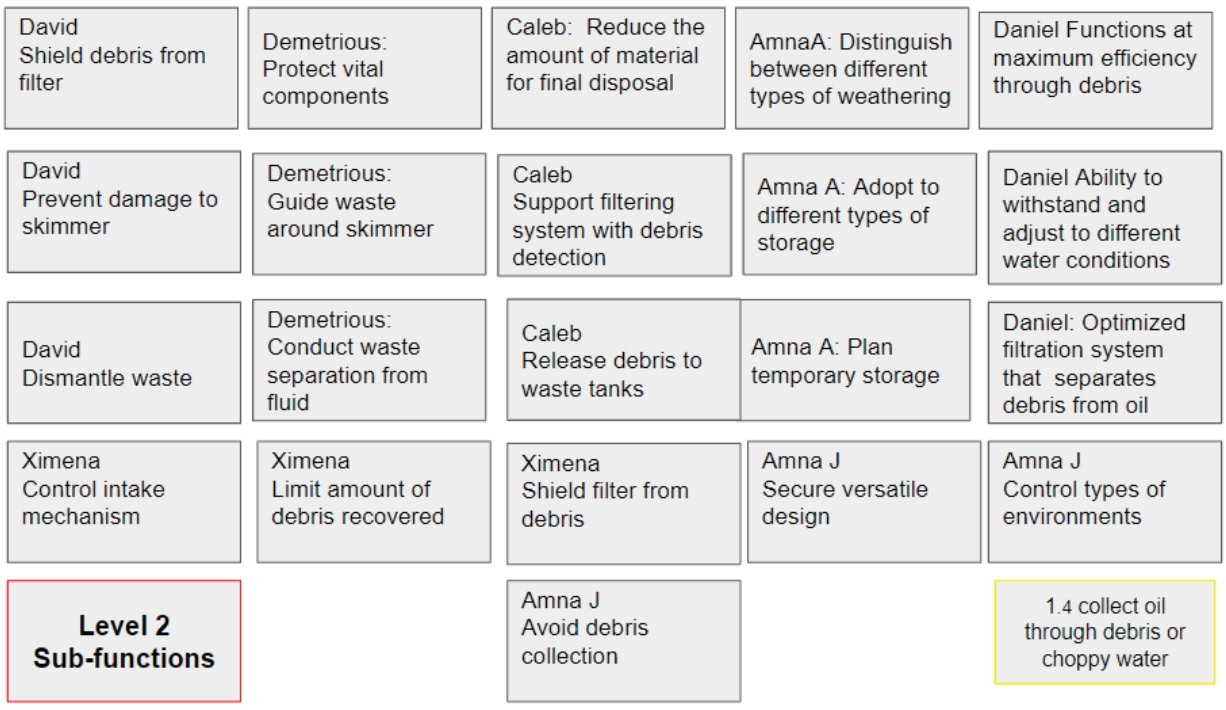


Figure 4.8 Collect Oil Through Debris or Choppy Water - Level 2 Sub-functions Splashguard

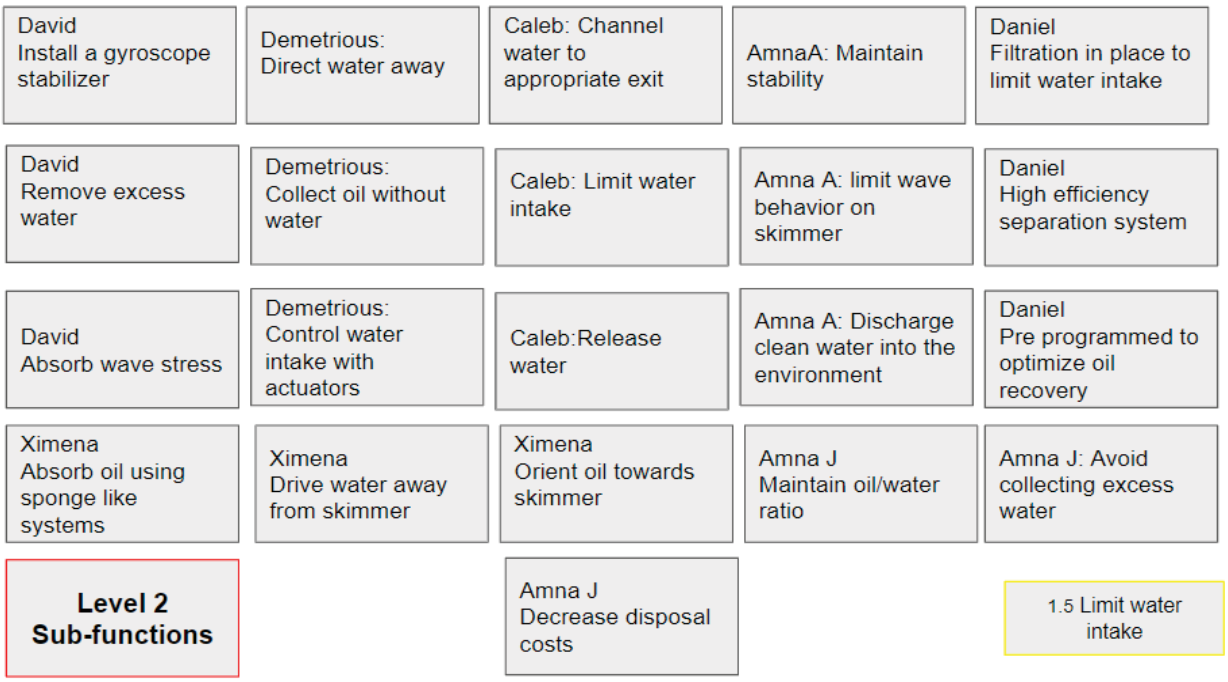


Figure 4.9 Limit Water Intake - Level 2 Sub- functions Splashguard

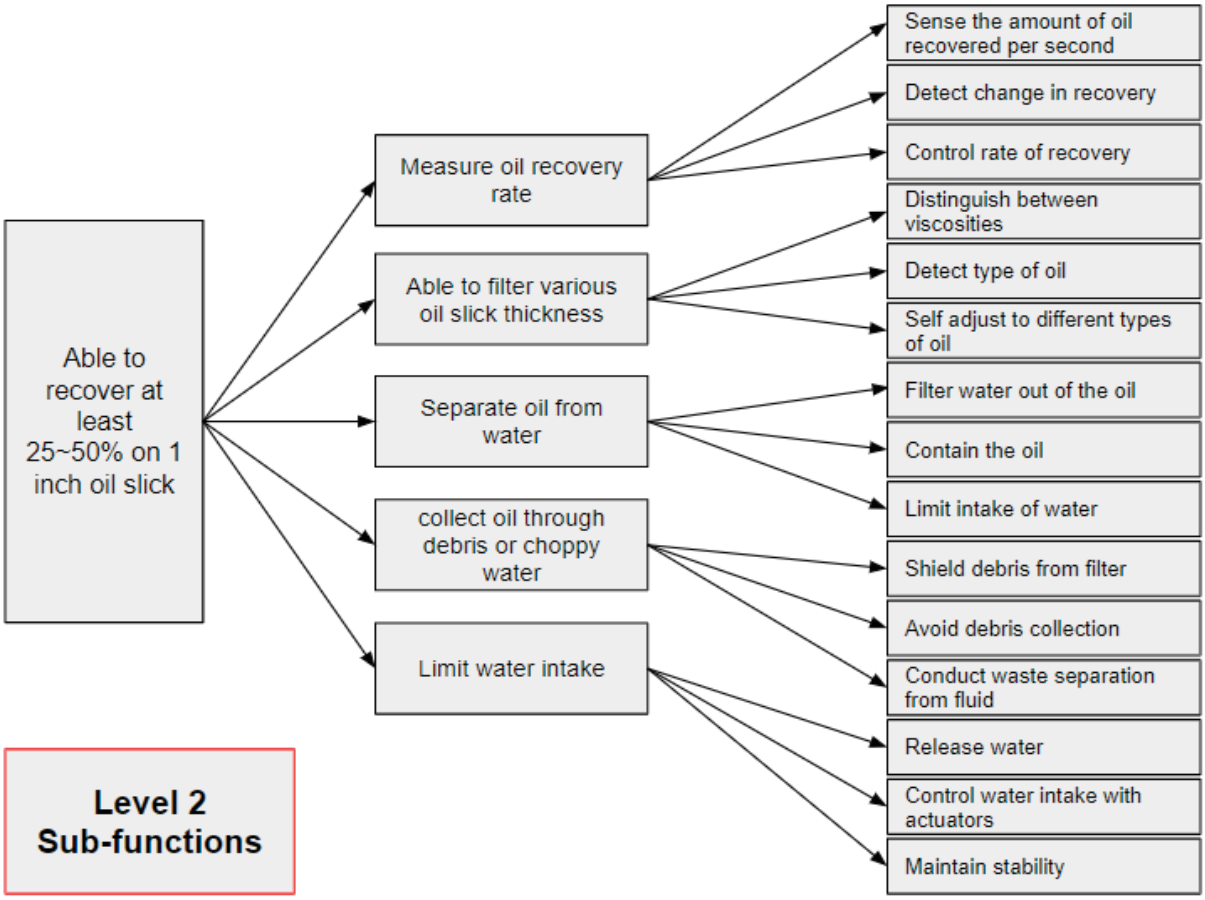


Figure 4.10 Level 2 Sub-functions Tree

In this section, each individual generated three different level 3 sub-functions for five of the level 2 sub-functions selected in the previous section. Once each team member was ready to share their 15 level 3 sub-function ideas, a sticky note splashguard was made available to each member for each one of the level 2 subfunctions to repeat the same process done in the previous sections. At that point each team member was given around 12 minutes to input their ideas on the google sticky note splashguards as shown on Figures 4.11 - 4.15. Next, all the group members were able to discuss the level 3 sub-functions in a Zoom meeting. Subsequently, the team selected 15 out of 105 level 3 sub-function ideas based on the level 2 sub-functions identified in the previous section. In figure 4.16 the full functionality decomposition for the prospective skimmer design is displayed.

Through the analysis of the level 3 functions, it was concluded that for the design to be able to sense the amount of oil recovered per second, the skimmer should be able to transform rate readings, calculate amount of oil intake, and accurately detect through sensors. It was also concluded that for the skimmer to be able to distinguish between viscosities, the design must be able to verify oil thickness, measure oil resistance to flow, and detect surface tension. In addition, the team decided that to successfully filter water out of the oil, the prospective skimmer must be able to dissipate excess water, increase filtration rate, and avoid water contamination.

Furthermore, it was determined that for the skimmer to be able to avoid debris collection, the design must successfully limit debris entering skimmer, divert debris using its filtration system, and remove debris through aversion technology Finally, the team decided that to control the water intake with actuators, the skimmer design should be able use specific gravity differential to limit water intake, perform floatation stabilization, collect optimal level of oil.

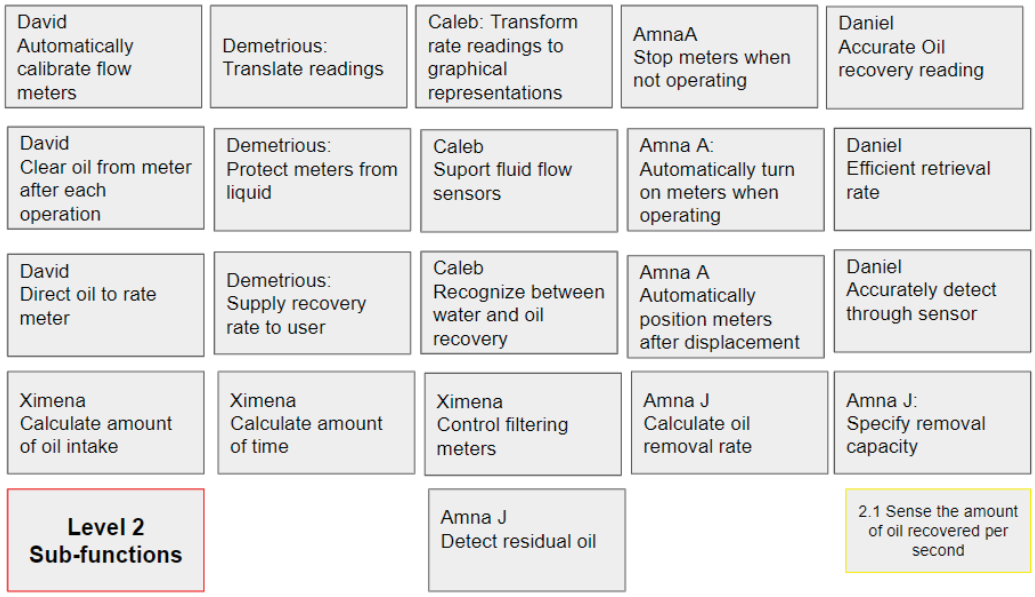


Figure 4.11 Sense the Amount of Oil Recovered /Second - Level 3 Sub-functions Splashguard

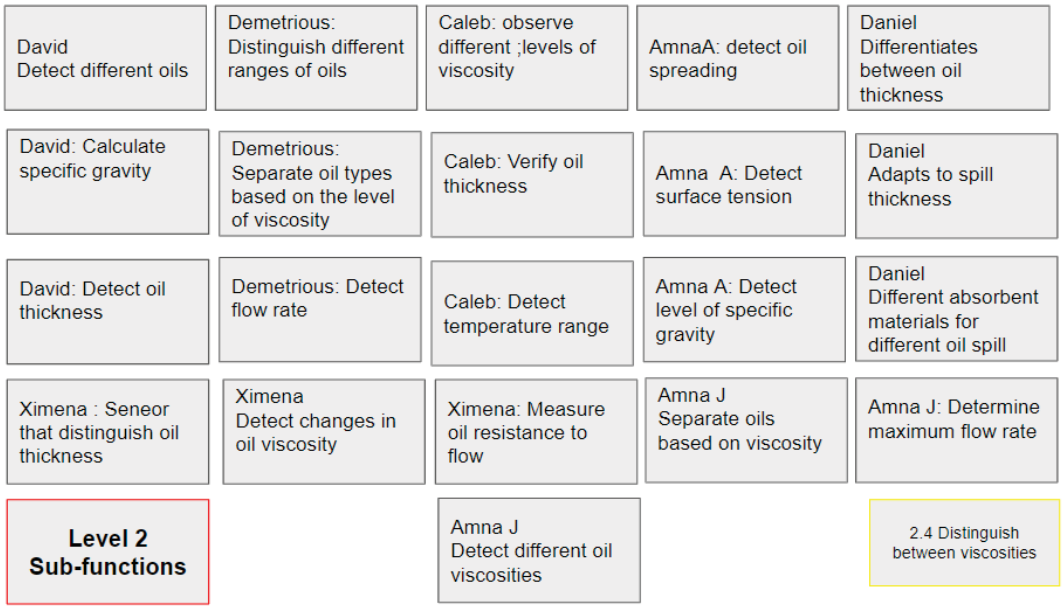


Figure 4.12 Distinguish Between Viscosities - Level 3 Sub-functions Splashguard

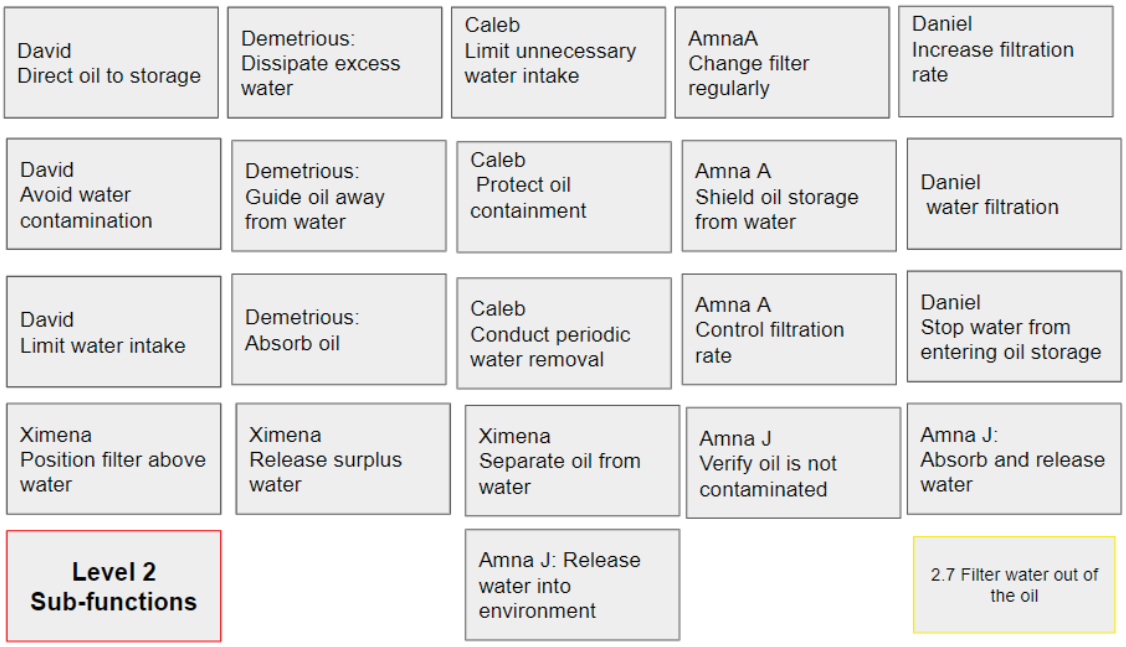


Figure 4.13 Filter Water Out of Oil - Level 3 Sub-functions Splashguard

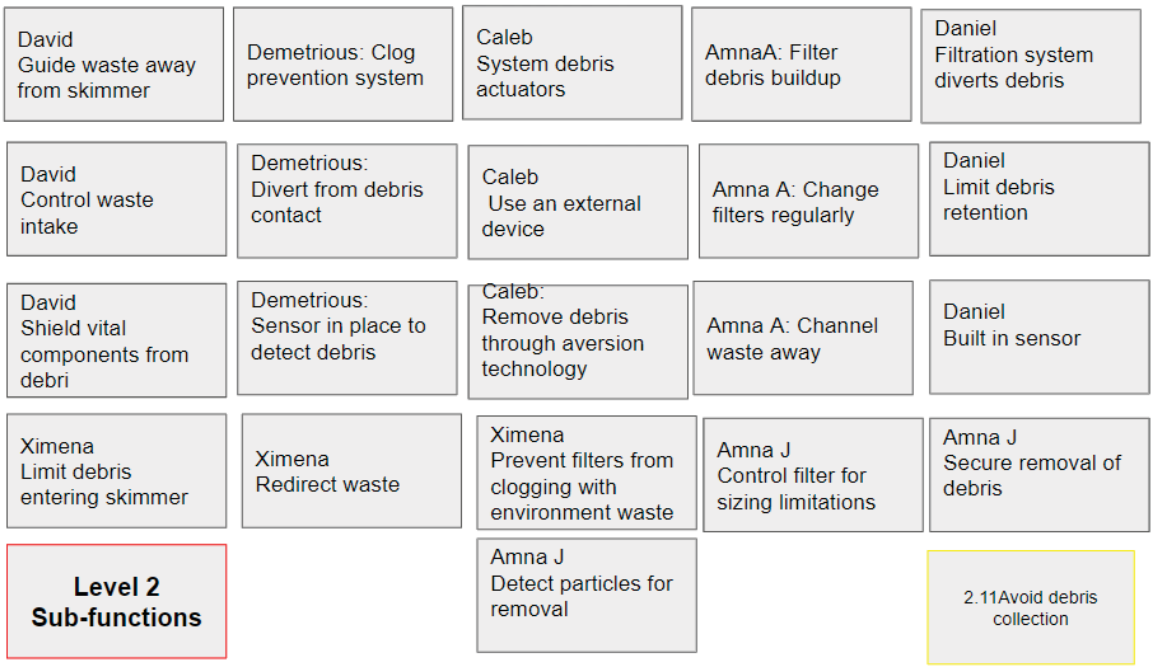


Figure 4.14 Avoid Debris Collection - Level 3 Sub-functions Splashguard

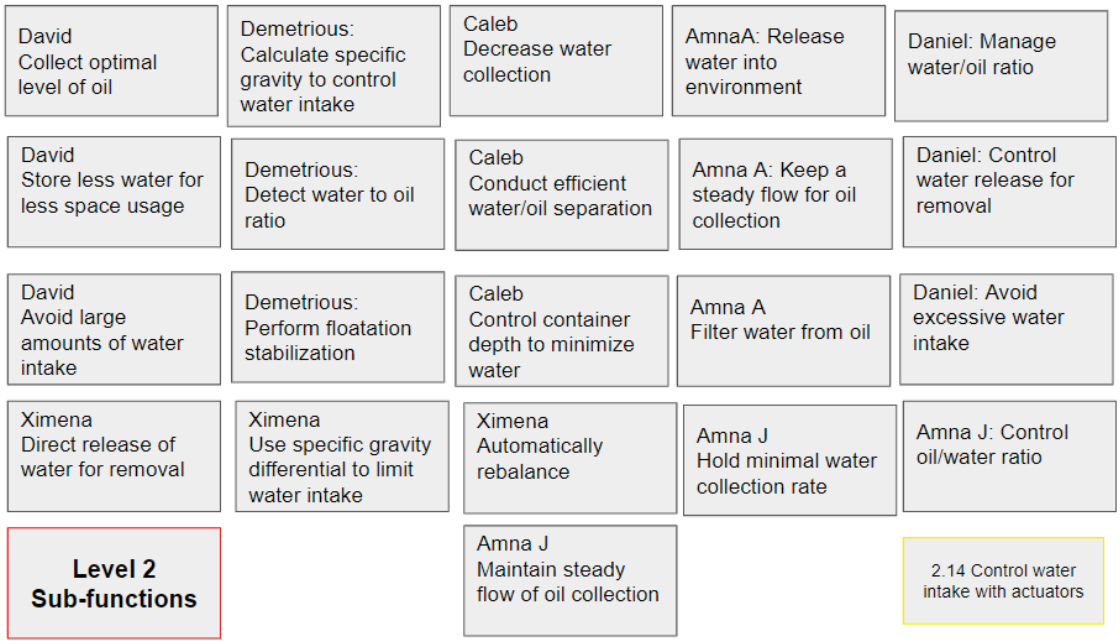


Figure 4.15 Control Water Intake with Actuators - Level 3 Sub-functions Splash Guard

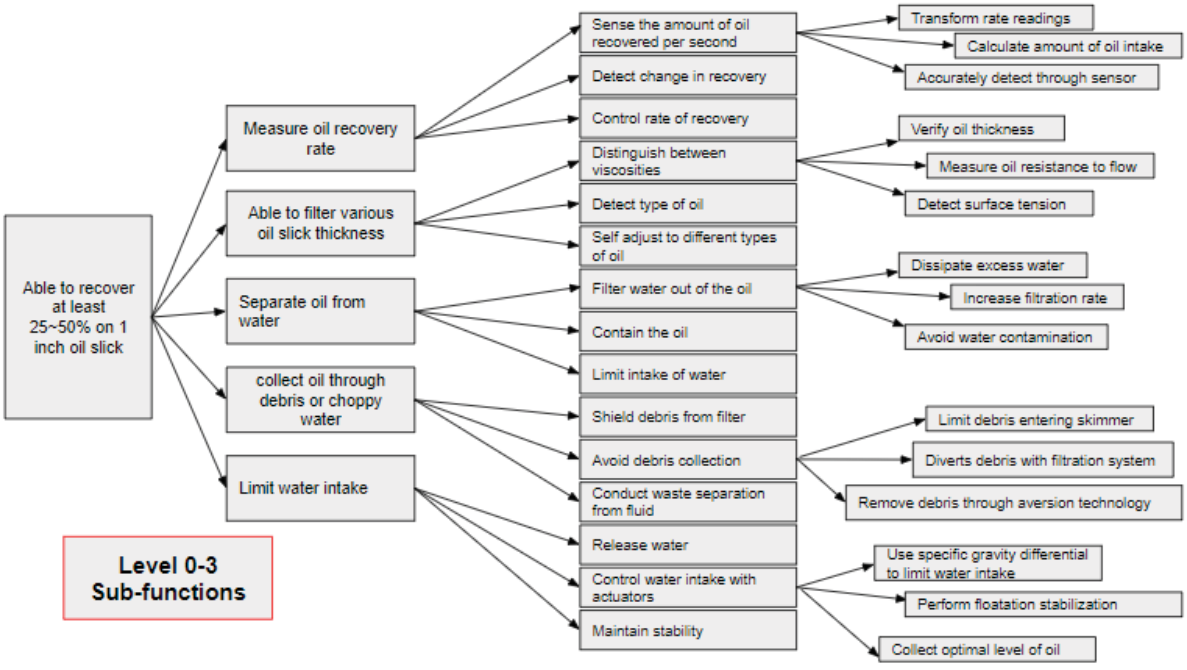


Figure 4.16 Level 3 Sub-functions Tree

Table 4.2, given below, is a morphology table that represents the current status of the generated sub-functions levels 1-3 created through adaptations of the overall function of the skimmer being able to recover at least 25~50% on 1 inch oil slick. The table is organized in levels of sequential order from sub-function 1 to 2 to 3. As shown below, some of sub-level 2 functions do break down into a third sublevel. These breaks help to express which sub-functions were further chosen to be expanded based upon their vitality and functionality

Table 4.2 Morphology (Functional Decomposition and Concepts) Table

Overall Function	Level 1 Sub-functions	Level 2 Sub-functions	Level 3 Sub-functions	Concept 1		Concept 2		Concept 3		Concept 4	
				Description	Sketch	Description	Sketch	Description	Sketch	Description	Sketch
Recover at least 25~50% on 1 inch oil slick	Measure oil recovery rate	Sense the amount of oil recovered per second	Transform rate readings								
			Calculate amount of oil intake								
			Accurately detect through sensor								
		Detect change in recovery									
		Control rate of recovery									
	Able to filter various oil slick thickness	Distinguish between oil viscosities	Verify oil thickness								
			Measure oil resistance to flow								
			Detect surface tension								
		Detect type of oil									
		Self-adjust to different types of oil									
	Separate oil from water	Filter water out of the oil	Dissipate excess water								
			Increase filtration rate								
			Avoid water contamination								
		Contain the oil									
		Limit the intake of water									
	Collect oil through debris or choppy water	Shield debris from filter									
		Avoid debris collection	Limit debris entering skimmer								
			Filtration system diverts that debris								
			Remove debris through aversion technology								
		Conduct waste separation from fluid									
	Limit water intake	Release water									
		Control water intake with actuators	Use specific gravity differential to limit water intake								
			Perform floatation stabilization								
			Collect optimal level of oil								
		Maintain stability									

5. RESULTS & DISCUSSION

5.1 Summary of Goals and Objectives

This project's main goal is to design an automated oil skimmer that offers greater than or equal to efficiencies of oil recovery rates of today's industrial skimmers. Within this goal, some major objectives needed to be fulfilled include establishment of identifying relevant topics of information to this project as well as potential sources for research. By doing this, the team can begin researching and observing current oil skimmers in order to address current deficiencies/limitations as well as current successes. The scope of this goal is to design a system that offers greater efficiencies of recovery rates for oil slicks that are less than 1/2-inch thickness. A goal that offers progression to this project is task identification. This goal allows the group to analyze and decide which actions and procedures need to be taken to advance. A timeline was the next objective implemented to sequence these tasks followed by a Gantt chart to create a visual chronological representation of the overall project memos. Finally, a literature review was performed to ascertain which skimmers are currently used today for oil spill recoveries and response. During the development of the design process, the team will aim to prioritize the responder safety, portability of technology, simplicity of use, and reduction of waste during recovery operations.

5.2 Discussion of Completed Work (Chapter by chapter for the three chapters above)

The completed work for this project is as follows: Within the first chapter, the first work objective completed was to determine and establish the project scope as well as the problem statement for the project. The completion of this allowed for the project to rely on a focus area. The area of focus from the problem statement then allowed for the determining of potential project client's and needs. From determining these key aspects, a clear-cut project goal statement as well as design objectives were developed in order to maintain and fulfill the success of meeting the clients' needs and interests. Finally, within the first chapter, after observing the client's needs as well creating design objectives, initial project constraints as well as operating environments were determined based on project scope and goal analysis.

The second chapter's work objectives helped to generate a structure for the process of the project completion. Project planning and task identification served as a basis for structural development of a timeline for the oil skimmer completion. The timeline helped to chronologically order the subtasks, objectives and deliverables in a way that will guide smooth transitions of project protocol. The timeline was then structured into a Gaant chart that visually represents all activities and checkpoints with respected dates that may be subject to change throughout the project.

The third chapter of this mid-term report required the generation and discussion of a literature review. The work in the literature review consisted of the procurement of potentially relevant information and sources that could be used to identify what guidelines and strategies should be taken to successfully complete the project. Analysis of skimmer types, oleophilic and non-oleophilic as well as weir skimmers were researched and examined to obtain a better understanding of the current skimmer capabilities and functionalities. These literary sources were

also used to examine which skimmers are better suited for different situations and environments. Observation of various skimmer patents served to help the guidance and relevancy of today's skimmer designs and how they have advanced over time based on technology advancement. A common theme of the literature reviews was the advantages and disadvantages of efficiencies of each kind as well as their major components of operation. Through all of the reviews, a decision of which skimmer of suitability can be developed in the future

The final chapter of this report involved the functional decomposition analysis. Within this chapter, developments of the skimmer functions were generated. Through individual brainstorming and evaluation, an overall function was determined to be further analyzed into three levels of subfunctions. The overall function is for the skimmer to be able to recover at least 25~50% on 1-inch oil slick. This is the level 0 of the decomposition. To further its subfunctions, each member created lists of possible subfunctions to be evaluated to determine the next new level of sub functionality. This process was repeated for 5 sub function levels at level 1. Furthermore, this process was again repeated to break these down into three second level sub functions at level 2. And finally, these three second level sub functions were then expanded into a final level 3 sub function in which not all level 2 subfunctions expanded. The entirety of this process allowed for the consistency of thought as well as the collaboration of vital functionalities needed for the skimmer design. This process will allow for the next step of concept design to begin.

5.3 Summary of Constraints and Codes Identified for Project

The automated oil skimmer project will be based upon specifications given by The Bureau of Environmental Enforcement (BSEE). This is an agency that is within the United States Department of Interior and is the lead agency in charge of improving safety and environmental protection relating to offshore energy industries. Testing optimization within BSEE requires operations of oil skimmer efficiencies to be .25-.50 for oil thicknesses of 1 inch. The current disadvantages of today's oil skimmers create issues for oil recovery of thicknesses less than 1 inch. A summary of the initial project constraints are as follows: the skimmer must be waterproof as well as buoyant. Stated constraints include that the skimmer will be automatic and cannot exceed operation parameters of 5ft by 5ft. Based upon current skimmers, this skimmer must also be accustomed to oil slick thicknesses up to 3 inches and must be climate resistive. Additionally, the skimmer efficiency must be comparable to the efficiencies of current skimmers. Meaning that the skimmer must at least be within the same level of success as the industrial skimmers operating currently. Some other developed constraints featured are that the skimmer must be adaptable to recover different temperatures of oil slick as well as possess an oil containment device. Codes and regulations are based upon the Oil pollution act which was passed in 1990. The act was established as an amendment under the Clean Water Act in which some oil storage facilities were required to develop facility response plans for spills. The lead federal response agency EPA is the agency for oil spills occurring in inland waters. Some of EPA's top priorities are to prevent, prepare for, and respond to oil spills that occur in and around inland waters of the United States. EPA's oil spill prevention program includes the Spill Prevention, Control, and Countermeasure (SPCC) and the Facility Response Plan (FRP) [17].

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The Automated Oil Skimmer Project is subject to many tasks, objectives and deliverables that serve to meet client needs as well as environmental needs. The lack of consistency of oil recovery response has led to environmental damage as well as unnecessary costs to environmental and oil industries. Although oil incidents are not always preventable, the quantity of damage they can cause can be. Through education and observation of current skimmer capabilities, advancements can be made, and technological implementation can wield a greater performance of skimmers and that can reverse the effects of human mistakes. The ethical gratitude's of this project must also be taken into consideration. Although the main goal is to increase the performance of the skimmer, accountability for protecting the environment must also be simultaneously considered. As expressed within the fourth chapter the overall function of the skimmer design is for it to be able to recover at least 25~50% on 1-inch oil slick.

All decisions and actions that are to be performed will serve to not only successfully help improve skimmer performance, but also maintain ethical conduct within the field of Engineering.

6.2 Recommendations

The lack of consistency of oil recovery response has led to environmental damage as well as unnecessary costs to the environment and oil industries. Therefore, we seek to advance a current oleophilic skimmer design that abides by BSEE and EPA specifications.

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AVERAGE

MECHANICAL ENGINEERING DEPARTMENT
PRAIRIE VIEW A&M UNIVERSITY

MCEG 4472 Y01/Y02/Y03

SENIOR DESIGN MIDTERM REPORT

Design and Analysis of Steering and Suspension System

Fall 2020

Group 8

Robert Barbee, Jonathon Horta, Aramis King, Todd Maxwell, Michael Samuel, Daniel Ward & Titus Woodard

Letter of Transmittal

October 10, 2020

Dr. Peng, Dr. Biney & Dr. Duan

Mechanical Engineering Department

Prairie View A&M University

Dear Professors:

The attached report contains relevant information as a result from collaborating and researching on Steering and Suspension Systems for Off-Road Vehicles between September 4, 2020 and October 10, 2020. This report contains a detailed description of the project formulation, project planning, literature review, and concept generation portions of the design project.

Sincerely,

Group 8

Acknowledgment

In great contribution to the design and analysis of steering and suspension systems, Dr. Duan and Dr. Peng assisted the team in the overall production requirements of this midterm report. Baja Club Team leaders, Carrie Conton and Vicaessee Paul helped influence ideas to organize research and begin the design process. Special thanks to Dr. Park and other department faculty and staff for their contributions and feedback as well.

ABSTRACT

1. The purpose of the project

The purpose of this project is to construct unique steering and suspension systems capable of withstanding challenging off-road terrains while also avoiding easy steering disengagements and suspension component dislocations.

2. The brief description of the method used

Up to this point of the project, credible resources have been utilized to create tables and figures critical to completing a successful design. The tables used up to this point elaborate on objectives, sub objectives, tasks, deliverables, and methodologies in an organized manner. The figures used up to this point include an objective tree, gantt charts, system components, necessary math equations, result examples, black boxes, and sticky notes. All these tables and figures assist the audience in better understanding the background of the project before any fabricating or testing begins.

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1. Project Scope

This chapter will cover a series of information that will help the audience comprehend the purpose and background of the project from a bird's eye point of view. A project scope, problem statement, client identification and recognition of need, goals, objectives, and constraints will all be included in this chapter. However, tables and figures are included in this to assist with project organization due to the need of referencing from this chapter in the near future.

1.1 Problem Statement

There's a need for a unique steering and suspension system for an off-road vehicle that's reliable enough to withstand all forces and loads applied onto it by challenging terrains. This project is important because different industries rely on off-road transportation to get missions completed and the steering and suspension system is the part of the off-road vehicle that is put under the most stress. Some benefits from this project are the unique system being able to be utilized in diverse areas such as space exploration and also the military, and it possibly being adopted by automotive companies into future off-road vehicle designs. Some applications of this project consist of creating literature reviews on how the system operates, designing a steering and suspension system that is compatible with a chassis provided, formulating a test that will analyze the design with multiple forces acting on itself, fabricating and assembling the steering and suspension after multiple iterations until the system passes all tests and can withstand all forces for the chassis. The steering and suspension mechanisms should withstand all internal and external stresses on the off-road vehicle for a provided off-road course.

1.2 Client Identification and Recognition of Need

This section will discuss the clients that this project can be proposed to for better steering and suspension systems. This section will also show the recognition of the need for this project with problems with current steering and suspension systems.

1.2.1 Client Identification

Toyota, the U.S. Army, and NASA are the clients for this project. This system will be designed and fabricated for an off-road vehicle. Once the system is fabricated and can withstand all forces and stresses, the system could be sold to companies needing off-road vehicles with similar specs, such as weight and chassis design to accomplish similar goals. Off-roads vehicles are getting more attention drawn towards them and over $200 million dollars is being spent on these vehicles each year. When designing the steering and suspension system, our goal is to improve stability and increase range of motion for the vehicle which will improve desirability from other potential clients.

1.2.2 Domestic Use

The PV Baja team's off-road vehicle will be showcased in the SAE Baja competition as a contestant [1]. SAE calls for bright minded students to produce various vehicles to compete and prove their skills in a tedious competition style format based on engineering, science and overall knowledge of automobiles. Under these circumstances, SAE is the team's main audience but there are still plenty of other consumers who could possibly take interest in the vehicle design.

Prairie View A&M is only one of many schools who participate in the annual Baja competition. It is definitely plausible for other institutions to take interest in the team's project if it proves to be a great design satisfactory for competition [1]. Other students will be able to be influenced by the PV Baja team for future builds and design specs.

Aside from student based programs, the vehicle may appeal to those who may want to utilize it for personal use [2]. Whether it be hunting, recreational off-roading or sports, this design may also be used for these purposes as an all-weather, all-terrain resource.

1.2.3 Commercial Use

Other than competition and the possibility of domestic use, there may be a plausible case for the vehicle to be utilized in industry on a much larger scale. The team has partnered with Toyota who is known for their very own off-road vehicle and baja programs [3]. It wouldn't be a surprise if the Japanese powerhouse were to reach out to the team for design implementations to use for their own competitive means. To piggyback, it may also be appealing for other manufacturers and car companies to bear interest in the vehicle to compete amongst their industry.

The possibility of this vehicle to be used in the fields of aerospace and defense are remarkably high as well. NASA is well known for its space exploration projects and taking on outer space missions to the moon and even Mars [4]. Most have heard about NASA's space exploration vehicle; the Rover program is used to track various terrains and withstand a differentiation of unknown elements. Based on this, it is very likely that the government would be interested in seeking an outside contractor, as they do already through companies such as Raytheon Technologies and Lockheed Martin, to provide a concept vehicle for extra-terrestrial purposes and planetary exploration. Northrop Grumman may also be a contender for a project such as this, as this company is looking to be 'number one in space' in the next few years [5]. Such a vehicle would allow them to assist or even compete with NASA for certain contracts and expand their opportunities in the industry.

Outside of space systems, the military may also have some use for this type of vehicle for mission systems [6]. The military is known to use a great deal of vehicles by means of combat and transportation. Most of these vehicles are plated with armor, specialized equipment and tailored for off-road capabilities for combat and even non-combat situations. Figure 1.1 and Figure 1.2 show examples of commercial use that this project can improve.



Figure 1.1: NASA Rover on Mars mission [5]



Figure 1.2: Heavily armored and fully equipped military grade buggy [6]

1.2.4 Recognition of Need

As far as steering alone, there has been dissatisfaction in maneuverability for off-road vehicles. Since the steering faces challenging environments, many issues can occur in the off-road vehicle's steering system. The steering system has become disengaged in previous off-road vehicle designs and has caused the driver to lose control. This is a major safety issue for the driver. As far as the suspension, there has been dissatisfaction in joints for off-road vehicles. The stresses of different terrains apply larger stresses than usual on the suspension, which calls for different areas on the suspension to absorb these stresses. Joints can be the weakest points on a suspension and can result in dislocation from high stresses. This could also be a safety issue.

1.3 Project Goals and Objectives

This section will be covering project goals and objectives in detail. This will consist of listing the project's objectives and sub objectives, creating an objective tree from this information, and stating the measurement basis, criteria, and units for each objective. The information in this section was put together by the entire group brainstorming on ideas and braking these ideas down to their smallest factor.

1.3.1 Project Goal

The project goal is to present a high quality and affordable suspension and steering design for PV Racing Team's off-road vehicle. Also, to meet design deadlines given by SAE Baja as well as abide design constraints given by the organization. Consistently keep track of all progress made within meetings and share this information with the organization. Test the off-road vehicle suspension and steering system to make adjustments to the design if necessary. Successfully complete the off-road vehicle design before the competition date and present the final design to the organization.

1.3.2 Project Objectives

The project objectives were found as a collaborative effort as a group. From a meeting the students discussed all the objectives that were wanted to be accomplished for the suspension and steering system. As the group discussed the project, some research was done to fulfill all needs for a better suspension and steering system than that is already designed. The list below contains all of the objectives collected for this project that will aid in improvement of current suspension and steering systems.

Project Objectives:

A. Safety
B. Durability
C. Economical
D. Safe for environment
E. Driver safety
F. Low Maintenance
G. Safety of bystanders
H. Affordable
I. Easy Repair
J. Range of motion
K. Withstand high speeds

L. Stability of vehicle
M. Sustainable
N. Handle all weather conditions
O. Interchangeable with other vehicles
P. Able to adjust to different terrains
Q. Fixed alignment
R. Able to support weight of vehicle but lightweight

~~Objectives specify the characteristics of the system that are to be optimized in order to achieve the goals. They are the desired attributes of the design. Design objectives depend on the specific design problem being addressed. The list of objectives in the PowerPoint notes were specifically for the problem mentioned in the notes which is completely different from your design problem. The group needs to produce original well-thought-out objectives for the specific design and not use the list provided in the notes because different design problems need different objectives.~~

This section consists of presenting an organized table of all the design objectives and sub objectives created by the group. This section required the group matching design sub objectives into similar categories and identifying the major objectives. This section would help further sections interpret information in a more organized manner.

Table 1.1 includes all the design objectives and sub objectives the entire group came up with. The main objectives are identified at the top of the table, and the sub objectives trail directly under the objectives they correspond to. Table 1.1 reflects the list of objectives created for section 1.3.2.

Table 1.1 Design Objectives

Safety	Durability	Economical
Safety of driver	Able to withstand several terrains	Affordable
Safety of bystanders	Able to support weight of vehicle	Low maintenance
Safe for environment	Range of motion	Sustainable
Handling all weather conditions	Withstand high speeds	Easy repair
	Stability	Interchangeable with other vehicles
	Fixed alignment	

This section consists of using a different tool to create an objective tree. Microsoft powerpoint was the tool utilized to create an objective tree for this section. The purpose of this section was to

present an organized set of objectives and sub objectives to the audience in an amplified visual manner.

Figure ~~1.1~~ presents an objective tree, which reflects Table 1.1. This tree helps the audience understand the order of objectives and sub objectives visually. This figure was put together through a series of connecting the dots between all the objectives and sub objectives the group came up with.

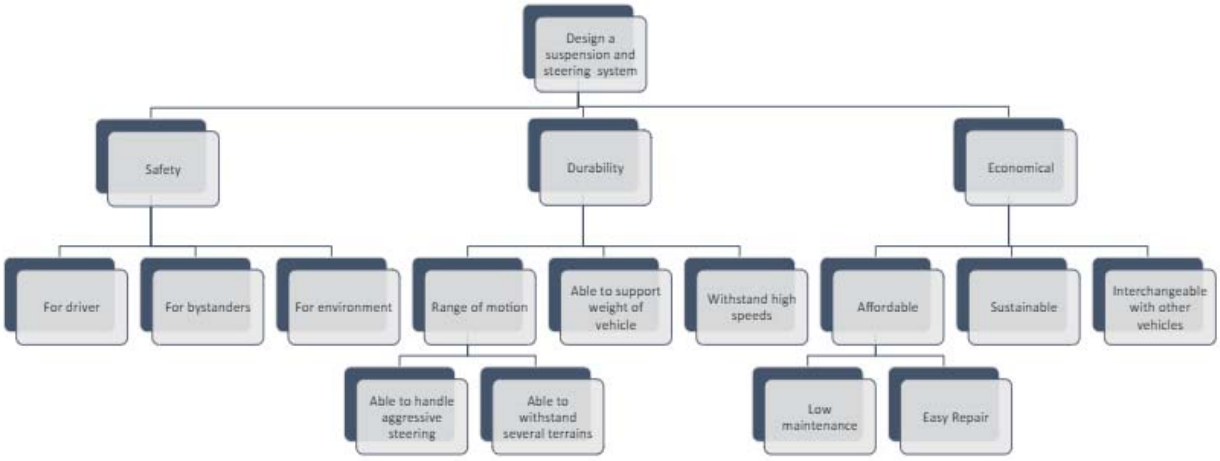


Figure 1.3 Objective Tree

Table 1.2 presents all the project objectives and their measurement basis, criteria, and units. These objectives give us a broader view on what everything falls under and exactly how they can be measured.

Table 1.2 Objectives and Units of Measurement

Objective	Measurement Basis	Criteria	Units
Economical	Steel material machined and assembled as designed	cost	USD
Durability	Internal & external load acting on the suspension	Force	N/m^2 (si) or lb/in^2
Safety	Life expectancy of suspension	Factor of safety	Unitless
Range of motion	Motion	Movement	Degrees

Table 1.3 presents a list of the project objects categorized into detailed subsections reflecting the major objectives**.** This shows a broader scope of what areas and viewpoints we are taking as a group through a measurement basis , criteria and units.

Table 1.3 Objectives and Units of Measurement Subsections

Safety of driver	Life expectancy of suspension	Factor of safety	Unitless
Safety of bystanders	Life expectancy of suspension	Factor of safety	Unitless
Safe for environment	Life expectancy of suspension	Factor of safety	Unitless
Handling all weather conditions	Life expectancy of suspension	Factor of safety	Unitless
Able to withstand several terrains	Internal & external load acting on the suspension	Force	N/m^2 (si) or lb/in^2
Able to support weight of vehicle	Internal & external load acting on the suspension	Force	N/m^2 (si) or lb/in^2
Range of motion	Internal & external load acting on the	Force	N/m^2 (si) or lb/in^2

	suspension		
Withstand high speeds	Internal & external load acting on the suspension	Force	N/m^2 (si) or lb/in^2
Stability	Internal & external load acting on the suspension	Force	N/m^2 (si) or lb/in^2
Fixed alignment	Internal & external load acting on the suspension	Force	N/m^2 (si) or lb/in^2
Affordable	Steel material machined and assembled as designed	cost	**USD**
Low maintenance	Steel material machined and assembled as designed	cost	**USD**
Sustainable	Steel material machined and assembled as designed	cost	**USD**
Easy repair	Steel material machined and assembled as designed	cost	**USD**
Interchangeable with other vehicles	Steel material machined and assembled as designed	cost	**USD**

1.4 Initial Project Constraints and Operating Environment

This section will dive deeper into what are the project constraints for both the suspension and steering systems. It will also discuss the operating environmental conditions these systems will experience.

1.4.1 Initial Project Constraints

Within manufacturing and production, my team was delivered with certain constraints and regulations that we must follow in order to meet the necessary specifications given by the company as well as follow the rules given by the SAE Baja Organization. This list below are the constraints for this project:

- The suspension included with the off-road vehicle and tires cannot be wider than 64” as stated in the baja rule book
- The suspension must be conceived, designed, manufactured and fabricated by the team members without direct involvement from professional engineers, faculty or professionals
- The suspension must be able to operate while holding the weight of the vehicle
- Kit Vehicles Prohibited
- The steering system must be compatible with the suspension system

1.4.2 Operating Environment

In manufacturing and design of a suspension and steering in an Off-road motor vehicle you have to understand the conditions and measure the vehicle will face while operating on different forms of terrain.

List of operating environmental conditions:

- The vehicle must be capable of safe operation over rough land terrain including obstructions such as rocks, sand, logs, steep inclines, mud, and shallow water in any or all combinations and in any type of weather including rain, snow and ice.
- The vehicle must have adequate ground clearance and traction for the terrain type at the competition.

2. Project Planning and Task Definition

This chapter is about how the group is to handle tasks in greater detail. This chapter will also contain how the tasks and subtasks were developed as well as the order of those tasks.

2.1 Task identification

During the semester there are tasks that need to be completed during set time windows to ensure the team meets deadlines set by project owner's and advisors. With each of these tasks there are a set of activities which need to be performed to ensure completion. These specified tasks were identified by collaborating on the weekly team zoom call along with the Baja Project president and board members and were distributed accordingly. Each individual within the group was assigned a specific task based on the previously constructed Gantt Chart. The first task is to complete the project scope. The activities that are involved with this task is to define the objective and create the project formulation which goes in detail regarding the formulation of the project scope, problem statement and other various deliverables, including the identification of the client, needs, constraints, goals and objectives. The second task is project planning in which the Gantt Chart and objective tree will be constructed with emphasis on the identification of the team's tasks and overall project timeline. The third task is to complete the literature review and this will be conducted finding the details needed and identify the sources to ensure the literature review is accurate and organized with coherent facts and information needed. The next tasks will be the functional decomposition as well as the generation and evaluation of concepts. The final tasks that will need to be completed is the preliminary and detailed design. These tasks will be the most time consuming and have the highest number of activities that need to be completed. These activities consist of reviewing codes and standards that must be met, analysis of equations and specified parameters; taking in consideration other underlying factors regarding safety and welfare, CAD design for prototype model, and complete an analysis on the prototype. The project tasks, subtasks and activities associated with each task are listed below.

- Problem Formulation
  - Define Project scope - primary focus and expected results
  - Identify Problem statement - determination of problem and applied tasks
  - Identify the client - who does this project serve
  - Identify the needs - determine measurable performance characteristics of design
  - Define project goals and objectives - arrange characteristics into higher/lower level objectives; utilizing tree structures to determine hierarchy and interconnections
  - Identify the constraints and operating environments - permissible range and parameters
- Project Planning
  - Identify Tasks - identification of major tasks and needs
  - Create Timeline - length of tasks
  - Generate Gantt chart - organization of timeline based on specified tasks
  - Create Detailed Table -create a table that contains project tasks, objectives, deliverables, task duration & responsible personnel
- Literature Review
  - Identify information needed - important project information and details
  - Identify sources - necessary source location
  - ~~Compose the literature review~~ - full review of relevant information found
- Functional Decomposition
  - Identify functions and subfunctions - list of all functions
  - Generate functional decomposition diagram - graph of related functions
- Concept Generation
  - Develop individual concept generation - each team member develops their own concept of design functions
  - Gather group concept generation - combined ideas of group developed by individual functions

- Concept Evaluation
    - Use multiple evaluation techniques - concepts developed by stated methods
    - Utilize techniques to arrive at overall design - mentioned techniques and methods to produce the design
- Preliminary Design
    - Review codes and standards - relevant codes and specifications that must be followed
    - Identify analysis equations - list of critical equations needed for design specifications
    - Perform engineering detailed analysis needed to size and specify parameters for selecting parts and components - Sketches based on calculations
    - Interpret details regarding public health, safety, welfare and other factors in the design - design must meet needs and provide a safe environment for personnel
- ~~Detailed Design~~
    - ~~Generate NX and CAD model~~s - 3D modeling of parts and components

2.2 Timeline

Tasks that are assigned are collaborated and agreed upon by each group member. Reading over the syllabus during the first meeting really helped us organize assigned tasks and deliverables throughout both semesters. Also the group decided to individually find resources such as articles, videos and previous reports so there would be a variation of perspectives on how to attack each objective. This will help us gradually complete every topic on time. During meetings with Dr. Jiang and Dr. Peng, necessary questions were asked to keep the reports as detailed and efficient as possible. Their experience and feedback really helped make sure the divided roles, assignments and objectives were not disorganized. Lastly, meeting with The Baja Club regularly really helps complete all goals including putting in extra hours, understanding the total design and most importantly having every group member participate and be hands on. The gantt chart and table 1 are the exact goals and deadlines needed to be successful in this design.

Below is a brief description and synopsis of timeline, that includes the duration period for the different objectives given along with the duration it takes to complete this task and which team member participated. The team has prepared for the duration of the Steering and Suspension of an Off-road motor vehicle, breaking the sections down throughout the different group members, some objectives have been assigned due to the strong area of expertise that individuals have. As well as some areas are assigned through collaboration of team members to better understand given tasks.

1.1 Project Scope

- **To identify the client with what is set out to be completed**
- **A description of what major points should be focussed on throughout the project and what are the expected results**
- **Duration: 7 days 9/3/20-9/10/20 Robert Barbee**

1.2 Problem statement

- **To determine the problem and the task that will be taken to solve the problem**
- **Complete description of the problem behind this project and how it will be solved**
- **Duration: 7 days 9/3/20-9/10/20 Jonathon Horta**

` 1.3 Identify the client

- **To identify the client what is the purpose behind the project**
- **A structured statement that defines the overall project goal**
- **Duration: 7 days 9/3/20-9/10/20 Michael Samuel**

1.4 Identify the needs

- **To define measurable performance characteristics of design**
- **A list of all measurable performance characteristics with units**
- **Duration: 7 days 9/3/20-9/10/20 Aramis King**

1.5 Project goals and objectives

- **To arrange performance characteristics into higher-level & lower-level objectives in diagrammatic tree structure showing hierarchical relationships and interconnections**
- **Well drawn and labelled objective tree showing hierarchical relationships and interconnections of the performance characteristics**
- **Duration: 7 days 9/3/20-9/10/20 Titus Woodard/ Daniel Ward**

1.6 Identify constraints and operating environments

- **To identify the permissible range of the design and performance parameters and the operating environment**
- **A list of permissible range for the design parameters, description of the environment in which the design will operate**
- **Duration: 7 days 9/3/20-9/10/20 Todd Maxwell**

2.1 Task identification

- **To identify the major tasks that need be completed for the project**
- **Complete a list including the project's major tasks**
- **Duration: 14 days 9/10/20-9/24/20 Aramis King/ Daniel Ward**

2.2 Timeline

- **Develop a timeline for the length of how long each task should take**
- **List of tasks with the estimated time to complete to be transferred to a Gnatt chart**
- **Duration: 14 days 9/10/20-9/24/20 Todd Maxwell /Titus Woodard**

2.3 Gantt Chart

- **Create a Gantt Chart based off the timeline developed**
- **Gantt Chart With actual time to complete tasks as well as estimated time to complete the tasks**
- **Duration: 14 days 9/10/20-9/24/20 Michael Samuel**

2.4 Detailed Project Tasks, Objectives, Deliverables, Task Duration & Responsible Personnel

- **Create a detailed table based off the Gantt chart and actions taken for the project**
- **Complete a table including specific information for all portions of the project**
- **Duration: 14 days 9/10/20-9/24/20 Jonathon Horta/ Robert Barbee**

3.1 Identify information needed

- **To identify important information needed for the project**
- **Complete a description of important information needed for project**
- **Duration: 12 days 9/17/20-9/29/20 Robert Barbee/ Jonathon Horta/Michael Samuel**

3.2 Identify sources

- **To identify where the important project information will be coming from**
- **Create a list of sources used**
- **Duration: 12 days 9/17/20-9/29/20 Jonathon Horta/Robert Barbee/ Daniel Ward**

3.3 Composing the literature review

- **Create a full literature review with all relevant information found**
- **A Finalized literature review**
- **Duration: 12 days 9/17/20-9/29/20 Todd Maxwell/ Titus Woodard/ Aramis King**

4.1 Identify functions and subfunctions

- **To create a list that contains all functions**
- **A detailed listed of all functions**

- **Duration: 7 day 9/23/20-9/30/20 Jonathon Horta/ Robert Barbee/ Daniel Ward**

4.2 Functional decomposition diagram

- **Compose a graph showing how all functions are related to each other**
- **Create a diagram that shows functions and their sub-functions and how they relate to each other**
- **Duration: 7 day 9/23/20-9/30/20 Michael Samuel/Todd Maxwell**

5.1 Individual Concept Generation

- **Each member creates their own concept of functions for a design**
- **A concept list of functions for a design**
- **Duration: 7 days 9/30/20-10/07/20 Everyone**

5.2 Group Concept Generation

- **The group combining their ideas to come up with all functions**
- **Collaborating all concepts with each member to form a full function list for consideration of a design**
- **Duration: 14 days 9/30/20-10/14/20 Everyone**

6.1 Using multiple Evaluation techniques

- **Evaluate concepts using multiple methods including feasibility study, go-no-go, and decision matrix**
- **Positive evaluation results which push our project to its design stage**
- **Duration: 7 days 10/14/20-10/20/20 Robert Barbee/ Michael Samuel**

6.2 Using techniques to arrive at the overall design

- **Apply concept evaluation techniques for each function to get to an overall design**
- **A list of functions tested to make sure all functions were considered and the design stage may now begin**
- **Duration: 3 days 10/20/20-10/23/20 Jonathon Horta/ Todd Maxwell**

7.1 Review codes and standards

- **Pull up relevant codes and standards that should be followed throughout the project**
- **Provide a list of standards that were followed to approve our design**
- **Duration: 1 days 10/21/20-10/22/20 Jonathon Horta**

7.2 Identify analysis equation

- **Find list of equations critical to project that is needed to come up with the design**
- **Provide a list of equations that we used to come up with our design**
- **Duration: 3 days 10/22/20-10/25/20 Robert Barbee/ Daniel Ward**

7.3 Perform engineering detailed analysis needed to size and specify parameters for selecting parts and components

- **Sketch the idea of the design based of calculations**
- **A beginning sketch of our design based on the calculation and standards for the system**
- **Duration: 8days 10/24/20-11/1/20 Robert Barbee/ Daniel Ward**

7.4 Consider public health, safety, welfare, and other factors in the design

- **Make sure design is not harmful to the environment or the public**
- **Considerations that were made to the design for the safety of everyone**
- **Duration: 5 days 10/30/20-11/4/20 Titus Woodard/ Aramis King**

8.1 Use NX or CAD to model parts and components

- **Create a NX model for all the parts of the system**
- **A NX or CAD model of all the individual parts**
- **Duration: 8 days 11/4/20-11/12/20 Michael Samuel**

8.2 Assemble all parts and components

- **Assemble all parts of the system to show the design**
- **An assembly of all of the parts**
- **Duration: 3 days 11/10/20-11/13/20 Robert Barbee**

8.3 Use analysis software to test individual/whole assembly

- **Use Ansys to run stress tests to see how the system relates to the calculations**
- **Stress analysis test results which determine if we need to make changes to our design**
- **Duration: 5 days 11/12/20-11/17/20**

8.4 Making changes to design

- **Make changes in design based on the analysis tests to make a suitable and passing system**
- **Updated design with passing stress tests**
- **Duration: 2 days 11/17/20-11/19/20**

9.1 Use NX or CAD software to create detailed drawings

- **Use Nx software to come up with detailed drawings of all parts and assemblies**
- **Detailed drawings of all parts and assemblies**
- **Duration: 10 days 11/4/20-11/14/20 Jonathon Horta**

9.2 Apply drawing standards to drawings

- **Make sure drawings are up to standards**
- **Drawings that will be used to send to vendors for quotes**
- **Duration: 6 days 11/14/20-11/20/20**

10.1 Project cost analysis

- **Determine the price of all parts in the system**
- **A table showing total cost of the project and the cost of all individual parts**
- **Duration: 7 days 10/21/20-11/4/20 Jonathon Horta**

10.2 Part specifications needed

- **Determine the parts needed to be ordered**
- **A list of all the parts needed to be ordered and their detailed drawings**
- **Duration: 7 days 10/21/20-11/4/20 Aramis King/ Daniel Ward**

10.3 Receiving vendor quotes

- **Research companies that can make the parts needed for the system**
- **A List of at Least 3 companies we will send our drawings to**
- **Duration: 7 days 10/21/20-11/4/20 Robert Barbee/ Michael Samuel**

11.1 Prepare detailed drawings to meet prototype requirements

- **Gather all information that will be sent to companies to produce our parts/materials**
- **A list that was sent to the company for the fabrication of our parts**
- **Duration: 7 days 2/19/21-2/26/21 Titus Woodard**

11.2 Discussion of timelines for equipment on order

- **Discuss when each part needs to be ordered to fit timeline to begin fabricating the system**
- **A table of when all of the parts that will be needed to order from third party companies**
- **Duration: 7 days 2/19/21-2/26/21 Robert Barbee**

11.3 Selection of vendors for components

- **Choose which companies the team will be outsourcing from**
- **A list of companies that we ordered from**
- **Duration: 7 days 2/19/21-2/26/21**

12.1 Detailed plans on manufacturing and assembly of system

- **Create a detailed plan stating the order of how parts will be assembled**
- **A Timeline of how we are going to assemble the system**
- **Duration: 34 days 2/26/26-4/1/21 Robert Barbee**

12.2 Conduct testing in the lab

- **Find real world testing techniques to run on the system**
- **Results from our system with found techniques that are used in automobile industries**
- **Duration: 34 days 2/26/21-4/1/21**

12.3 Test system on Chassis

- **Weld system to chassis to see performance of the design**
- **The success of our system ran on homemade obstacle course**
- **Duration: 34 days 2/26/21-4/1/21 Daniel Ward/ Aramis King**

13.1 Complete each part of the report along the way

- **To complete each section of the report as each assignment is fulfilled**
- **A final report of all the work done to successfully finish our system**
- **Duration: 28 days 04/1/21-04/29/21 Everyone**

13.2 Create a project poster for visual representation

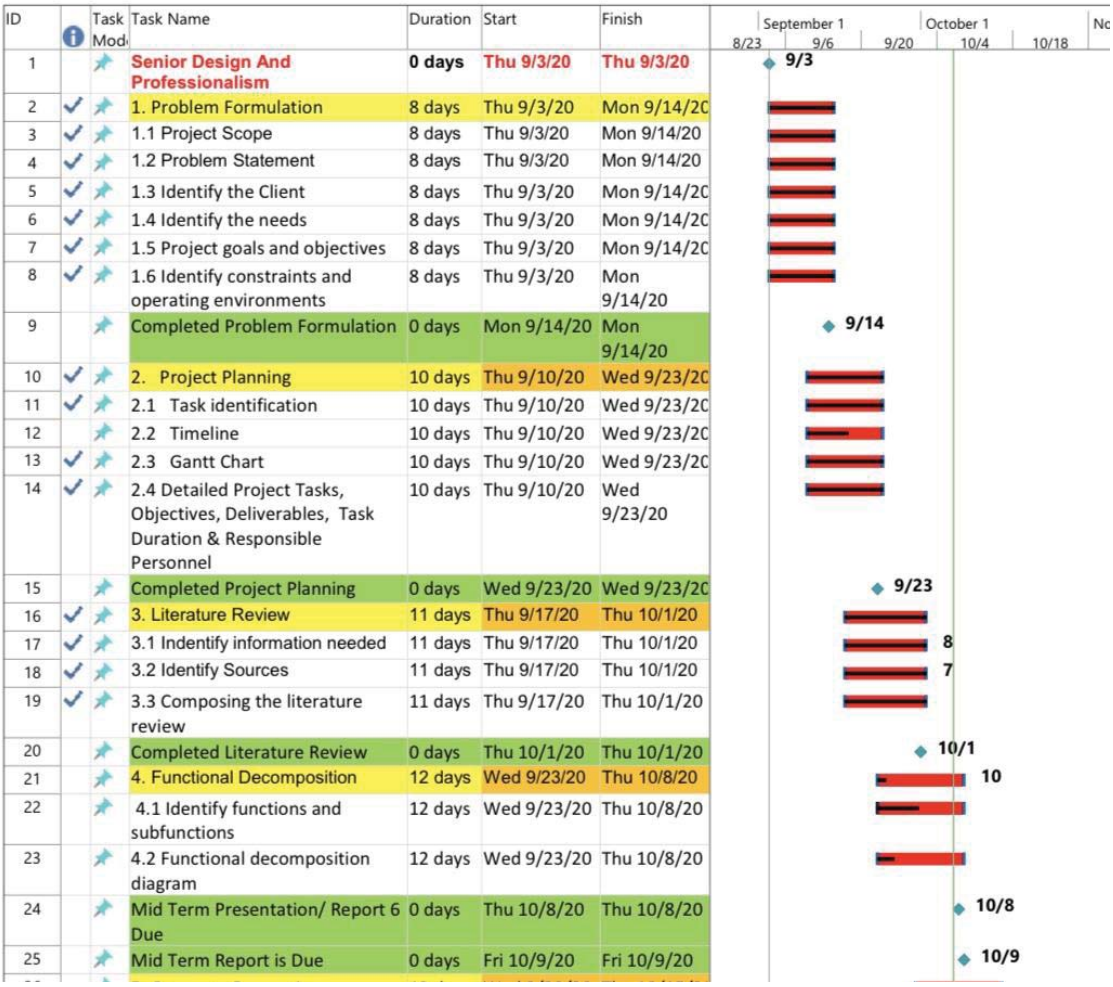
- **Create a project poster and powerpoint for presentation**
- **A poster and powerpoint to visualize our system and how we achieved it**
- **Duration: 28 days 04/1/21-04/29/21 Michael Samuel**

13.3 Prepare for presentation

- **Prepare how information will be presented from the overall experience of this project**
- **Presented our project with the desirables of the panel**
- **Duration: 28 days 04/1/21-04/29/21 Everyone**

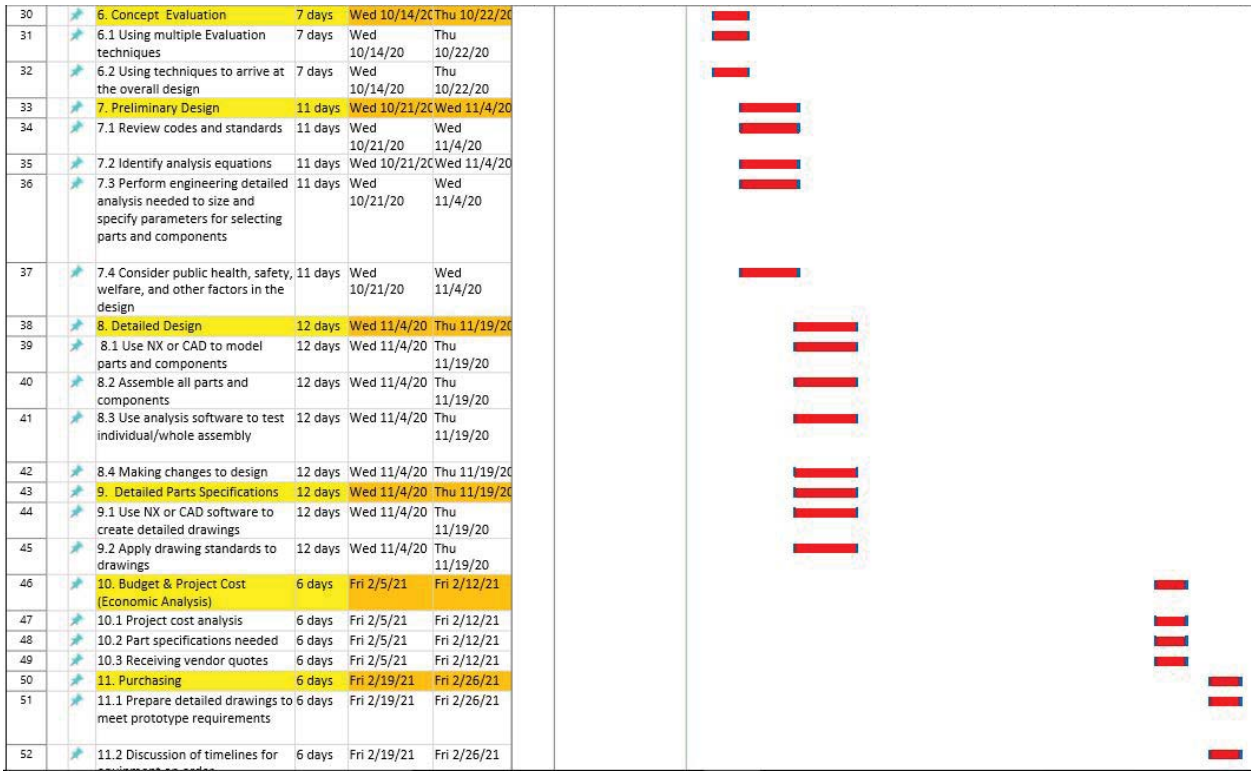
2.3 Gantt Chart

This section will show a visual of the gantt chart and the estimated timeline for each task as well as show important milestones. Figure 2.1 is the gantt chart for this project created on microsoft project for the Fall 2020 semester. Figure 2.2 is the gantt chart for this project created on microsoft project for the Spring 2021 semester.



ID	Task Mode	Task Name	Duration	Start	Finish
1		**Senior Design And Professionalism**	**0 days**	**Thu 9/3/20**	**Thu 9/3/20**
2	✓	1. Problem Formulation	8 days	Thu 9/3/20	Mon 9/14/20
3	✓	1.1 Project Scope	8 days	Thu 9/3/20	Mon 9/14/20
4	✓	1.2 Problem Statement	8 days	Thu 9/3/20	Mon 9/14/20
5	✓	1.3 Identify the Client	8 days	Thu 9/3/20	Mon 9/14/20
6	✓	1.4 Identify the needs	8 days	Thu 9/3/20	Mon 9/14/20
7	✓	1.5 Project goals and objectives	8 days	Thu 9/3/20	Mon 9/14/20
8	✓	1.6 Identify constraints and operating environments	8 days	Thu 9/3/20	Mon 9/14/20
9		Completed Problem Formulation	0 days	Mon 9/14/20	Mon 9/14/20
10	✓	2. Project Planning	10 days	Thu 9/10/20	Wed 9/23/20
11	✓	2.1 Task identification	10 days	Thu 9/10/20	Wed 9/23/20
12		2.2 Timeline	10 days	Thu 9/10/20	Wed 9/23/20
13	✓	2.3 Gantt Chart	10 days	Thu 9/10/20	Wed 9/23/20
14	✓	2.4 Detailed Project Tasks, Objectives, Deliverables, Task Duration & Responsible Personnel	10 days	Thu 9/10/20	Wed 9/23/20
15		Completed Project Planning	0 days	Wed 9/23/20	Wed 9/23/20
16	✓	3. Literature Review	11 days	Thu 9/17/20	Thu 10/1/20
17	✓	3.1 Indentify information needed	11 days	Thu 9/17/20	Thu 10/1/20
18	✓	3.2 Identify Sources	11 days	Thu 9/17/20	Thu 10/1/20
19	✓	3.3 Composing the literature review	11 days	Thu 9/17/20	Thu 10/1/20
20		Completed Literature Review	0 days	Thu 10/1/20	Thu 10/1/20
21		4. Functional Decomposition	12 days	Wed 9/23/20	Thu 10/8/20
22		4.1 Identify functions and subfunctions	12 days	Wed 9/23/20	Thu 10/8/20
23		4.2 Functional decomposition diagram	12 days	Wed 9/23/20	Thu 10/8/20
24		Mid Term Presentation/ Report 6 Due	0 days	Thu 10/8/20	Thu 10/8/20
25		Mid Term Report is Due	0 days	Fri 10/9/20	Fri 10/9/20

Figure 2.1: Gantt Chart for Fall 2020



30	6. Concept Evaluation	7 days	Wed 10/14/20	Thu 10/22/20
31	6.1 Using multiple Evaluation techniques	7 days	Wed 10/14/20	Thu 10/22/20
32	6.2 Using techniques to arrive at the overall design	7 days	Wed 10/14/20	Thu 10/22/20
33	7. Preliminary Design	11 days	Wed 10/21/20	Wed 11/4/20
34	7.1 Review codes and standards	11 days	Wed 10/21/20	Wed 11/4/20
35	7.2 Identify analysis equations	11 days	Wed 10/21/20	Wed 11/4/20
36	7.3 Perform engineering detailed analysis needed to size and specify parameters for selecting parts and components	11 days	Wed 10/21/20	Wed 11/4/20
37	7.4 Consider public health, safety, welfare, and other factors in the design	11 days	Wed 10/21/20	Wed 11/4/20
38	8. Detailed Design	12 days	Wed 11/4/20	Thu 11/19/20
39	8.1 Use NX or CAD to model parts and components	12 days	Wed 11/4/20	Thu 11/19/20
40	8.2 Assemble all parts and components	12 days	Wed 11/4/20	Thu 11/19/20
41	8.3 Use analysis software to test individual/whole assembly	12 days	Wed 11/4/20	Thu 11/19/20
42	8.4 Making changes to design	12 days	Wed 11/4/20	Thu 11/19/20
43	9. Detailed Parts Specifications	12 days	Wed 11/4/20	Thu 11/19/20
44	9.1 Use NX or CAD software to create detailed drawings	12 days	Wed 11/4/20	Thu 11/19/20
45	9.2 Apply drawing standards to drawings	12 days	Wed 11/4/20	Thu 11/19/20
46	10. Budget & Project Cost (Economic Analysis)	6 days	Fri 2/5/21	Fri 2/12/21
47	10.1 Project cost analysis	6 days	Fri 2/5/21	Fri 2/12/21
48	10.2 Part specifications needed	6 days	Fri 2/5/21	Fri 2/12/21
49	10.3 Receiving vendor quotes	6 days	Fri 2/5/21	Fri 2/12/21
50	11. Purchasing	6 days	Fri 2/19/21	Fri 2/26/21
51	11.1 Prepare detailed drawings to meet prototype requirements	6 days	Fri 2/19/21	Fri 2/26/21
52	11.2 Discussion of timelines for	6 days	Fri 2/19/21	Fri 2/26/21

Figure 2.2: Gantt Chart for Spring 2021

The team will use the gantt chart to make sure tasks are completed on time and in an orderly fashion. Also, to document all of the start and end date of each task. With roles assigned to each member, it is easy for each member to know when they need to start the task and the deadline for that task. The member assigned the role will be able to wrap up each task or know when to ask for help if the deadline is approaching. This gantt chart will allow us to stay focused on the project and show everyone what is in progress and what is next to start.

This is a detailed table of each major task with its subtasks. It also includes the objectives, deliverables, the duration of the task, start/ end date, and the person it was assigned to. Table 2.1 is a detailed table for both semesters and contains all major tasks, sub-tasks, objectives and deliverables for each sub-task, estimated duration for each sub-task and the student assigned to that sub-task.

Table 2.1 Detailed Table for Tasks, Objectives and Deliverables

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
1. Problem Formulation	1.1 Project Scope	To identify the client with what is set out to be completed	A description of what major points should be focussed on throughout the project and what are the expected results	7	9/3/20	9/10/20	Robert Barbee
	1.2 Problem statement	To determine the problem and the task that will be taken to solve the problem	Complete description of the problem behind this project and how it will be solved	7	9/3/20	9/10/20	Jonathon Horta
	1.3 Identify the client	To identify the client what is the purpose behind the project	A structured statement that defines the overall project goal	7	9/3/20	9/10/20	Michael Samuel
	1.4 Identify the needs	To define measurable performance characteristics of design	A list of all measurable performance characteristics with units	7	9/3/20	9/10/20	Aramis King
	1.5 Project goals and objectives	To arrange performance characteristics into higher-level & lower-level objectives in diagrammatic tree structure showing hierarchical relationships and interconnections	Well drawn and labelled objective tree showing hierarchical relationships and interconnections of the performance characteristics	7	9/3/20	9/10/20	Titus Woodard/ Daniel Ward
	1.6 Identify constraints and operating environments	To identify the permissible range of the design and performance parameters and the operating environment	A list of permissible range for the design parameters, description of the environment in which the design will operate	7	9/3/20	9/10/20	Todd Maxwell

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
2. Project Planning	2.1 Task identification	To identify the major tasks that need be completed for the project	Complete a list including the project's major tasks	14	9/10/20	9/24/20	Aramis King/ Daniel Ward
	2.2 Timeline	Develop a timeline for the length of how long each task should take	List of tasks with the estimated time to complete to be transferred to a Gnatt chart	14	9/10/20	9/24/20	Titus Woodard/Todd Maxwell
	2.3 Gantt Chart	Create a Gantt Chart based off the timeline developed	Gantt Chart With actual time to complete tasks as well as estimated time to complete the tasks	14	9/10/20	9/24/20	Michael Samuel
	2.4 Detailed Project Tasks, Objectives, Deliverables, Task Duration & Responsible Personnel	Create a detailed table based off the Gantt chart and actions taken for the project	Complete a table including specific information for all portions of the project	14	9/10/20	9/24/20	Jonathon Horta/ Robert Barbee
3. Literature Review	3.1 Identify information needed	To identify important information needed for the project	Complete a description of important information needed for project	13	9/17/20	9/29/20	Robert Barbee/ Jonathon Horta/ Michael Samuel
	3.2 Identify sources	To identify where the important project information will be coming from	Create a list of sources used	13	9/17/20	9/29/20	Jonathon Horta/Robert Barbee/ Daniel Ward
	3.3 Composing the literature review	Create a full literature review with all relevant information found	A Finalized literature review	3	9/27/20	9/30/20	Todd Maxwell/ Titus

4. Functional Decomposition	**4.1 Identify functions and subfunctions**	**To create a list that contains all functions**	**A detailed listed of all functions**	**4**	**9/23/20**	**9/27/20**	**Jonathon Horta/ Robert Barbee/ Daniel Ward**
	4.2 Functional decomposition diagram	**Compose a graph showing how all functions are related to each other**	**Create a diagram that shows functions and their sub-functions and how they relate to each other**	**4**	**9/27/20**	**10/10/20**	**Michael Samuel/Todd Maxwell**
Major Tasks Description	**Sub-Task Description**	**Objective(s) for Task**	**Deliverables to be Submitted**	**Duration (Days)**	**Start date**	**End Date**	**Primary Responsible Person**
5. Concepts Generation	**5.1 Individual Concept Generation**	**Each member creates their own concept of functions for a design**	**A concept list of functions for a design**	**15**	**9/30/20**	**10/14/20**	**Everyone**
	5.2 Group Concept Generation	**The group combining their ideas to come up with all functions**	**Collaborating all concepts with each member to form a full function list for consideration of a design**	**15**	**9/14/20**	**10/22/20**	**Everyone**

6. Concept Evaluation	**6.1 Using multiple Evaluation techniques**	**Evaluate concepts using multiple methods including feasibility study, go-no-go, and decision matrix**	**Positive evaluation results which push our project to its design stage**	**6**	**10/14/20**	**10/29/20**	**Robert Barbee/ Michael Samuel**
	6.2 Using techniques to arrive at the overall design	**Apply concept evaluation techniques for each function to get to an overall design**	**A list of functions tested to make sure all functions were considered and the design stage may now begin**	**3**	**10/29/20**	**11/5/20**	**Jonathon Horta/ Todd Maxwell**
Major Tasks Description	**Sub-Task Description**	**Objective(s) for Task**	**Deliverables to be Submitted**	**Duration (Days)**	**Start date**	**End Date**	**Primary Responsible Person**

7. Preliminary Design	**7.1 Review codes and standards**	**Pull up relevant codes and standards that should be followed throughout the project**	**Provide a list of standards that were followed to approve our design**	**3**	**11/5/20**	**11/8/20**	**Jonathon Horta**
	7.2 Identify analysis equations	**Find list of equations critical to project that is needed to come up with the design**	**Provide a list of equations that we used to come up with our design**	**6**	**11/8/20**	**11/12/20**	**Robert Barbee/ Daniel Ward**
	7.3 Perform engineering detailed analysis needed to size and specify parameters for selecting parts and components	**Sketch the idea of the design based of calculations**	**A beginning sketch of our design based on the calculation and standards for the system**	**8**	**10/24/20**	**11/1/20**	**Robert Barbee/ Daniel Ward**
	7.4 Consider public health, safety, welfare, and other factors in the design	**Make sure design is not harmful to the environment or the public**	**Considerations that were made to the design for the safety of everyone**	**5**	**10/30/20**	**11/4/20**	**Titus Woodard/ Aramis King**

8. Detailed Design	8.1 Use NX or CAD to model parts and components	Create a NX model for all the parts of the system	A NX or CAD model of all the individual parts	8	11/4/20	11/12/20	Micheal Samuel
	8.2 Assemble all parts and components	Assemble all parts of the system to show our design	An assembly of all of the parts	3	11/10/20	11/13/20	Robert Barbee
	8.3 Use analysis software to test individual/whole assembly	Use Ansys to run stress tests to see how the system relates to our calculations	Stress analysis test results which determine if we need to make changes to our design	5	11/12/20	11/17/20	Aramis King
	8.4 Making changes to design	Make changes in design based on the analysis tests to make a suitable and passing system	Updated design with passing stress tests	5	11/12/20	11/28/20	Todd Maxwell
9. Detailed Parts Specifications	9.1 Use NX or CAD software to create detailed drawings	Use Nx software to come up with detailed drawings of all parts and assemblies	Detailed drawings of all parts and assemblies	4	11/26/20	11/30/20	Daniel Ward
	9.2 Apply drawing standards to drawings	Make sure drawings are up to standards	Drawings that will be used to send to vendors for quotes	2	11/30/20	12/2/20	Jonathon Horta
10. Budget & Project Cost (Economic Analysis)	10.1 Project cost analysis	Determine the price of all parts in the system	A table showing total cost of the project and the cost of all individual parts	3	2/05/21	2/8/21	Jonathon Horta
	10.2 Part specifications needed	Determine the parts needed to be ordered	A list of all the parts needed to be ordered and their detailed drawings	3	2/5/21	2/8/21	Aramis King/ Daniel Ward
	10.3 Receiving vendor	Research companies that can make the	A List of at Least 3 companies we will send				Robert Barbee/

	quotes	parts needed for the system	our drawings to	4	2/8/21	2/12/21	Michael Samuel
Major Tasks Description	**Sub-Task Description**	**Objective(s) for Task**	**Deliverables to be Submitted**	**Duration (Days)**	**Start date**	**End Date**	**Primary Responsible Person**
11. Purchasing	11.1 Prepare detailed drawings to meet prototype requirements	Gather all information that will be sent to companies to produce our parts/materials	A list that was sent to the company for the fabrication of our parts	7	2/19/21	2/26/21	Titus Woodard
	11.2 Discussion of timelines for equipment on order	Discuss when we need to order each part to fit our timeline to begin fabricating our system	A table of when all of the parts that will be needed to order from third party companies	7	2/19/21	2/26/21	Robert Barbee
	11.3 Selection of vendors for components	Choose which companies we will be outsourcing from	A list of companies that we ordered from	7	2/19/21	2/26/21	Michael Samuel
12. Fabrication & Testing	12.1 Detailed plans on manufacturing and assembly of system	Create a detailed plan stating the order of how we are going to assemble the parts	A Timeline of how we are going to assemble the system	34	2/26/21	4/1/21	Robert Barbee
	12.2 Conduct testing in the lab	Find real world testing techniques to run on the system	Results from our system with found techniques that are used in automobile industries	34	2/26/21	4/1/21	Todd Maxwell
	12.3 Test system on Chassis	Weld system to chassis to see performance of our design	The success of our system ran on homemade obstacle course	34	2/26/21	4/1/21	Daniel Ward/ Aramis King

13. Final Report & Presentation	**13.1 Complete each part of the report along the way**	**To complete each section of the report as we are finishing each assignment**	**A final report of all the work done to successfully finish our system**	**28**	**4/1/21**	**4/29/21**	**Everyone**
	13.2 Create a project poster for visual representation	**Create a project poster and powerpoint for presentation**	**A poster and powerpoint to visualize our system and how we achieved it**	**28**	**4/1/21**	**4/29/21**	**Michael Samuel**
	13.3 Prepare for presentation	**Prepare how we are going to present the information from the overall experience of this project**	**Presented our project with the desirables of the panel**	**28**	**4/1/21**	**4/29/2021**	**Everyone**

3. LITERATURE REVIEW

This chapter discusses all of the information needed to understand this project. Topics such as the Baja car for which this steering and suspension system will be a part of will be discussed in literature review. The descriptive functions of these systems as well as different designs that are available for each system with their pros and cons. After that, this report will present relevant equations for each system that will need to be solved to come up with a design later on. The report will end with elaborating on clients that this project is relevant to along with the safety factors we are considering throughout this project.

3.1 Identification of Information Relevant to the Project

For the information relevant to this project, the group had a meeting to talk about what would need to be researched to give a complete overview of this project. During this time, we began to break down the project as a whole to see what was included. We came up with a list to start out with and if any more topics came up as we began research it, bring it to the group to discuss if we should create a new section for that topic. We assigned at least one person to each topic to cover every section to give a complete overview of this project. The list of topics that we concluded are:

- General information over baja car
- Suspension system
- Steering system
- Math equations involved
- Safety Considerations
- Audience/ Clients

3.2 Potential Sources of Information for Project

As mentioned in the section above, every member was assigned to a different section to pull sources that would help provide more information for the overall of this project. The sources were pulled from several different articles, reports, textbooks, and detailed videos on each individual topic. The reference page will include all of the sources that were used for this literature review.

3.3 Miscellaneous Information on Baja Vehicle

This section will be covering miscellaneous information about the baja vehicle based on design requirements and suggestions from groups with previous experiences. This section also helps the audience understand the environment around the steering and suspension systems, and how exactly it collaborates with the design.

3.3.1 Overall Miscellaneous Information

The vehicle will be travelling in the conditions of an off-road terrain, which include bumpy surfaces, muddy surfaces, loose dirt, and shallow waters. The vehicle will be graded by judges observing the vehicle go through a total of 12 tests [7]. The performance side focuses on the vehicle’s instant reactions based on the different terrains [7]. A report on the vehicle’s design and marketing cost is required by the judges [7]. The most expensive areas on the kart would be the suspensions and the differential/axles [8]. Reverse direction tread on the vehicle's tires are one of the things that helps for medium to dry surfaces and soft or muddy surfaces [8]. The courses for this competition will be challenging, so there’s a higher chance for failures to occur.

Table 3.1 presents the specifics on how the performance on the vehicle will be graded. Each event is associated with points and has a description of what results the judges are looking for in a vehicle.

Table 3.1 Description of Formula SAE Competition Trials [7]

Events	Points	Description
Preliminary tests	**0**	**Pre-competition safety tests.**
Technical inspection	-	General check of car by judges.
Tilt	-	Car inclination up to 60º checking its stability and that no type of liquid is leaking.
Brakes	-	Simultaneous blocking of all four wheels after a brief acceleration.
Noise	-	Check to ensure vehicle emits less than 110 dB under certain acceleration conditions.
Static	**325 in total**	**Presentations and oral defence in front of the judges of technical solutions adopted.**
Design	150	Technical defence of vehicle design and solutions proposed.
Presentation	75	Marketing presentation, convincing the judges to choose their car compared to the others.
Costs	100	Written report detailing cost of each part and component of the unit built.
Dynamic	**675 in total**	**Different on-track trials with the single-seater.**
Acceleration	75	Cover 75 m on a straight run in the shortest possible time
Manoeuvrability (Skidpad)	50	Manoeuvrability to run a 9 metre circle in both directions.
Sprint	150	Quick lap of the circuit.
Endurance	350	Overall vehicle performance and reliability in 22 laps of a circuit.
Fuel	50	Minimum consumption in endurance trial
Total	**1000**	

3.3.2 Steering and Suspension Miscellaneous Information

Steering and suspension systems are two different portions of the vehicle, but they are connected through linkages and work together. A minimum of 11in. clearance of the suspension has been used and recommended by groups with previous designs [8]. Weight, cost, and functionality are the main factors of a rear suspension.. The upper arm should be slightly shorter than the lower arm. As the vehicle's suspension system compresses, the roll center typically moves upward and eventually causes deflection. Having an axis of motion in vertical direction helps the suspension react in horizontal and vertical direction as a result of impacts [8]. The steering system makes up

about 4% of the weight distribution of the vehicle, while the suspension system makes up about 26% of the weight distribution. The vehicle will have higher net weight towards the back of the vehicle. The rear suspension should be lightweight, but remain strong. The rear suspension could be adjustable to assist in traveling through different terrains [9].

3.4 Suspension system

In this section the various types of suspension systems and components involved with the designs are discussed and compared. There are various types of systems and component combinations can be used and some are more suitable for off-road vehicles than others.

3.4.1 Types of Suspension

There are two types of suspension systems. They are classified as dependent and independent. The dependent system is a beam connecting two wheels which transmits a load or movement to both wheels. It is a rigid system and there is a lack of adjustability. Independent systems allow more flexibility needed for off-road driving[10]. The types of various independent systems and their pros and cons are described below.

The Double Wishbone (Double A-Arm) is a suspension system setup that uses two control arms and a shock assembly[10]. The two control arms are connected to the chassis and the wheels of the vehicle. The system can be used in the front or rear of the vehicle. There are two different types of wishbone systems. The first is equal length. With an equal length setup, both the top and bottom control arms are the same length. The second double wishbone setup in an unequal length setup. With this set up the upper control arm is shorter than the bottom control arm. Below are the pros and cons related to choosing the Double Wishbone system. Figure 3.1 below shows the Double Wishbone system[10].

Pros: Resistive to high loads, load handling abilities, easy to adjust

Cons: Weight, high cost, complex components, takes up a lot of space

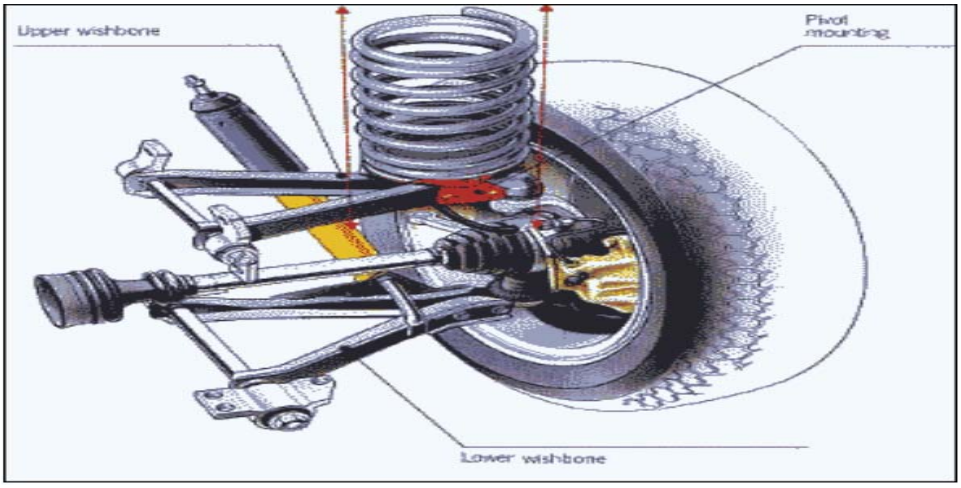


Figure 3.1: Double Wishbone System [10]

The Macpherson system (A-Arm) is also known as the single control arm system[10]. The design consists of one control arm, a wheel hub, and shock or strut assembly. The strut and control arm connects directly to the chassis of the vehicle. The other side of the control arm connects to the bottom of the wheel hub to get connection to the wheels. The strut or shock assembly connects at the top of the hub assembly. The pros and cons of the Macpherson system are as follows. Figure 3.2 below is the image of a Macpherson system[10].

Pros: Simple setup, low cost, light weight, does not take up a lot of space

Cons: Increased ride height, more difficult to turn

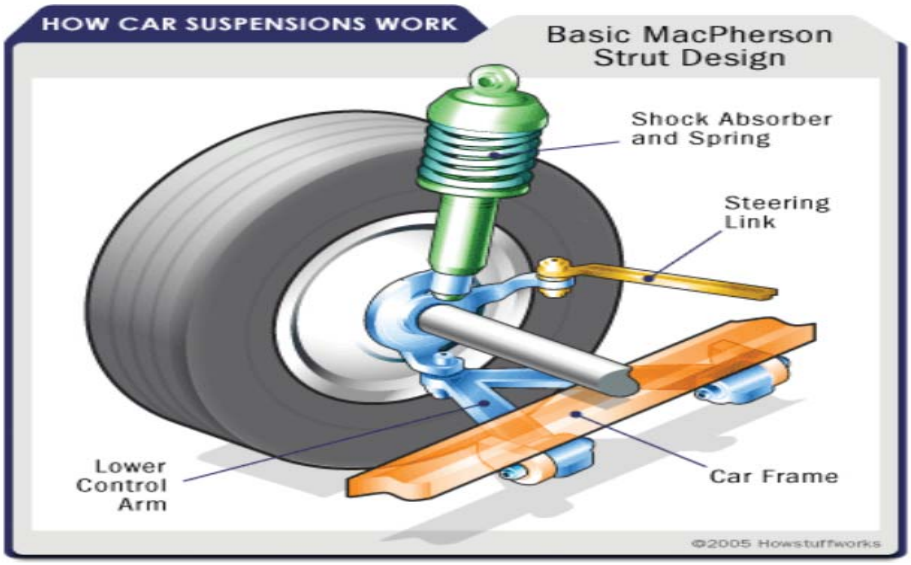


Figure 3.2: Macpherson System [10]

The semi-trailing and trailing arm systems use pivoting arms that are attached to the vehicle. These two systems are only used for the rear of the vehicle. The arms are also located in the front of the wheel which creates a trailing effect. The difference between the semi-trailing and trailing arm lies in the position of the pivot points. Semi-trailing arms are positioned at an angle to the centerline and trailing arms are positioned perpendicular to the centerline. Figure 3.3 below shows the difference between a trailing and semi-trailing arm[10].

Pros: Rigid design, simple, not many mechanical components

Cons: Can only be used in rear of vehicle, weight, high cost

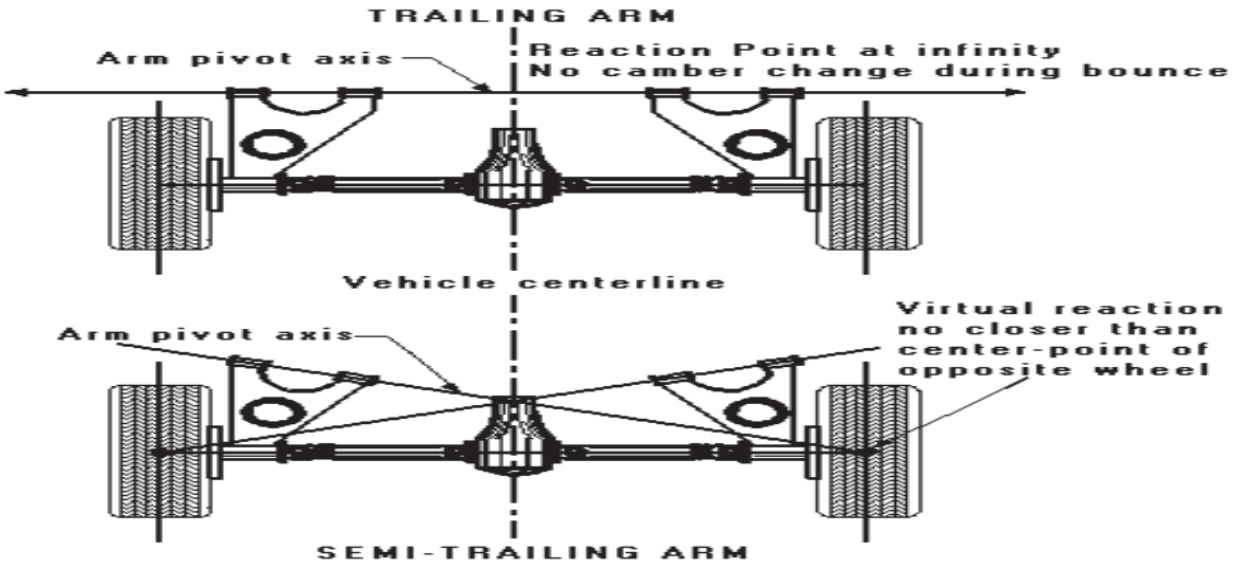


Figure 3.3: Trailing/Sem-Trailing System [10]

The Swingaxle suspension is a very old system that provides independent shock absorption. It isn't used much today due to weakness of the system and does not have good handling. Figure 3.4 below is an image of how swing axle suspension operates[11].

Pros: Independent shock absorption

Cons: Difficult handling, weak system, old system

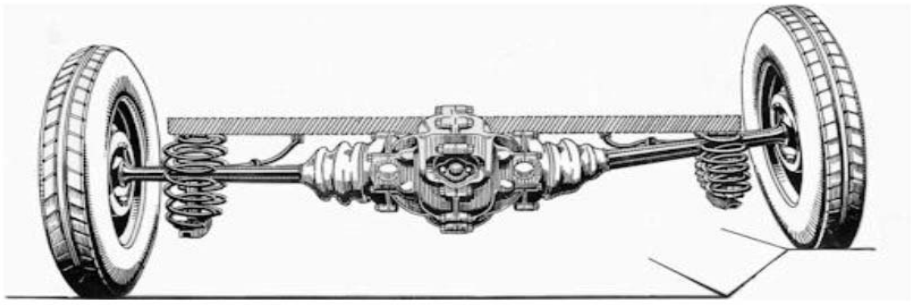


Figure 3.4: Swing axle suspension [11]

The Leaf Spring suspension system is made up of a stack of arc shaped pieces of steel that are bolted together. All the pieces of steel are different sizes with the longest on top and decreases in size with each bottom piece. It is then attached to the rear axle of the vehicle. There are also more advanced leaf spring systems such as the transverse leaf spring suspension but uses very high cost composite materials. Figure 3.5 below shows the leaf spring system[12].

Pros: light weight, added support

Cons: Not flexible, high cost

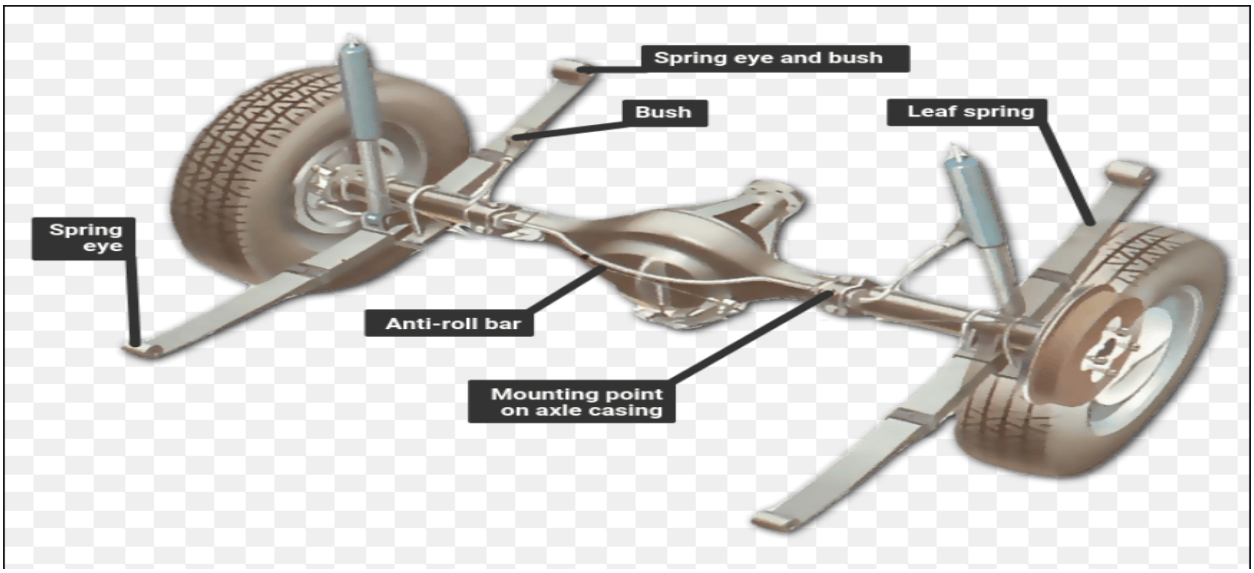


Figure 3.5: Leaf Spring System [12]

3.4.2 Components that make up a suspension

This section will dive deeper into each individual component of a suspension system. The list below will include the parts name, its function, and the pros and cons of that part.

Shocks- Keeps the vehicle from bouncing. Figure 3.6 shows what shocks look like.

Pros: Good for off road vehicle

Cons: High Cost, can be difficult to tune


Figure 3.6: Shocks System

Coil springs- The function of coil springs is to support the vehicle at its desired height, to maintain proper alignment angles and to absorb road shock transmitted through the tires and shock absorbers. Figure 3.7 shows what coil springs look like.

Pros:Performance and Off-Road Capability, Customizable, flexible and comfortable

Cons:Not For Heavy Vehicles, can be expensive



Figure 3.7: Coil Springs

Control Arms- (lower & Upper)- control arms connect the suspension to the actual vehicle frame. They are connected to the frame through a component called bushings, while they attach to the suspension through the ball joint. That allows the vehicle to turn its wheel and pivot, connecting the tire to the car's suspension~~[15]~~. Figure 3.8 shows what control arms look like.

Pros: allow you to set the camber to your desired setting.

Cons:you will spend hours messing with it and trying to decide the right angles



Figure 3.8: Control Arms System

Ball joints- Ball joints consist of a ball and socket similar to the hip joint of the human body. Ball joints of your front suspension provide pivoting movement between the steering knuckles and control arms to provide a safe, smooth ride and allow you to precisely control your vehicle[16]. Figure 3.9 shows what ball joints look like.

Pros: Allows free movement in two directions at the same time, including rotating

Cons: Dry ball joints increases frictions and can cause steering stiffness

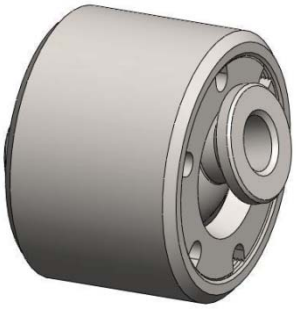


Figure 3.9: Ball Joint

Sway bar (if needed)- a bar that torsionally couples the right and left front-wheel suspensions of an automobile to reduce roll and sway[17]. Figure 3.10 shows what the sway bar looks like.

Pros: Allows less body roll

Cons:High cost



Figure 3.10: Sway bar

Steering box / system - The steering gearbox contains the gears that transmit the driver's steering inputs to the steering linkage that turns the wheels, and it multiplies the driver's steering changes so that the front wheels move more than the steering wheel[15]. Figure 3.11 shows what the steering box look like.

Pros: simple construction

Cons: Sensitive to impact



Figure 3.11: Steering box

Tire- A tire is a ring-shaped component that surrounds a wheel's rim to transfer a vehicle's load from the axle through the wheel to the ground and to provide traction on the surface over which the wheel travels.

Pros:Improves traction

Cons:High cost

3.5 Steering System

The steering system is a complex system which integrates between several other systems in a vehicle. The steering is composed of linkages that move side to side based on the way the steering wheel is turned to turn the vehicle. The way that those linkages are placed will determine the turning radius of the vehicle. The geometry will also determine the movement of the tires when approaching and during the turns. The placement of the system is crucial due to the drivetrain and suspension being inches away from each other. The geometry and design will have to be considered based on the pros and cons of each geometry and design as well as the

room available in the chassis. There are three steering geometries that a vehicle can have. The three geometries are Ackerman, parallel, or reverse Ackerman steering. These geometries are used for different types of scenarios such as desired turn radiuses and speeds at turns. Along with these geometries there are different designs that can be considered. A steering box can be used to steer the car or a rack and pinion can be used to achieve steering to our desirability. This section will discuss the pros and cons of each geometry and designs for the steering system.

3.5.1 Steering Geometries

The three steering geometries used today are the ackerman, parallel and reverse ackerman. These geometries are used for different applications that one is looking for. Figure 3.12 will show the different geometries and with the corresponding turning radius possible.

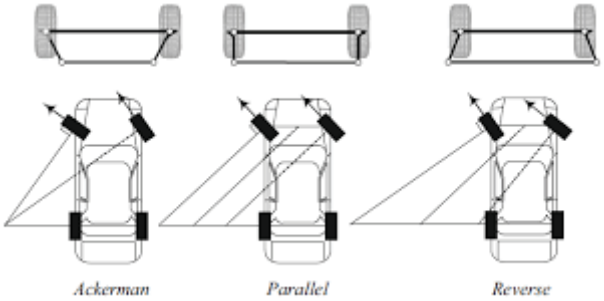


Figure 3.12: This image above shows the difference between the three geometries [18].

Ackerman steering

The first type of steering geometry and most commonly used for off-road vehicles is the Ackerman geometry. The theory of ackerman is having the inside tire of the vehicle to turn more than the outside tire allowing for a greater turn radius. By having a greater turn radius, the vehicle will have to approach the turn at lesser speeds. A higher tire angle is achieved on the inside tire. Slip angle is the angle between the direction the tire is pointing and the direction the car is actually moving. A low slip angle is desired when it comes to turning a common vehicle to reduce drag and to prevent an increase in temperature in the front tires. A higher slip angle causes more drag for the inside tire and higher temperature of that tire. This is important in a competitive setting. When using the Ackerman geometry the joint connected to the wheel needs to be aligned with one end of the steering rod all the way to the center of the rear axle. Figure 3.13 shows the imaginary lines that connect the tire connection, steering rod joint and the center of the rear axle.

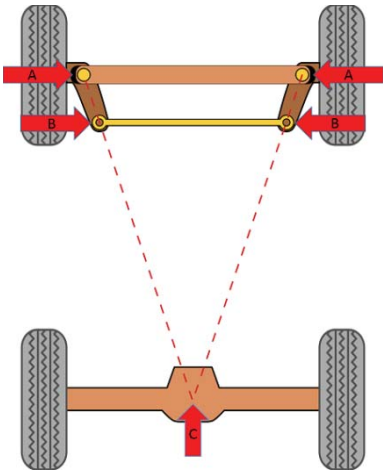


Figure 3.13: The picture above shows the Ackerman geometry [19].

The list below will show the pros and cons on using the Ackerman geometry.

Pros

- Sharper turns
- Easy to fabricate
- Avoids front tire slippage
- Simple geometry
- Lower slip angle at lower speeds

Cons

- Lower speeds at turns
- Not ideal on flat surfaces
- Increased drag on inside tire causing increase in temperature on that tire

Parallel steering

When the front tires are turned at the same angle when the steering wheel is turned is called parallel steering. This steering geometry is commonly used for racing cars. This geometry puts lower slip angles for the front tires. With the front tires moving at the same angle, there is less drag on the inside tire which means there is no increase in temperature for the tire not slowing the vehicle down. Figure 3.14 will show what the geometry of parallel ackerman will look like.

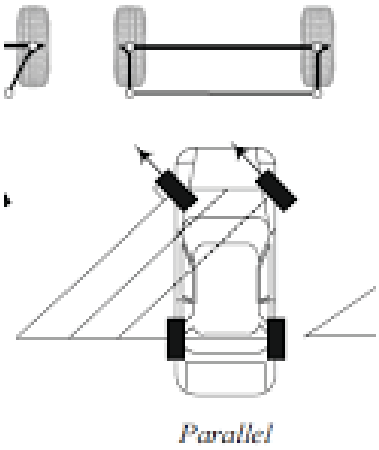


Figure 3.14: The picture above is to show the front tires turning at the same angle.

The list below will show the pros and cons for the parallel steering geometry.
Pros

- Less drag on the tires
- Can approach turns at higher speeds
- Less increase in tire temperature
- Good static turning radius

Cons

- Not ideal for off-road surfaces
- Limited turn radius
- Understeering may occur

Reverse Ackerman

The steering geometry where the outside front tire turns more than the inside tire is called reverse Ackerman. This geometry is ideal for indie and formula cars. This geometry is for very high speeds and wider turns. The tires achieve the best grip when it is taking a wider turn. Since this car is traveling very fast and approaching turns at higher speeds it is noticeable that the cars using this geometry are low to the ground to prevent the car from tumbling on a turn. Figure 3.15 shows what the geometry of reverse ackerman looks like and the unsymmetrical rotation of the tires.

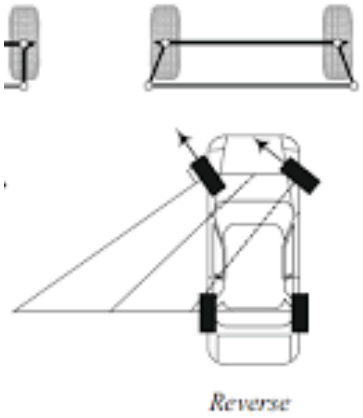


Figure 3.15: The picture above is to show how the outside front tire turns more than the front inside tire during a turn.

The list below will show the pros and cons of the reverse ackerman steering geometry.

Pros

- Better grip on tires on wider turns
- Approach turns at higher speeds
- Ideal for flat surfaces

Cons

- Wider turns
- Need lower center of gravity
- Drag on outside tire slowing down vehicle
- Not practical for off-road setting

3.5.2 Steering Designs

There are several designs when it comes to steering systems. Since our design will be intended for off-road vehicles and need to have four wheel drive we are choosing a basic steering design. These designs are easier to fabricate because these designs are less complex. The main steering designs are rack and pinion, worm and sector, and recirculating ball [20]. This section will dive deeper into the pros and cons of these steering designs.

Rack and Pinion

The rack and pinion steering design consists of the fewest moving parts compared to the others [21]. The main object for rack and pinion is designing the gearset to our best interest. With the gears continually grinding against each other, there is no repair available. The only option is to replace the gears and steering rod. The driver would turn the steering wheel therefore turning the pinion which would move the rack side to side turning the tires to their desired location. The gearbox needs to consider making the pinion bigger or smaller with certain parameters of each. If the pinion is smaller than the steering wheel would be easier to turn but more revolutions of the

wheel would be necessary to make a tighter turn. If the pinion is bigger then it would be harder to turn but the driver would barely need to move the steering wheel. This type of steering design is very precise compared to the others. Figure 3.16 will show all components of the rack and pinion steering system.

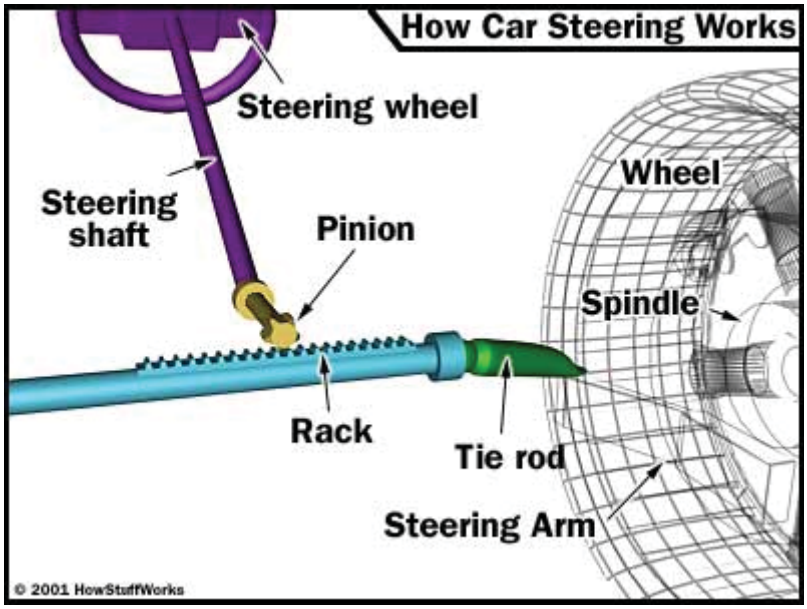


Figure 3.16:The illustration above shows all parts of a rack and pinion design [22].

Worm and sector

The worm and sector design is more complex than the rack and pinion design. This steering design does have more moving parts and is more difficult to assemble correctly. With more moving parts in this design, there is more room for loss of motion. When there is a lot of loss of motion, the car will not move appropriately. This design is easier for new drivers but with more moving parts, this design has a lot of areas where parts can lock up and will not allow any steering for the vehicle. Also, with many bumps and rocks in the road there is an increased chance that joints can lock up during unexpected forces from the environment. This design is not ideal for off-road environments. Figure 3.17 will show the overall design for the worm and sector steering design.

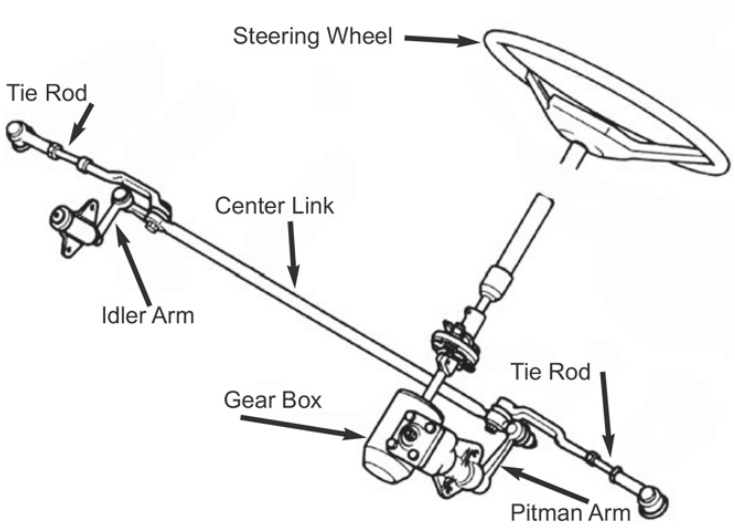


Figure 3.17: The diagram above shows the parts of a worm and sector steering design [23].

Recirculating Ball

The most complex of these three designs is the recirculating ball steering design. This design is similar to a rack and pinion with several tiny spheres in the middle of the gears contact points. These tiny spheres help slow down the wear in the gears providing a longer life to the steering system as a whole. The spheres also help reduce slop in the gear. Slop is the feeling when you change direction in the gears and it wheels loose when turning the steering wheel [24]. With more components in the steering system, there is more room for loss of motion and the cost of this system will be significantly higher than the others. This system works more like levers pushing and pulling the tires side by side. Figure 3.18 shows the complexity of the recirculating ball steering design. Figure 3.19 shows the overall setup for the recirculating ball steering system.

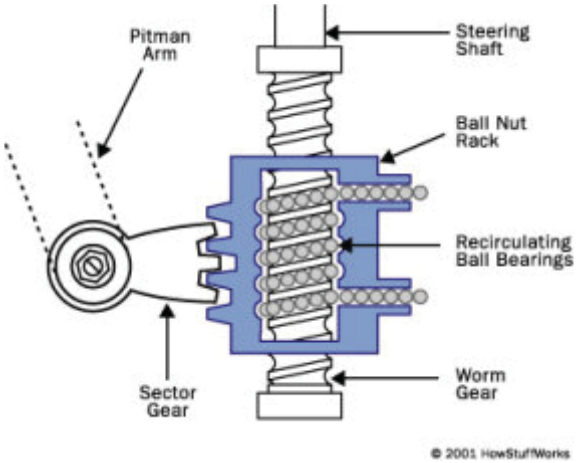


Figure 3.18: The picture above shows the tiny spheres within the grooves [24].

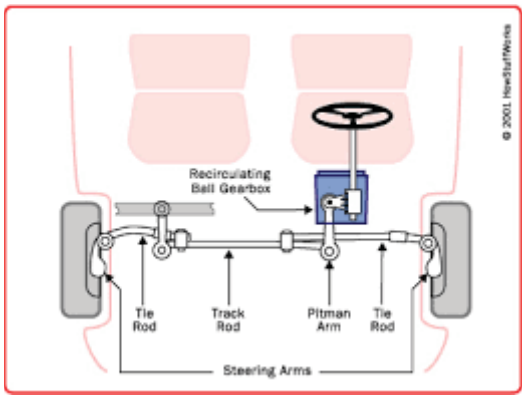


Figure 3.19: This diagram shows the whole recirculating ball steering design [24].

3.6 Math Equations involved

This section of the literature review will include the equations that will be used throughout this entire project. This section is split between three categories which are finite element, kinematic, and machine design equations.

3.6.1 Finite Element

Finite elements is a commonly used tool in engineering systems, as you can calculate solutions for vibrating systems. This was measured by the FEA to better understand the behavior of a structure that is placed in boundary conditions and loads. This strategy is used by breaking the systems into different sections in order to understand the displacement the system is facing. The calculations are represented by nodes and the collaboration of the Finite Elements to determine the mesh of programs which determine the effect of the loads. The system most commonly used is the quarter of the suspension system. Figure 3.20 shows the simulation of one quarter of the suspension system. Figure 3.21 shows the displacement of nodes in a system.

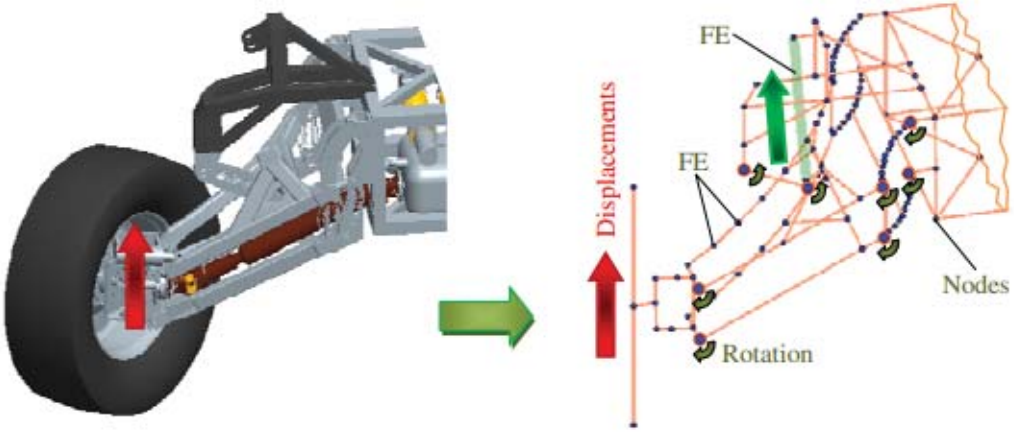


Figure 3.20: This diagram shows quarter of the suspension system

$$[k]\cdot\{u\}=\{f\},$$

- K: denotes the global stiffness matrix of a structure

- U: defines the global nodal vectors displacement , $u_i,\ v_i,\ w_i$
- F: introduces the global nodal vectors of applied forces

1. Defines the rotational vectors, $\theta_x,\ \theta_y,\ \theta_z$

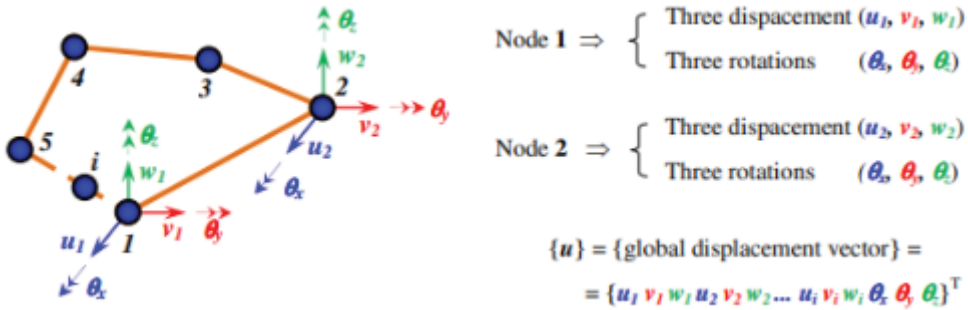


Figure 3.21 Shows the displacement of nodes

Analysis:
In this understanding we were able to use the Global Equation to measure the nonlinear formation of two joining nodes which allows to measure the displacements and rotational movement in the vehicle. With the Global Equation you are able to break down the measurement system into multiple categories, with relations to the stiffness matrices, vector displacements and the applied forces nodes can be determined. As shown in ~~figure~~ 3.20 we are able to show the vibrations of stresses through a simulation to categorize the displacement the vehicle withstands through various obstacles.

3.6.2 Kinematics

Kinematic Design Analysis is used to calculate motion of a machine during movement while being able to calculate the geometry of motion in the system.Kinematics is being used to measure the dynamic movement of the suspension and steering system. Figure 3.22 and Figure 3.23 shows the overall linkage system for each suspension design.

The MacPherson system removes the top a-arm from the previous system and instead connects the damper directly to the knuckle through a struct.	Double wishbone system (DWS), requires two a-arms connected to a knuckle that connects to the tires through a steering link, while the damper system is placed on the bottom a-arm and connects to the car while both a-arms connect to the chassis.

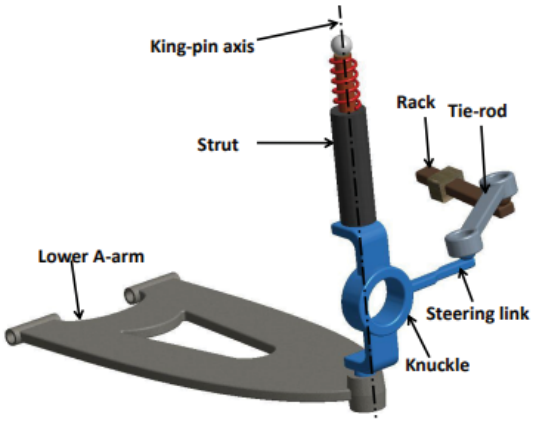


Figure 3.22: Solid model of the MacPherson system

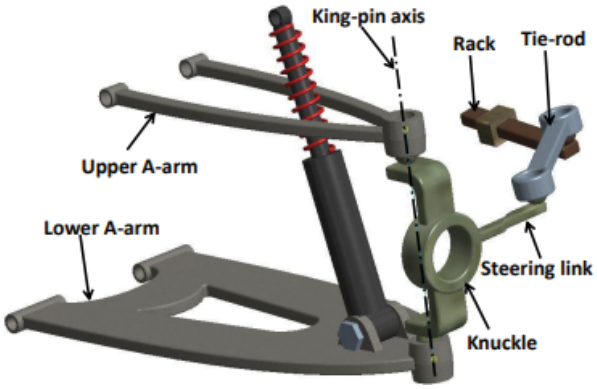


Figure 3.23: Solid model of the DWS

Figure 3.24 and Figure 3.25 shows the variables involved in solving kinematic problems and will help us design a system with the desired movement from all the components. Using kinematics will also allow the group to prevent an unwanted motion that would cause failure to the system.

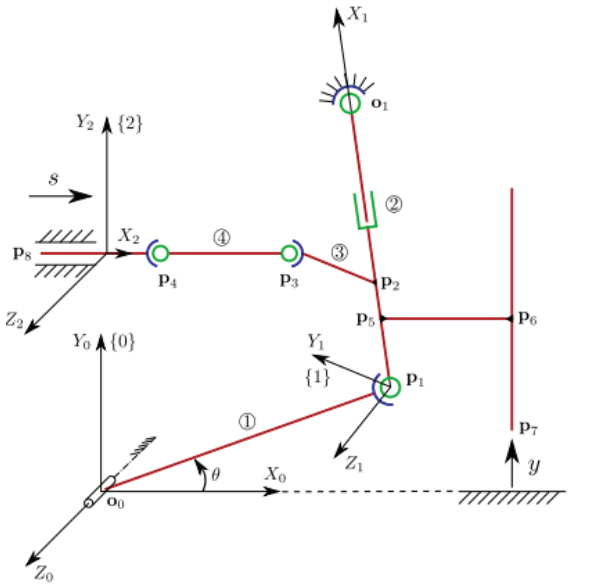


Figure 3.24 Kinematic diagrams before movement

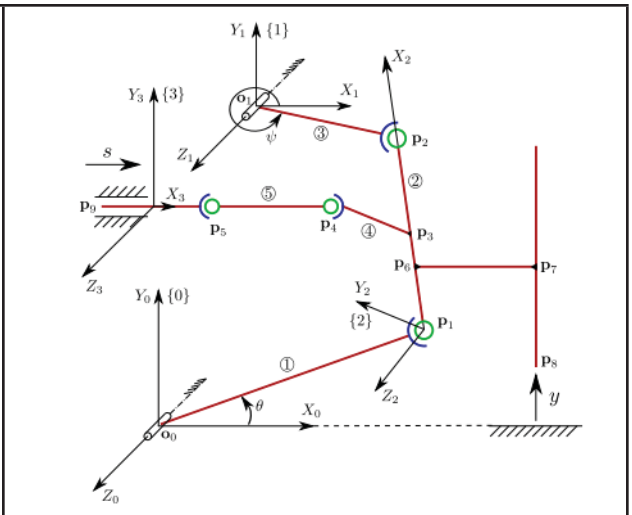


Figure 3.25 Kinematic diagram after movement

Analysis:
Through Kinematic Analysis we are able to understand that in both The Macpherson and The Double Wishbone Systems are compiled of a four bar spatial and five linkages. With that information we are able to measure both systems in the same manner using the linkages of the suspension to calculate the machine's motion, displacement and overall geometry. As shown in Figure 3.24 and Figure 3.25 both have different formation of movement that can be measured through a genetic algorithm to calculate various angles and dimensions displaying the dynamic movement of suspension and steering system of motion through various.

3.6.3 Machine design

For the machine design math equations involved are centered toward creating a gearbox for certain steering designs. These equations range from generating the gearbox ratio to stress equations on each tooth. These equations are being pulled from the textbook "SHIGLEY'S MECHANICAL ENGINEERING DESIGN, TENTH EDITION". This textbook contains all equations for creating gearboxes from start to finish. The list of equations below show equations to arrive at important parameters of each gear [25].

$$P = N/d$$
$$m = d/N$$
$$p = \pi d/N = \pi m$$
$$pP = \pi$$

where P = diametral pitch, teeth per in
N = Number of teeth
d = pitch diameter, in or mm
m = module, mm
p = circular pitch, in or mm

$$V = \pi dn/12$$

where V = pitch-line velocity, ft/min
d = gear diameter, in
n = gear speed, rev/min

$$W_t = 33000\frac{H}{V}$$

where Wt = transmitted load, lbf
H = power, hp
V = pitch-line velocity, ft/min

The next three equations are used to find the transmitted load on the gear that is needed to move the rack that will then move the tires in the direction that is desirable. If necessary, equations for all transmitted forces are provided below.

$$W_r = W sin\phi_n$$
$$W_t = W cos\phi_n cos\psi$$
$$W_a = W cos\phi_n sin\psi$$

where W = total force
Wr = radial component
Wt = tangential component (transmitted load)
Wa = axial component (thrust load)

When designing this gearbox, the material will be an important fact as far as life for the system. Also, a goal is to make a gearbox with the highest efficiency possible to prevent any failures while the vehicle is in motion.

3.7 Safety considerations

Safety is the most integral part of any designing process of machinery. Without hours of testing and errors, vehicles would not be able to legally operate under any circumstances. Off road vehicle safety has some the same standard rules as regular vehicles, but adding safety designs to your off road vehicle according to [26].

3.7.1 Driver Safety

Driver Safety is very important when operating any moving mechanism. In order to understand the danger of operating a vehicle, especially an off road vehicle, one must follow all safety guidelines to limit incidents. Figure 3.26 shows all of the safety equipment necessary for the driver demonstrated by another group. Based on research through , here is a list of recommended off-road Driver Safety [26].

- Operator must be 18yrs or older.
- Operator must NOT be more than 250lbs.
- Protective headgear/eye and gloves are recommended.
- Operator must wear a Harness/seatbelt
- Neck collar is recommended
  (Optional for the driver, but reduces uncontrolled neck movements.)
- Operator must wear long sleeve bottoms/tops and No synthetic materials.



Figure 3.26 All necessary safety gear [27]

3.7.2 Design Safety

Design safety limits any danger to potential consumers. The group's design process includes the safest practices to prevent harm to the driver. The safety approach to building the group's vehicle will allow for the design to withstand rigid terrains, harsh conditions and competition success. With devoted research from where the group found these safe ways to create a proper design [27].

- Deep treaded tires
- Allows safe traction for off road driving.
- Ground clearance
- With proper clearance it allows the underbelly to not scrape ground when operating on rocky terrains or bumps.
- Roll cage
- Protects the driver during off road challenges, also prevents structural integrity
- Harness
- The strap restraint to hold the driver in place.
- Kill switch
- Stops electrical flow from the ignition system if any accident/danger occurs.
- Fire wall
- Machined metal separating the driver from the engine compartment.
- Fire Extinguisher
- In case of fire

- Daily/weekly inspections are also recommended to maintain upkeep of every component of the vehicle.

Figure 3.27 and Figure 3.28 are detailed visuals for the roll cage and the harness.

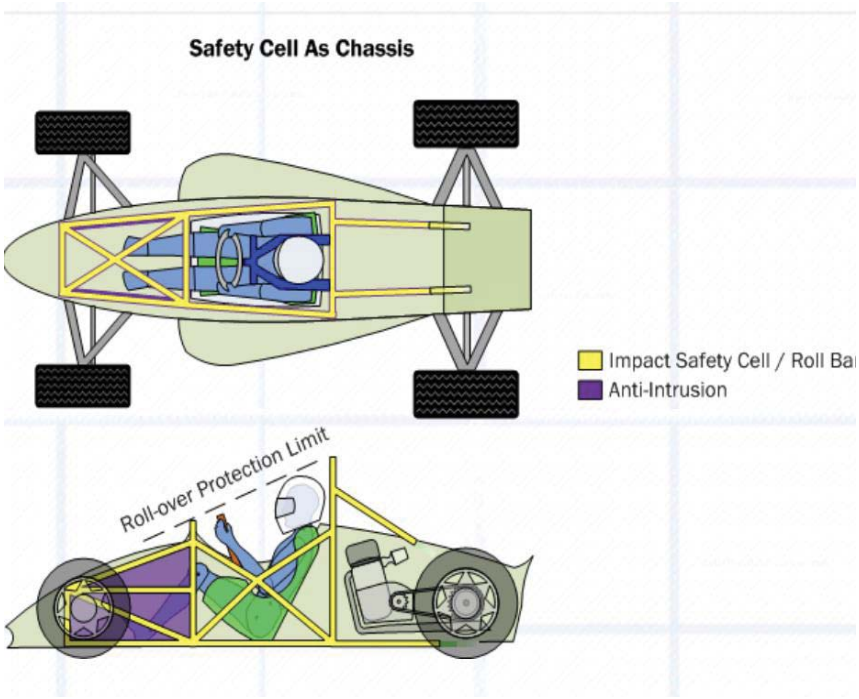


Figure 3.27: Roll Bar/Roll Cage [28]

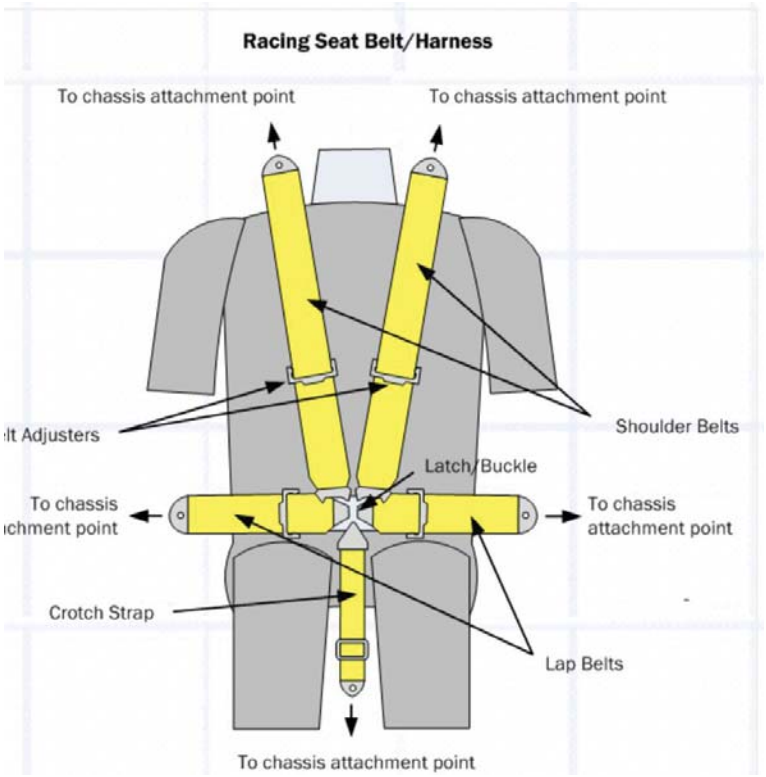


Figure 3.28: Proper harness/seatbelt [28]

4. PRELIMINARY DESIGN

This chapter will show the breaking down of this project from an overall most important function. The group decided to break this project into two different sections. One for the suspension system and one for the steering system. By separating the two systems, the group will be able to optimize the performance of each system.Each student will bring forward their idea for a function and sub function. The group will collaborate and determine the next level subfunction. By breaking down the overall function, the group will be able to develop sketches and designs.

4.1 Functional Decomposition

This section will dive deeper in the process that the group took to come up with the overall function of each system and break them down all the way to level 3 sub-functions. For this project, there are two different systems that the group will design, analize, and fabricate. To optimize each system the group decided to use the functional decomposition method on each system.

The overall most important function of each system was generated from using the sticky note system. This system involves each student to come up with at least three black boxes for each function and sub-function. When every student generated three black boxes, the group gathered them all together and collaborated to create the most important overall function. Figure 4.1 will demonstrate the first process of using the sticky note system for the suspension system. Figure 4.2 will show the overall most important function and all of the variables going in and out of the suspension system. Figure 4.3 demonstrates the sticky note system that was used to come up with the overall function of the steering system. Figure 4.4 shows the overall function of the steering system that was decided by the group.

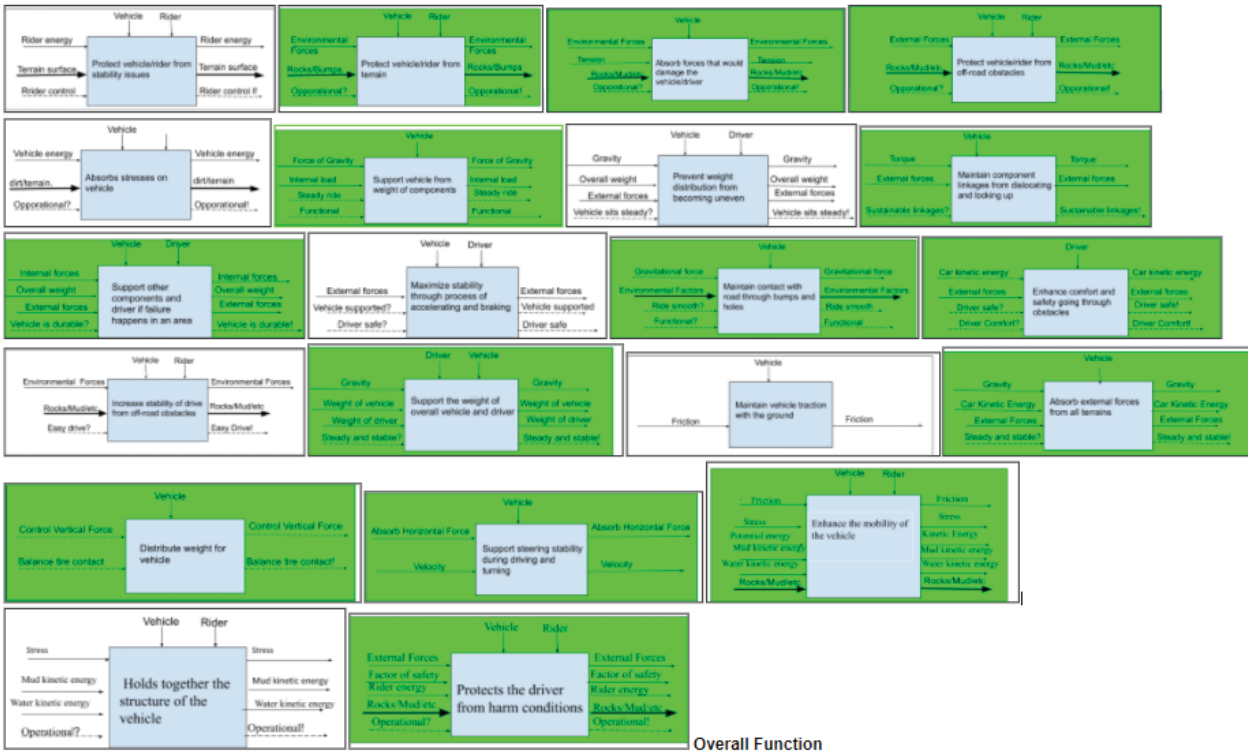


Figure 4.1 The sticky note system for the overall function of the suspension system

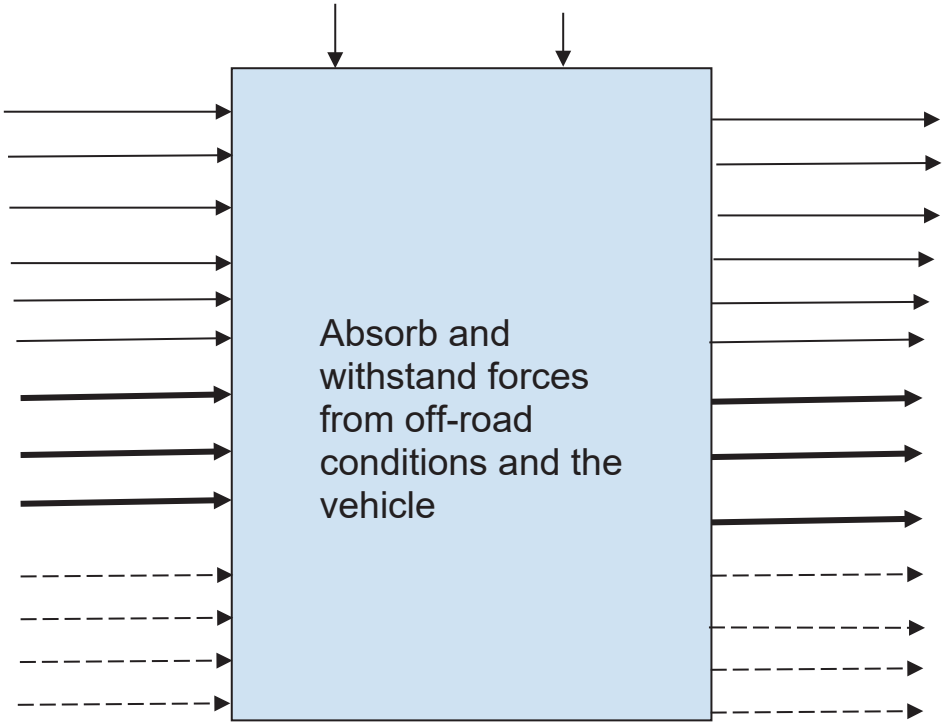


Figure 4.2 The overall most important function for the suspension system

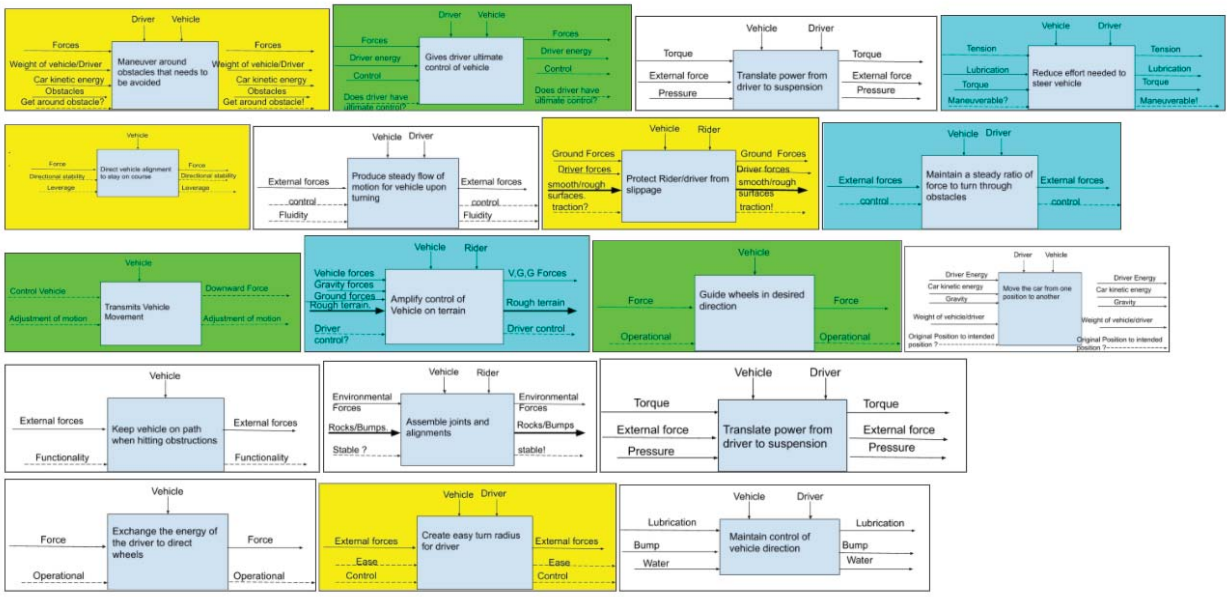


Figure 4.3 Sticky note system for the overall function for the steering system

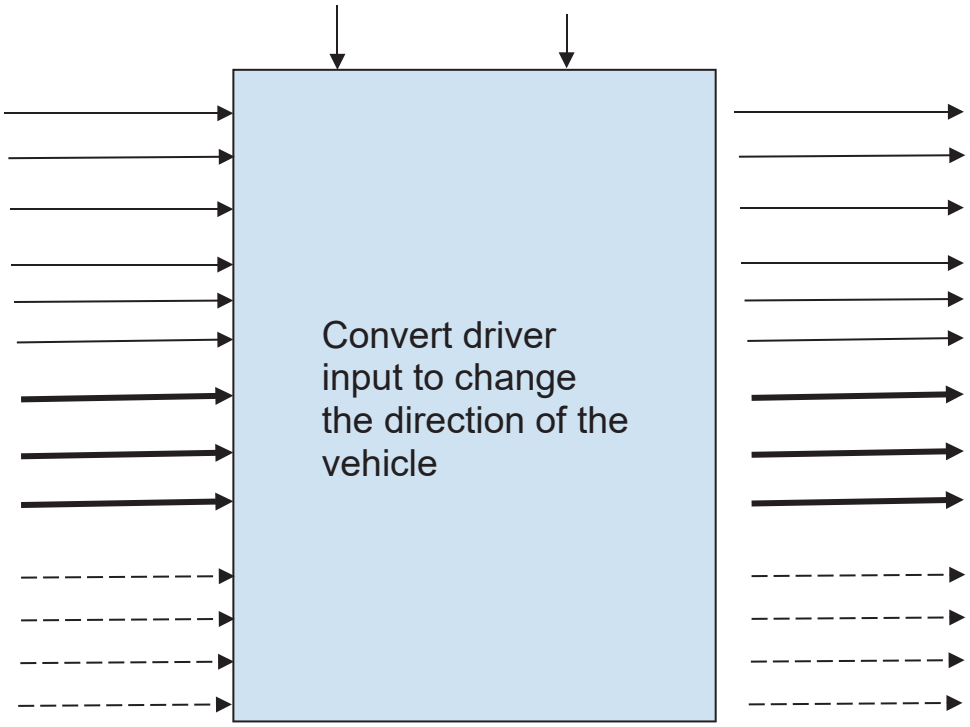


Figure 4.4 The overall most important function for the steering system

Once the overall function for each system was decided, the group had to generate more black boxes to break the overall function into level one sub functions. Each student had to come up with at least three level one sub-functions and bring them to the group. When all the students brought their black boxes together, the group began to work together to gather similar black boxes and created a level one sub-function. The perk of the sticky note system was the group was able to see other students' ideas together as the group discussed what should be a level one sub-function. The group tried to generate as many level one sub functions as possible to make sure the overall function was covered in every aspect. When all of the level one sub-functions were generated, the overall function black box was updated with all the level one sub-functions included. Figure 4.5 shows the sticky note system used to create the level one sub-functions for the suspension system. Figure 4.6 shows the updated overall function black box for the suspension system. Figure 4.7 shows the sticky note system used to create the level one sub-functions for the steering system. Figure 4.8 shows the updated overall function black box for the steering system.

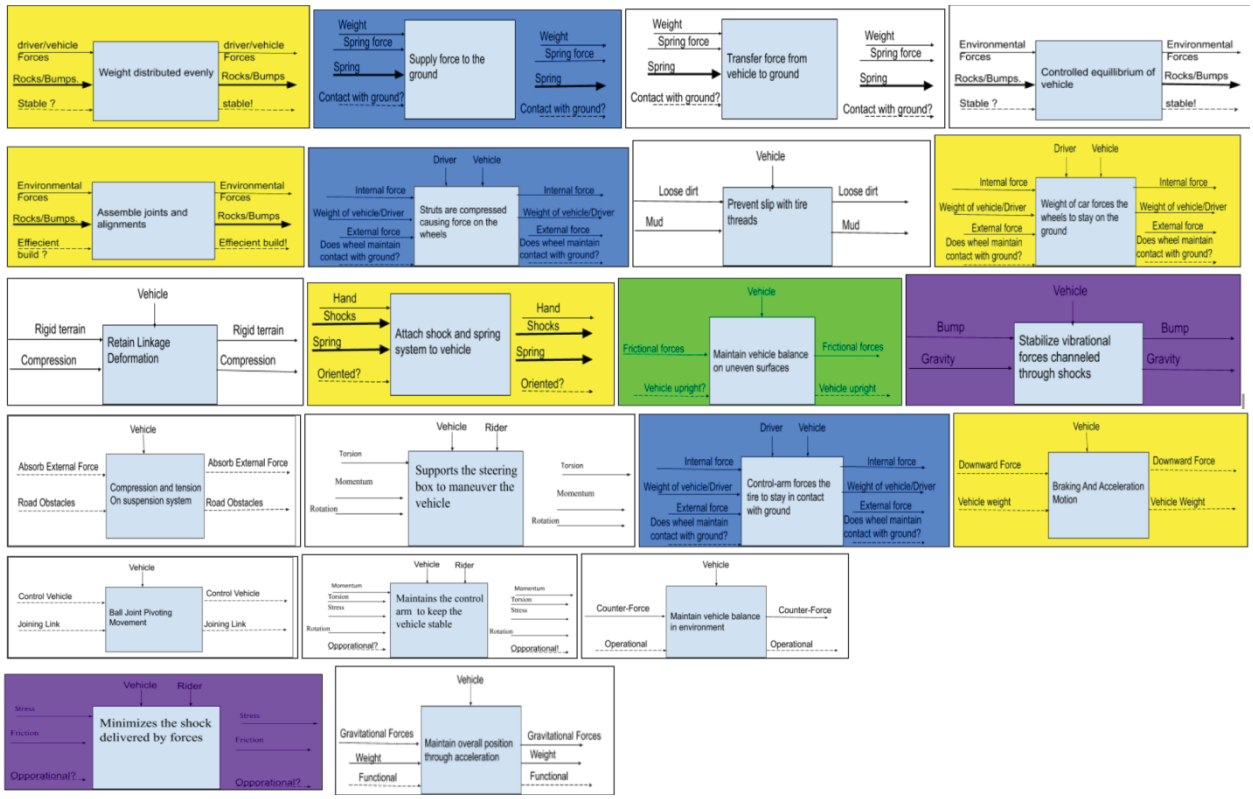


Figure 4.5 The sticky note system of the level one sub-function for the suspension system

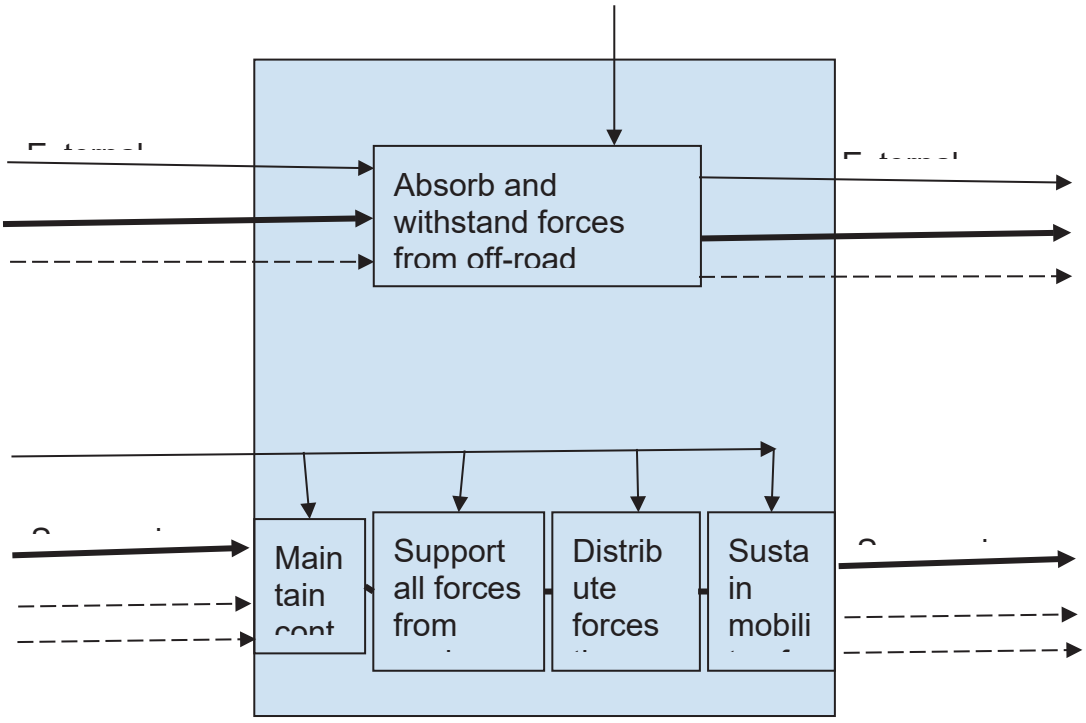


Figure 4.6 The overall function and the level one sub-function for the suspension system

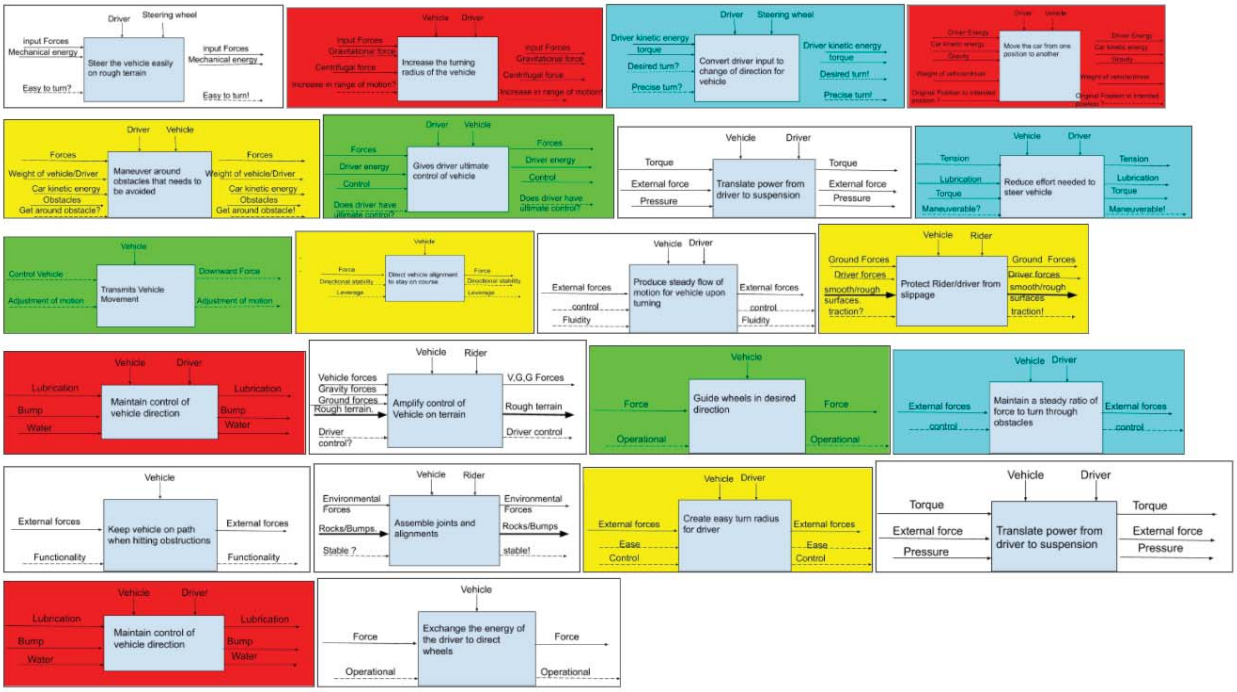


Figure 4.7 The sticky note system that was used for the level one sub-function of the steering system

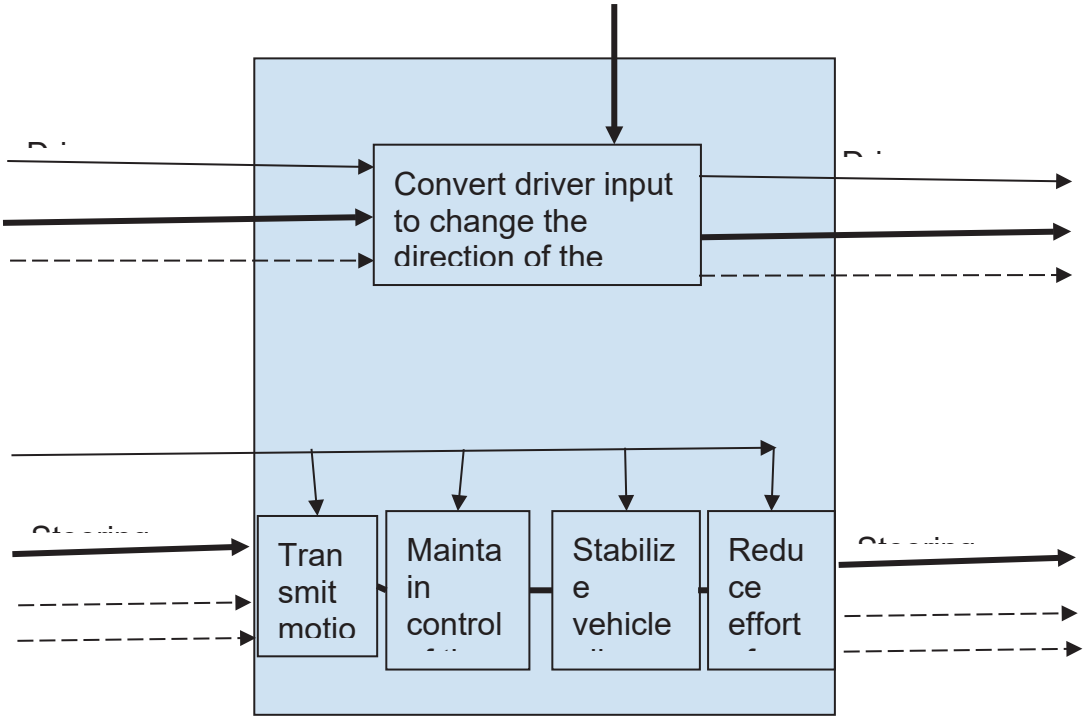


Figure 4.8 The overall function and level one sub-functions of the steering system

After the level one sub-functions were created, the group repeated the process of the sticky note system. This time the group had to come up with their own ideas for the level two sub-functions for each level one sub-function. Once the group all had their own ideas, all of the ideas were combined and the group decided on what the level two sub functions are for each system. After the level two sub-functions were agreed upon, a new diagram was created for each level one sub-function. Figure 4.9 shows the sticky note system for the level two sub-functions for maintaining contact with the ground for the suspension system. Figure 4.10 shows the new diagram for maintaining contact with the ground. Figure 4.11 shows the sticky note system for the level two sub-function for sustaining the mobility of moving parts of the suspension system. Figure 4.12 shows the new diagram for sustaining mobility of moving parts. Figure 4.13 shows the level two sub-functions for distributing forces throughout the suspension system. Figure 4.14 shows the new diagram for distributing forces throughout the suspension system. Figure 4.15 shows the sticky note system used to come up with the level two sub-functions for supporting internal and external forces from vehicle conditions. Figure 4.16 shows the new diagram for supporting all forces from vehicle conditions. Figure 4.17 shows the sticky note system for the level two sub-functions for maintaining control of the vehicle for the steering system. Figure 4.18 shows the new diagram for maintaining control of the vehicle. Figure 4.19 shows the sticky note system for the level two sub-function for transmitting motion of the vehicle of the steering system. Figure 4.20 shows the new diagram for transmitting motion of the vehicle. Figure 4.21 shows the level two sub-functions for stabilizing the vehicle alignment to stay on course for the steering system. Figure 4.22 shows the new diagram for stabilizing the vehicle alignment to stay on course. Figure 4.23 shows the sticky note system used to come up with the level two sub-functions for reducing effort of the driver of the steering system. Figure 4.24 shows the new diagram for reducing effort of the driver.

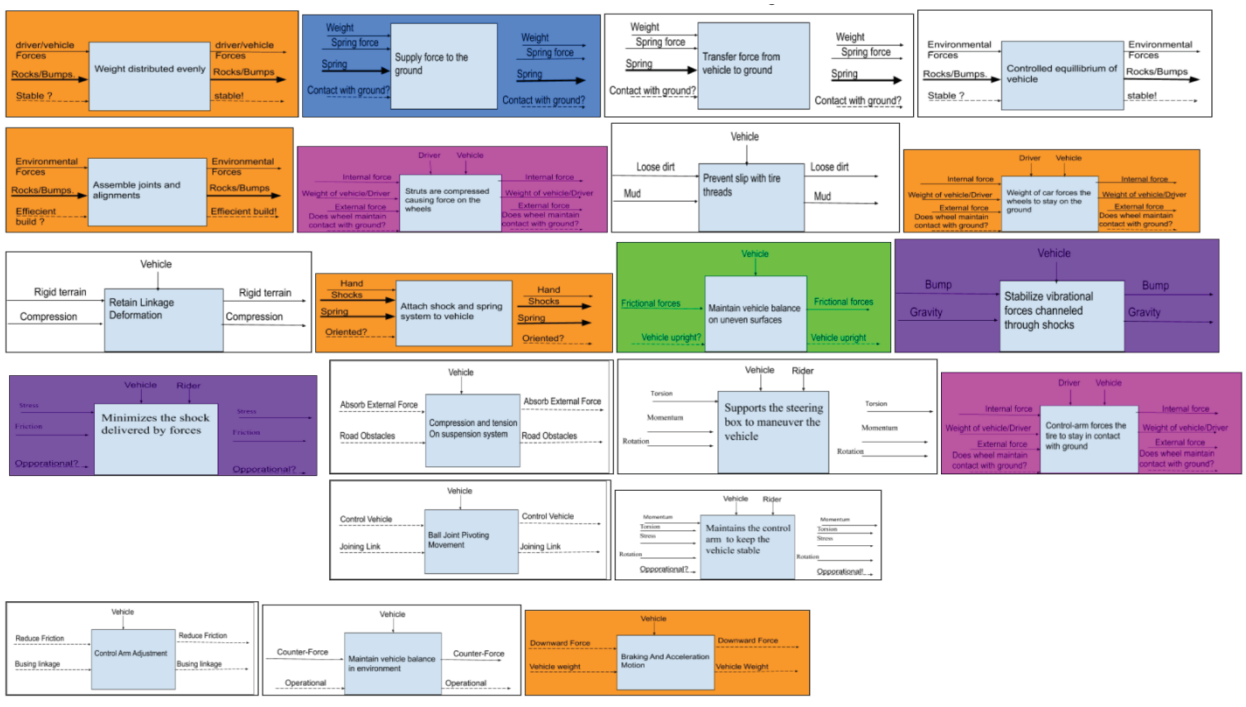


Figure 4.9 Sticky note system for level 2 sub function maintaining contact with ground

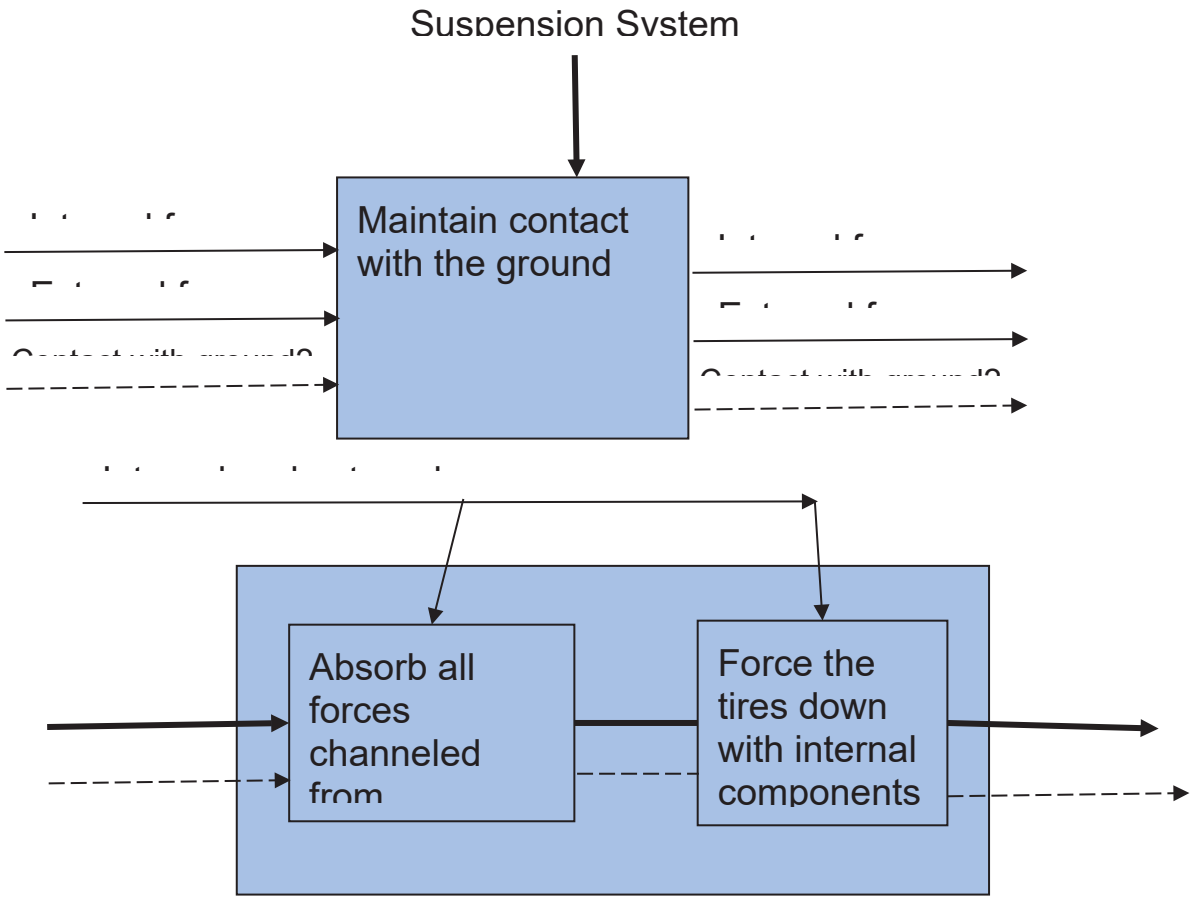


Figure 4.10 Diagrams breaking down of level one sub-function maintaining contact with the ground

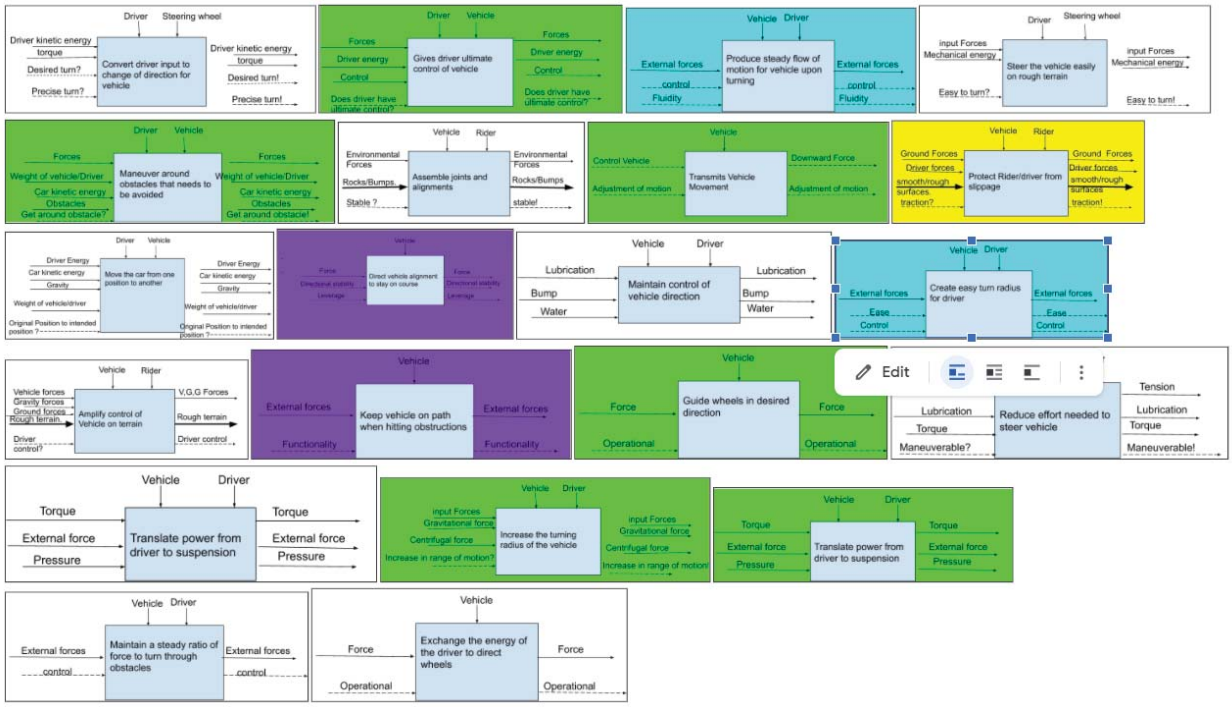


Figure 4.11 Sticky note system for the level two sub-function for sustaining the mobility of moving parts of the suspension system

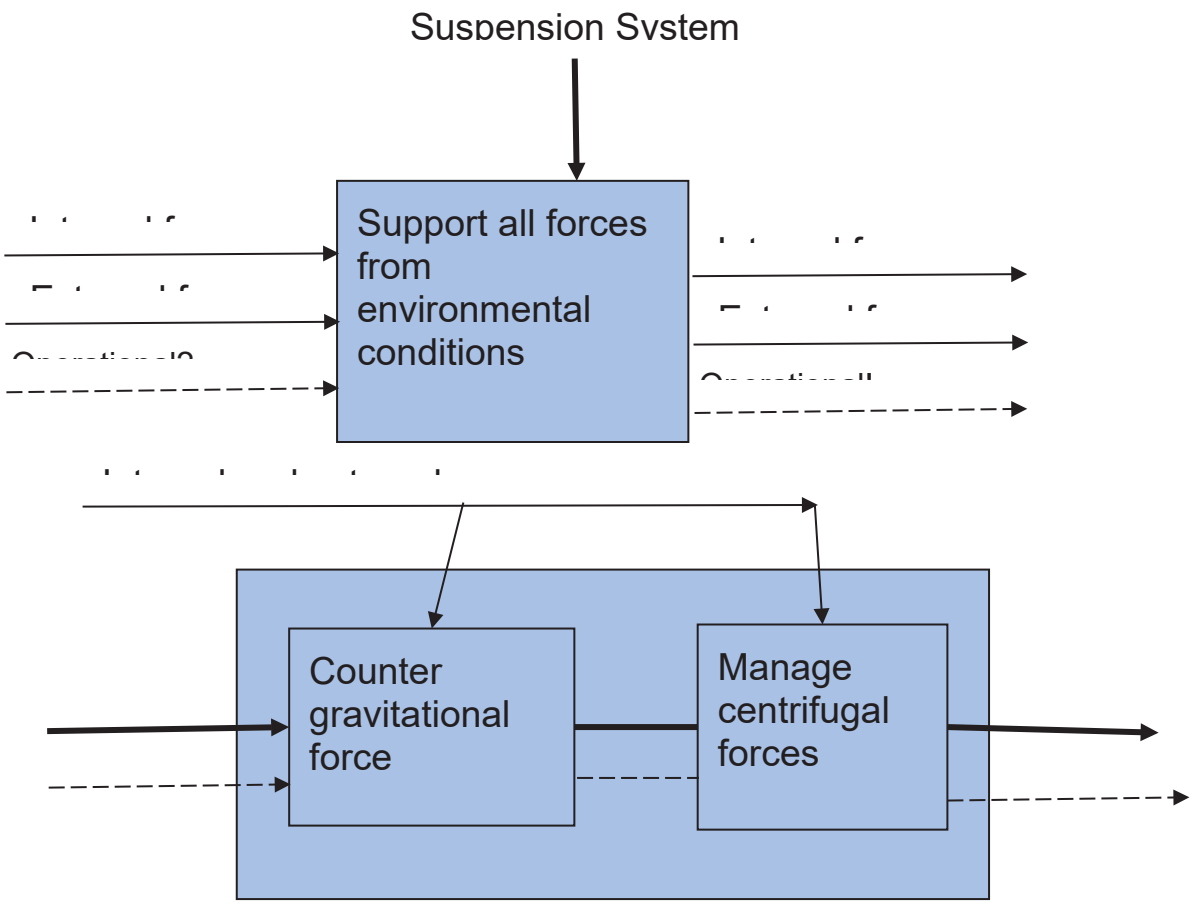


Figure 4.12 Diagrams breaking down of level one sub-function supporting all forces from environmental conditions

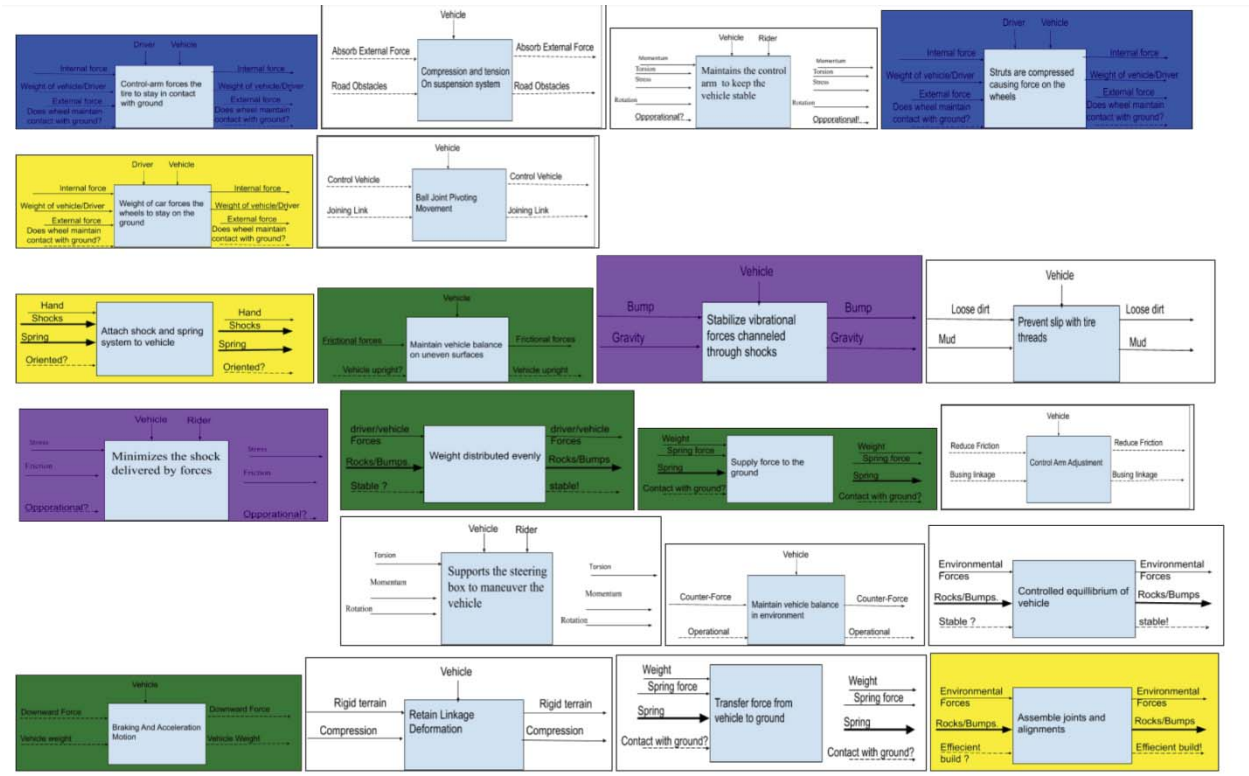


Figure 4.13 Sticky note system for level 2 subfunction distributing forces throughout suspension

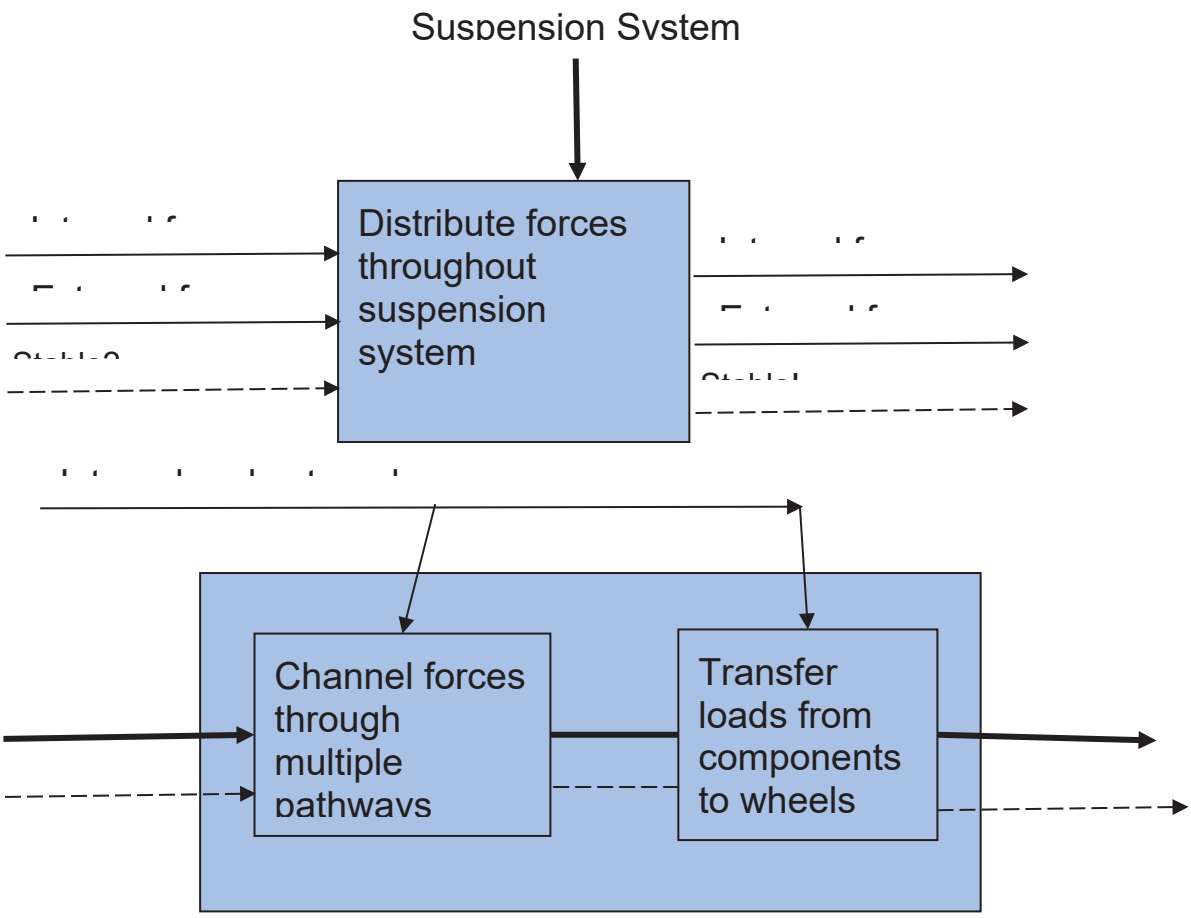


Figure 4.14 Diagrams breaking down of level one sub-function distributing forces throughout the suspension

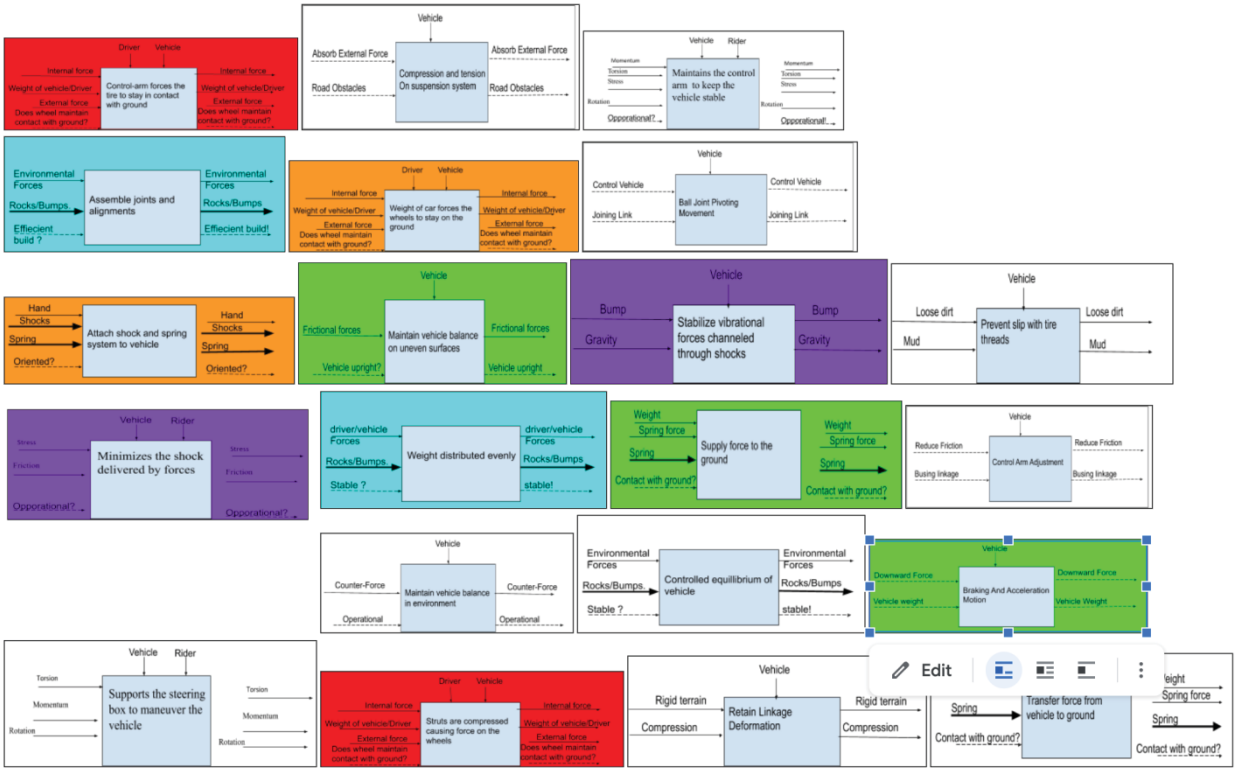


Figure 4.15 Sticky Note System for suspension sublevel 2 sustaining mobility of moving parts

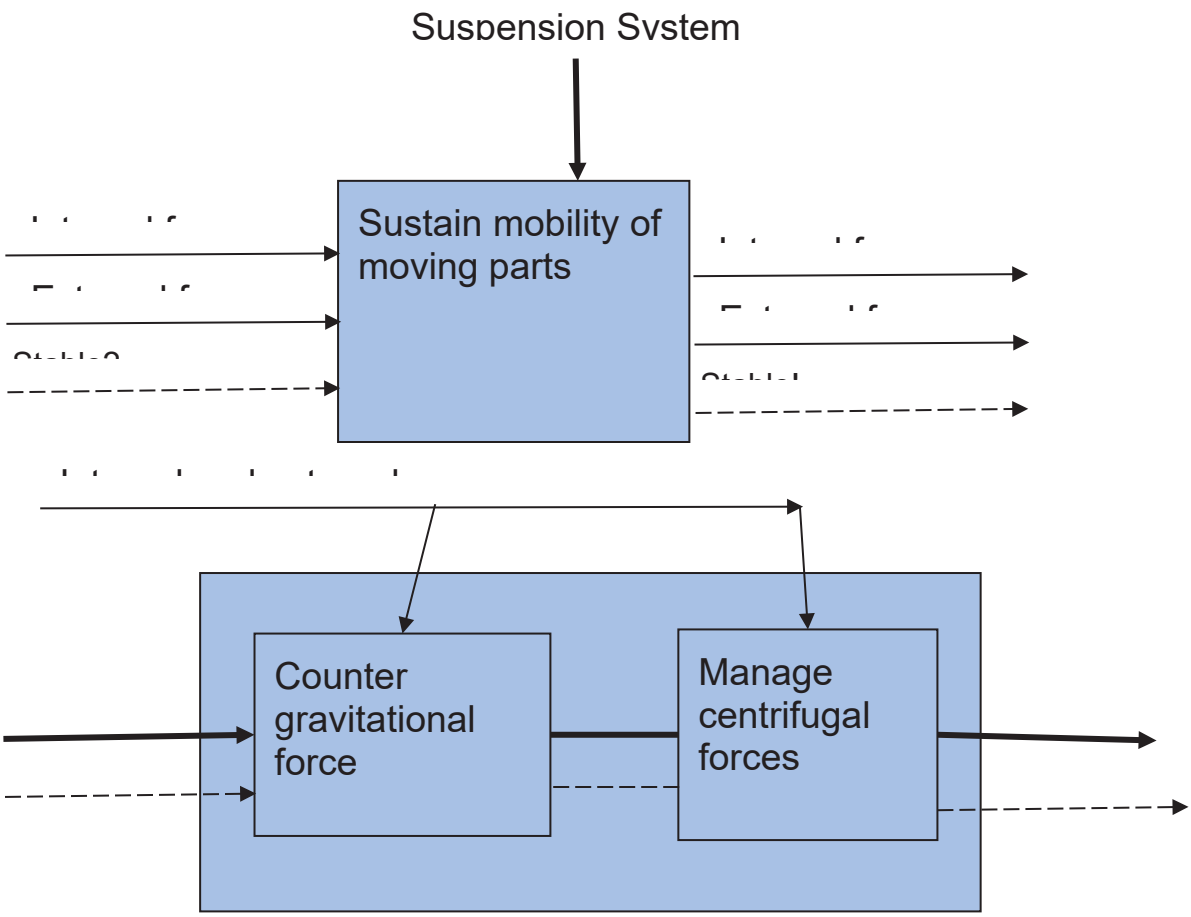


Figure 4.16 Diagrams breaking down of level one sub-function sustaining mobility of moving parts

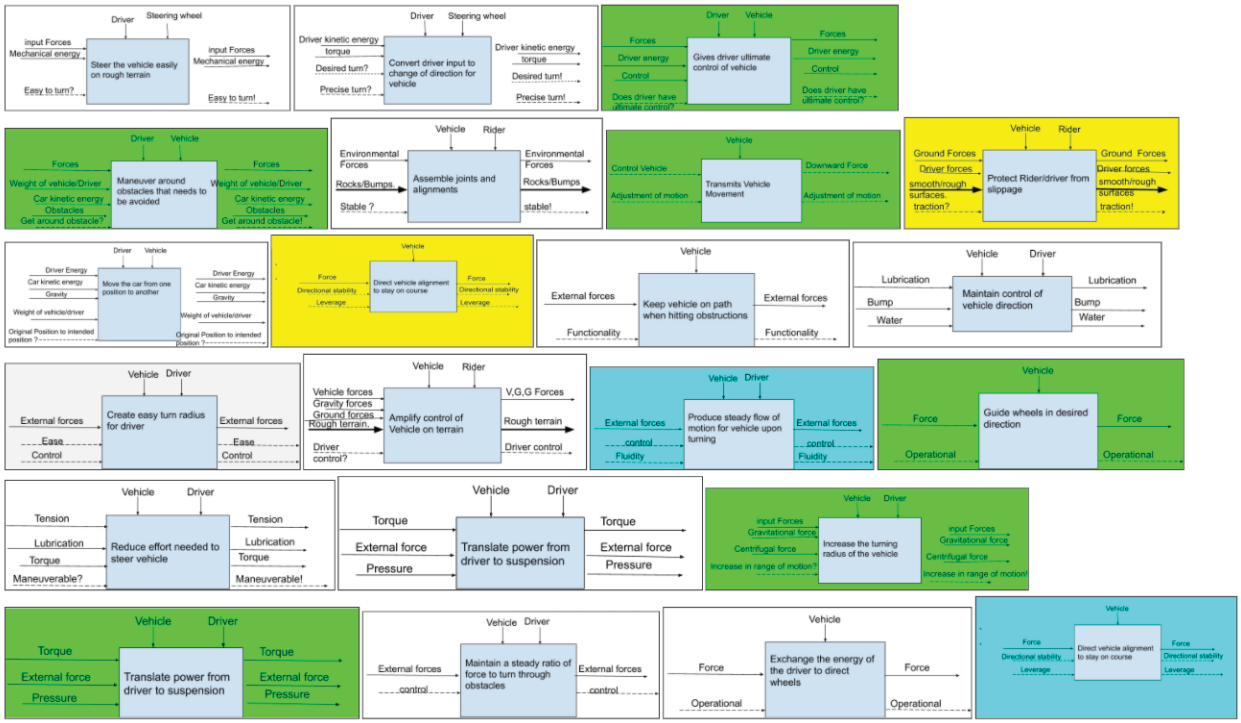


Figure 4.17: Sticky Note System for Steering Level 2 Subfunctions for transmitting motion of the vehicle

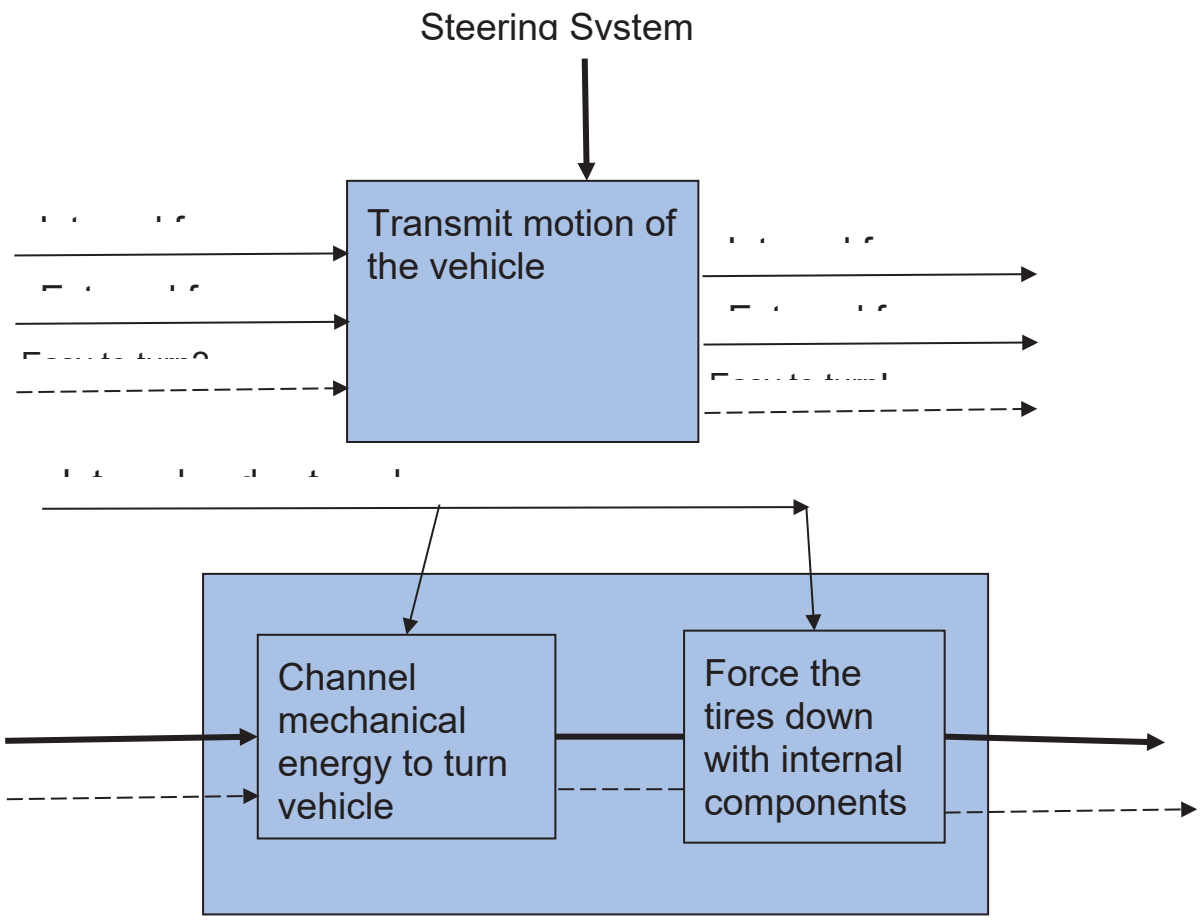


Figure 4.18 Diagrams breaking down of level one sub-function transmitting motion of the vehicle

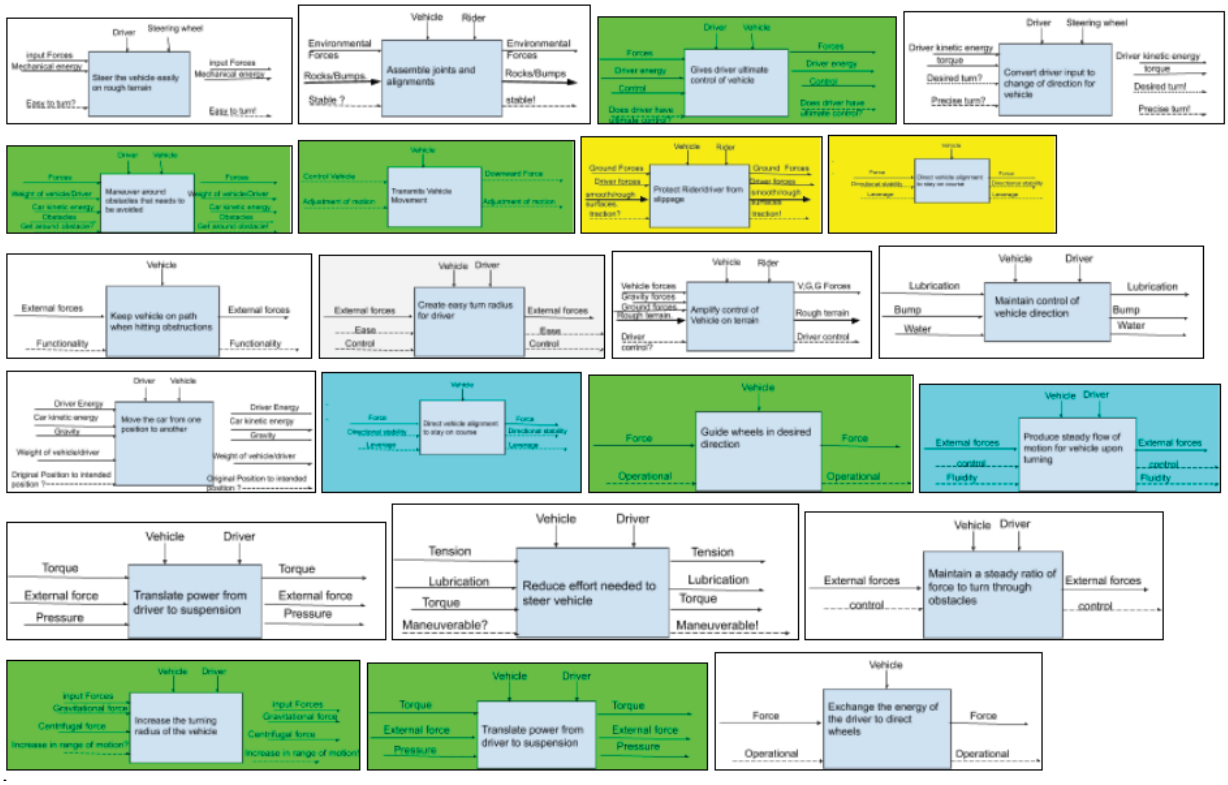


Figure 4.19: Sticky Note System for Steering Level 2 Subfunctions for maintaining control of the vehicle

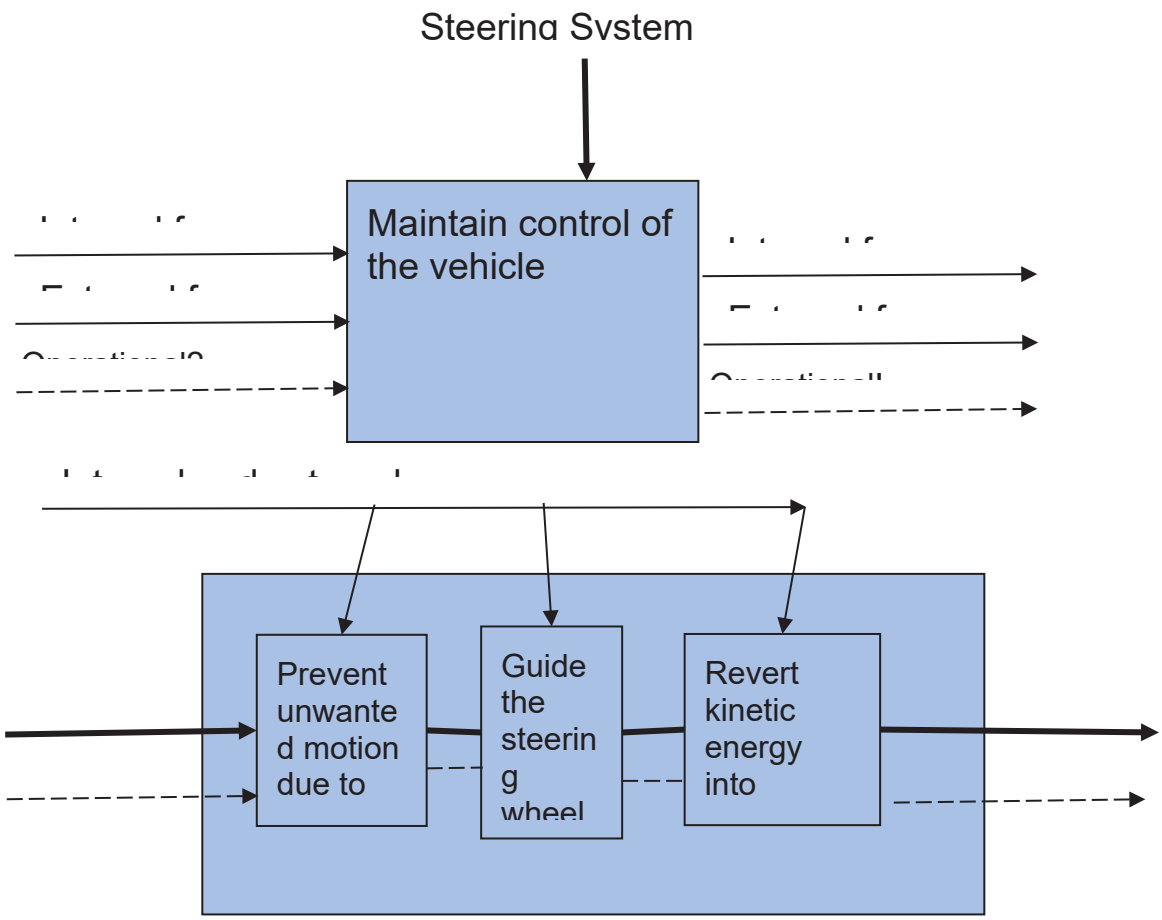


Figure 4.20 Diagrams breaking down of level one sub-function maintaining control of the vehicle

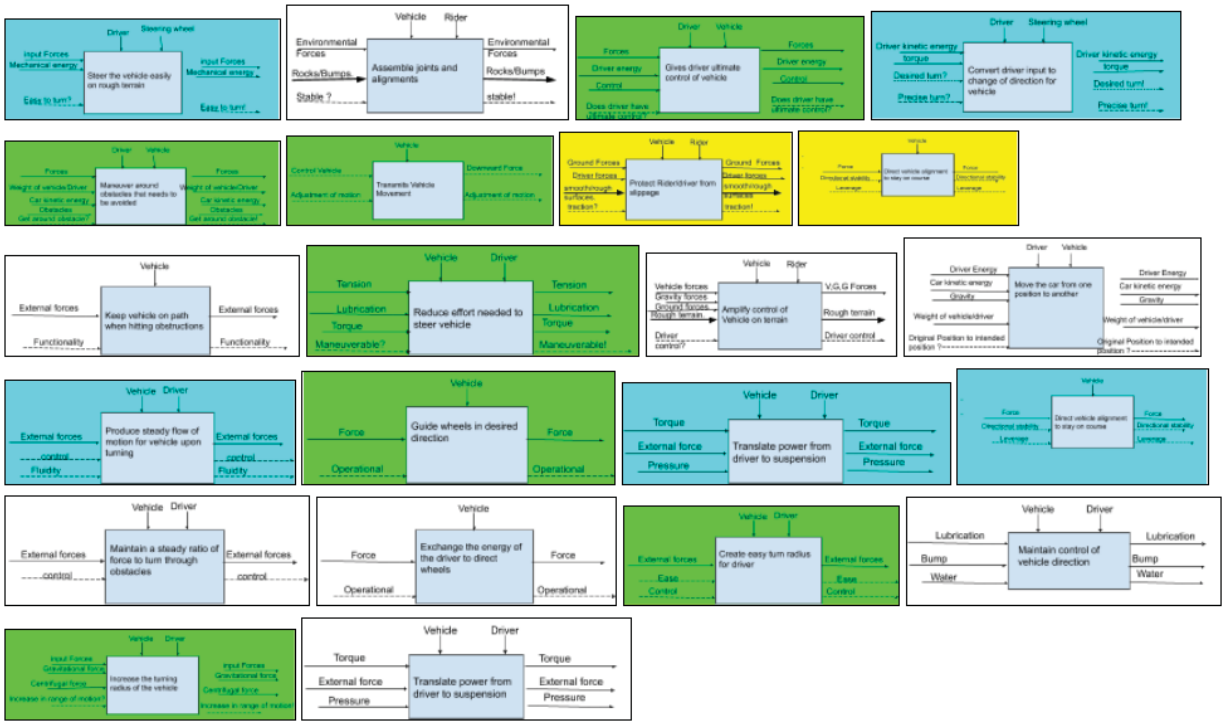


Figure 4.21: Sticky Note System for Steering Level 2 Sub-functions for Stabilization

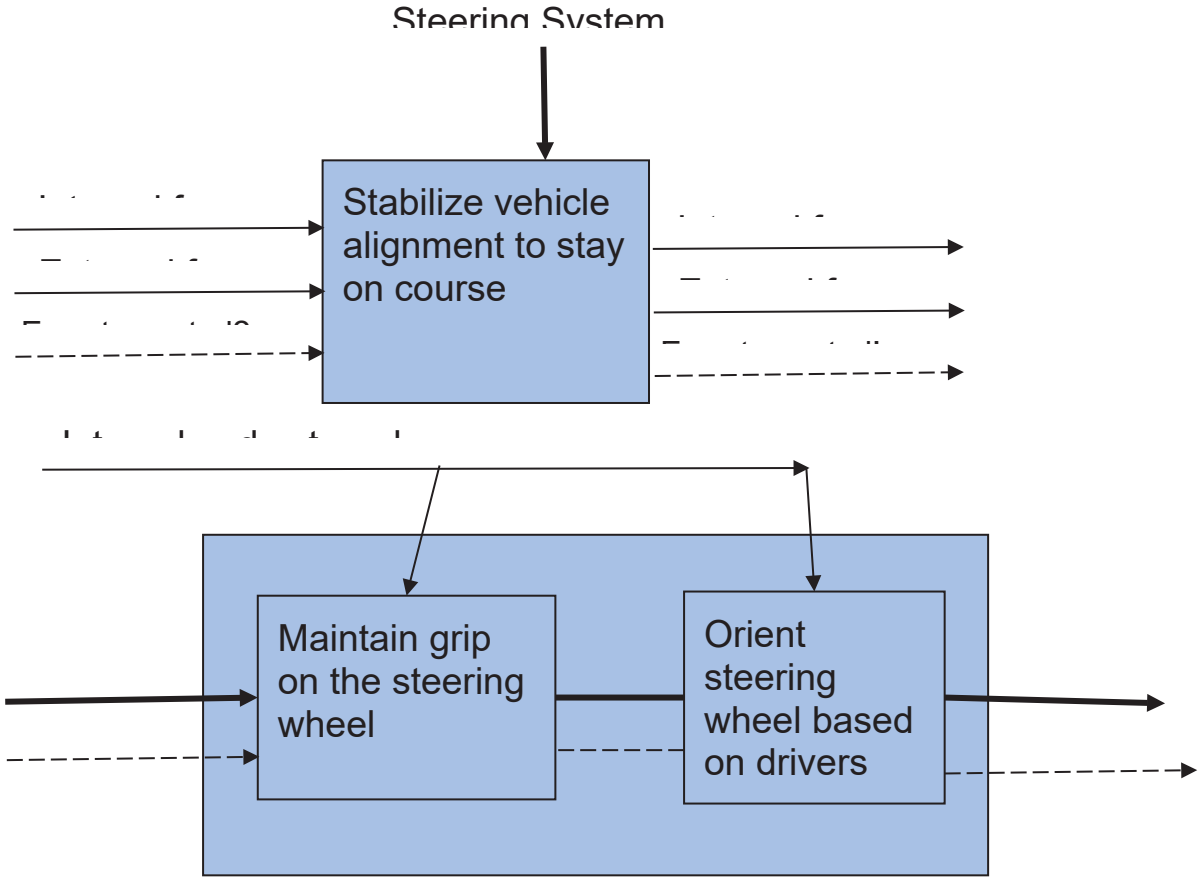


Figure 4.22 Diagrams breaking down of level one sub-function for stabilization

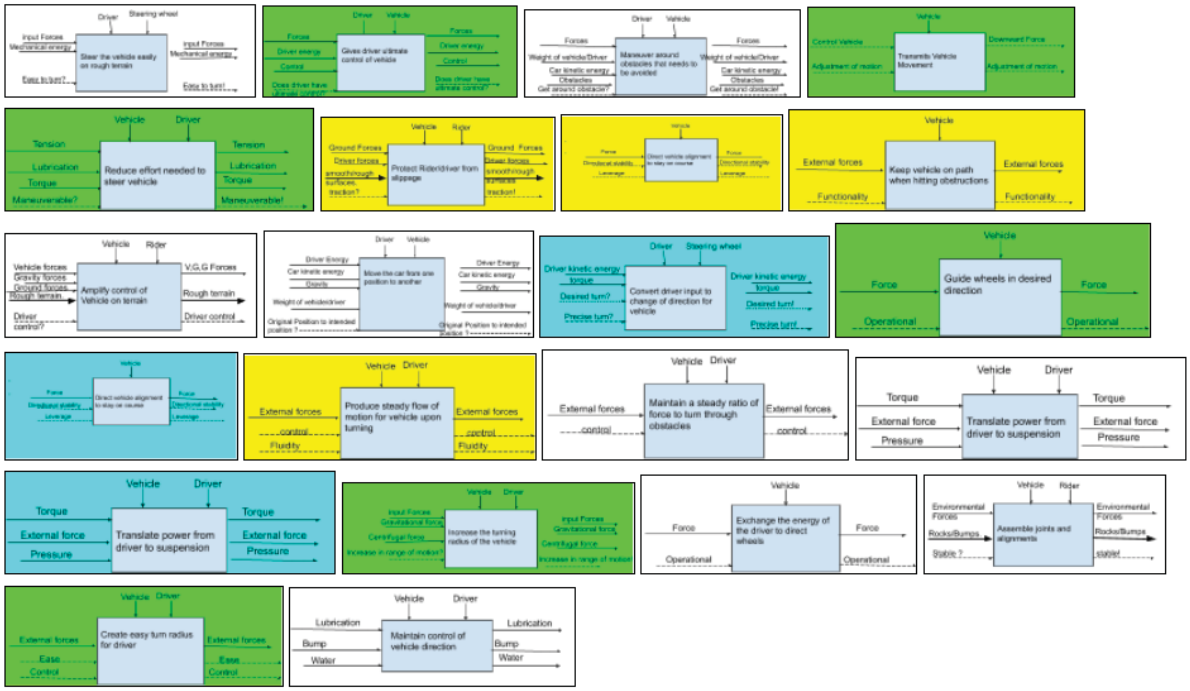


Figure 4.23: Sticky Note System for Steering Level 2 Sub-functions for Reducing Effort

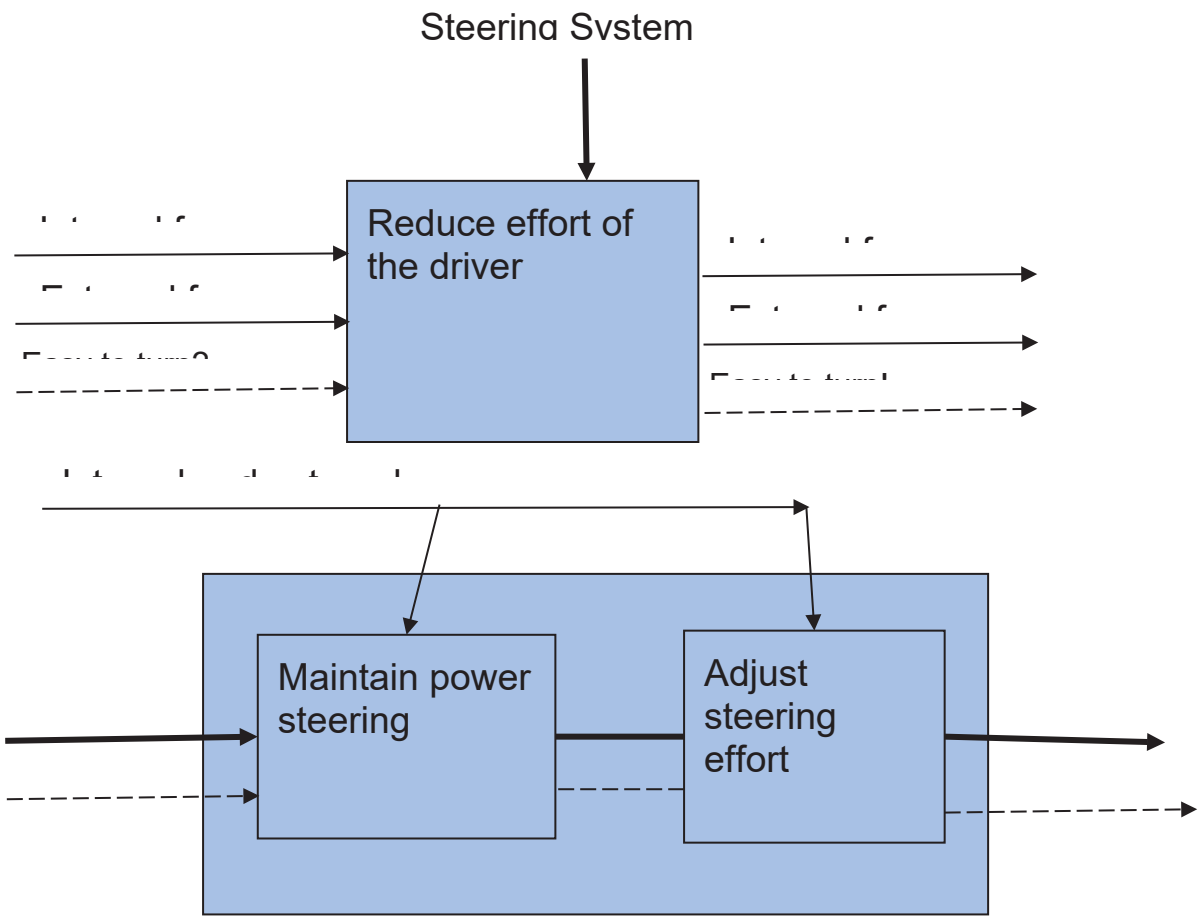


Figure 4.24 Diagrams breaking down of level one sub-function reducing effort

After all of the students created the level two sub functions, the group did not use the sticky note system to come up with the level three sub-function. The group instead had a meeting to discuss them verbally. This was sped of the process to generate the level three sub-functions. To organize everything, a morphology table was created for each suspension and steering system. Table 4.1 shows all of the functions and sub-functions for the suspension system Table 4.2 shows all of the functions and sub-functions for the steering system.

Table 4.1 Morphology Table for Suspension System

Overall Function	Level 1 Sub-functions	Level 2 Sub-functions	Level 3 Sub-functions
Absorb and withstand forces from off-road conditions and the vehicle	Maintain contact with the ground	Force tires down with internal components	Release force from coils to the ground
			Release energy from shocks to the tires
		Absorb All forces channeled from environment	Compress the springs from the external forces
			Compress the shocks from external forces
			Rotate the control arms to decrease force intake
	Sustain mobility of moving parts	Allow freedom of suspension components	Rotating of control arms to absorb excess forces
			Rotating of ball joints to absorb excess forces
			Compressing of shocks and springs from external forces
		Stabilize movement of vehicle	Absorb forces with shocks and springs
			Move control arms based off environment
			Rotate ball joints from contact of force
	Distribute forces throughout suspension system	Channel forces through multiple pathways	Collect force through the shocks
			Collect force through coils
			Transfer force through ball joint
		Transfers loads from components to wheels	Transfer load from control arms
			Transfer load from coils
			Transfer load from shocks
	Support external and internal forces from	Counter Gravitational Force	Release force from spring to the ground
			Release force from shock to ground

	vehicle conditions	Manage centrifugal forces	Transfer vehicle load through shocks while turning
			Transfer vehicle load through coils while turning
			Rotate control arms while turning

Table 4.2 Morphology Table for Steering System

Overall Function	Level 1 Sub-functions	Level 2 Sub-functions	Level 3 Sub-functions
Convert driver input to change the direction of the vehicle	Maintain control of vehicle	Prevent unwanted motion due to external factors	Allow forces to be absorbed
			Rotate gears only from steering wheel
		Guide the steering wheel in direction desired	Hold the steering wheel firmly
			Turn the steering wheel when adjusting to external forces
			Allow horizontal motion with steering rod
		Revert kinetic energy into another direction	Allow gears to move in both directions
			Allow steering rod to move horizontally in both directions
	Transmit motion of the vehicle	Channel mechanical energy to turn vehicle	Transfer energy from steering wheel to Steering shaft
			Translate motion from gears to steering rod
			Move tires side to side from steering rod
		Grasp the steering wheel firmly	Contact the steering wheel tactfully
			Hold the steering wheel with hand
	Stabilize vehicle alignment to stay on course	Maintain grip on the steering wheel	Contact the steering wheel firmly
			Hold the steering wheel until leaving the vehicle
		Orient steering wheel based on drivers view	Avoid extreme conditions of the course
			Drive along calmer environmental conditions
	Reduce effort of driver	Maintain Power Steering	Apply pressure to reduce force input
			Absorb external force to reduce driver control

			Reduce the turn of the steering wheel to perform a sharp manuever
		adjusting steering effort	Allow easy motion of gears
			Allow easy motion of steering rod
			Allow easy motion of steering wheel

5. RESULTS & DISCUSSION

This chapter will contain the results of the project so far as well as any discussions. This chapter dives deeper into the results that were found during all of the research that has been conducted so far.

5.1 Summary of Goals and Objectives

In designing and analyzing the steering and suspension of the baja car there are a few key goals and objectives that were defined. For the design of the suspension it is critical that we choose a suspension system that allows for easy maintenance and repair. It also needs to be designed where the suspension is of high performance so that the vehicle and driver is safe while navigating through given obstacles of the Baja competition. In designing the steering it is critical the design gives the driver total control and allows for easy but precise driving.

5.2 Discussion of Completed Work

The group has finished creating the project scope for the suspension and steering system. The group has also finished project planning for the rest of this semester as well as next semester. A literature review has been conducted over the suspension and steering system. The group also used functional decomposition on the suspension and steering system to breakdown each system.

5.3 Summary of Constraints and Codes Identified for Project

The main constraints and codes that were identified for this specific project includes the necessary applications based on the SAE rules and regulations. The latter constraints were created by the group itself; taking into consideration the overall task. It was understood that SAE would oversee the Baja competition with guidelines as far as: vehicle width and weight, no utilization of kits and prohibiting the assistance from professionals. Functional constraints include but are not limited to: the steering being compatible with the suspension.

6. CONCLUSIONS AND RECOMMENDATIONS

This chapter is going to conclude the report. This chapter will discuss what we have gotten from our research and give recommendations for those interested in this project.

6.1 Conclusions

From doing all of the research on suspension and steering systems, there are many options when creating these systems. This report covers the simple systems that can be chosen for suspension and steering. By having a simpler system, the math part will not be as bad as the complex ones.

6.2 Recommendations

When it comes to off-road vehicles, the steering geometry should be the Ackerman steering geometry. It is perfect for having a great turning radius. For the suspension system of an off road vehicle, the double wishbone is preferred due to supporting the vehicle more and preventing any damage to the driver or the vehicle.

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BELOW AVERAGE

SENIOR DESIGN & PROFESSIONALISM I

FALL 2020

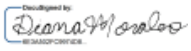
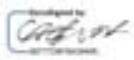
PROJECT PROGRESS REPORT COVER SHEET

PROJECT TITLE: Design of Experiment to Measure Heat Transfer Coefficient and Effective Thermal Conductivity in Nanofluids Under Different Boundary Conditions

GROUP NUMBER ___3_____

Progress Report Title:____Midterm Report_____

Due Date:_10-10-2020_____

No	Group Member Name Group Member signature	Brief Description of Work Assigned to Member	% Completed by Member*	Your Score
1	Diana Morales 	Assigned to put the base report together, to divide assignments to teammates, proofread, format before submission and acknowledgments.	100	
2	Christian White 	Assigned to write abstract for midterm report and write summary for constraints and codes. Edited past reports for the midterm report	100	
3	Marcelo Epam Ona 	Assigned to write the recommendation and discussion of all chapters seen so far.	100	
4	Abdullah EL Aker 	Assigned to write the letter of transmittal, references, appendix and to adjust previous work on reports based on the comments given	100	
5	Fanta Kaba 	Completed table of content, proofread report for misspelling and punctuation, and made sure page number and labels are correct.	100	
6	Yemboado Yonli 	Found the constraints of the project Comtributed to find the needs of the project Found three different apparatus and their working system Completed the conclusion of the report Found a list of sources and referenced them in th report	100	
7				

8				

*100% means the member completed his/her assigned work
By signing this assignment cover sheet, I agree that the percentages stated in the % completed column reflect the contribution made by me and the other members of the group.

"Experimental Design to Measure Heat Transfer Coefficient and Effective Thermal Conductivity in Nanofluids Under Different Boundary Conditions"

Senior Design & Professionalism I
Midterm Report

Submitted by

Diana Morales
Fanta Kaba
Christian White
Yemboado Brayan Yonli
Abdullah EL Aker
Marcelo Epam Ona

To

Dr. Xiaobo Peng
Senior Design Instructor

Department of Mechanical Engineering
College of Engineering

Prairie View A&M University

October 9, 2020

LETTER OF TRANSMITTAL

THE MEASUREMENT OF HEAT TRANSFER COEFFICIENT AND THERMAL CONDUCTIVITY OF NANOFLUIDS UNDER DIFFERENT BOUNDARY CONDITIONS

100 University Dr. Prairie View, TX. 77446 (512) 400-3333

October 9, 2020

Dr. Xiaobo Peng
Office: Room 102A
C. L. Wilson Engineering Building
Prairie View, TX 77446

Dear Dr. Peng:

The attached technical report contains the current and completed phases of the experiment to measure heat transfer coefficient and effective thermal conductivity in nanofluids under different boundary conditions. We used the solution criteria established by Dr. Shahin Shafiee current instructor and project owner at Prairie View A&M to evaluate the design:

- Heat transfer coefficient
- Effective thermal conductivity in nanofluids
- Different boundary conditions
- Heat convection
- Heat transfer rate with changes in boundary conditions

Dr. Shafiee recommends the use of the measurement design on campus for future engineering studies and research purposes. The experiment provides a detailed measurement of heat transfer coefficient under different boundary conditions, second is to study the effectiveness of thermal conductivity in nanofluids and finally to monitor the heat convection undergoing the process. This design best meets the needs of the project requirement.

Dr. Shafiee or one of our group members is available to answer any questions you may have concerning this report or the project in general. you can contact Dr. Shafiee by email at shshafiee@pvamu.edu

Sincerely,



Senior Design Group 3

Acknowledgment

We, the project team members, would like to express our deepest appreciation and gratitude to our project advisors, Dr. Shahin Shafiee and Dr. Xiaobo Peng, as their knowledge and guidance has made this research project possible. We are grateful for their constant support and dedicated involvement throughout the process, as well as their patience and willingness to instruct us on the proper procedures involved in this project. This would include their assistance and guidance on research, problem analysis and the writing of all conclusive reports. We would also like to express our gratitude to all of our respective course professors who have been detrimental to the success of our academic careers. Without them, our education level would not be at such a high level as it is today. We thank them for kindly sharing all of their understanding and wisdom, as well as their encouragement through these particularly difficult subjects. We also give a very special and kind appreciation to our families and their continuous support as we undertake the many challenges and learning experiences associated with academia.

Abstract

This project will address an issue that professors, scientists, engineers, and engineering students face when it comes to understanding nanofluids and their behaviors under different boundary conditions. The group is undergoing research on how to better measure heat transfer coefficient and effective thermal conductivity in nanofluids under those different boundary conditions by creating a system designed to conduct an experiment that will measure different nanofluids and their behaviors. The constraints that we face deal with inflexible boundary conditions, applicable techniques for such nanofluids, selecting the appropriate material, ensuring the nanofluid(s) has an ability to withstand high pressure, and the apparatus size. Although these constraints can make difficult this projects' experiment, the solution will be to establish set boundary conditions, research different techniques from past experiments, select the appropriate material, research which nanofluids can withstand high pressures, and ensure the apparatus size is applicable with the system and nanofluid(s). The results will be that the system that has been designed is successful in measuring the heat transfer of multiple nanofluids under different boundary conditions as well as its thermal conductivity. The conclusion drawn from this result is that there are more effective ways in measuring the behavior of different nanofluids that will help those who are under the study of heat transfer use to gain a better understanding of the overall function of nanofluids when placed in different boundary conditions.

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1. PROJECT SCOPE

This chapter represents the project scope of the entire project. It will begin by defining the project through establishing the problem statement for clarity and understanding. The clients will be identified and a need for this project will be defined. It will be followed by goals and objectives aimed to further understand the scope of the project. Furthermore, this chapter will conclude with establishing some project constraints and defining the operating environment for this entire project.

1.1 Problem Statement

Measurement of heat transfer coefficient and thermal conductivity of nanofluids do not accommodate different boundary conditions; therefore, an effective measurement technique will be selected to adapt to the change of properties of the nanofluids.

This project is to select the proper measurement technique amongst the current methods used in the industry to measure the convection transfer coefficient for nanofluids. The technique will measure the heat transfer coefficient and thermal conductivity of the nanofluid while accommodating for changes in boundary conditions and common constraints. Experimental testing will be performed for comparison in order to study the effects of heat transfer rates under different boundary conditions. To ensure functionality in the measurement technique selected, measurements of the convection coefficient for some nanofluids will be compared to the results of the published values given.

1.2 Client Identification and Recognition of Need

This project pertains to specific clients that have professional backgrounds in the study of heat transfer, thermal conductivity, and thermodynamics. This would include engineers, professors, scientists, and engineering firms, such as Koch Heat Transfer Company, who conduct research for industry use. An experiment will be conducted to measure thermal conductivity of nanofluids under different boundary conditions. Therefore, it is imperative that those who want to start or maintain a career in heat transfer have an effective system.

The suspended nanoparticles of conventional fluids have been the subject of intense study worldwide for many years by pioneering researchers due to their anomalous thermal behavior. Over time, existing theories cannot seem to explain the behavior of these fluids with small-particle concentrations. We know that the current methods do not adequately predict the order of magnitude of thermal conductivity. This is due to a driven argument that nanofluids carry an enhanced thermal conductivity, relative to the base fluid. This in turn makes them superior agents for heat transfer in a variety of circumstances. As a result, finding the right ratio of nanoparticles to base fluid is needed to attain the most effective thermal conductivity in research. Along with obtaining the lowest possible effective viscosity from the fabricated nanofluid to ensure the application of heat transfer is met. A proper measurement technique will then help to form an educated hypothesis on understanding how to manipulate the nanofluid and the environment to gain accurate readings. Without a proper thermal conductivity measuring technique, researchers, engineers, professors, and scientists will ultimately find difficulty in understanding the true function of nanofluids. Including, how to effectively manipulate them to achieve the desired outcomes.

In many industries fluids are used to cool down the machinery used. Nanofluids are thought to be having higher heat transfer coefficient and thermal conductivity than regular fluids like water due to the suspension of metal particles in them. However, boundary conditions change can significantly affect the performance

of rate of heat transfer of the nanofluid which means that the heat transfer coefficient and thermal conductivity of the nanofluid are influenced by the boundary conditions. For example, a magnetic field will create a pull force that can disturb the agglomeration of the metal particles in the nanofluid. Finding a way to safely, quickly, and accurately be able to measure the heat transfer coefficient and thermal conductivity of a nanofluid would be a great time and money saver for many industries.

1.3 Project Goals and Objectives

In this section, a well-defined goal will be established to further understand the scope of the project. It will include making a list of objectives that will be broken down into high level and low-level objectives. It will be followed by an objective tree to optimize the characteristics of the system in order to achieve the goal at hand.

Goal Statement:
The project goal is to select a proper setup with reliable and common results for convection heat transfer coefficient in nanofluids. The designed measurement technique establishes a system for data collection for the study of nanofluids under different boundary conditions.

Project Objective:

(i) List of Objectives

Objectives List

- Measurement technique
- Method for measurements
- Experimental Set-up

(ii) High-Level & Low-Level Objectives

High Level Objectives

- Proper equipment and testing setup
- Efficient measurements for transferring heat
- Ability to measure heat transfer under constraints

Low Level Objectives

- Proper apparatus and experimental setup
- Effective measurement of convection heat transfer coefficient
- Ability to measure heat transfer coefficient of nanofluids with changing boundary conditions

(iii) Objective Tree

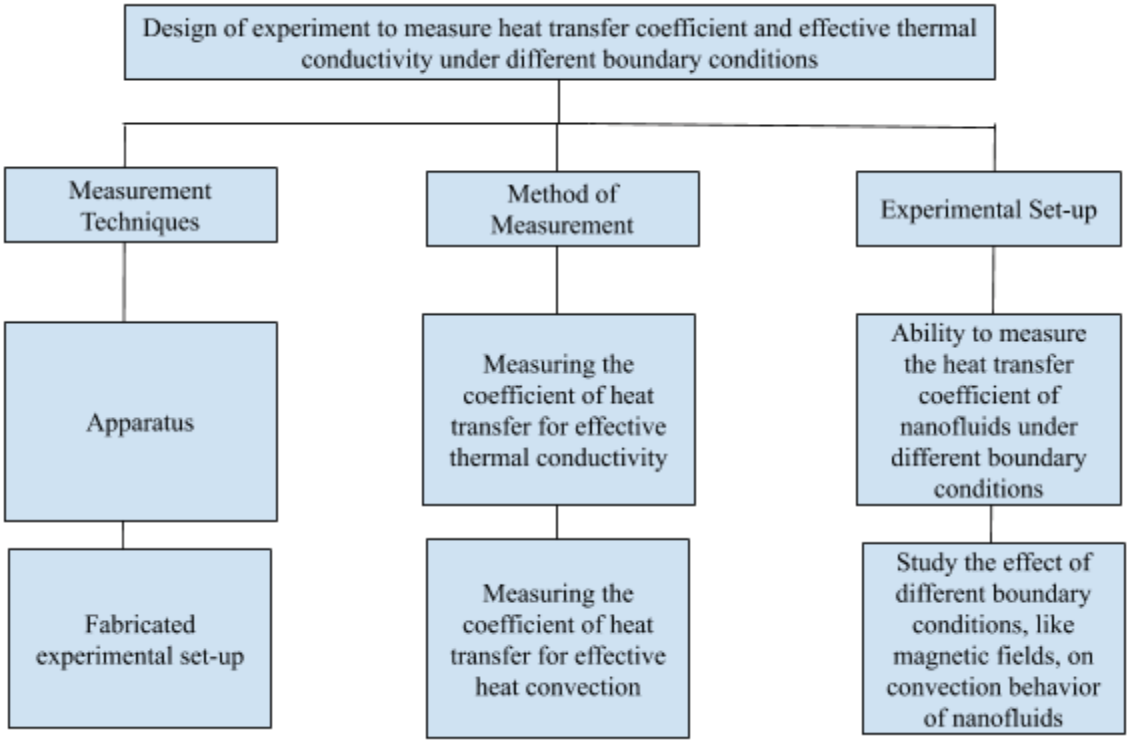


Figure 1.1 Objective Tree for the Measurement of Convection Heat Transfer

Breakdown of Objectives for Measurements and Units

Table 1.1 Basis for, and Units of, Measuring Objective

Objective	Measurement Basis	Criteria	Units
Accurate measurement of temperature	Accuracy & Consistency	Temperature Gauge	K or °C
Accurate measurement of pressure	Accuracy & Consistency	Pressure Gauge	J or kg·m2·s−2
Deliver consistent results	Accuracy	System Efficiency	W/(m^{2}K)

1.4 Initial Project Constraints and Operating Environment

Every Project has some limitations that the engineers have to be aware of. Those are called constraints and are a good indicator of things that need to be taken into consideration while going through designing and building. There are 3 different types of constraints that are the equality constraints, the inequality constraints and the "Yes or No" constraints.

A.) Initial Constraints

Equality constraints

The results in these experiments must be comparable to the published values of the experiment with the same background providing a range of trustable values. This can be identified as an equality constraint. The material chosen for this experiment must be able to sustain high level temperatures. For example if using glass in the apparatus it is to know that maximal thermal shock resistance for glass is 160 °C. Borosilicate glass can easily handle a temperature of 400 °C. Maximus Pressure that can be handled by the materials used is also listed as an equality constraint. Again, with glass as an example the maximum pressure supported by lab glass is around 25 to 30 Psi. When it comes to accuracy the percentage error would be great at + or - 1%. However, the instruments used during the experiment will help to set the accuracy. all this would be part of project budgeting as the more accurate the instrument the more expensive it is.

Inequality constraints

The flexible boundary conditions in which the experiments are supposed to be performed can be classified as an inequality constraint as the boundary conditions are not fixed to one condition but are varying. The apparatus and the experimental setup must be designed in order to be able to withstand different boundary conditions when performing experiments on nanofluids, such as adding or removing magnetic fields.

"Yes or No" constraints

Another constraint in the design of the experiment is to choose the appropriate convection measurement techniques for nanofluids. Therefore, to obtain reliable results, selecting the appropriate technique is necessary. This could be put as a Yes or No constraint, as it would answer the question "can the technique be used to measure the heat transfer coefficient and thermal conductivity in nanofluids?

B.) List of Operating Environment Operating Environment

The operating environment for the experiment can vary from schools or to engineering workplaces. it is important that the experiment be conducted in a lab. the environment in which is conducted must be able to support:

- High Pressures (depending on the nanofluid used)
- High Temperature (depending on the nanofluid)
- A strong Magnetic field (1000 Gauss or more)

2. PROJECT PLANNING AND TASK DEFINITION

Every single project or design should be thought and planned out properly before starting. For example, it can be seen how architects first create and obtain the model of a particular building before getting into constructing such an establishment. In this chapter, the focus would be mainly on planning and having an schematic on how this senior design project is going to look like, taking into consideration the hours, days or months that it is going to take to carry out each major task. To do that, two main objectives were considered. First, project planning and task definition. This section was mainly focused on organizing and arranging the different tasks as well as understanding what those are and how to perform them. Since that is the only way groups can estimate the time might take to perform every single one of them. And second, the Gantt chart, which is where a series of horizontal lines shows the amount of work done or production completed in certain periods of time in relation to the amount planned for those periods.

2.1 Task identification

The task identification is in detail, to convey what will be done currently and in the future for the project. The detailed task list is the focal point for the manufacturing, conceptual design, ASME code & standards, and CAD modeling aspect of the project. The resources used to create the detailed list was the senior design manual and the syllabus. We specified the technical and non-technical aspects that will be presented in the final presentation. The non-technical component includes the research and study behind the project. The technical component includes the step by step process on how to design and develop the experiment for the project. Beneath are the identified tasks and subtasks in detail.

Senior 1

Problem Formulation (from 09/02/2020 to 09/09/2020)

- ~~Identify~~ and Recognize the Need.
- Define Goals.
- Define the objectives.
- Identify the Constraints and Operating Environment.

Project Planning (from 09/10/2020 to 09/16/2020)

- Identify the task.
- Develop objectives of each task.
- Set up the Timeline.
- Create a Gantt Chart.

Literature Review (from 09/16/2020 to 09/22/2020)

- Identify Potential Sources and Relevant Information
- Study convection of nanofluids
- Study convection of nanofluids under different boundary conditions.
- Study of Different measurement techniques for convection and their advantages
- Identify and collect comparable results
- Conclude the literature review.

Functional Decomposition (from 09/23/2020 to 09/29/2020)

- Use strategies to develop Level 1 Sub functions.
- Use strategies to develop Level 2 Sub functions.

- Use strategies to develop level 3 Sub functions.
- Develop the Morphology Table.

Concepts Generation (from 09/30/2020 to 10/05/2020)
- Generate techniques for the Concepts from Functions.
- Develop a Conceptual Designs of the experimental set up that would be based on the properties of nanofluid and the boundary conditions that would be applied

Concepts Evaluation (10/14/2020 to 10/20/2020)
- Evaluate based on go-no-go.
- Evaluate based on decision matrix.

Preliminary Design (10/21/20 to 11/05/20)
- Make the design sizing and components Analysis.
- Develop Methods for presenting design analysis.
- Apply ASME codes & Standards
- Consider public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors in Design.

Detailed Design (11/06/21 to 11/21/20)
- To develop CAD models of project parts & components.
- Develop Engineering Drawings from part models.
- Develop sub-system assembly and system assembly.

Detailed Parts Specification (11/22/20 to 11/29/20)
- Specify of parts
- Identify the use of each part.

Budget and Project Cost (11/30/20 to 12/06/20)
- Identify the material needed for the parts
- Identify parts that can directly be bought
- Identify the manufacturing cost
- Summarize into a budget that can cover up for all costs.

Purchasing (01/25/21 to 02/06/21)
- Research Vendors able to manufacture the needed parts based on the Design.
- Obtain Quotes Generation by vendor
- Generate a cost/quality Analysis
- Choose the vendor best suited for Project Budget.
- Purchase from the vendor

Manufacturing and Testing (02/07/21 to 04/16/21)
- Manufacture the parts based on the design.
- Assemble of the part
- Testing of the experiment and testing of the equipment

Final senior Design Presentation (04/17/21 to05/12/21)

- To come with a detailed Project Presentation of the Problem.
- To come with Detailed explanation on the project planning.
- To come with Detailed Presentation on the Literature Review.
- To come with Detailed Presentation of functional decomposition.
- To come with Detailed presentation on the concept generation.
- To come with Detailed presentation on the design analysis.
- Etiquette and laws applied to the project**.**

2.2 Timeline

To successfully undertake the design of this experiment in its entirety, it was important that the framework for this project was clearly outlined and defined. This was done by initially defining the major tasks. These tasks represent the basic building blocks of what it takes to complete this design experiment from start to finish. From this point, each task is followed by its objectives. These objectives give clear understanding to the purpose of the task associated with it. Once the objectives are clear, there is a specific deliverable for each objective. The deliverables define exactly what needs to be done to fulfill the assigned objective. These are awfully specific jobs that needed to be carried out for the task to be considered complete. Every deliverable was allotted a time frame that was estimated for its completion. This time frame was estimated depending on the difficulty and ease of the deliverable. More days were given to more difficult deliverables and fewer days to those that were considered less time consuming. Once the process was broken down to clear and precise deliverable associated with the task, it was assigned a specific person to carry out the deliverable. Each team member's knowledge and personal strengths were taken into consideration with this step. Some deliverables were given more than one person to accommodate time restrictions, a person's knowledge/strengths or for the importance of collaboration needed. A list of tasks, objectives, deliverables, responsible members, and time frame is shown below in the following format.

1. Problem Formulation

1.1 Identify clients and recognize needs.
-Objective: Identify the consumer.
-Deliverable: Specify at least 3 clients.
-Members: Marcelo Epam Ona/Christian White
-Timeline: 3 days

1.2 Define goals.
-Objective: Clear understanding of need.
-Deliverable: Define 3 specific needs.
-Members: Christian White
-Timeline: 3 days

1.3 Define objectives.
-Objective: Clarify objectives.
-Deliverable: List objectives for each task.
-Members: Yemboado Yonli
-Timeline: 2 days

1.4 Identify the constraints and operating environment.
-Objective: Understand limitations of design.
-Deliverable: List all constraints.
-Members: Marcelo Epam Ona/Abdullah El Aker
-Timeline: 5 days

2. Project Planning

2.1 Identify the tasks.

-Objective: Clear understanding of task.
-Deliverable: List of tasks.
-Members: Diana Morales
-Timeline: 2 days

2.2 Develop objectives for each task.

-Objective: Develop objectives.
-Deliverable: Specify all requirements to complete task.
-Members: Fanta Kaba
-Timeline: 2 days

2.3 Set up a timeline.

-Objective: Estimate timeline for completion.
-Deliverable: Estimate dates for tasks.
-Members: Fanta Kaba
-Timeline: 3 days

2.4 Create a Gantt chart.

-Objective: Visual representation of timeline.
-Deliverable: Create a Gantt Chart.
-Members: Abdullah El Aker
-Timeline: 2 days

3. Literature Review

3.1 Identify potential sources and relevant information.

-Objective: Understand the background of the project.
-Deliverable: List of research previously found on convection of nanofluids.
-Members: Marcelo Epam Ona/Christian White
-Timeline: 2 days

3.2 Study convection of nanofluids.

-Objective: Understand the mechanism.
-Deliverable: List of research on heat convection under different boundary conditions.
-Members: Diana Morales/Fanta Kaba
-Timeline: 2 days

3.3 Study convection of nanofluid under different boundary conditions.

-Objective: Understand change of boundary condition.
-Deliverable: List boundary conditions.
-Members: Yemboado Yonli
-Timeline: 2 days

3.4 Study measurement techniques of convection and their advantages.

-Objective: Identify different measurement techniques for convection.
-Deliverable: List 3 techniques.
-Members: Yemboado Yonli/Christian White
-Timeline: 2 days

3.5 Identify and collect of comparable results.

-Objective: Obtain a range of results that satisfy results.
-Deliverable: List comparable results.

-Members: Marcelo Epam Ona/Abdullah El Aker
-Timeline: 2 days

3.6 Conclude the literature review.
-Objective: To summarize research.
-Deliverable: Write paragraph on summary of research.
-Members: Christian White
-Timeline: 1 day

4. Functional Decomposition

4.1 Use strategies used to develop Level 1 Sub Functions.
-Objective: Define the general function of the experiment.
-Deliverable: Give definition of the major function based on the project statement.
-Members: Christian White/Marcelo Epam Ona/Abdullah El Aker
-Timeline: 1 day

4.2 Use strategies used to develop Level 2 Sub Functions.
-Objective: To define the main functions of what is to be accomplished.
-Deliverable: To break each second level function into sub functions.
-Members: All members
-Timeline: 3 days

4.3 Develop the Morphology Table.
-Objective: To break each second level function into sub function
-Deliverable: An assignment for each member to build up in order to complete the project.
-Members: All members
-Timeline: 2 days

5. Concept Generation

5.1 Generate techniques for concept.
-Objective: To Generate concepts using concept generation techniques.
-Deliverable: Brainstorm and generate 3 concepts for each function.
-Members: Christian/Fanta/Bryan/Marcelo/Diana/Abdullah
-Timeline: 2 days

5.2 Develop a conceptual design of the experimental.
-Objective: To consolidate individual concepts and sketches.
-Deliverable: Combine concepts/sketches.
-Members: Christian/Fanta/Bryan/Marcelo/Diana/Abdullah
-Timeline: 3 days

6. Concept Evaluation

6.1 Evaluate based on Go-No-Go.
-Objective: Select and acquire relevant information.
-Deliverable: Select 4 merits that may meet the needs of the customer.
-Members: Diana Morales/Cristian White/Abdullah El Aker
-Timeline: 6 days

6.2 Evaluate based on decision matrix.
-Objective: Decisions made based on a descriptive matrix evaluation method.
-Deliverable: Select the best choice from the matrix with an explanation on its selection
-Members: Yemboado Yonli/ Marcelo Epam Ona/Fanta Kaba

-Timeline: 1 day

7. Preliminary Design

7.1 Make the Design Sizing & Components Analysis.

-Objective: Analyze project and design from basic science.
-Deliverable: Select the proper tools needed for the experiment.
-Members: Diana Morales/Cristian White/Abdullah El Aker
-Timeline: 5 days

7.2 Develop methods for design analysis.

-Objective: Choose different methods used.
-Deliverable: Proper method is chosen for each respective part.
-Members: Yemboado Yonli/ Marcelo Epam Ona/Fanta Kaba
-Timeline: 4 days

7.3 Apply ASME Codes & Standard to experiment.

-Objective: Rules and ethics applied to obtain best results.
-Deliverable: Defining 5 rules that are necessary for this experiment to function with the most accurate results.
-Members: Diana Morales/Cristian White/Abdullah El Aker
-Timeline: 4 days

7.4 Consider public health, safety, and welfare factors into design.

-Objective: Assure experiment is safe.
-Deliverable: List at least 10 rules that would make this experiment safe for consumers and environment.
-Members: Yemboado Yonli/ Marcelo Epam Ona/Fanta Kaba
-Timeline: 4 days

8. Detailed Design

8.1 Design CAD models of project parts & components.

-Objective: Generating a design of the different parts needed with precise measurements.
-Deliverable: Parts with precise measurement.
-Members: White/Marcelo Epam Ona/Abdullah El Aker
-Timeline: 7 days

8.2 Develop Engineering Drawings from part models.

-Objective: Have perspective and schematic of project.
-Deliverable: Schematic of design experiment.
-Members: Yemboado Yonli/ Marcelo Epam Ona/Fanta Kaba
-Timeline: 7 days

8.3 Develop sub-system assembly and system assembly.

-Objective: Creating a simpler system.
-Deliverable: Part fit perfectly for a simple design.
-Members: Diana Morales/Cristian White/Abdullah El Aker
-Timeline: 5 days

9. Detailed Parts Specifications

9.1 Specify the parts.

-Objective: To be able to identify each part.
-Deliverable: Parts
-Members: White/Marcelo Epam Ona/Abdullah El Aker

-Timeline: 7 days

9.2 Identify the use of each part.

-Objective: To identify the utility of each part.
-Deliverable: Utility of part
-Members: Diana Morales/Cristian White/Abdullah El Aker
-Timeline: 5 days

10. Budget and Project Cost

10.1 Identify the material needed for the parts.

-Objective: Know what should be purchased.
-Deliverable: List of material needed and where it can be found.
-Members: Christian White.
-Timeline: 3 days

10.2 Identify parts that can directly be purchased.

-Objective: Identify what can be directly acquired.
-Deliverable: List of parts that can be directly purchased.
-Members: Fanta kaba/Diana Morales
-Timeline: 2 days

10.3 Identify manufacturing cost.

-Objective: Know how much it would cost to manufacture the part.
-Deliverable: Cost of the part that can be directly acquired.
-Members: Yemboado Yonli
-Timeline: 2 days

10.4 Summarize budget plan to cover all costs.

-Objective: Make sure that every dollar is properly spent.
-Deliverable: Estimated cost and final budget.
-Members: Marcelo Epam Ona/ Abdullah El Aker
-Timeline: 4 days

11. Purchasing

11.1 Research vendors that can provide manufactured parts.

-Objective: Know the companies or manufacturers that can build necessary parts.
-Deliverable: List of the parts specifications to be purchased and manufactured.
-Members: Yemboado Yonli
-Timeline: 13 days

11.2 Have the vendors generate quotes.

-Objective: To list the possible vendors or providers for the different parts needed.
-Deliverable: Detailed drawings and prototypes of desired parts.
-Members: Marcelo Epam Ona
-Timeline: 13 days

11.3 Generate a cost quality analysis.

-Objective: Understand and prepare a budget.
-Deliverable: List 3 or more quotes of parts worth more than $50.
-Members: Fanta Kaba
-Timeline: 13days

11.4 Choose the vendor that best suits Project Budget.
-Objective: Pick the parts to satisfy experiment needs at low cost and highest quality available.
-Deliverable: List of parts for assembly.
-Members: Abdullah El Aker/Christian White
-Timeline: 13 days

12. Fabricating and Testing

12.1 Manufacture parts based on the design.
-Objective: Have tangible parts.
-Deliverable: Detailed plan for manufacturing and assembly.
-Members: Yemboado Yonli/Marcelo Epam Ona
-Timeline: 20 days
12.2 Assembly of the parts.
-Objective: Verify the functionality of the designed product.
-Deliverable: List of parts to meet the project requirements.
-Members: Abdullah El Aker
-Timeline: 10 days

13. Final Report and Presentation

13.1 Presenting the problem in detail.
-Objective: Assure audience understands the task at hand.
-Deliverable: Utilizing Microsoft PowerPoint, provide a slide defining the problem.
-Members: Yemboado Yonli
-Timeline: 7 days
13.2 Detailed explanation on the project planning.
-Objective: Show how the project has been divided into multiple steps that allow for full development.
-Deliverable: A list of steps taken to create our physical system.
-Members: Marcelo Epam Ona
-Timeline: 7 days
13.3 Detailed presentation on the literature review.
-Objective: A brief overview of the information helps the concept generations.
-Deliverable: Show the helpful documents used through individual research and result.
-Members: Fanta Kaba
-Timeline: 7 days
13.4 Detailed Presentation of functional decomposition.
-Objective: Help the audience understand the material, energy and information inputs and outputs for the overall subfunctions.
-Deliverable: Show various components of the system and explain why they have been chosen.
-Members: Diana Morales
-Timeline: 7 days
13.5 Detailed presentation on the concept generation
-Objective: Present to the audience chosen concept for full understanding.
-Deliverable: Explanation on why this concept was the most acceptable for this project.
-Members: Abdullah El Aker
-Timeline: 7 days
13.6 Detailed presentation on the design analysis.

-Objective: Present to the audience how the design was generated.
-Deliverable: Bullets points on the major concepts behind the experiment.
-Members: Christian White
-Timeline: 7 days

13.7 The etiquette and laws of the project.
-Objective: Show rules and laws of the engineering were respected.
-Deliverable: A list of rules that were abided by.
-Members: Diana Morales
-Timeline: 7 days

The section above describes the list of tasks that need to be performed to fulfill the goals and objectives of this project. It was mainly done or created by following the Prairie View A&M Department of Engineering Senior Design Project manual, which helps mechanical engineers build a list of actions that need to be completed in the process of designing or building a product. The dates were set up by identifying and recognizing the importance of each task, which led this to come out with an estimated date that such task might take to be completed. Based on how much or little work each task seemed to have once identified, a certain amount of days and hours were given to complete it. For example, when it comes to the Literature review, it is understood that this is actually one of the tasks that will definitely take some time to complete because it mostly focuses on objectives like Identifying most of the potential sources and relevant information related to Measurement of heat transfer coefficient and thermal conductivity of nanofluids that do not accommodate different boundary conditions. As it can be seen, there will be a lot of research and work to do on this objective alone, which also means a lot of time invested into identifying these potential sources. Furthermore, the hours were set up by putting into this project at least 6 hours a week which translate into for every two weeks a total of 12 hours were invested into accomplishing every single objective.

Senior 1

- Problem Formulation (From 09/02/2020 to 09/08/2020) 6 hours are to be invested.
- Project Planning (From 09/10/2020 to 09/15/2020) 6 hours are to be invested.
- Literature Review (From 09/16/2020 to 09/22/2020) 6 hours are to be invested.
- Functional Decomposition (From 09/23/2020 to 09/29/2020) 6 hours are to be invested.
- Concepts Generation (From 09/30/2020 to 10/03/2020) 6 hours are to be invested.
- Concepts Evaluation (From 10/14/2020 to 10/21/2020) 6 hours are to be invested.
- Preliminary Design (From 10/02/2020 to 11/05/2020) 24 hours are to be invested.
- Detailed Design analysis (From 11/06/2020 to 11/21/2020) 12 hour are to be invested.
- Detailed parts specifications (From 11/22/2020 to 11/29/2020) 6 hours are to be invested.

- Budget & Project Cost (From 11/02/2020 to 12/06/2020) 24 hours are to be invested.
- Purchasing (From 01/25/2021 to 02/06/2021) 12 hours are to be invested.
- Fabrication & Testing. (From 02/07/2120 to 04/16/2120) 6 hours are to be invested.
- Final Presentation for Senior 1(From 04/17/2120 to 05/12/2120) 6 hours are to be invested.

Table ~~1~~ is an organized representation of each task, subtasks, and deliverables the group judged important to be performed for the goals and objectives of the project to be reached. The timeline has also been divided in a way that each deliverable would have a specific time during which it has to be completed which is breaking the whole project into smaller and more achievable goals. The group will work in the most diligent way to make good use of its time.

Table ~~1~~ Detailed Project Tasks, Objectives, Deliverables, Task Duration & Responsible Personnel

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
1. Problem Formulation	1.1 Identify clients and Recognize need	To identify the consumer that may need the product and understand the reason why the product needs to be built	A list of at least 4 potential customers & why they will need our product .	3	9/2	9/4	Marcelo Epam Ona/Christian White
	1.2 Define goals	To have a clear understanding of the output that is needed	A list of objectives such as how the design of this heat transfer measuring system will expel any confusion about how nanofluids interact with different boundary conditions.	3	9/2	9/4	Christian White
	1.3 Define objectives.	To have clear cut objectives while designing the product	zoom meeting setup, a list of 4 different constraints, formulation of the problem statement.	2	9/3	9/4	Yemboado YONLI
	1.4 Identify the constraints and operating environment.	To understand the limitation of the design and the product	A list of all measurable performance characteristics with units. A well-drawn and labelled objective tree showing hierarchical relationships and interconnections of the performance characteristics. A list of permissible range for the design parameters, description of the environment in which the design will operate and specifying why different constraints will hinder successful experiments.	5	9/4	9/8	Marcelo Epam Ona/Abdullah El Aker

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
2. Project Planning	2.1 Identify the tasks	To have a schematic and a clear idea about what the project and its different tasks will look like.	A list of all the tasks needed to be accomplished for the project.	2	9/10	9/11	Diana Morales
	2.2 Develop objectives for each task	To develop objectives (actions needed) for each task.	Detailed list of specific requirements to assure completion of each individual task.	2	9/10	9/11	Fanta Kaba
	2.3 Set up a timeline	To set up estimate dates in which each task might be completed.	Various dates of meetings that involve discussion and time spent applying what has been discussed into the project.	3	9/12	9/14	Fanta Kaba
	2.4 Create a Gantt chart.	To give a visual representation of the timeline	Physical Gantt Chart to give a detailed description of time spent in a 24 hour day.	2	9/14	9/15	Abdullah El Aker

3. Literature Review	3.1 Identify potential sources and relevant information.	To understand the background of the project and I have a clear idea of what it is needed for each task to be completed.	A list of research previously found about convection of nanofluid	2	09/16	09/18	Marcelo Epam Ona/Christian White
	3.2 Study convection of nanofluids.	To understand the mechanism behind convection heat transfer for nanofluids	A list of papers about heat convection of nanofluids under different boundary conditions.	2	09/16	09/18	Diana Morales/Fanta Kaba
	3.3 Study convection of nanofluid under different boundary conditions	To understand how a change of boundary condition like magnetic field will affect the properties of the nanofluid	A thorough documentation on measurement techniques for convection and their advantages A choice of the most advantageous measurement technique	2 2	09/17 09/18	09/19 09/20	Yemboado YONLI Yemboado Yonli/Christian White
	3.4 Study measurement techniques of convection and their advantages	to identify different measurement technique for convection and sort them out to to get the one that will work best for that project	A good understanding on the instrumentations used for the experiment A list of comparable results	2 2	09/18 09/20	09/20 09/21	Marcelo Epam Ona/Abdullah El Aker
	3.5 Identify and collect of comparable results 3.6 Conclude the literature review	To obtain a range of results that will help make sure that experiment is generating satisfying results To summarize all the information obtained and organize them in a way that will be beneficial for the project	Conclusion of literature review	1	09/21	09/22	Christian White
Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person

4. Functional Decomposition	4.1 Use strategies used to develop Level 1 Sub functions. 4.2 Use strategies used to develop Level 2 Sub functions. 4.3 Develop the Morphology Table.	To define the general function and what is to be accomplished by the system To define the main functions of what is to be accomplished To break each second level function into sub function until the point of basic functionality	A definition of the major task based on the project statement A List of all ask the major task can be divided in to have more attainable goals a breakdown of the second level function into subfunctions An assignment to each group member of a task to build up in order to complete the project.	1 2 3 2	09/23 09/24 09/25 09/27	09/24 09/26 09/28 09/29	Christian White/Marcelo Epam Ona/Abdullah El Aker Yemboado YONLI/Fanta Kaba Diana Morales/Cristian White/Abdullah El Aker Yemboado Yonli/ Marcelo Epam Ona/Fanta Kaba
5. Concept Generation	5.1 Generate techniques for generating concepts from functions. 5.2 Develop a conceptual design of the experimental set up that would be based on the properties of nanofluid and the boundary conditions that would be applied	To Generate concepts using concept generation techniques To Consolidate individual concepts and sketches into team concepts for each function.	Techniques to generate a concept would be brainstorming, developing, and communicating abstract ideas. Combining individual concepts and sketches by communicating collectively on the concept each person has come up with. Then choosing the best concepts that are aligned with the scope of the project.	2 3	09/30 10/3	10/2 10/05	Christian/ Fanta/Bryan/Marcelo/Diana/Abdullah Christian/ Fanta/Bryan/Marcelo/Diana/Abdullah

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
6. Concept evaluation	6.1 Evaluate based on Go-No-Go 6.2 Evaluate based on decision matrix	To select and acquire relevant information based on how it might relate to the project. Decisions will be made based on a descriptive matrix evaluation method.	Select 4 merits that may meet the needs of the customer. Select the best choice from the matrix with an explanation on why it was selected.	6 1	10/14 10/19	10/19 10/20	Diana Morales/Cristian White/Abdullah El Aker Yemboado Yonli/ Marcelo Epam Ona/Fanta Kaba

7. Preliminary Design	7.1 Make the design Sizing & Components Analysis	Where the project must be designed and analyzed, it is essentially a decision-making process in which analytical tools are derived from basic sciences.	Select the proper tools needed for the experiment to give the desired results.	5	10/21	10/28	Diana Morales/ Cristian White/Abdullah El Aker
	7.2 Develop methods for design analysis	Where the different methods used have to be chosen and accommodated to its respective part of the project.	A proper method is chosen for each respective part so that the experiments give needed results as expected.	4	10/26	10/30	Yemboado Yonli/ Marcelo Epam Ona/Fanta Kaba
	7.3 Apply ASME Codes & Standards	Where the different rules and ethics must be applied in order to obtain the best of the product.	Defining 5 rules that are necessary for this experiment to function with the most accurate results.	4	10/29	11/023	Diana Morales/ Cristian White/Abdullah El Aker
	7.4 Consider public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors in Design.	Where it must be made sure that the product is safe for consumers and that it will be used in its designated environment	List at least 10 rules that would make this experiment safe for consumers and environment.	4	11/02	11/05	Yemboado Yonli/ Marcelo Epam Ona/Fanta Kaba
Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person

8. Detailed design	8.1 Design CAD models of project parts & components 8.2 Develop Engineering Drawings from part models 8.3. Develop sub-system assembly and system assembly	Generating a design of the different parts needed with the precise measurements. Having access to different apps and software that can give a perspective or schematic of how the project will look like. Creating a simpler system that can be used to assemble all the different parts of the experiment. Making sure that each part fits perfectly and functions accordingly.	The designed parts needed are generated with precise measurement. A schematic of the design is obtained through the different mechanical software, which could be NX or AutoCAD. A simpler system is created to assemble all the different parts of the experiment. It is made sure that each part fits and works for the purposes it was made for. Every part of the design fulfills its task.	7 7 5	11/06 11/12 11/16	11/13 11/19 11/21	White/Marcelo Epam Ona/Abdullah El Aker Yemboado YONLI/Fanta Kaba Diana Morales/ Cristian White/Abdullah El Aker
9. Detailed part Specification	9.1 specify of parts 9.2 Identify the use of each part	To be able to identify each part To identify the utility of each part	Identify each part Determine the utility of each part build each part	3 3 2	11/22 11/24 11/27	11/25 1/27 11/29	White/Marcelo Epam Ona/Abdullah El Aker Yemboado YONLI/Fanta Kaba Diana Morales/Cristian White
10. Budget and Project cost	10.1 Identify the material needed for the parts 10.2 Identify parts that can directly be bought 10.3 Identify manufacturing cost 10.4 Summarize into a budget that can cover all costs	to know what should be bought To identify what does not need to be bought but can be directly acquired To know how much it would cost on average for manufacturing the part To create a sound budget and make sure that every dollar is properly spent.	Determine the material needed and where it can be found identify every part that can be directly bought identify the cost of the part that can be directly acquired add the supposed cost together set up a final budget	3 2 2 2 2	11/30/20 12/01/20 12/02/20 12/03/20 12/04/20	12/02/20 12/03/20 12/04/20 12/05/202 12/06/20	Christian White. Fantakaba/Diana Morales. Yemboado Yonli Marcelo Epam Ona Abdullah El Aker

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
11. Purchasing	11.1 Research Vendors able to manufacture the needed parts based on the Design	To list the companies or manufacturers that can build the parts needed to develop the product.	Prepare a list of the parts specifications to be purchased and manufactured.	13	01/25	02/06	Yemboado Yonli
			Prepare Detailed drawing and prototypes of desired parts.				Marcelo Epam Ona
	11.2. Have the Vendors Generate quotes.	To list the possible vendors or providers of the different parts needed for the project, contact them to get an estimate on the prices and delivery dates.	List 3 or more quotes of parts more than $50	13	01/25	02/06	
	11.3 Generate a cost quality analysis	To come out with a budget of what they need and what they might not for the desirable project.	List the parts with prices and quotes for the product.	13	01/25	02/06	Fanta Kaba
			Purchase the parts and start manufacturing.				Diana Morales
			Test and inspect the parts to proceed to assembly of the product.				
	11.4 Choose the vendor that best suits Project Budget	To pick the parts to satisfy their needs at lower cost possible and at the highest quality available.		13	01/25	02/06	Abdullah El Aker
							Christian White

12. **Manufacturing and Assembly of the Product**	12.1 **Manufacture part based of the design** 12.1 Assemble **of the part**	To have tangible parts To assemble the parts and verify the functionality of the designed product	Prepare detailed codes and standards used in the project. Establish a detailed plan for manufacturing and assembly of the product. Risk assessment and identifications of critical issues for in depth analysis. Assemble the parts to meet the project requirements. Test the product and collect measurements and data	20 20 14 10 10	02/07/21 02/27/21 03/11/21 03/25/21	02/27/20 03/11/21 0\3/25/21 04/05/21 04/16/21	Yemboado Yonli/Marcelo Epam Ona Fanta Kaba Diana Morales Abdullah El Aker Christian White
Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
13. **Final senior Design Presentation**	13.1 Detailed Project Presentation of the Problem 13.2. Detailed Explanation on the Project Planning 13.3. Detailed Presentation on the literature Review 13.4. Detailed Presentation of functional decomposition 13.5. Detailed presentation on the concept generation	To make the audience understand the task at hand. Show how the project has been divided into multiple steps that allow its good development. A brief overview of the information that has been found on previous projects of that same kind and how it helped the concept generations. Make the audience understand the material, energy and information inputs and outputs for the overall and the subfunctions. To present to the audience the concept chosen and the reason why this concept was the most acceptable for this project	Utilizing Microsoft PowerPoint, a specific slide will be incorporated defining the problem. Reference the timeline and Gantt chart created earlier in the project. Create a list of steps taken to create our physical system. Show our helpful documents conducted through individual research within the group pertaining to specific functions of the project. Show various components of the system and explain why they have been chosen. Show personal meeting notes with the project advisor and professors who have insight on this specific project. Show feedback given by	7 7 7 7 7	04/17/21 04/19/21 04/23/21 04/24/21 04/27/21	04/24/21 04/23/21 04/30/21 05/01/21 05/03/21	Yemboado Yonli Marcelo Epam Ona Fanta Kaba Diana Morales Abdullah El Aker

	13.6. Detailed presentation on the design analysis 13.7. The etiquette and laws of the project	Present to the audience how the design must be generated based on the concept that was brought up and how the design will be created. To show to the that the rules and laws of the engineering world were respected	professors who grade weekly assignments. Create bullets points on the concept behind the experiment and its functionality and why it works on PowerPoint slides. Make a list of rules that were abided by that show rules were followed.	7 7	05/01/21 05/05/21	05/08/21 05/12/21	Christian White DIana Morales

2.3 Gantt Chart

Using the Gantt chart will help the group member to stay on top of the project and its tasks, we can easily access the Gantt chart to look at the day and what we are supposed to do and accomplish, this way is more efficient than looking for each major task and subtask individually. We were able to identify each task and what needs to be done to complete the milestone. Currently we completed the first 3 major tasks of the report as shown in Figure 2.1, 2.2, 2.3. At the moment we are completing the 4th major task as shown in Figure 2.4 and by looking at figure 2.5 we can tell by next week we have to start the work on the major task 5 and finish before October 5th, 2020 to be able to stick with the deliverables and the milestone of that task.

task

ID	Task Name	Duration	Start	Finish
1	1. Problem formulation	5 days	Wed 9/2/20	Tue 9/8/20
2	1.1 Identify the consumer that may need the product and understand the reason why the product needs to be	3 days	Wed 9/2/20	Fri 9/4/20
3	1.2 Have a clear understanding of the output that is needed	3 days	Wed 9/2/20	Fri 9/4/20
4	1.3 Have clear cut objectives while designing the product	2 days	Thu 9/3/20	Fri 9/4/20
5	1.4 Understand the limitation of the design and the	3 days	Fri 9/4/20	Tue 9/8/20

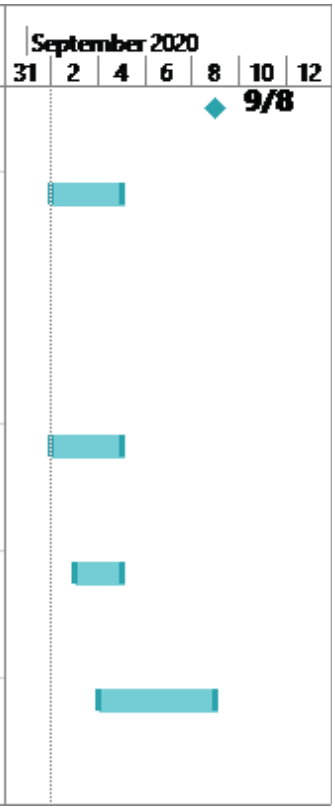


Figure 2.1 ~~shows the Gantt chart of the Major task and its corresponding sub-tasks to complete the milestone for that~~

ID	Task Name	Duration	Start	Finish
8	2.1 Have a schematic and a clear idea about what the project and its different tasks will	2 days	Thu 9/10/20	Fri 9/11/20
9	2.2 Develop objectives (actions needed) for each	2 days	Fri 9/11/20	Sat 9/12/20
10	2.3 Set up estimate dates in which each task might be completed.	2 days	Sat 9/12/20	Mon 9/14/20
11	2.4 Give a visual representaation of the timelime	2 days	Mon 9/14/20	Tue 9/15/20

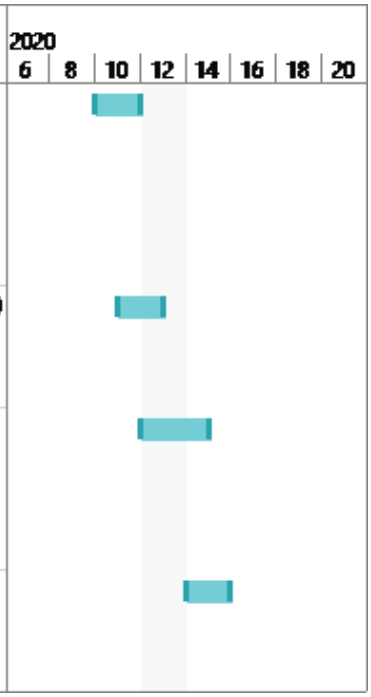


Figure 2.2 shows the Gantt chart of the Major task and its corresponding sub-tasks to complete the milestone for that task

ID	Task Name	Duration	Start	Finish
12	3 Literature Review	4 days	Wed 9/16/20	Mon 9/21/20
13	3.1 Understand the background of the project and I have a clear idea of what it is needed for each task to be completed.	3 days	Wed 9/16/20	Fri 9/18/20
14	3.2 Understand the mechanism behind convection heat transfer for	3 days	Wed 9/16/20	Fri 9/18/20
15	3.3 Understand how a change of boundary condition like magnetic field will affect the properties of the	3 days	Thu 9/17/20	Sat 9/19/20
16	3.4 Identify different measurement technique for convection and sort them out to to get the one that will work best for that	2 days	Fri 9/18/20	Sun 9/20/20
17	3.5 Obtain a range of results that will help make sure that experiment is generating satisfying results	2 days	Sun 9/20/20	Mon 9/21/20
18	3.6 Conclusion of the literature review	2 days	Mon 9/21/20	Tue 9/22/20

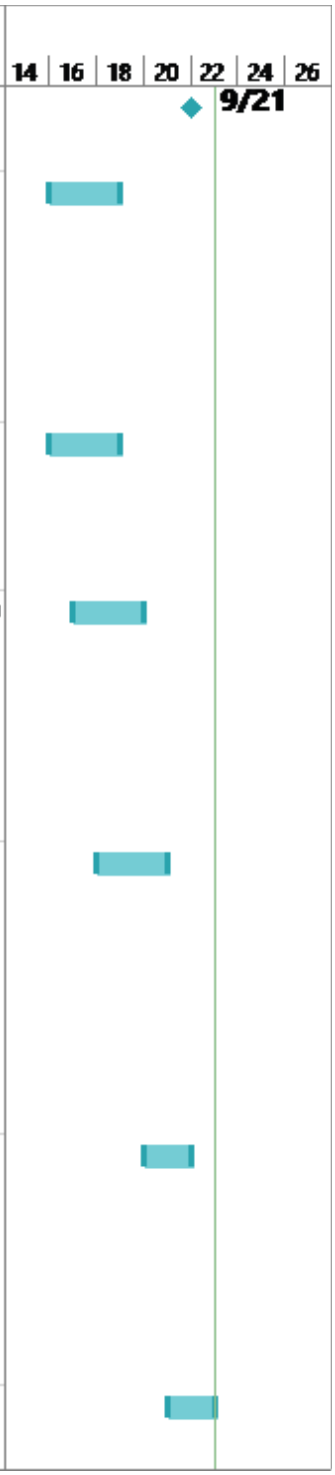


Figure 2.3 shows the Gantt chart of the Major task and its corresponding sub-tasks to complete the milestone for that task

ID	Task Name	Duration	Start	Finish
19	4. Functional Decomposition	5 days	Wed 9/23/20	Tue 9/29/20
20	4.1 Define the general function and what is to be accomplished by the	2 days	Wed 9/23/20	Thu 9/24/20
21	4.2 Define the main functions aof what is to be accomplished	3 days	Thu 9/24/20	Mon 9/28/20
22	4.3 Break each second level function into sub function until the point of	3 days	Sun 9/27/20	Tue 9/29/20

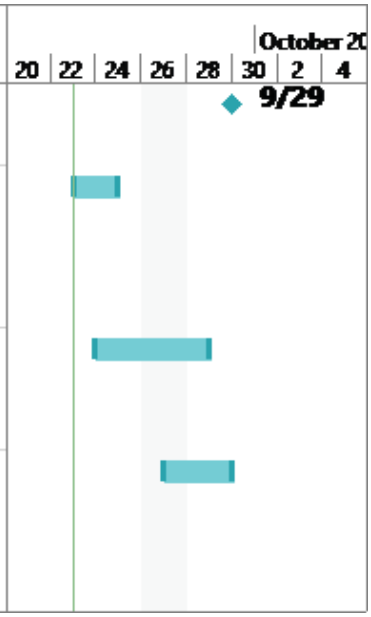


Figure 2.4 shows the Gantt chart of the Major task and its corresponding sub-tasks to complete the milestone for that task

ID	Task Name	Duration	Start	Finish
23	5. Concept Generation	4 days	Wed 9/30/20	Mon 10/5/20
24	5.1 Generating concepts using concept generation	3 days	Wed 9/30/20	Fri 10/2/20
25	5.2 Consolidating individual concepts and sketches into team concepts for each function.	2 days	Sat 10/3/20	Mon 10/5/20

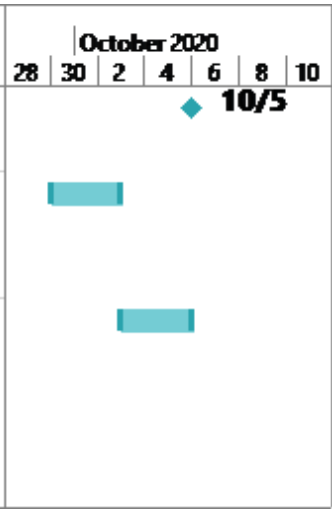


Figure 2.5 shows the Gantt chart of the Major task and its corresponding sub-tasks to complete the milestone for that task

ID	Task Name	Duration	Start	Finish
26	6. Concept evaluation stage	5 days	Wed 10/14/20	Tue 10/20/20
27	6.1 Select and acquire relevant information based on how it might relate	4 days	Wed 10/14/20	Mon 10/19/20
28	6.2 Decisions will be made based on a descriptive matrix evaluation method.	2 days	Mon 10/19/20	Tue 10/20/20

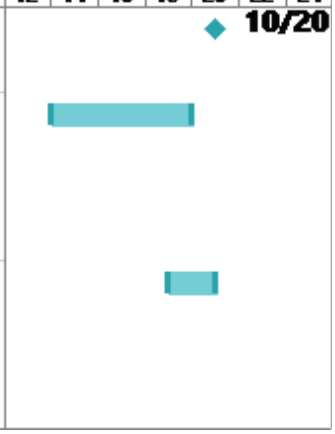


Figure 2.6 shows the Gantt chart of the Major task and its corresponding sub-tasks to complete the milestone for that task

ID	Task Name	Duration	Start	Finish
29	7. Preliminary Design	12 days	Wed 10/21/20	Thu 11/5/20
30	7.1 Select the proper tools needed for the experiment in order to give the desired results.	6 days	Wed 10/21/20	Wed 10/28/20
31	7.2 A proper method is chosen for each respective part so that the experiments give needed results as expected.	5 days	Mon 10/26/20	Fri 10/30/20
32	7.3 Defining 5 rules that are necessary for this experiment to function with the most accurate	3 days	Thu 10/29/20	Mon 11/2/20
33	7.4 List at least 10 rules that would make this experiment safe for consumers and environment.	4 days	Mon 11/2/20	Thu 11/5/20

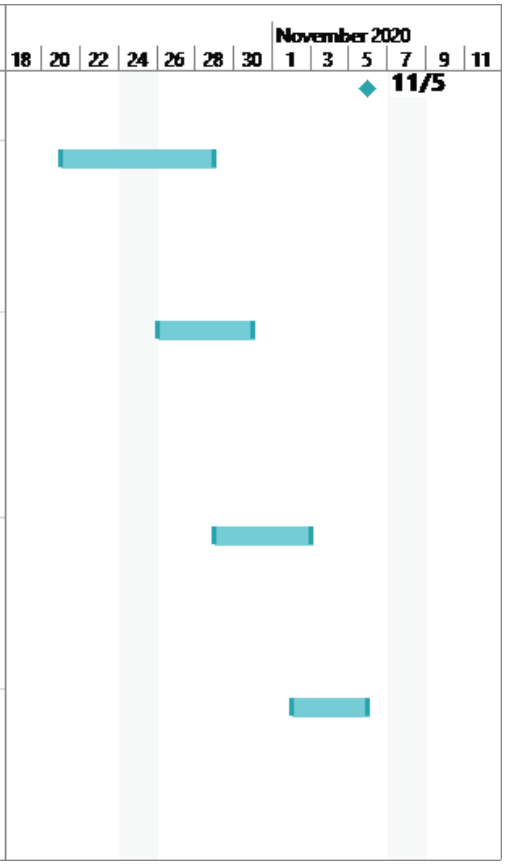


Figure 2.7 shows the Gantt chart of the Major task and its corresponding sub-tasks to complete the milestone for that task

ID	Task Name	Duration	Start	Finish
34	8. Detailed Design Analysis	12 days	Fri 11/6/20	Sat 11/21/20
35	8.1 Where the project has to be designed and analysed, it is essentially a decision-making process in which analytical tools are derived from basic	6 days	Fri 11/6/20	Fri 11/13/20
36	8.2 Where the different methods used have to be chosen and accommodated to its respective part of the	6 days	Fri 11/6/20	Fri 11/13/20
37	8.3 Where the different rules and ethics have to be applied in order to obtain the best of the product.	6 days	Thu 11/12/20	Thu 11/19/20
38	8.4 Where it must be made sure that the product is safe for consumers and that it will be used in its designated environment	6 days	Mon 11/16/20	Sat 11/21/20

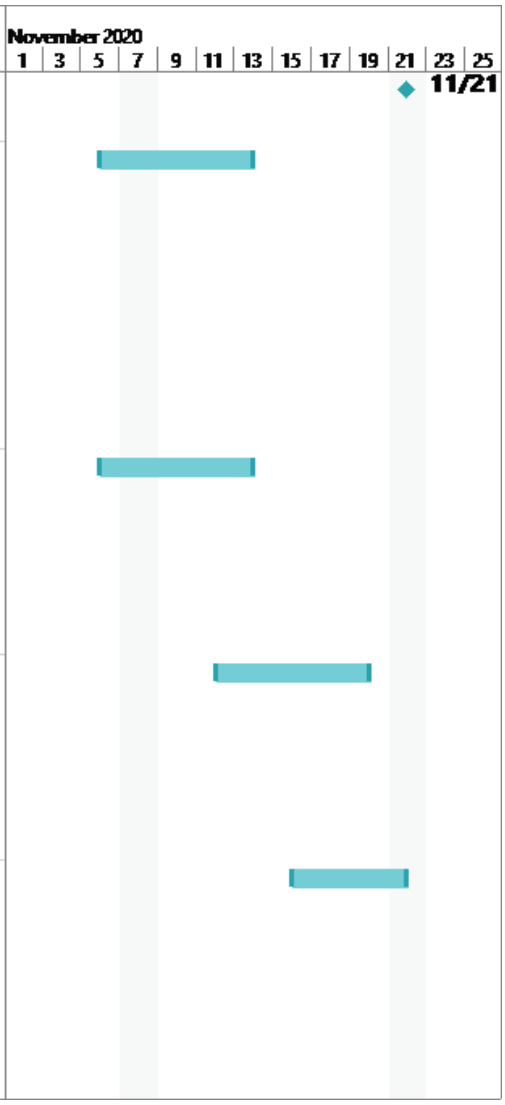


Figure 2.8 shows the Gantt chart of the Major task and its corresponding sub-tasks to complete the milestone for that task

ID	Task Name	Duration	Start	Finish
39	9. Detailed part Specification	14 days	Wed 11/11/20	Mon 11/30/20
40	9.1 Identify each part	14 days	Wed 11/11/20	Mon 11/30/20
41	9.2 Determine the utility of each part	7 days	Thu 11/12/20	Fri 11/20/20
42	9.3 Build each part	14 days	Wed 11/11/20	Mon 11/30/20

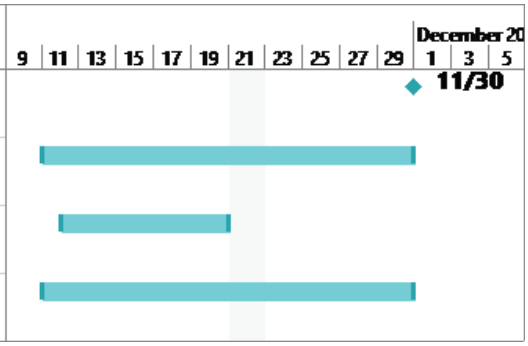


Figure 2.9 shows the Gantt chart of the Major task and its corresponding sub-tasks to complete the milestone for that task

ID	Task Name	Duration	Start	Finish	December 2020 1 3 5 7 9
43	10. Budget and Project cost	2 days	Wed 12/2/20	Thu 12/3/20	12/3
44	10.1 Determine the material needed and where it can be	2 days	Wed 12/2/20	Thu 12/3/20	
45	10.2 Identify every part that can be directly bought	1 day	Wed 12/2/20	Wed 12/2/20	
46	10.3 Identify the cost of the part that can be directly	1 day	Wed 12/2/20	Wed 12/2/20	
47	10.4 Add the supposed cost	1 day	Wed 12/2/20	Wed 12/2/20	
48	10.5 Set up a final budget	1 day	Wed 12/2/20	Wed 12/2/20	

Figure 2.10 shows the Gantt chart of the Major task and its corresponding sub-tasks to complete the milestone for that task

ID	Task Name	Duration	Start	Finish
49	11. Purchasing	11 days	Mon 1/25/21	Sat 2/6/21
50	11.1 list the companies or manufacturers that are able to build the parts needed to develop the product.	11 days	Mon 1/25/21	Sat 2/6/21
51	11.2 List the possible vendors or providers of the different parts needed for the project, contact them to get an estimate on the prices and	11 days	Mon 1/25/21	Sat 2/6/21
52	11.3 Come out with a budget of what they need and what they might not for the desirable project.	11 days	Mon 1/25/21	Sat 2/6/21
53	11.4 Pick the parts to satisfy their needs at lower cost possible and at the highest quality available.	11 days	Mon 1/25/21	Sat 2/6/21

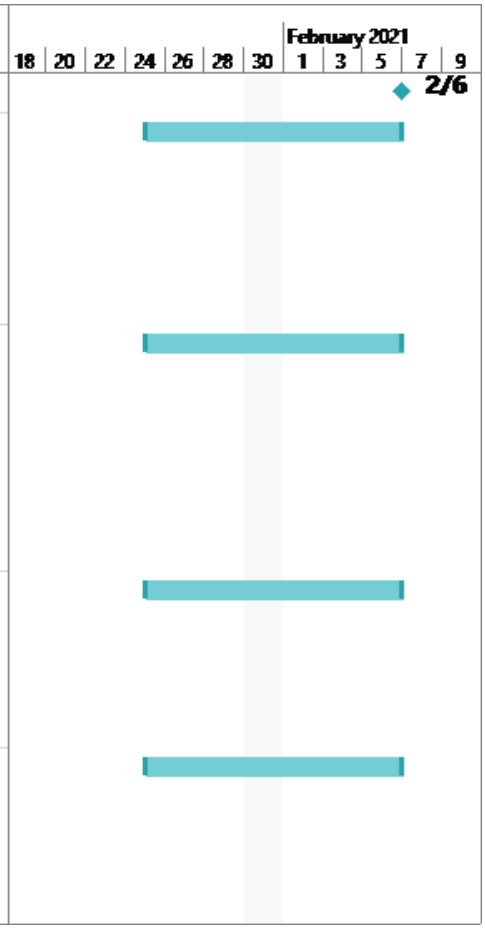


Figure 2.11 shows the Gantt chart of the Major task and its corresponding sub-tasks to complete the milestone for that task

ID	Task Name	Duration	Start	Finish
54	12. Manufacturing and Assembly of the Product	51 days	Sun 2/7/21	Fri 4/16/21
55	12.1 Prepare detailed codes and standards used in the project.	17 days	Sun 2/7/21	Sat 2/27/21
56	12.2 Establish a detailed plan for manufacturing and assembly of the product.	25 days	Sun 2/7/21	Thu 3/11/21
57	12.3 Risk assessment and identifications of critical issues for in depth analysis.	11 days	Thu 3/11/21	Thu 3/25/21
58	12.4 Assemble the parts to meet the project requirements.	8 days	Thu 3/25/21	Mon 4/5/21
59	12.5 Test the product and collect measurements and data	9 days	Tue 4/6/21	Fri 4/16/21

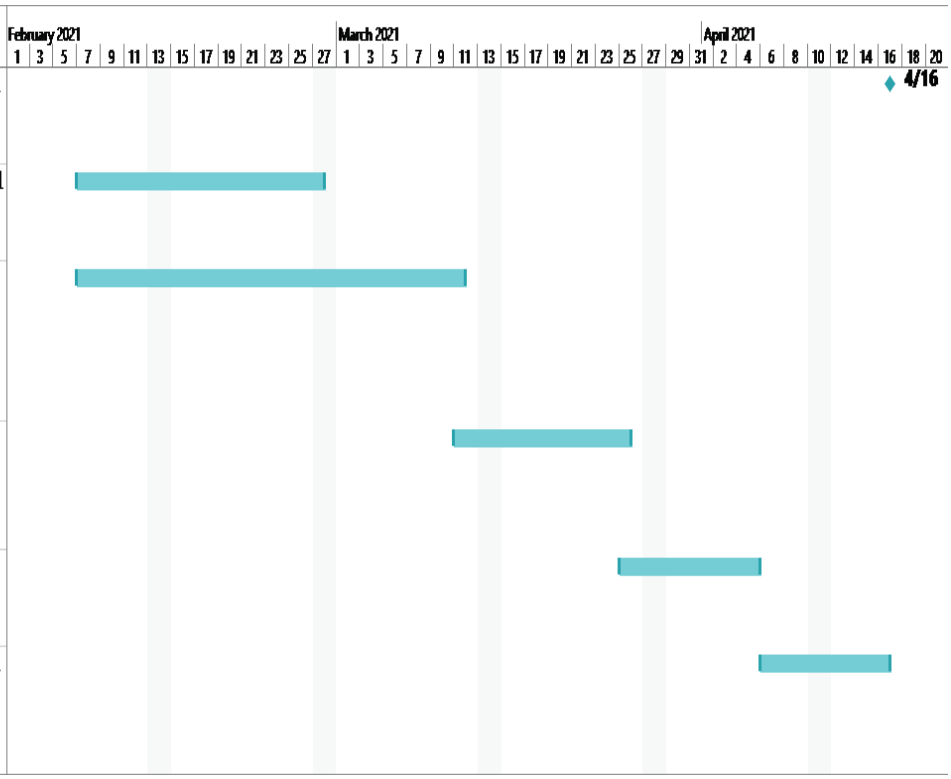


Figure 2.12 shows the Gantt chart of the Major task and its corresponding sub-tasks to complete the milestone for that task

ID	Task Name	Duration	Start	Finish
60	13. Final senior Design Presentation	19 days	Sat 4/17/21	Wed 5/12/21
61	13.1 Utilizing Microsoft Powerpoint, a specific slide will be incorporated defining	7 days	Sat 4/17/21	Sat 4/24/21
62	13.2 Reference the timeline and Gantt chart created earlier in the project. Create a list of steps taken to create our physical system.	5 days	Mon 4/19/21	Fri 4/23/21
63	13.3 Show our helpful documents conducted through individual research within the group pertaining to specific functions of the	6 days	Fri 4/23/21	Fri 4/30/21
64	13.4 Show various components of the system and explain why they have been chosen.	7 days	Sat 4/24/21	Sat 5/1/21
65	13.5 Show personal meeting notes with the project advisor and professors who have insight on this specific project. Show feedback given by professors who grade weekly	5 days	Tue 4/27/21	Mon 5/3/21
66	13.6 Create bullets points on the concept behind the experiment and its functionality and why it works on	7 days	Sat 5/1/21	Sat 5/8/21
67	13.7 Make a list of rules that were abided by that show rules were followed.	6 days	Wed 5/5/21	Wed 5/12/21

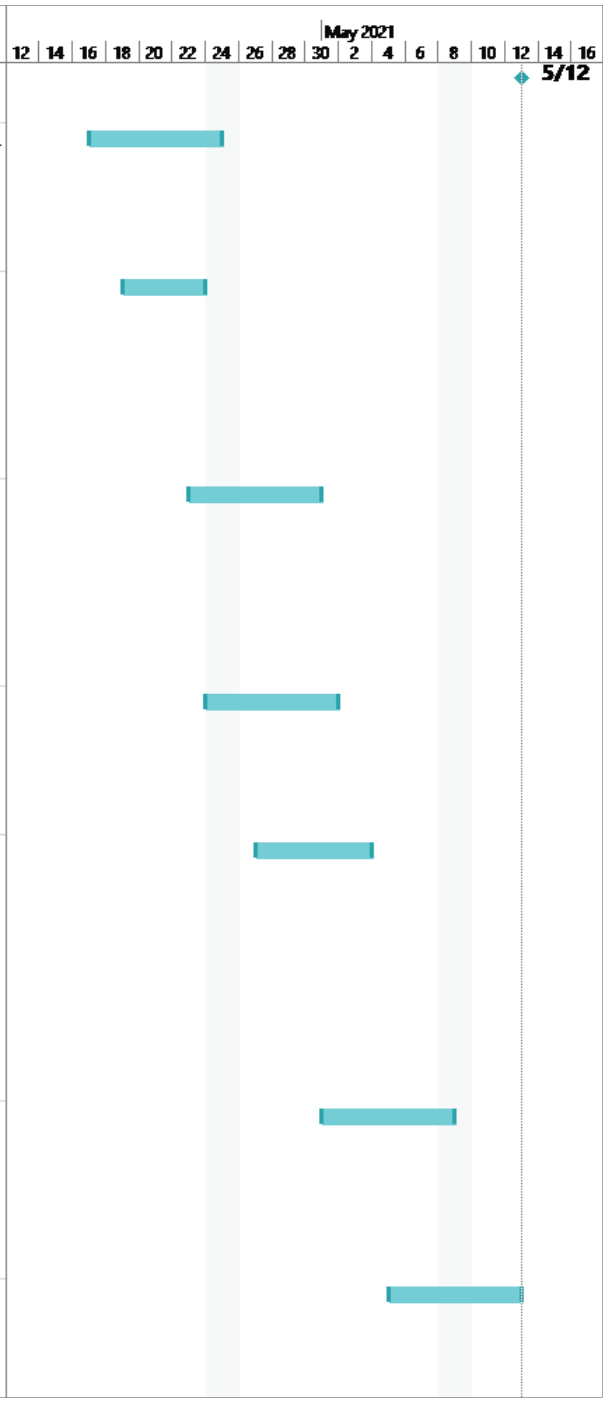


Figure 2.13 shows the Gantt chart of the Major task and its corresponding sub-tasks to complete the milestone for that task

3. LITERATURE REVIEW

The purpose of this project is to design a proper method to measure the convection transfer coefficient for nanofluids under different boundary conditions. In order to completely understand the scope of this experiment, the identification of relevant information is necessary to ensure the functionality in the measurement technique selected. Relevant sources are reviewed to establish a well-planned literature review, which focuses on examining existing similar designs and its components, relevant design analysis methods, fabrication, and testing, as well as relevant codes and standards.

3.1 Identification of Information Relevant to the Project

These specific resources were determined through intense study and research to better understand the scope of our specific project. This project is a design of a system that will efficiently measure heat transfer coefficient and effective thermal conductivity in nanofluids under different boundary conditions. Knowing that, it was determined that the best way to approach this project was by first researching other experiments conducted by professionals who have studied the different types of nanofluids, as well as respective measuring techniques. It was also determined that research on the concentration of nanoparticles, controlled parameters, and hybrid nanofluids will help to gain an understanding for the design of this project.

The types of information to be reviewed to understand the systematic approach for measuring the heat transfer coefficient and effective thermal conductivity in nanofluids consists of past experimental projects, research documents that highlight the study of nanofluids under different boundary conditions, studies stating the effects of temperature and nanoparticles concentration, documents that describe multiple measuring techniques regarding a nanofluids heat transfer coefficient, documents that determine efficient measurement techniques for the measuring of thermal conductivity, a review on the control parameters of natural convection, and lastly, the review of past experiments for the determination of viscosity of water-based magnetite nanofluid in heating and cooling systems. Determination of viscosity of water-based magnetite nanofluid in heating and cooling systems.

3.2 Potential Sources of Information for Project

These references were identified by the group to state that the following resources are the best options to efficiently understand the system for this project. The reference list contains articles which were written by professionals who have studied different measuring techniques as well as nanoparticles related to various boundary conditions.

- Masoud, M.E., *"Experimental study on thermal conductivity of water-based Fe3O4 nanofluid: Development of a new correlation and modeled by artificial neural network"* Islamic Azad University, Najafabad, Iran pp 262-269

- Masoud, M.E., *"Effects of temperature and nanoparticles concentration on rheological behavior of Fe3O4–Ag/EG hybrid nanofluid: An experimental study"*Islamic Azad University, Najafabad, Iran pp 38-44

- Colmanetti, P.O., *"Heat transfer coefficient: a review of measurement techniques"*Heat Transfer Research Group, Department of Mechanical Engineering, Sao Carlos School of Engineering, University of São Paulo pp 264

3.3 Existing Similar Designs & Functions

In the process of learning more about measuring the heat transfer coefficient of nanofluid (h), a few devices capable of doing so were discovered. Each Design brings with it a lot of advantages but also some disadvantages. Care has been put into finding devices that were used in experiment with conditions as similar as the one this group is aiming to perform. For that matter two designs were identified.

3.3.1 Design 1

An interesting device was the one used by S. Rostami, E. Raki, A. Abdollahi, A. S. Goldanlou [1],which is represented by Figure ~~3.3.1.1~~

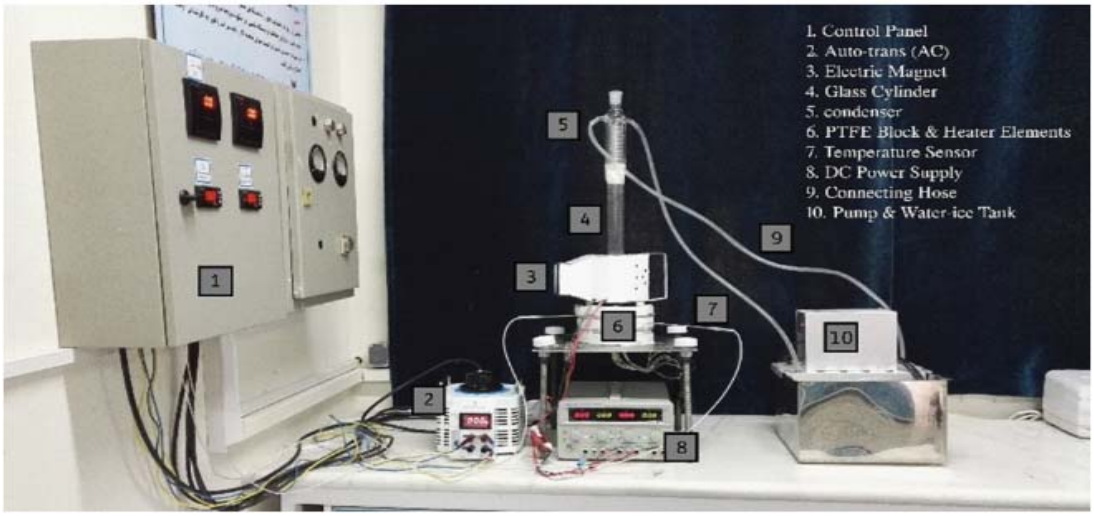


Figure ~~3.3.1.1~~ An overview of the device used by S. Rostami, E. Raki , A. Abdollahi , A. S. Goldanlou [1]

According to Fig. ~~3.3.1.1~~, the pool boiling device with the specified components was utilized to calculate the heat transfer in the pool boiling. The components of the device, in accordance with the performed numbering, include the control panel, DC power supply, temperature sensors, electric magnet, boiling glass cylinder condenser, cooling water pipes, pump, cold water tank, Teflon body (insulated), auto trans, and heat elements.

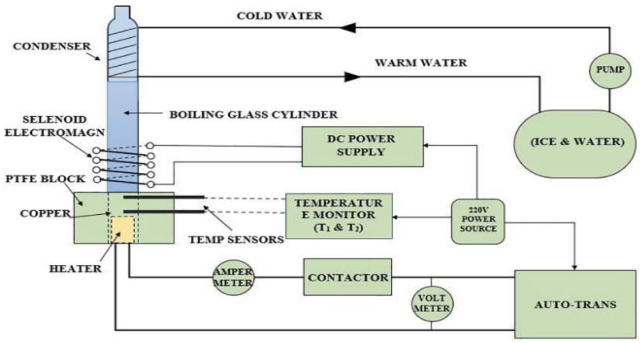


Fig. ~~3.3.1.2~~ The operational diagram of the device

According to Figs. 3.3.1.1 and 3.3.1.2, the application of the introduced components includes: the control panel has a monitoring system for the ampere, the input voltage (Autonics TC4Y) to the heat elements, and the temperature of the resistance temperature detector (RTD) sensors embedded in the copper block. The copper block is cylindrical with high purity, with a diameter of 40 mm and a length of 90 mm. The thermal conductivity coefficient of the high purity copper was measured using a KD2 Pro device manufactured by the Decagon Company (401 W/m.K). The whole copper wall is completely threaded. The length of the thread pitches is 2 mm. Four steel elements (electric heaters) with a diameter of 6 mm and a length of 40 mm, with 200 W power each, are embedded inside the copper cylindrical block from below. The copper cylindrical block is heated by these four elements. The Teflon cylinder has a height of 90 mm and a diameter of 150 mm. The Teflon around the copper is polytetrafluoroethylene (PTFE), where its thermal conductivity coefficient is measured using the KD2 Pro device (0.25 W/m.K). Due to the insulation effect of PTFE Teflon around the copper block, the radial heat transfer is ignored. The copper cylinder is Teflon-wrapped and fastened in the hole using the threads on its exterior wall. PTFE tapes, produced by the Sitco Company with ISO9001 standard, were also used on the threads of the copper wall to prevent the fluid leakage. The positions of the sensors, the heat elements, and the copper block are shown in Fig. 3.3.13. The sensors are passed through a hole with a diameter of 3 mm and placed in the center of the copper block. The upper surface of the copper block is in touch with the fluid, and the glass cylinder into which the fluid is poured is installed on top of it using holding clips. The height of the glass is 350 mm, its external diameter is 40 mm, and the thickness of the wall is 3 mm. An electromagnet, which is generated using a solenoid and a tubular core is installed around the glass cylinder (Fig. 3.3.14). This magnet has a variable magnetic field intensity that changes by changing the input ampere of the magnet. The intensity of the magnetic field was examined and measured using a magnetometer (Lutron MG-3003SD) in several steps and for various amperes. By generating magnetic fields with a maximum capacity of 1000 gauss in the wall of the metal core and 300 gauss in the central core, this device is designed and produced for a maximum amperage of 10 A DC and is set up using a DC power supply. Its contour and field direction are shown in Fig. 3.3.1.5. The condenser, which is connected to the pump and the cold-water tank using two flexible hoses, is installed on top of the glass cylinder. The cold water is pumped to the condenser using the pump, and this circulation leads to the cooling of the condenser and conversion of the vapor produced through boiling to the fluid and returning to the initial volume of the fluid. This causes the fluid volume to be constant. According to Fig. 3.3.1.6, the top surface of the condenser is open, which causes the boiling pressure to be equal to the environment pressure. Due to the effect of the roughness of the boiling copper surface on the heat transfer, a 600-grit sandpaper was used to achieve a constant roughness for all of the experiments.

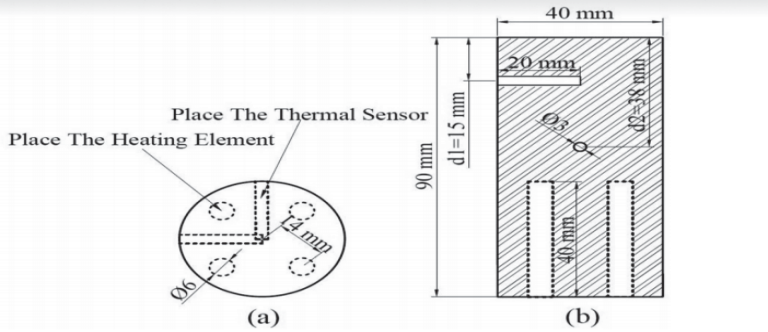


Fig. 3.3.1.3 Schematic view of the position of the sensors, heat elements inside the copper block (a) from the top and (b) from the side

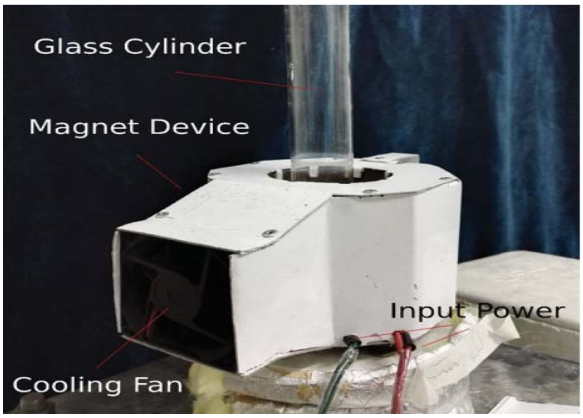
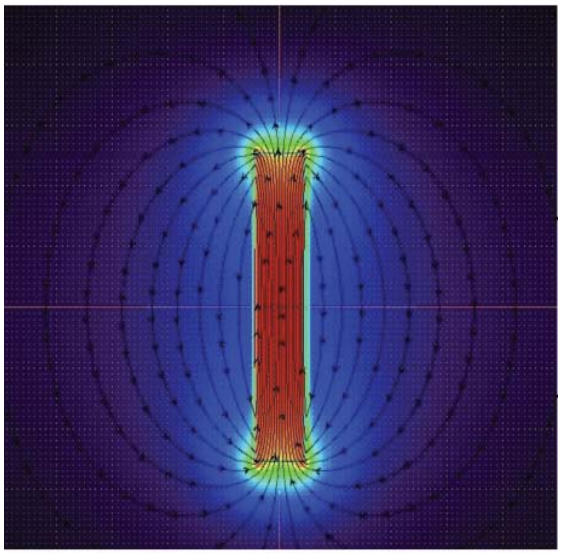


Fig ~~3.3.1 4~~ An image of the magnetic field Generator


Fig. ~~3.3.1.5~~ Magnetic field contours (electromagnet with tube cores)

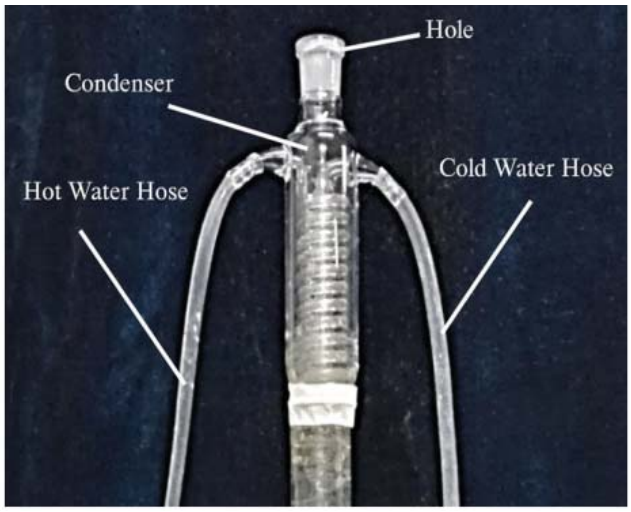


Figure ~~3.3.1.6~~ A view of the condenser used to cool the vapor down

Advantages of Design 1

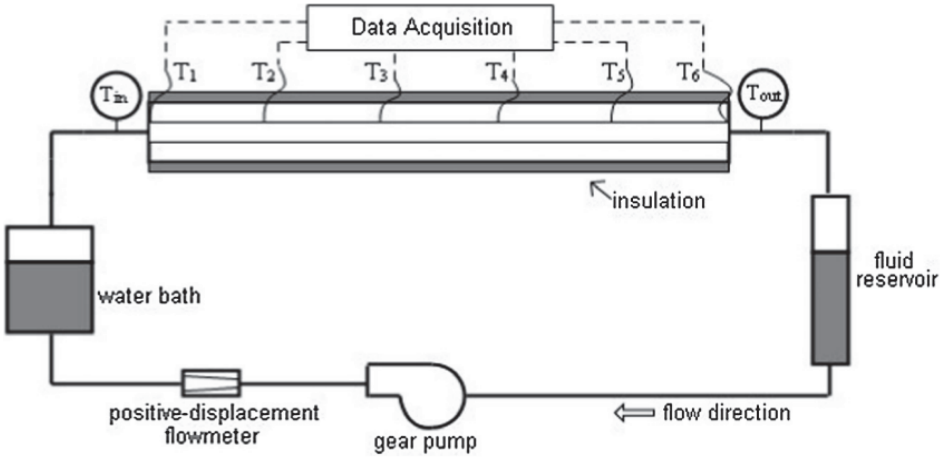
The most important advantage of that device is the condition in which it has been used. ~~the~~ magnetic field has been changed many times, affecting then the heat transfer coefficient of the nanofluids used during the experiment. This is a major change in boundary conditions in the experiment which goes along with the kind of apparatus that would be beneficial for the current project. This also suggests that the magnetic field does not affect the material used to fabricate the experimental set up which is a huge advantage for that experiment. the insulation around the copper block also allows the heat transfer coefficient to be measured as a one-dimensional parameter which is also a good advantage

Disadvantage of Design 1

The device was used in that experiment to measure the boiling heat transfer coefficient of the nanofluid. For the experiment that group number 3 wants to practice the heat transfer coefficient does not have to be measured only at boiling point. So, the device might have to be adapted to the situation. Another problem is that the only change in boundary condition applied was the change in magnetic field. The device used by group 3 for the experiment must be able to sustain other changes in boundary conditions. Also, the device does not measure directly the temperature. the temperature must be manually calculated.

3.3.2 Design 2

Another design that looked interesting and could fit the project was the one used by [2] M. Ahmadi & G. Willing represented in Fig. ~~3.3.2.1~~. The heat transfer coefficients of prepared base and nanofluids were measured using a lab-built test rig. The entire system is made from 1⁄4 in stock copper tubing and fittings. The fluid flows from the reservoir with 1.5 l capacity through a variable speed gear pump (Grainger 6NY97). Flow rates are measured using an inline flow meter connected into an electronic readout. From here the fluid flows through a copper coil held in a hot water bath which can maintain the test fluid at any temperature from room temperature up to 96C. The fluid then enters the heat exchange section. There are two thermocouples placed in the fluid at both the inlet and outlet of this section. The section itself is formed from high thermal conductivity copper refrigerator tubing that is 1.095 m length and 0.0048 m inner diameter. Six type-T thermocouples are attached equidistant along the exterior of the copper tube in this section. The entire heat exchange section is wrapped in heat tape that provides a constant heat flux to the fluid. Two layers of insulation are wrapped around the heating tape to ensure low heat loses within the heat exchange section. Temperatures are monitored in real time using a Labview program designed for the system. The heat transfer coefficient enhancement ratio at an inlet fluid temperature of 70 C and different CuO concentrations were calculated from experimental measurements.



~~Fig. 3.3.2.1~~ Schematic of heat transfer Test rig used by M. Ahmadi, G. Willing [2]

Advantages of Design 2

The design is simple which makes it more understandable and potentially easier to build and easier to improve. This design has a flowmeter that allows to read directly the flow of fluid going through the apparatus. The thermocouples also allow the temperature to be directly measured.

Disadvantages of Design 2

This device has been used in steady state boundary condition. the device might have to be revised in order to be able to apply boundary conditions that will only affect the fluid.

3.3.3 Device 3

The experimental set-up used in the study is B. Sahin, E. Manay,E.F. Akyurek ~~[5]~~ schematically shown in Figure ~~3.3.3.1~~, which consists of a heating unit, a cooling unit, a flow circulation unit, a control, and the measurement unit. The test section made from aluminum pipe has thermocouples, heater tapes, and pressure transmitters (Huba Control Inc.). The inner diameter of the aluminum test pipe with a length of 770 mm is 11.7 mm and the thickness is 1.5 mm. The test pipe was heated with coiled heaters, which provided a constant heat flux boundary condition. The heater output power was 2000 W at 187 V, and the measurement current was 10.7 A. The electrical power input to the heater was controlled by a Variac transformer to obtain constant heat flux along the test tube. The power supplied to the heater was controlled and measured with a power analyzer (Hioki USA Inc.). The outside of the test pipe was insulated with a layer of glass wool and rock wool. The flow rates were measured with an electromagnetic flowmeter (Euromag International) and the flowmeter was validated before the use. A pump, a flowmeter, a tank, and a collecting tank are used in the flow circulation unit. For the data collection, a computer, a data acquisition card, a multiplexer, and a printer were used. Two thermocouples were inserted into the flow at the inlet and outlet of the test section to measure bulk temperatures of nanofluids. The steady-state inlet and outlet bulk temperatures of the nanofluids and the surface temperature of the pipe at seven stations were measured by copper-constantan thermocouples with 0.25 mm inner diameter.The copper-constantan thermocouples were calibrated in a thermostat (Polyscience) within ±0.1∘C deviation before using them in the experiments. The readings of the thermo-couples were recorded using a computer via a data acquisition card (ADVANTEC, HG818 and 789D multiplexer), and the average of these readings was taken. The temperature of the pipe surface was taken as the average of the readings from the seven thermocouples. It is assumed that the steady state conditions were reached when the variations on each temperature station were lower than 0.5. C. Whenever

the thermal equilibrium was reached, the measured data was recorded. The Reynolds number of the CuO-water nanofluid ranging from 4.000 to 20.000 was based on the bulk mean properties and the pipe inner diameter.

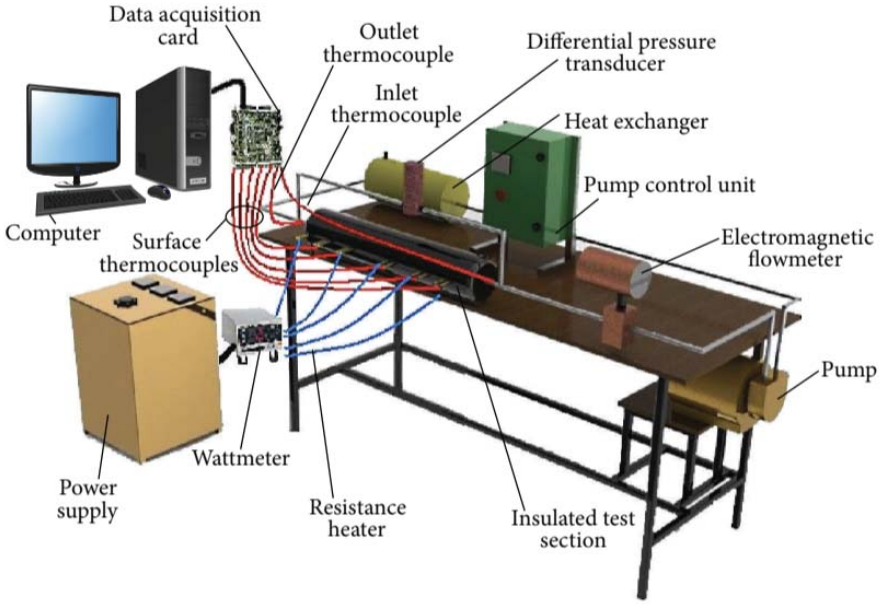


Figure ~~3.3.3.1~~ Experimental set-up ~~[~~5]

Advantages

This experimental set-up is advantageous because it also measures the pressure drop of the nanofluid through the piping system. It is also a simpler apparatus that uses the voltage and the current intensity to calculate the convection heat transfer rate that allows to calculate the convection heat transfer rate and the heat transfer coefficient. The Reynolds number and Nusselt is also determined through the piping system. It also uses multiple thermocouples.

Disadvantages

The boundary conditions in the apparatus are kept stable and are not changing. This is something that has to be taken into consideration.

3.4 Codes and Standards applied to Design

Any engineering design generated must be submitted to certain codes and standards in order to make sure that the safety of the one using it is taken into account. This is not only about safety but also about usability, cost and quality and also the innovation that is brought through the design. In the United States the ASME (American Society of Mechanical Engineers) is the one to set the standards. For this experiment the heat transfer coefficient of nanofluid is to be measured. It is to assume then that the ASME Boilers and Pressure vessel codes will be used. The code the has been taken is the code fully detailed will be listed below:

1. Section I, Power Boilers.

2. Section II, Material Specifications.

3. Section III, Rules for Construction of Nuclear Power Plant Components.

    - Division 1, Nuclear Power Plant Components.
    - Division 2, Concrete Reactor Vessel and Containments.
    - Division 3, Containment Systems and Transport Packaging for Spent Nuclear Fuel and High-Level Radioactive Waste.

4. Section IV, Heating Boilers.

5. Section V, Nondestructive Examination.

6. Section VI, Recommended Rules for Care and Operation of Heating Boilers.

7. Section VIÏ, Recommended Rules for Care of Power Boilers. Section VIII, Pressure Vessels

    - Division 1, Pressure Vessels.
    - Division 2, Pressure Vessels (Alternative Rules).
    - Division 3, Alternative Rules for Construction of High- Pressure Vessels.

8. Section IX, Welding and Brazing Qualifications. Section X, Fiber-Reinforced Plastic Pressure Vessels.

9. Section XI, Rules for In-Service Inspection of Nuclear Power Plant Components.

10. Section XII, Rules for Construction and Continued Service of Transport Tanks.

11. Code Cases: Boilers and Pressure Vessels. Code Cases: Nuclear Components.

For more detail on each section the 2017 edition of the Process Piping **Design** Handbook ~~[3]~~can be visited.

As the design is supported a lot by pipes, we will try to use the ASTM codes and standards.

A typical American Standard for Testing Materials covers, among many things, the following:

- Scope.
- Referenced documents.
- Ordering information.
- Chemical composition.
- Mechanical requirements—tensile strength, yield strength^ elongation.
- Dimension, mass, and permissible variations
- Length
- Heat treatment.
- Workmanship, finish, and appearance. Additional supplementary requirements.
- End Finish
- Test
- Retest
- Safety

- Certification
- Product making

3.5 Identifying Major Components

The first design shown in Figure ~~3.3.1.1~~ by S. Rostami , E. Raki , A. Abdollahi , A. S. Goldanlou has major components of control panel, DC power., supply, temperature sensors, electric magnet, boiling glass cylinder condenser, cooling water pipes, pump, cold water tank, Teflonbody (insulated), autotrans, and heat elements. The **control panel** manages the peripheral devices and communicates between the host computer and the peripheral devices. The control panels have the following functions: Consolidation of all connections to peripheral devices. Provision of power as needed, to peripheral devices. In other words it connects the module with a computer and maintains the power and input between the two. it also can be used as the command center of the module/design. The **DC power** converts direct current coming from the power source (a battery) from one voltage level to another depending on the point-in-time needs of the device being supplied. ... Just like with AC power supplies, DC-DC power supplies may use regulators to smooth out the signal and eliminate ripple voltage. It can be summed to the control center of the power going in and out of the device to the module. The **temperature sensors** convert thermal energy sent from an object in a wavelength range of 0.7 to 20 um into an electrical signal that converts the signal for display in units of temperature after compensating for any ambient temperature. These sensors are used to measure temperature when: Thermocouples or probes cannot be used. Another program can be used with correlation of the data collected from the sensors to shut down the module if the temperature is going above or below the safe limit. The electromagnet can be used to generate electricity with adding a coil of wire or moving it around one. It pushes the electrons in the wires and creates an electrical current, it will then convert kinetic energy into electrical energy (power). The **Condenser** condenses incoming refrigerant vapor into liquid, a compressor to raise the pressure of the refrigerant and move it along, and a fan for blowing outside air through the heat exchanger section to cool the refrigerant inside. The amount of cooling will depend on the temperature sensors. The condenser must have access to a low temperature reservoir (cold water tank), and will be moved inside pipes. The **Teflonbody** is used to coat the parts to insulate any heat or energy loss. The **Storage** is where the energy is being conserved.

Another design used by M. Ahmadi & G. Willing in Figure 8 has some similarity in the major components. The **pump** moves thermal energy in the opposite direction of spontaneous heat transfer, by absorbing heat from a cold reservoir and releasing it to a warmer one. It works similar to the condenser as they are both used to cool the device using a cold source and release it into the environment or a hot reservoir.

3.6 Relevant Subject Areas & General Equations

Most of the subject areas used in our project falls under the big umbrella of Thermodynamics, Fluids mechanics and Heat transfer. We will always start with the basic energy balance equation Etot=Ein - Eout + EStorage and derive based on the needs.

3.6.1 Sizing the Thermal Fluid Heater

The heater needs to be sized for the maximum BTU/hr requirements of the system during peak load. If the customer plans on expanding in the future, the future BTU/hr requirements also should be considered. In most cases, the customer knows what size heater is required. Otherwise, the heat required must be calculated by using the following equation:

$$Q=M \times Cp \times \Delta T \ldots \text{~~[6]~~}$$

where
Q is the heat required.

M is the quantity of material being heated.
CP is the ~~specific heat of material~~
ΔT is the difference between final temperature and initial temperature.

This calculation must include the product being heated as well as the vessel containing the product and any piping that carries the hot fluid to the product. Remember that the vessel must heat up in order to heat its contents. Heat losses also must be taken into consideration, and proper engineering practices must be followed to determine an appropriate safety factor.

3.6.2 Determining the Required Flow Rate

When flow rates have to be calculated, it is important to revert back to the equation to determine how much flow is required to remove the appropriate amount of heat from the thermal fluid flow stream. However, for this calculation, we must rearrange the equation to solve for flow rate. It looks like this:

$$M=Q / (Cp \times \Delta T) \quad ...[6]$$

where
Q is the heat being transferred to the user from the thermal fluid.
M is the required flow rate of the thermal fluid
CP is the specific heat of the thermal fluid
ΔT is an allowable temperature drop for the thermal fluid across the inlet and outlet of the user.

3.6.3 Heat Losses to the Environment

Conduction Losses:

These occur when a hot object is in touching contact with a cooler object and heat energy passes from the hot object to the cool one. It can be calculated using the following equation:

~~LConduction = Thermal Conductivity of Material Accepting Heat x Area of Contact x ΔT x 1 Hour Per Thickness of Material Accepting Heat~~...*[7]*

Convection Losses:

Heat losses due to convection are more difficult to calculate because there are many ways for heat to be removed from an object through a surrounding medium. The main challenge, among others, is due to the fact that the convection medium can be motionless or flowing, referred to as natural convection or forced convection. Convection rates also are affected by the orientation of the object in the medium due to the effects of convection boundary layers in the medium. It can be calculated using the following equation:

~~LConvection= Surface Loss (W/in2) x Area x 1 hr~~...*[7]*

Radiation Losses:

Losses due to radiation usually are insignificant at low temperatures, but they can be a large contributor of heat loss at temperatures above 500oF and should be considered when calculating wattage requirements.

~~LRadiation= Radiation Loss (W/in2) x Area x Emissivity x 1 hr~~...*[7]*

3.6.4 Resistance Temperature Detectors (Sensors)

RTDs are used to measure temperature by correlating the resistance of the RTD with temperature. This correlation between the resistance and temperature of the RTD is described by the **Callendar-Van Dusen** equation:

For Temperature: -200˚C ≤ t ≤ 0˚C,

$$RT=Ro[1 + AT +BT2 + (t-100)CT3]...[7]$$

Where,
RT= Resistance at Temperature, T
Ro= Resistance at 00C
T = Temperature in °C

For Temperature: 0˚C ≤ t ≤ 661˚C

$$RT=Ro(1+AT+BT2)...[7]$$

A, B and C are known as the Callendar-Van Dusen constants, defined by the following equations:

$$A=\alpha + (\alpha\delta)/100...[7]$$
$$B= -(\alpha\delta)/1002...[7]$$
$$C= -(\alpha\beta)/1004...[7]$$

$$\alpha= (R100-Ro)/(100+Ro)...[7]$$
$$\beta= \text{constant if } t < 0 \text{ °C, else zero}...[7]$$

$$\delta= (Ro[1+\alpha(260)]-R200)/(4.16\ Ro\alpha)...[7]$$

3.6.5 Heat Loads and Condensers

Total heat load can be calculated using the following equation:

$$h = c_p \rho\ q\ dt...[7]$$

where,

h = heat load (Btu/h)

c_p = 1 (Btu/lb_m ^oF) for water

ρ = 8.33 (lb_m/gal) for water

q = water volume flow rate (gal/min)

dt = temperature difference (^oF)

***Evaporator water flow rate** can be expressed as:*

$$qevap=24\ hevap/dt...[6]$$

where

qevap = evaporator water flow rate (gallons per minute - gpm)

hevap = air condition load

***Condenser water flow rate** can be expressed as:*

qcond=30 hcond/dt…[6]

where

qcond = condenser water flow rate (gallons per minute - gpm)

hcond = air condition load

3.7 Identifying Fabrications, Testing Methods and Procedure For Similar Designs

3.7.1 Identifying Testing Methods

Based on an article published by the Journal of the Brazilian Society of Mechanical Sciences and Engineering on May 27 2019, there are five experimental methods used for the measurement of heat transfer coefficient, which were classified into five major groups: (1) direct method, (2) transient method, (3) Wilson method, (4) heat/momentum/mass transfer analogy method and (5) boundary layer thickness method. However, this chapter will mainly be focused on two direct and transient methods since these seem to be so closer to the group project. To analyze these methods, it should be considered the constraints and accuracy reported by the improvement in the temperature and heat flux measurements techniques.

3.7.2 Direct Methods and Fabrications

The direct method is based on the application of the heat transfer definition that is given by Newton's cooling law, where all the variables that are found in this equation are measured. These variables are (1) fluid bulk temperature $T_{\infty,}$(2) wall surface temperature $T,$ (3) heat flux on the wall surface q'':

$$h = \frac{q''}{T_s - T_\infty}$$

This technique has been widely employed in research involving single-phase convection, boiling and condensation. Now, the temperature and heat flux are measured using methods such as mechanical, electrical and optical. Mechanical measurement techniques, in which liquid column expansion thermometer is one of the most widespread temperature measurement techniques, the principle involved in this method is the thermal expansion of liquid due to changes in the surrounding temperature bulb. Mercury, the most widely fluid employed due to its low vapor pressure, wide temperature range (-30 to 300 °C) and high accuracy (<0.1 °C). Electrical measurements techniques, which are defined by the use of sensing elements that produce an electrical output signal when temperature is changed. These electrical output signals are voltage, current and electrical resistance. Optical measurement techniques, which are a set of emerging techniques that maximize new applications hardly solved by mechanical or electrical temperature sensors. Their main advantages are non contact measurements, which are easy integration for obtaining high-resolution 2D temperature techniques. These techniques are chosen based on their respective application's restrictions.

The ~~table~~ below shows recent experiments that used this technique, describing the used temperature and heat flux measurement methods, the convection mode, application and reported uncertainties. More than 12 distinct direct-mode techniques are included in this table.

Table 3.1 Application and reported uncertainties

Convection mode	References	Temperature/heat flux technique	Application	Reported HTC uncertainty (%)
Gas free convection	[70,71,72]	Thermocouple/interferometry	Vertical flat plate, air	9
		Thermocouple/heat flux sensor	Building wall, air	
Gas forced convection	[54, 73]	Thermocouples/boundary layer temperature profile	Flame heat transfer	7.5
		Thermocouples/enthalpy		8–45
Liquid free convection	[74,75,76]	Thermocouple/interferometry	Supercooled water, flat plate	–
		Thermocouple/Joule effect	Horizontal gap water	–
		Platinum wire self-temperature and heating by Joule effect	Horizontal platinum wire, water	21
Liquid forced convection	[77, 78]	Thermocouple/Joule effect—direct tube heating	Water-based nanofluid	4.5
Nucleated boiling	[80, 81]	Thermocouple/Joule effect—cartridge resistance	Cylindrical surfaces with R123, R22, R134a	1.3–20 > 1
		Infrared/Joule effect	Flat horizontal surface, water	
Convective boiling	[82, 83]	Thermocouple/Joule effect—tape resistance	Horizontal copper tubes, R22, R134a, R404a	17
		Thermocouple/enthalpy profile (water)	Horizontal flat tubes, R22, R404a	6

Microchannel flow boiling	[84]	Infrared thermocouple/direct tube Joule effect	Ethanol/water flow boiling	15
	[29]	Liquid crystal/Joule effect	Vertical rectangular microchannel, R123 and R11	16.45
	[42, 85, 86]	Thermocouple/direct tube Joule effect	Single microchannel, R134a, R245fa	< 30
	[87]	Infrared RTD/Joule effect	Flow boiling multi-microchannel	15
	[88]	Thermocouple/enthalpy profile	Flow boiling inside a single microchannel, R134a and R32	8
	[41]	Infrared-TSP-thermocouple/direct tube Joule effect	Flow boiling, HF7100	–
In-tube condensation	[89]	PT100/enthalpy	Smooth and microfin tube	23
Microchannel condensation	[90]	Thermocouple/Joule effect similarity	Single channel, R134a	19.9
	[43]	Thermocouple/Peltier heat flux sensor	Parallel microchannels, R134a	5–70
Film condensation	[91]	Thermocouple/enthalpy	Steam condensation of hydrophobic surface	11.1

3.7.3 Transient Methods and Fabrications.

The transient technique is used when unsteady boundary conditions or non-equilibrium initial conditions in convective problems can be applied. First, a mathematical model of the system describing the transient response in terms of the heat transfer coefficient must be produced. With this model, the problem resumes to minimize the error between the mathematical transient model and the experimental transient data. The value of the heat transfer coefficient of the mathematical model that minimizes the error between a chosen parameter of the model and the experiment is assumed as the heat transfer coefficient value for the experiment. The main benefit of the transient method is the simplification of experiment procedure since temperature becomes the only variable needed to be considered for a long time. The transient thermal mathematical model can be of any complexity, from single lumped parameter to multidimensional transient system solved by finite-element techniques. The boundary conditions used in the experiment are bulk fluid temperature step change, plug flow and square-wave or sine wave heat flux boundary condition. Parameters used for the minimization between the mathematical model and the experimental data are maximum slope temperature derivatives, system thermal time constant, system thermal phase lag, system gain, frequency response and temperature derivatives, frequency response and temperature curve fitting usually by least square methods.

The ~~table below~~ shows some studies of HTC measurements that used the transient technique. The table provides a description of the mathematical models using the boundary condition or initial conditions, type of convection problem, application, time and spatial resolution obtained for the HTC and experimental uncertainty ranges.

Table 3.2 application, time and spatial resolution obtained for the HTC and experimental uncertainty ranges.

Transient mathematical model type/boundary conditions	References	Convection mode/application	HTC temporal/spatial resolution	Reported HTC uncertainty
1D axial conduction solid porous matrix/convection fluid bulk temperature step change	[92]	Liquid forced convection/packed bed	Time and space average	–
1D axial conduction solid porous matrix/convection fluid bulk temperature step change	[93]	Gas forced convection/bed of solids	Time and space average	–

1D conduction solid porous matrix/convection fluid bulk temperature step change	[94]	Heat exchanger surfaces/plate-fin type	Time and space average	7.5–15% (Colburn factor)
1D conduction solid porous matrix/convection fluid bulk temperature step change	[95]	Gas forced convection/heat exchanger surfaces/plate-fin type	Time and space average	< 4.32%
1D conduction, Fourier analyses/oscillating fluid temperature	[96]	Liquid forced convection water	Time and space average	< 27% (Colburn factor)
1D Fourier analyses/oscillating fluid temperature	[97]	Plate heat exchangers|	Time and space average	2.9%
1D and lumped model transfer function between fluid and solid, frequency response analysis/plug flow temperature changes	[98]	Plate heat exchangers|	Time and space average	5%
1D conduction sphere/bulk temperature step change in the convection boundary	[99]	Natural convection/food HTC	Instantaneous/space average	–
2D conduction, phase delay/square-wave radiant laser heat input	[100]	Spray cooling	Time-average/2D spatial resolution	< 20.8%
Lumped conduction/non-equilibrium initial condition in solid temperature	[101]	Natural convection/food HTC	Instantaneous/space average	–
2D conduction/square wave radiant laser heat input	[102]	Plate heat exchangers| IR measurement	Time -average/2D spatial resolution	11%
1D radial conduction/convection fluid bulk temperature step change	[103]	Air jet impingement. IR measurement	Time-average/1D radial resolution	–
Lumped conduction/bulk temperature step change	[104, 105]	Boiling, single-phase convection/quenching	Instantaneous/space average	–

in the convection boundary				
1D radial conduction/sinusoidal oscillation wall heat flux (Joule heating)	[106]	Tube internal liquid forced convection. IR measurement	Time and space average	11%
2D cylindrical coordinates heat conduction FEM inverse method/bulk temperature step input in the convection boundary	[107]	Boiling, single-phase convection/quenching	Instantaneous/space average	<8%
Lumped conduction/bulk temperature step change in the convection boundary	[108]	Natural convection/container	Time and space average	10%
1D axial conduction/sinusoidal oscillation wall heat flux (Joule heating)	[109]	Air water multiport internal liquid forced convection. IR measurement	Time and space average	13.2%
1D conduction/convection fluid bulk temperature step change	[110]	Gas forced convection/plate	Time and space average	< 10%
1D conduction/convection fluid bulk temperature step change, maximum slope method	[111]	Gas forced convection/compact heat exchanger air	Time and space average	12%

The simplest mathematical models used in transient experiments are mostly focused on single lumped models for low Biot numbers (Bi ≪ 1). Biot numbers smaller than 0.1 provide 5% maximum temperature different among all the existing points inside the boundary of the system and lumped models can be modeled by the following equation:

$$h \times As(T-T\infty) = m \times c \frac{dTdT}{dt\, dt}$$

With the initial condition given by T (t=0) = Ti. The instantaneous heat transfer coefficient can be obtained by solving for the heat transfer coefficient "h", which remains constant over time. The only variable that does not remain constant over time is the temperature "T" considering that T∞ also remains constant, which shows how simple this method is. If the heat transfer coefficient remains constant over time, the time constant of the system can also determine the time-average heat transfer coefficient as:

$$h = \frac{m \times c}{As \times T} = \frac{m \times c}{As \times T}$$

When Biot number becomes close to or higher than the unity multidimensional transient does conduction models are necessary.

3.7.4 Procedure Taken for the Direct Method

Here are some example of the direct methods used to measure the heat transfer coefficient, where it can be also shown the different procedures and approaches taken by his main protagonist:
Naylor and Duarte measured the free convection heat transfer coefficient over a vertical flat plate for air using interferometry technique. The surface and fluid bulk temperatures were measured by thermocouples, and the heat flux was measured by interferometry. Electrical strip heaters impose the heat flux on the back surface of the plate. Interferometry enabled the measurement of one-dimensional heat transfer coefficient over the entire vertical plate profile. Yoon applied a similar technique for water as the fluid. Water has higher Prandtl than air making the boundary layer thinner, which makes the optical reading of the isothermal strips obtained from interferometric readings more difficult.Yang used thermocouples to measure wall and fluid bulk temperature in free convection over a building wall. Heat flux sensors measured the wall heat flux, and they were able to measure both convective and radiant heat transfers. The advantage of the technique is that no external heat flux was imposed on the wall for the heat flux determination. Problems, however, are related to the intrusiveness of the heat flux sensor, which can add a thermal resistance layer and disrupt surface heat transfer characteristics near the wall. Han and Goldstein measured the HTC of air flowing over the surface of the turbine endwall. They used a thermocouple probe to measure the temperature profile inside the fluid boundary layer using a five-axis measurement unit (four axial and one rotational degrees of freedom). The thermocouple junction had 76 μm diameter, and the measurement unit had a 5 μm position resolution. The heat flux was determined.

3.7.5 Procedure Taken for the Transient Methods

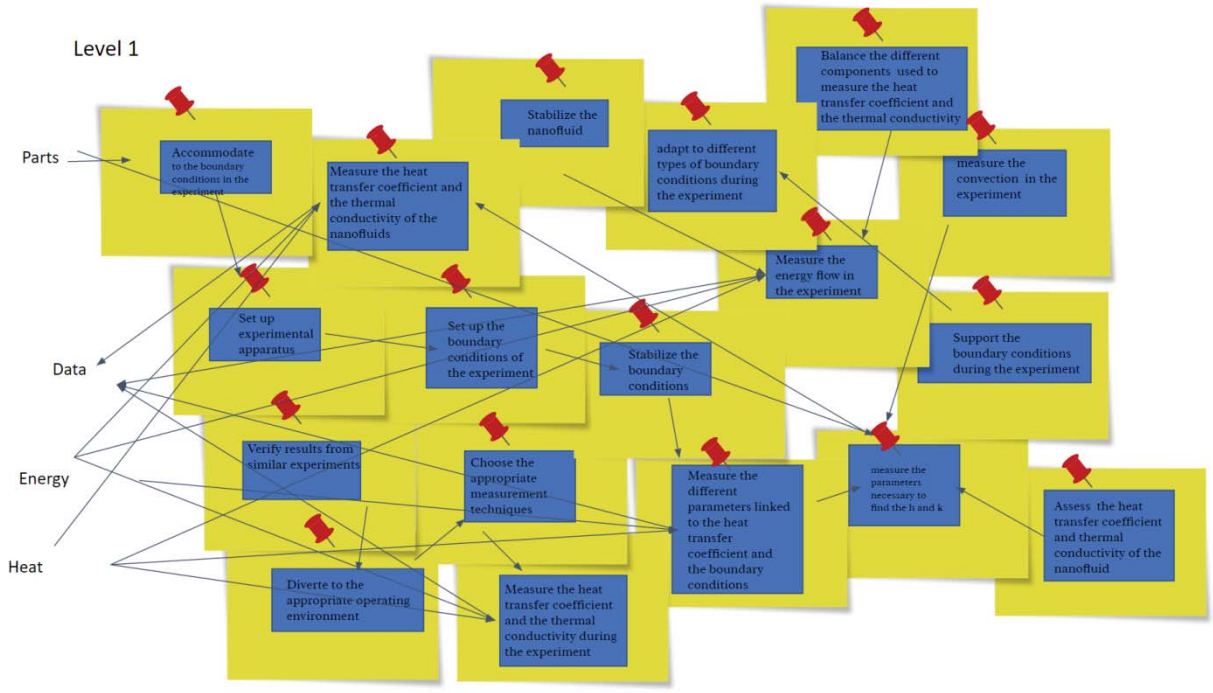
Here are some example conducted by this method:
Schumann was the first to solve the transient one-dimensional problem systematically for HTC measurements. He demonstrated a solid porous matrix with internal flow as a one-dimensional transient conduction problem subject to fluid bulk step alteration initial condition. This technique is also known as single-blow transient technique and characterized by a fluid stream flowing steadily in the test matrix up to an instance where a transient perturbation of the fluid temperature is forced. The variation in the test matrix temperature enables the heat transfer coefficient determination. Furnas, Pucci, Heggs and Burns adapted the method to different conditions, as a bed of solids and heat exchangers. Becker and Fricke utilized an one-dimensional transient conduction model of a sphere to analyze the heat transfer coefficient of food during a cooling process. Krishnakumar reviewed the single-blow method for transient heat transfer coefficient measurements.
Freund developed a spray cooling system measuring the two-dimensional HTC distribution on the wall. The spray cooled one side of the wall, and the backside was heated by a 0.25-Hz-pulsed laser source. An infrared camera with 0.4 mm spatial resolution and 30 Hz acquisition rate measured the temperature field in the back wall. A two-dimensional mathematical model of the system was developed and solved by a finite-difference method in order to transform the measured temperature field into the equivalent heat transfer coefficient of the spray side. Freund and Kabelac applied a similar technique to study a plate heat exchanger.

4. PRELIMINARY DESIGN

This status report covers some of the information on the preliminary design chapter of the project report, which was mostly based on the functional decomposition and how the group members were able to come out with different ideas to solve the problem that was presented to them during the senior design project selection. In this status report, group members had the chance to participate and present their ideas on how the problem could be solved through the functional decomposition method. This selection method focuses on three main levels where the best ideas were selected through a process run by four levels. Those are level zero, which is where the problem statement or overall function is presented, level one, where the first and different functions were extracted from group members, level two, which is taken form level one due to similarities among the different ideas and level three, which follows and was taken from level two also due to the same reasons as level two was extracted from level one.

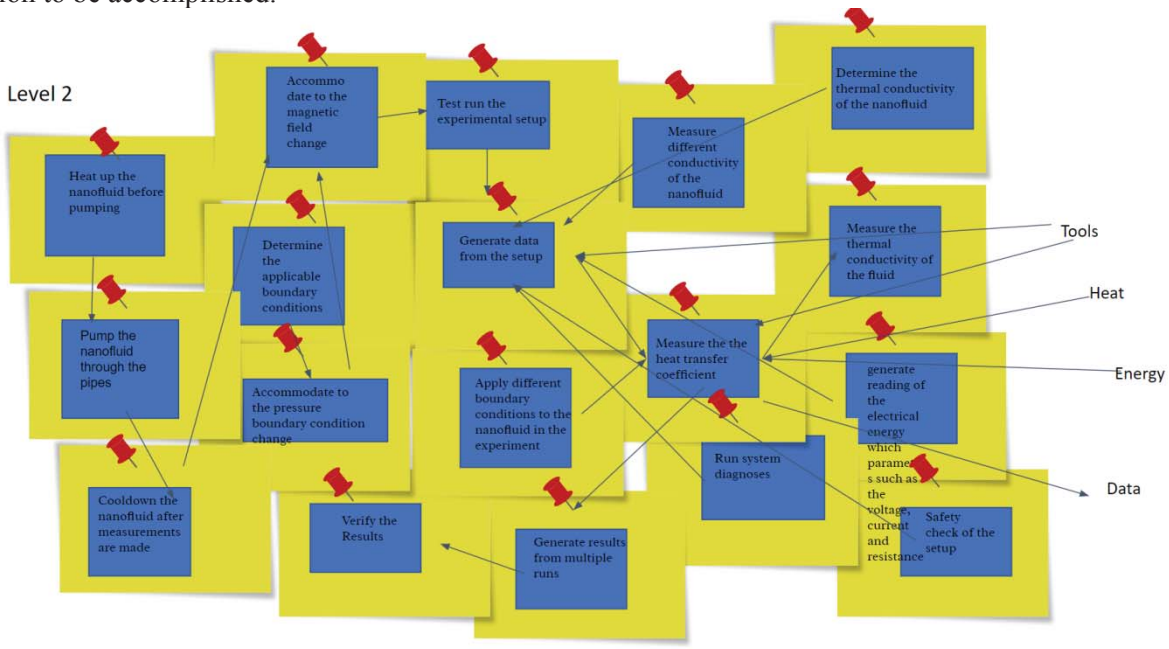
4.1 Functional Decomposition

In this section, three suggestions were provided by each group member for the overall function and then, collected by the group leader as sticky notes. These sticky notes were later pasted on one page as participation and representation of every group member's idea. This was the initiation of level one, since level zero is mostly made up of the overall function or problem statement. Then, the group analyzed the differences and similarities that were found in every single idea to determine the overall function that needs to be accomplished by the design and used them to identify overall functions, create the black box for your project showing the overall function, inputs, and outputs.

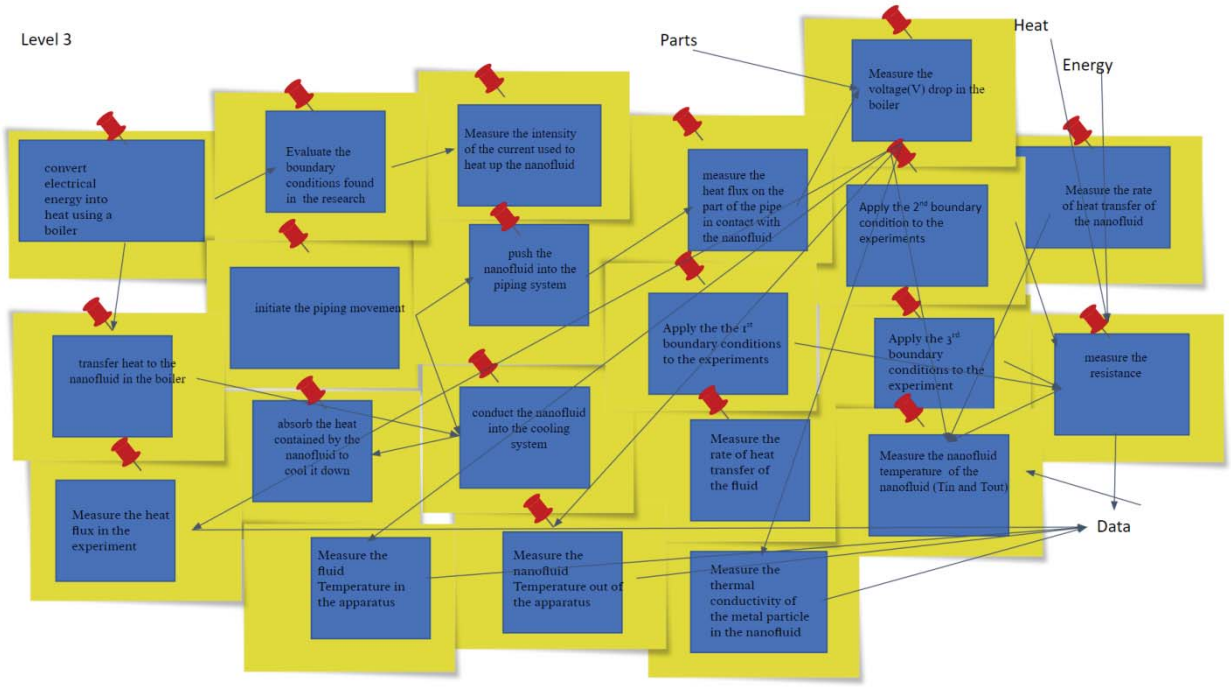


In this section, the sticky notes sheets were used to decompose the overall function into simple level 1 sub-function descriptions using the guidelines provided by the mechanical engineering senior manual. The sticky notes from each group member were then collected and pasted on a page to produce a figure similar

to Figure 3 in the splash guard found on the senior design manual. .To describe the sub functions verbs nouns and modifiers were used to better describe the goal and objective of each sub function. From the suggestions on the sticky notes, group members discussed, combined or eliminated in order to arrive at suitable level 1 sub-functions for the project similar to that shown in Figure 4 for the Splash guard. Then, the inputs and the outputs for each sub-function were identified as detailed on what it is needed for the function to be accomplished.



To determine the level 2 sub-functions, each member of the group was tasked with decomposing each of the level 1 sub-functions. As a group, sticky notes were created on an external website (canvas) to stay decent and in order and keep track of which group member suggested the respective level 1 sub-functions. Each sticky note was represented with an overlapping text box containing potential level 2 sub-functions in the form of action items and verbs. After compiling each sticky note on a blank page, the group discussed which sub-functions could be combined, eliminated, or conformed to be appropriate to the project pertaining to our group. This would lead into suitable level 2 sub-functions that the group approves of as a whole and gives the group an opportunity to identify the inputs and outputs for our now level 2 sub-functions.



After identifying the level 2 sub-functions, we repeated step 3 to create step 4 which would be our level 3 sub-functions. We continued to decompose the remaining sub-functions until we were unable to decompose any further which gave us a clear understanding of our sub-functions for each level as well as any sub-functions that were extended past level 3 sub-functions.

For the last section of our functional decomposition, a table was created to show a visual representation of what our group wrote on the sticky notes. This table will identify the overall function, level 1 sub-functions, level 2 sub-functions, and level 3 sub-functions. The overall functions, and sub-functions are broken down into verbs, nouns, and modifiers to make clear the description of the sub-functions to the project owner and customers.

Overall Function	Level 1 Sub-functions	Level 2 Sub-functions	Level 3 Sub-functions	Concept 1		Concept 2		Co
				Description	Sketch	Description	Sketch	Descripti
Measure the heat transfer coefficient and the thermal conductivity of nanofluid under different boundary conditions	make t the nanofluid during the experiment	Heat up the nanofluid before pumping	convert electrical energy into heat using a boiler					
			transfer heat to the nanofluid in the boiler					
		Pump the nanofluid Through the pipes	initiate the piping movement					
			push the nanofluid into the piping system					
		cool down the	conduct the nanofluid into					

		nanofluid after the measurements are made	the cooling system absorb the heat contained by the nanofluid to cool it down					
	accommodate to different type of boundary conditions for the experiment	Accomodate to the magnetic field change	~~Find~~ different ~~types of~~ ~~boundary~~ ~~conditions for~~ the ~~experiment~~					
			~~Evaluate the boundary conditions found in~~ the research					
		Accomodate to the pressure boundary condition change						
		Accommodate the boundary layer change of the nanofluid						
	Measure the heat transfer coefficient and the thermal conductivity of the nanofluid	Measure the heat transfer coefficient of the nanofluid in the experiment	Measure the voltage(V) drop in the boiler					
			Measure the nanofluid temperature of the nanofluid (Tin and Tout)					
			Measure the intensity of the current used to heat up the nanofluid					
		Measure the thermal conductivity of the nanofluid in the experiment	measure the heat flux on the part of the pipe in contact with the nanofluid measure the nanofluid temperature					

			Measure the rate of heat transfer of the nanofluid					
		generate reading of the electrical energy which parameters such as the voltage, current and resistance	be able to read the voltage					
			To analyze the current flowing on device					
			measure the resistance					

VNM= **V**erb action-**N**oun the verb is acting on-**M**odifier E.g. Protect-Rider-From Dirt

5. RESULTS & DISCUSSION

5.1 Summary of Goals and Objectives

The goal for that project is to be able to create an experimental setup that can help in the measurement of the heat transfer coefficient and thermal conductivity of nanofluids. The experimental setup must be able to generate fast results without compromising the accuracy of the results. In order to build the apparatus and conduct the experiment it is important to collect data on and understand different measurement techniques for convection and choose the ones that would be appropriate for nanofluids under different boundary conditions. The accuracy of the results will be judged on the fact that whether or not it is in the range of results from previous experiments of the same kind. However, the goal is to have results more accurate than any previously conducted experiment and this will be made by knowing the flaws of the apparatus in those experiments and make sure that the newly created apparatus is as much as possible free of these flaws.

5.2 Discussion of Completed work

Important subjects such as project planning, literature review, and functional decomposition were discussed throughout the different chapters. For instance, throughout the project planning it can be observed how this group had a chance to identify and divide the different tasks and gave an estimated time on how long it was going to take to complete each and every single one of them. However, on the other hand, chapters like the literature were able to introduce the group to a deeper analysis as far as the project is concerned. For example, the measurements, techniques, apparatus, fabrications equations, advantages and disadvantages that other engineers or scientists came across while dealing with similar projects or designs. This was able to provide important content that was going to help the group have a better understanding of what needed to be done to successfully conduct this project. And finally, finally the functional decomposition, which gave the group the chance to come up with suggestions that were later on turn out into functions made up of verbs, nouns and modifiers that will help the group solve the overall function or original problem scope where the need is well presented.

5.3 Summary of Constraints and Codes used and met by Design

The constraints that were determined were based on past experiments and studies done that previous engineering students, professors, and scientists have conducted to deduce the proper techniques for this project. The codes used were derived from the ASME Boilers and Pressure vessel codes. These were the standards that the group adhered to in order to develop proper language for the project. The constraints consisted of equality constraints which deal with dealing with high level temperatures, inequality constraints which deal with a flexible or inflexible boundary conditions, and lastly "yes or no" constraints which have to deal with success or failure in measuring the heat transfer coefficient and thermal conductivity in the nanofluids. These codes and constraints are essential to the success of this systematic project due to the fact that without these guidelines in place the problem that must be solved within the heat transfer mechanics will go unanswered.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

In conclusion the problem of obtaining fast and accurate results on the measurement of heat transfer coefficient and the thermal conductivity is a problem that needs to be solved. Many previous experiments have been conducted on that subject. However, this project is intended to create a better and safer apparatus while respecting the different constraints linked to the execution of the project and while making it also easy to use. The creation of this experimental set up will be a game changer for the industries that work directly with nanofluid as it would be a great time saver and therefore a money saver.

6.2 Recommendations

As it was stated before, there are many advantages and disadvantages scientists came across with when trying to measure the heat transfer coefficient and thermal conductivity of nanofluids under different

boundary conditions. From the apparatus to the measurement used and recommendations were made based on how important or useful those were.

For instance, when it comes to looking at design 1, it can be found that one of the devices used on the experiment was the laboratory test rig, which allows the users to change the magnetic fields many times. This affects the heat transfer coefficient of the nanofluids, which is a major change in boundary conditions and could be totally recommended for the current project since one the aspect we will be dealing with as boundary condition is the magnetic field.

Another recommendation would be to use thermocouple to measure wall and fluid bulk temperature in the free convection in the free convection over the building wall since that way, the Heat flux sensors would be able to measure both convective and radiant heat transfer coefficient w just as Yang, one of the scientist who measure the heat transfer coefficient did through the direct method.

LIST OF REFERENCES

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- [7]Kothandaraman, C. P. (2012). *Fundamentals of heat and mass transfer*. New Delhi: New Age International (P) Limited.

APPENDIX A

A.1 Project Selection and Team Formation

	Name of Group Member	Assigned Role	Phone Number	e-mail Address
1	Fanta Kaba	Writer & Recorder	832-762-1173	fantakaba50@gmail.com
2	Yemboado Brayan Yonli	Design Analysis Leader & Budgeter/Burchaser	713-894-4648	yyonli@student.pvamu.edu
3	Diana Morales	Proof Reader and Ideas Facilitator	281-236-0581	dmorales4@student.pvamu.edu
4	Abdullah EL Aker	Manufacturing & Testing Leader	832-421-0808	aelaker@student.pvamu.edu
5	Marcelo Epam Ona	Group Leader & Organizer	832-614-2426	mepam@student.pvamu.edu
6	Christian White	Graphics & Presentation	713-517-1509	cwhite52@student.pvamu.edu

A.3 Team Management and Assessment

Day of the Week	Meeting Times Start time & End time	Total meeting hours for day	Meeting Location (Location, Building, Room) Or How group plans to meet Provide link, etc. if Zoom or other electronic meeting forms being used
Tuesday	12pm - 3pm	3	https://us04web.zoom.us/j/8188851036?pwd=M083VG9mdGgzNklvUGNNS1lCRndhQT09
Friday	11am - 2pm	3	https://us04web.zoom.us/j/8188851036?pwd=M083VG9mdGgzNklvUGNNS1lCRndhQT09
Saturday	10am - 12am	2	https://us04web.zoom.us/j/8188851036?pwd=M083VG9mdGgzNklvUGNNS1lCRndhQT09

Total Meeting Hours for the week (outside class period)	8 hrs	

Meeting times with Project Faculty Owner [3]

Day of the Week	Meeting Times Start time & End time	Meeting Location (Location, Building, Room) Or How group plans to meet Provide link, etc. if Zoom or other electronic meeting forms being used
Tuesday	11am - 12pm	https://pvpanther.zoom.us/j/8487601860?pwd=TVdIVFpKZ0JHa1NoRWNpWENuNWRqQT09

A.2 Team Organization and Agreement

Dear Group 3 Members,

This letter (the "Agreement") summarizes my understanding of the agreement that we reached on September 8, 2020 after our zoom conference. If this Agreement is acceptable to you, please sign below in the space in the space designated for your signature.

As I understand it, we have agreed as follows:

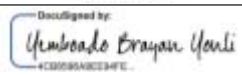
1. Agreement

It is my understanding we have agreed to the following in regards to: Group 3.

- *I have read and understood the requirements of the course and the grading policies as stated in the final course syllabus*
- *I agree to abide by the university's policy on scholastic dishonesty*

- *I hereby assign all of my intellectual property rights on the project to the sponsor of the project*
- *I agree to attend every single meeting established by the group and the project adviser unless we had a valid reason such as being in class, sick or work.*
- *Each group member agrees to be penalized by the group leader if they do not complete the part of the project that has been assigned to them.*
- *Each group member agrees to be respectful to other group members when it comes to communicating their ideas and suggestions to the group.*

Printed names, signatures and dates on agreement.

	Printed Name	**Signature**	**Date**
1	Fanta Kaba		9/5/2020
2	Yemboado Brayan Yonli		9/5/2020
3	Diana Morales		9/5/2020
4	Christian White		9/5/2020
5	Abdullah EL Aker		9/5/2020
6	Marcelo Epam Ona		9/5/2020

The agreement signed is binding on each student until the end of the semester, and violating the agreement may require you to drop the course.

Note: All signatures must be obtained through DocuSign
Note: Attach a copy of this status report sheet to your work (placed after the cover sheet) [2]
Note: Assignment for Outcome 5 in the syllabus

NOTES ON TEAM ROLES

Technical Team Roles may include but not limited to

1. **Organizer**

Leads in developing, maintaining task scheduling, and reviews progress on project schedule and refocuses efforts to meet deadlines in project schedule.

2. **Ideas Facilitator**

Leads in generating, collecting and organizing ideas.

3. **Graphics/Models Leader**

Oversees development of models, drawings, and simulations.

4. **Design analysis leader**

Oversees the various analysis needed for the design and ensures designated members present accurate design analysis and integrate analysis into the design report.

5. **Manufacturing and Testing Leader**

Oversees the fabrication, assembly, manufacture and testing of the system designed.

Non-Technical Roles may include but not limited to

1. **Budgeter /Purchaser**

Prepares detailed budget and coordinates purchasing of parts for the design

2. **Presentation Manager**

Leads in the organization, preparation and oversees presentation roles of team members.

3. **Technical Writer**

Leads in organizing, structuring and writing of the report using contributions from designated members.

4. **Proof Reader**

Responsible for ensuring the report has no grammatical or spelling errors and that the report is written using acceptable clear English language.

5. **Recorder**

Takes minutes and documents all meeting and design activities for the group. Short video clips can be used to catalog the group's activities.

Note: Group can add more roles if needed.

SENIOR DESIGN AND PREFESIONALISM I
FALL 2020

Title of Assignment: Final Report

Outcome 3
Outcome 3 Written Communication

Final Written Report used for Communication Abilities

	Relevant to ABET OUTCOME	Points Assigned	Group 3
1. Ability to organize, plan and properly format a written technical report		**450**	**379**
REPORT FORMAT DETAILS			
(i) Students are able to organize report by categorizing ideas for the report into well and logically organized chapters, major sections, subsections and paragraphs blended within the larger units.		100	95
(ii) Students provide Title Page, Abstract, and Table of Contents, list of Figures, and List of Tables properly formatted.	3	70	56
(iii) Students provide figure number and title for each figure in the report, reference each figure, and completely discuss each figure in the report in accord with standards in the project manual	3	70	60
(iv) Students provide table number and title for each table in the report in accord with standards in the project manual, reference each table and completely discuss each table in the report	3	70	70
(v) Students properly cite references in the report and provide well formatted reference list at the end.	3	**70**	**42**
(vi) Students prepare the written report in accord with standard report formatting provided in the Senior Projects Report Manual.		**70**	**56**
Total for PC1		**450**	**379**
2. Ability to compose original texts and properly apply the conventions of written language.	3	**350**	**285**
WRITTEN COMMUNICATION, GRAMMAR, SPELLING & STYLE			
(i) properly apply capitalization, punctuation, and penmanship, to communicate clearly	3	100	70
(ii) Spell proficiently	3	50	50
(iii) Apply standard grammar and usage to communicate clearly and effectively in writing • **using complete sentences**, varying the types such as compound and complex to match meanings and purposes • properly employing standard English usage in writing for audiences, including subject-verb agreement, pronoun referents, and parts of speech • properly using adjectives (comparative and superlative forms) and adverbs appropriately to make writing vivid or precise • properly using prepositional phrases to elaborate written ideas • properly using conjunctions to connect ideas meaningfully	3	150	120
(iv) Use available technology to support aspects of creating, revising, editing, spell checking, and publishing the report.		50	45
Total for PC2		**350**	**285**
3. Ability to provide appropriate discussion, conclusions and recommendations		**200**	**140**
COMPREHENSIVE SUMMARIES OF REPORT, CONCLUSIONS &			
(i) Summarize the goals, objectives, and indicate whether they were met.	3	50	40
(ii) Summarize the results.	3	50	30
(iii) Summarize constraints and codes and indicate whether they were met.	3	50	35
(iv) Provide logical conclusions and recommendations (including strengths and weaknesses).	3	50	35
Total for PC3		**200**	**140**
Total for Written Report		1000	804
TOTAL PERCENTAGE		**100**	80.4

ESD	Max	Score	% Score
PC1	45	45	37.9
PC2	35.00	35.00	28.50
PC3	20.00	20.00	14.00
TOTAL	100.00	100.00	80.40

Did not make corrections	Did not make corrections	Adjusted Written	Design	Average
Epam Ona	-2.00	78.40	78.25	**78.33**
Kaba	-1.00	79.40	78.25	**78.83**
Morales	0.00	80.40	78.25	**79.33**
El Aker	-1.00	79.40	78.25	**78.83**
White	0.00	80.40	78.25	**79.33**
Yonli	-6.00	74.40	78.25	**76.33**

Final Design Report Grading
Group __3__

Outcomes 2 & 5
Ability to Design/Teamwork

PROJECT DESIGN CONTENT EVALUATION	Relevant to ABET Outcome	Points Assigned	Group 3
1. Ability to Define/Understand the Problem and then Plan the Project		**200**	**163**
PROJECT SCOPE	Team Work		
(i) Identify the customer and the needs.	5	20	16
(ii) Identify and list the design objectives.	5	40	24
(i) Identify the design constraints.	5	20	16
Potential impact of project on society	5	20	18
PROJECT PLANNING			
(iii) Identify and break down work into tasks and subtasks and identify the personnel and deliverables for each.	5	50	45
(iv) Develop a Gantt chart and critical path analysis for managing the project.	5	**30**	24
(v) Establish major milestones for tracking progress and define performance metrics to measure success	5	**20**	**20**
Total for PC1		**200**	**163**
2. Ability to Conduct a Review of the Literature, Generate Ideas and Apply Creativity	DESIGN	400	363
LITERATURE REVIEW			
(i) Identify the types of information needed for a complete understanding of all aspects of the project (Based on task described in the project planning).	2	20	16
(ii) Gather information on relevant fundamentals, theory / demonstrate technical competence and relate them to the design Bulk of Literature Review).	2	100	85
FUNCTIONAL DECOMPOSITION, CONCEPTS GENERATION & EVALUATION			
(iii) Define functional requirements for design (Specific required actions needed to be performed for the design to be achieved).	2	100	95
(iv) Transform functional requirements into candidate solutions / mathematical modeling.	2	100	95
(v) Evaluate candidate solutions to arrive at feasible designs.	2	80	72
Total for PC2		400	363
3. Ability to Perform Preliminary and Detailed Design	DESIGN	400	256.5
ENGINEERING DESIGN ANALYSIS			
(i) Applicable codes and standards for the design were identified and used	2	40	0
(ii) Perform relevant detailed analysis (engineering, mathematical, economic) in accord with applicable codes and standards.	2	150	127.5
(iv) Design done within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	2	**20**	**18**
SOLIDS MODELS, DRAWINGS, ASSEMBLIES, SPECIFICATIN			
(vi) Generate CAD solid models and drafts of components and a solid model of the assembly of the design.	2	150	75
(v) Select materials/components/software/test equipment.	2	0	
(iii) Develop final design specifications and list of components in system	2	40	36
Total for PC3		400	256.5
Total Score for All Outcomes		1000	782.5
TOTAL PERCENTAGE		**100**	**78.25**

SDP I	Max	Score	% Score
PC1	20	20	16.3
PC2	40.00	40.00	36.30
PC3	40.00	40.00	25.65
TOTAL	100.00	100.00	78.25

Outcome 3
Outcome 3 Written Communication

Final Written Report used for Communication Abilities

	Relevant to ABET OUTCOME	Points Assigned	Group 7
1. Ability to organize, plan and properly format a written technical report		**450**	**392.5**
REPORT FORMAT DETAILS			
(i) Students are able to organize report by categorizing ideas for the report into well and logically organized chapters, major sections, subsections and paragraphs blended within the larger units.		100	95
(ii) Students provide Title Page, Abstract, and Table of Contents, list of Figures, and List of Tables properly formatted.	3	70	42
(iii) Students provide figure number and title for each figure in the report, reference each figure, and completely discuss each figure in the report in accord with standards in the project manual	3	70	66.5
(iv) Students provide table number and title for each table in the report in accord with standards in the project manual, reference each table and completely discuss each table in the report	3	70	70
(v) Students properly cite references in the report and provide well formatted reference list at the end.	3	**70**	**63**
(vi) Students prepare the written report in accord with standard report formatting provided in the Senior Projects Report Manual.		**70**	**56**
Total for PC1		**450**	**392.5**
2. Ability to compose original texts and properly apply the conventions of written language.	3	**350**	**335**
WRITTEN COMMUNICATION, GRAMMAR, SPELLING & STYLE			
(i) properly apply capitalization, punctuation, and penmanship, to communicate clearly	3	100	95
(ii) Spell proficiently	3	50	50
(iii) Apply standard grammar and usage to communicate clearly and effectively in writing • **using complete sentences**, varying the types such as compound and complex to match meanings and purposes • properly employing standard English usage in writing for audiences, including subject-verb agreement, pronoun referents, and parts of speech • properly using adjectives (comparative and superlative forms) and adverbs appropriately to make writing vivid or precise • properly using prepositional phrases to elaborate written ideas • properly using conjunctions to connect ideas meaningfully	3	150	140
(iv) Use available technology to support aspects of creating, revising, editing, spell checking, and publishing the report.		50	50
Total for PC2		**350**	**335**
3. Ability to provide appropriate discussion, conclusions and recommendations		**200**	**140**
COMPREHENSIVE SUMMARIES OF REPORT, CONCLUSIONS &			
(i) Summarize the goals, objectives, and indicate whether they were met.	3	50	35
(ii) Summarize the results.	3	50	35
(iii) Summarize constraints and codes and indicate whether they were met.	3	50	35
(iv) Provide logical conclusions and recommendations (including strengths and weaknesses).	3	50	35
Total for PC3		**200**	**140**
Total for Written Report		1000	867.5
TOTAL PERCENTAGE		**100**	86.75

ESD	Max	Score	% Score
PC1	45	45	39.25
PC2	35.00	35.00	33.50
PC3	20.00	20.00	14.00
TOTAL	100.00	100.00	86.75

Did not make corrections	Did not make corrections	Adjusted Written	Design	Average
Janda	-6.00	80.75	84.96	**82.86**
Trevino	0.00	86.75	84.96	**85.86**
Akpan	-2.00	84.75	84.96	**84.86**
Riggins	-1.00	85.75	84.96	**85.36**
Sandford	0.00	86.75	84.96	**85.86**
Ansari	0.00	86.75	84.96	**85.86**
Cifuentes	-8.00	78.75	84.96	**81.86**

Final Design Report Grading
Group ____

Outcomes 2 & 5
Ability to Design/Teamwork

PROJECT DESIGN CONTENT EVALUATION	Relevant to ABET Outcome	Points Assigned	Group 7
1. Ability to Define/Understand the Problem and then Plan the Project		**200**	**186.25**
PROJECT SCOPE	Team Work		
(i) Identify the customer and the needs.	5	20	20
(ii) Identify and list the design objectives.	5	40	40
(i) Identify the design constraints.	5	20	19
Potential impact of project on society	5	20	10
PROJECT PLANNING			
(iii) Identify and break down work into tasks and subtasks and identify the personnel and deliverables for each.	5	50	48.75
(iv) Develop a Gantt chart and critical path analysis for managing the project.	5	**30**	28.5
(v) Establish major milestones for tracking progress and define performance metrics to measure success	5	**20**	**20**
Total for PC1		**200**	**186.25**
2. Ability to Conduct a Review of the Literature, Generate Ideas and Apply Creativity	DESIGN	400	376.8
LITERATURE REVIEW			
(i) Identify the types of information needed for a complete understanding of all aspects of the project (Based on task described in the project planning).	2	20	19
(ii) Gather information on relevant fundamentals, theory / demonstrate technical competence and relate them to the design Bulk of Literature Review).	2	100	90
FUNCTIONAL DECOMPOSITION, CONCEPTS GENERATION & EVALUATION			
(iii) Define functional requirements for design (Specific required actions needed to be performed for the design to be achieved).	2	100	100
(iv) Transform functional requirements into candidate solutions / mathematical modeling.	2	100	97
(v) Evaluate candidate solutions to arrive at feasible designs.	2	80	70.8
Total for PC2		400	376.8
3. Ability to Perform Preliminary and Detailed Design	DESIGN	400	286.5
ENGINEERING DESIGN ANALYSIS			
(i) Applicable codes and standards for the design were identified and used	2	40	0
(ii) Perform relevant detailed analysis (engineering, mathematical, economic) in accord with applicable codes and standards.	2	150	112.5
(iv) Design done within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	2	**20**	**18**
SOLIDS MODELS, DRAWINGS, ASSEMBLIES, SPECIFICATIN			
(vi) Generate CAD solid models and drafts of components and a solid model of the assembly of the design.	2	150	120
(v) Select materials/components/software/test equipment.	2	0	
(iii) Develop final design specifications and list of components in system	2	40	36
Total for PC3		400	286.5
Total Score for All Outcomes		1000	849.55
TOTAL PERCENTAGE		**100**	**84.96**

SDP I	Max	Score	% Score
PC1	20	20	18.625
PC2	40.00	40.00	37.68
PC3	40.00	40.00	28.65
TOTAL	100.00	100.00	84.96

Outcome 3
Outcome 3 Written Communication

Final Written Report used for Communication Abilities

	Relevant to ABET OUTCOME	Points Assigned	Group 8
1. Ability to organize, plan and properly format a written technical report		**450**	**389**
REPORT FORMAT DETAILS			
(i) Students are able to organize report by categorizing ideas for the report into well and logically organized chapters, major sections, subsections and paragraphs blended within the larger units.		100	95
(ii) Students provide Title Page, Abstract, and Table of Contents, list of Figures, and List of Tables properly formatted.	3	70	42
(iii) Students provide figure number and title for each figure in the report, reference each figure, and completely discuss each figure in the report in accord with standards in the project manual	3	70	70
(iv) Students provide table number and title for each table in the report in accord with standards in the project manual, reference each table and completely discuss each table in the report	3	70	63
(v) Students properly cite references in the report and provide well formatted reference list at the end.	3	**70**	**63**
(vi) Students prepare the written report in accord with standard report formatting provided in the Senior Projects Report Manual.		**70**	**56**
Total for PC1		**450**	**389**
2. Ability to compose original texts and properly apply the conventions of written language.	3	**350**	**335**
WRITTEN COMMUNICATION, GRAMMAR, SPELLING & STYLE			
(i) properly apply capitalization, punctuation, and penmanship, to communicate clearly	3	100	95
(ii) Spell proficiently	3	50	50
(iii) Apply standard grammar and usage to communicate clearly and effectively in writing • **using complete sentences**, varying the types such as compound and complex to match meanings and purposes • properly employing standard English usage in writing for audiences, including subject-verb agreement, pronoun referents, and parts of speech • properly using adjectives (comparative and superlative forms) and adverbs appropriately to make writing vivid or precise • properly using prepositional phrases to elaborate written ideas • properly using conjunctions to connect ideas meaningfully	3	150	140
(iv) Use available technology to support aspects of creating, revising, editing, spell checking, and publishing the report.		50	50
Total for PC2		**350**	**335**
3. Ability to provide appropriate discussion, conclusions and recommendations		**200**	**150**
COMPREHENSIVE SUMMARIES OF REPORT, CONCLUSIONS &			
(i) Summarize the goals, objectives, and indicate whether they were met.	3	50	35
(ii) Summarize the results.	3	50	40
(iii) Summarize constraints and codes and indicate whether they were met.	3	50	35
(iv) Provide logical conclusions and recommendations (including strengths and weaknesses).	3	50	40
Total for PC3		**200**	**150**
Total for Written Report		1000	874
TOTAL PERCENTAGE		**100**	87.4

ESD	Max	Score	% Score
PC1	45	45	38.9
PC2	35.00	35.00	33.50
PC3	20.00	20.00	15.00
TOTAL	100.00	100.00	87.40

Did not make corrections	Did not make corrections	Adjusted Written	Design	Average
Barbee	-5.00	82.40	73.13	**77.77**
King	-5.00	82.40	73.13	**77.77**
Woodard	-5.00	82.40	73.13	**77.77**
Horta	-5.00	82.40	73.13	**77.77**
Maxwell	-5.00	82.40	73.13	**77.77**
Samuel	-5.00	82.40	73.13	**77.77**
Ward	-5.00	82.40	73.13	**77.77**

Final Design Report Grading
Group ____

Outcomes 2 & 5
Ability to Design/Teamwork

PROJECT DESIGN CONTENT EVALUATION	Relevant to ABET Outcome	Points Assigned	Group 8
1. Ability to Define/Understand the Problem and then Plan the Project		**200**	**174.75**
PROJECT SCOPE	Team Work		
(i) Identify the customer and the needs.	5	20	20
(ii) Identify and list the design objectives.	5	40	40
(i) Identify the design constraints.	5	20	18
Potential impact of project on society	5	20	18
PROJECT PLANNING			
(iii) Identify and break down work into tasks and subtasks and identify the personnel and deliverables for each.	5	50	48.75
(iv) Develop a Gantt chart and critical path analysis for managing the project.	5	**30**	18
(v) Establish major milestones for tracking progress and define performance metrics to measure success	5	**20**	**12**
Total for PC1		**200**	**174.75**
2. Ability to Conduct a Review of the Literature, Generate Ideas and Apply Creativity	DESIGN	400	331
LITERATURE REVIEW			
(i) Identify the types of information needed for a complete understanding of all aspects of the project (Based on task described in the project planning).	2	20	18
(ii) Gather information on relevant fundamentals, theory / demonstrate technical competence and relate them to the design Bulk of Literature Review).	2	100	85
FUNCTIONAL DECOMPOSITION, CONCEPTS GENERATION & EVALUATION			
(iii) Define functional requirements for design (Specific required actions needed to be performed for the design to be achieved).	2	100	95
(iv) Transform functional requirements into candidate solutions / mathematical modeling.	2	100	65
(v) Evaluate candidate solutions to arrive at feasible designs.	2	80	68
Total for PC2		400	331
3. Ability to Perform Preliminary and Detailed Design	DESIGN	400	225.5
ENGINEERING DESIGN ANALYSIS			
(i) Applicable codes and standards for the design were identified and used	2	40	0
(ii) Perform relevant detailed analysis (engineering, mathematical, economic) in accord with applicable codes and standards.	2	150	97.5
(iv) Design done within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	2	**20**	**18**
SOLIDS MODELS, DRAWINGS, ASSEMBLIES, SPECIFICATIN			
(vi) Generate CAD solid models and drafts of components and a solid model of the assembly of the design.	2	150	90
(v) Select materials/components/software/test equipment.	2	0	
(iii) Develop final design specifications and list of components in system	2	40	20
Total for PC3		400	225.5
Total Score for All Outcomes		1000	731.25
TOTAL PERCENTAGE		**100**	**73.13**

SDP I	Max	Score	% Score
PC1	20	20	17.475
PC2	40.00	40.00	33.10
PC3	40.00	40.00	22.55
TOTAL	100.00	100.00	73.13

ABOVE AVERAGE

"Design, Fabrication, and Testing of an Automated Oil Recovering Skimmer"

Senior Design & Professionalism I

Final Report

Submitted by

Ximena Cifuentes

Caleb Riggins

Demetrious Sanford

Amna Ansari

Aamna Jangda

Daniel Akpan

David Trevino

To

Dr. Xiaobo Peng

Senior Design Instructor

Department of Mechanical Engineering

College of Engineering

Prairie View A&M University

December 7, 2020

SENIOR DESIGN & PROFESSIONALISM I FALL 2020 PROJECT PROGRESS REPORT COVER SHEET

PROJECT TITLE: _Design, Fabrication, and Testing of an Automated Oil Recovering Skimmer

GROUP NUMBER: ___7___

Progress Report Title: Final Report
Due Date: 12/7/2020

No	Group Member Name Group Member signature	Brief Description of Work Assigned to Member	% Completed by Member	Your Score
1	**Daniel Akpan** DocuSigned by: D752FAC3D5EC429...	**Section work:** Revise:Chapter 2 Assist: formatting and tables **Attendance:** attend meetings. **Participation:** participate in meetings.	**100%**	
2	**David Trevino** DocuSigned by: David Trevino 70629F9F1296489...	**Section work:** Revise:Chapter 7 Assist: formatting and tables **Attendance:** attend meetings. **Participation:** participate in meetings.	**100%**	
3	**Amna Ansari** DocuSigned by: Amna Ansari E25E51620421451...	**Section work:** Revise: Chapter 5 Assist: formatting and tables **Formatting**: indenting sections, font type and size consistency, page numbers. **Minutes:** Record meeting minutes for each meeting and record of attendance. **Attendance:** attend meetings. **Participation:** participate in meetings	**100%**	
4	**Demetrious Sandford** DocuSigned by: Demetrious Sandford C7D32FE84B0A419...	**Section work:** Revise:Chapter 6 Assist: formatting and tables **Proofreading:** Full report **Formatting:** indenting sections, font type and size consistency. **Meeting:** Organize meeting times. **Attendance:** attend meetings. **Participation:** participate in meetings.	**100%**	
5	**Caleb Riggins** DocuSigned by: Caleb Riggins 41AFA23858EE4BC...	**Section work:** Revise: Chapter 1 Assist: formatting and tables Complete: Chapter 5 and 6 **Technical writing review:** Full report **Formatting:** indenting sections, font type and size consistency, page numbers. **Attendance:** attend meetings. **Participation:** participate in meetings.	**100%**	
6	**Ximena Cifuentes** DocuSigned by: Ximena Cifuentes BD1F416D20884F6...	**Section work:** Revise: Chapter 4 Assist: formatting and tables **Formatting:** Cover page, empty report sheet, indenting sections, font consistency. **Communication:** Send report to Dr. Park for feedback, assign tasks. **Attendance:** attend meetings. **Participation:** participate in meetings.	**100%**	
7	**Aamna Jangda** DocuSigned by: Aamna Jangda 781C4B4D2C9D46D...	**Section work:** Revise: Project scope, project planning, literature review Assist: formatting and tables **Formatting:** Font consistency within certain parts, page numbers, table formatting **Attendance:** Attend meetings **Participation:** Participate in meetings	**100%**	

*100% means the member completed his/her assigned work

By signing this assignment cover sheet, I agree that the percentages stated in the % completed column reflect the contribution made by me and the other members of the group.

Didn't make corrections

Name of Person Responsible	Sections Assigned
Ximena Cifuentes	Chapter 4 • Make corrections page 50, 22, 23, 25, 26, 27, 28, 54 • Proofread • Format • Fix figure numbers -8 Project agreement Appendix
Caleb Riggins	Chapter 1 • Make corrections • Proofread page 1 -1 • Format • Fix figure numbers All References
Demetrious Sandford	Chapter 6 • Make corrections • Proofread • Format • Fix figure numbers All References
Aamna Jangda	Chapter 3 • Make corrections page 33, 34, 36, 38, 40,40 • Proofread • Format • Fix figure numbers -6
Amna Ansari	Chapter 5 • Make corrections • Proofread • Format • Fix figure numbers Meeting minutes
Daniel Akpan	Chapter 2 • Make corrections page 27 • Proofread • Format page 27 -2 • Fix figure numbers
David Trevino	Chapter 7 • Make corrections • Proofread • Format • Fix figure numbers • Table of contents

Letter of Transmittal

December 7, 2020
Mechanical Engineering Students
100 University Dr.
Prairie View, Texas 77446

Dr. Peng Xiaobo
Senior Design and Professionalism I Instructor
Prairie View A&M University
CL Wilson 102A
December 7, 2020

Dear Dr. Peng:

This detailed Final report of Senior Design and Professionalism I, MCEG 4472, entitles project 7, which is "Automated Oil Skimmer." This report addresses educational findings on potential preliminary methods to design an automated oil skimmer that offers greater than or equal to the industrial skimmers today. The team utilized many different techniques to establish foundations for the project. The group advisors, Dr. Park and Dr. Zhou, assisted and guided the students with questions, group research, and analysis of various components functions.

If you have any questions or concerns, please call or email the group Leader, Ximena Cifuentes at (832) 755-0117 or xcifuentes@student.pvamu.edu
Sincerely,

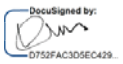
Ximena Cifuentes

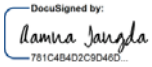

Caleb Riggins


Demetrious Sandford


David Trevino


Amna Ansari


Daniel Akpan


Aamna Jangda


Enclosure: Final Report

Acknowledgement

This manual was prepared using input from Demetrious Sandford, Caleb Riggins, Amna Ansari, Daniel Akpan, Aamna Jangda, David Trevino, and Ximena Cifuentes.

We would like to express our gratitude to Dr. Jaejong Park and Dr. Jianren Zhou for providing guidance and commitment to our project.

ABSTRACT

This project includes the design and fabrication of an automated oil skimmer to be used for oil recovery for waste management. Using codes and regulations based from the Bureau of Safety and Environmental Enforcement, Environment Protection Agency, and ASTM; preliminary procedures were taken to conduct research, fundamental analysis, concept generations and detailed CAD modeling. The team goal is to design an apparatus to enhance the oil recovery rate of oil thicknesses that are at least one-half inch. The main objectives are concerning the project aspects of safety, quality, convenience, environmental stability and economic enhancement .

The initial project constraints include the parameters of the setup, such as a 5ft by 5ft operational environment as well as operate automatically with a controlled algorithm.

A detailed analysis was performed to determine the dimensions of components to be designed into CAD modeling. Models of the main components of the skimmer are provided with detailed dimensions and overall functions.

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APPENDIX A PROJECT TEAM MANAGEMENT...……,……...ATTACHED

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All page no. are wrong for this chapter.

All page no. are wrong for this chapter.

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1. PROJECT SCOPE

In this chapter, the problem at hand will be introduced in a greater detail including the potential clients, their need, project goals, objectives, and project restraints.

1.1 Problem Statement

Today, the main form of energy source comes from crude oil and other liquids produced from fossil fuels in which they are refined into petroleum. With the advancement of technology, we can extract oil from wells through offshore drilling. However, this mode of extraction can cause harm to the environment during oil spill incidents. With the increase of incidents every year, we need to combat this using improved designs for oil skimmers which are used to ultimately recover crude oil slicks. Oil skimmers are devices that are used to remove floating oil from the surface of a body of water. With the different and unpredictable changes in the world, the current oil recovering skimmers have a lot of room for optimization. When an oil spill occurs, the skimmers need to be able to combat the situation while maintaining the safety of the environment quickly and effectively. The skimmers need to be able to retain durability and functionality. Meaning, if a situation occurs where the skimmer takes sufficient damage, it should be able to protect the oil already stored without allowing another spill.

The purpose of this project is to design, fabricate and test a fully functional automated oil skimmer for companies to use during oil spill cleanups and containment. This will be accomplished by improving upon existing oil skimmer designs and overall increase the efficiency through various constraints and innovations.

1.2 Client Identification and Recognition of Need

In this section we identified the potential clients for the automated oil skimmer. While this technology is still in development, there are dozens of companies who have created oil skimmers. The main companies our design is intended for are oil companies that operate in coastal regions. In addition, the section discusses the clients' needs. The clients' needs will open the doors to the identification of the project goal.

1.2.1 Identifying the project's client Didn't make correction

- Bureau of Safety and Environmental Enforcement: This client was chosen due to its leading division in oil recovery. Within this organization, there is a division called Oil Spill Preparedness Division (OSPD) where specialized improving spill responses are taken to help develop decision making strategies for oil spill response. The organization has developed a scientific program that seeks to improve oil spill response and oil behavior understandings. In addition, the organization focuses on detecting effective methods by using alternative solutions.

- Environmental Protection Agency: This client was chosen due to their mission in ensuring that all Americans have clean air and water. EPA is dedicated to reducing environmental risks by using the best scientific resources. One of EPA's top priorities is management of their (SPCC) Spill Prevention, Control, Countermeasure methods program.

- Marine Spill Response Corporation: This client was chosen as a potential contact due the recognition of the company. The Marine Spill Response Corporation is the largest oil response organization in the United States. In addition, if our product were to succeed, they have a robust network of qualified Spill Team Area Responders (STARs) in which we can apply and become a part of.

- Marine Preservation Association: This client was chosen due to its large influence in funding companies in the petroleum, energy, and related transportation industries. They are a leading organization in supporting the development and maintenance of effective spill response capability in the United States. They are the parent company of Marine Spill Response Corporation and include over 600 corporate members who utilize their technology in oil recovery.

- Occidental Petroleum Corporation: This client was chosen due to being an international energy company that operates in multiple regions such as the United States, Middle East, Africa, and Latin America. They are a leading producer of oil and gas and are looking into new innovations for oil skimmers to minimize damage to the environment and maximize oil recovery.

1.2.2 Identifying the client's need

A clear-cut problem for current Automated Oil skimmers is that their efficiency could be improved to where they can handle large amounts of oil in a timely manner, which in turn negatively affects marine life and potentially becomes an environmental pollutant. The Use of innovative materials like Super absorbent materials paired with nanotechnology, incorporated into an existing automated skimmer by replacing a disc or a drum would significantly increase its efficiency. The overall goal for this project is to combat oil spill situations and effectively while maintaining the safety of the environment.

Current skimmer capabilities can easily adapt to oil thicknesses that are greater than or equal to about 1-3 inches generally. If the thickness of the oil is lower than half of an inch, skimmers may ingest large amounts of water which makes the process inefficient. BSEE suggests that in actual oil spills, skimmers cannot be assumed to encounter enough oil to continuously conduct recovery operations to 50-75 mm. This is about 2-3 inches. So, it is important to understand how a skimmer's performance will vary based on oil thicknesses. Results from testing conclude that reduced oil thicknesses have a significant impact on the measured recovery capabilities.

1.3 Project Goal and Objectives

To break down the scope of the project, the team followed a series of steps. In this section, the goal statement is presented. In addition, the objectives were clearly defined and categorized to

allow the team to experience the design thinking process. Finally, the purpose of this section is to ensure that the goal allowed room for different approaches to fulfill the clients' needs.

1.3.1 Goal Statement

The project goal is to design an improved oil skimmer system with a refined process that will increase the recovery rate and oil containment capacity of current oil skimmers. The team will begin by researching and observing current oil skimmers in order to address current deficiencies/limitations as well as current successes. The scope of this goal is to design a system that offers greater efficiencies of recovery rates for oil slicks that are less than 1/2-inch thickness. During the development of the design process, the team will prioritize the responder safety, portability of technology, simplicity of use, and reduction of waste during recovery operations.

1.3.2 Design Objectives

In this subsection a variety of objectives were generated as the team collaborated about the different ways to access the clients' needs. In addition, the listed objectives were categorized between low-level and high-level objectives and their most relevant criteria category. Finally, the section demonstrates the hierarchical relationship between the objectives and their measurements units.

1. List of objectives

    - Cost effectiveness
    - Product safety
    - Durability
    - User friendly
    - Compact design
    - Eco friendly
    - Efficient recovery rate
    - Waterproof
    - Improved filtration
    - High pump capacity
    - Design should meet all federal and state regulations
    - Detachable parts
    - Oil containment capacity
    - Universal usage
    - Marketable
    - Oil removal concentration

2. Objectives in sets of higher and lower level

In Table 1.1 the objectives are organized based upon their roles within the completion of the skimmer design. All categories allow for a structured and complete analysis of possible skimmer design motives and desirables that may be considered for client needs.

Table 1.1 Categories of objectives

Safety	Quality	Environment	Economic	Workability	Conveniences
Product safety	Durability Compact design Oil removal concentration Oil Containment capacity Waterproof High pump capacity Improved filtration Detachable parts Marketable	Eco friendly	Cost effectiveness Design should meet all federal and state regulations	Efficient recovery rate Universal usage	User friendly

3. Objective Tree

Figure 1.1 is an organized assembly of the design objectives for the automated oil skimmer. Categories are presented to establish a hierarchy of requirements needed for the successful implementation of the project design process. These objectives are the major aspects of the design formulation.

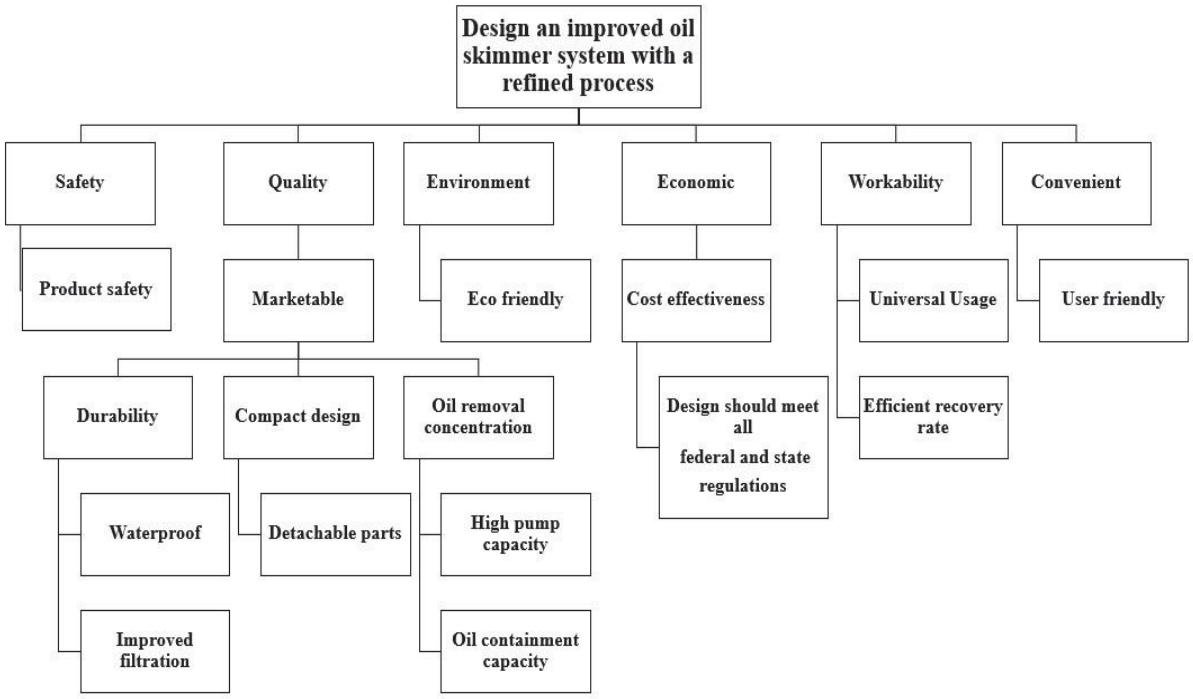


Figure 1.1 Objective tree

4. Table of measured objectives

Table 1.2 presents measured objectives that can be quantified based upon developed criteria. The basis of criteria allows for the design to offer a quantity of success within each objective that will in turn reflect the success of the design.

Table 1.2 Measured objectives

Objective	Measurement Basis	Criteria	Units
Cost effectiveness	Fabrication cost to not exceed 5000	Economic	Currency
Product safety	Product to achieve lower incident rate of current oleophilic skimmers.	Safety	Incidents/Product life cycle
Durability	Toughness of design	Quality	in·lbf·in.
Compact design	To not exceed 5ft X 5ft	Quality	ft
Eco friendly	Energy efficiency	Environment	%
Efficient recovery rate	Fast recover	Workability	recovery/min
User friendly	Completion rate	Convenient	start machine/min
Waterproof	150 fr	Quality	ft
Improved filtration	Design effective innovative filtering system	Quality	Micron
High pump capacity	High pump capacity	Quality	m3/h
Marketable	Sales performance	Quality	Number of sales
Universal usage	Product attractiveness	Workability	Number of sales
Design should meet all federal and state regulations	Compliance measurement	Economic	satisfaction rating/dollars
Detachable parts	Easy setup	Quality	Weight & quantity
Oil containment capacity	Increase in efficiency	Quality	Gallons
Oil removal concentration	Quality of pure oil removed	Quality	Grams/Gallons

1.4 Potential impact of project on society (global, national ,local) At least 1 page

The project at hand has a major impact on our society today on every level: Global, National and Local. This is due to the rising environmental instabilities created by the lack of efficient waste management around the globe today. The potential impact of developing an efficient oil skimmer that can recover oil slick thickness that are at least half an inch, can greatly contribute to the mass development and research that is currently transpiring to prevent mass environmental damage caused by human error. The continuous lack of oil spill prevention and control not only effects our environments and ecosystems, but it also indirectly effects our global, national, and local economies. Petroleum exploration in the oil and gas industry allows for stable growth for oil businesses as well as other industrial businesses, but methods of waste removal are still important to counteract accidents.
The fabrication of an efficient skimmer will not only directly impact research and development, but will also save an abundance of money, time, lawsuits, and the overall well being of our planet. This project can help affect and confront the problems at hand from the negative impacts from the oil spill crisis that we struggle with today.

1.5 Initial Project constraints and Operating Environment

All engineering designs require physical limitations to ensure that they are acceptable and functional. The design must be upheld to some initial constraints as well as be constructed within permissible parameters. The selection of these parameters and constraints were selected based on research as well as the mode of the operating environment. These selections are largely affected by the roles the design must perform within the given operating environment. This section will provide the generated lists of appropriate initial project constraints and the operating environment.

1. Initial Project Constraints

    -Must be buoyant.

    -Must be autonomous.

    -Needs to be an easily portable design.

    -Must rely upon a custom computer algorithm for tracking and movement (PROJECT 1037) (BSEE).

    -Cannot exceed an operating domain of 5 ft by 5 ft.

    -Must operate in and be accustomed to thick layers of oil, up to 3 inches.

    -Design requires an oil storage containment device.

-Skimmer must be adapted to recover different temperatures of oil.

-Skimmer design must be climate resistive or adaptable.

-Design needs a heat system to counteract ambient temperatures.

-Skimmer must include an oil capacity sensor for measuring oil thickness (Development of an Oil Thickness Sensor, PROJECT 1072). (BSEE)

-Design must be Oleophilic (An affinity to oil rather than water/be able to distinguish the difference).

-Must have a velocity between 3-5 knots or 3.5- 6 mph (Recent research has led to boom systems that can be towed at speeds up to 3-5 knots and have automated inflation and deployment capabilities. (BSEE)

-Must at least operate at an efficiency of 25%-50% in 1-inch oil thickness.

-Must have an acceptable nameplate capacity number (number which defines skimmer efficiency). (BSEE)

-ASTM F2709 calls for testing stationary oil skimmers in either pure oil, or in a threeinch layer of oil on water. However, in an actual oil spill it is likely that a skimmer will be operating in a thinner range of oil thicknesses. BSEE is conducting testing on various skimming systems in varying slick thicknesses to better understand the relationship between Oil Recovery Rates (ORR) and Recovery efficiencies (RE) and decreasing oil slick. thicknesses. (https://www.bsee.gov/research-record/evaluation-ofskimmer-performance-indiminishing-oilslick-thicknesses) TESTED ON OLEOPHILIC SKIMMERS. (BSEE)

2. Operating environment

The section below will describe the operating environment in which the skimmer will be able to function within. Decisions made for this environment were made based upon BSEE regulations as well as codes and standards given.

- Various water conditions including wavy and calm.
- Operational in different types of waters (Salt or freshwater).
- Houses in various types of marine life environments.

2. PROJECT PLANNING AND TASK DEFINITION

In this chapter, the planning of the Automated Skimmer Project will be discussed in detail. In addition, the chapter will reveal the key project tasks and subtasks that were vital to the execution of the project. The tasks will be delegated evenly depending on everyone's strengths. Finally, the chapter includes a visual representation of the fully developed project plan created by the team. The representation includes a timeline table and its interpretation in a Gantt chart form.

2.1 Task identification

In this section, the different project tasks are identified based on the hierarchy of needs for the design process. Analysis of these needs were driven through brainstorming and identifying which problems needed to be assessed to fulfill future design process requirements. In addition, each task is divided into subsections that detail the different stages required to successfully complete the tasks. In the subsection below, the tasks identified are listed with their respective sub-tasks. The combination of research and reference to the course syllabus, the team was able to successfully identify all the tasks needed to effectively complete the project.

- Problem Formulation
  - Identify project scope and problem statement
  - Define clients and recognition of need
  - Display project goals and objectives
    Point out initial project constraints

- Project Planning
  - Identify tasks to be completed
  - Generate a project timeline
  - Create a Gantt chart

- Literature Review
  - Identify relevant Information to project
  - Establish sources of relevant information
  - Research Oleophilic Skimmers
  - Analyze Non-Oleophilic Skimmers
  - Analyze Weir Skimmers
  - Make Inquiries into Operational Environment of skimmers

- Functional Decomposition
  - Define functional decomposition concept
  - Develop a strategy for the functions and subfunction
  - Generate a morphology table

- Concepts Generation
  - Develop a strategy to assign members to generate concept
  - Each member generate concept sketch individually
  - Combine concepts from all members into morphology table

- Concept Evaluation
    - Identify the Criteria
    - Organize the Criteria
    - Utilize the Go-no-go method
    - Create a decision matrix
    - Generate a Preliminary Design

- Preliminary Design
    - Rehabilitate existing designs
    - Identify options for flexibility
    - Approximate dimensions

- Detailed Design
    - Identify and plan for types of analysis needed for the design
    - Perform engineering analysis
    - Produce real life blueprint of design in Fusion 360
    - Run simulation in Fusion 360

- Detailed Parts Specifications
    - Create specifications of each component
    - Identify constraints of design
    - Design Evaluation/Modifications

- Budget & Project Cost (Economic Analysis)
    - Organize a list of suppliers
    - Generate a Budget Generation
    - Evaluate the Approval of the Budget agreement

- Purchasing
    - Generate a technical report that identifies all the parts.
    - Purchase parts
- Fabrication & Testing
    - Devise plan for manufacturing and assembly of Automated Skimmer
    - Create a detailed schedule for monitoring machine shop work
    - Conduct final testing and inspection for the Automated Skimmer

- Final Report & Presentation
    - Finalize report
    - Prepare presentation

2.2 Timeline

This section provides an overview of the active objectives' timeline for this project. The timeline serves to organize and present the objectives that will guide the accomplishment of deliverables through Fall 2020 and Spring 2021 in order for the construction of the automated oil skimmer to be completed. Selected tasks

were created and communicated to be organized and arranged into an appropriate chronological sequence. Persons responsible for a given task were determined through examining previous experiences and expertise that correspond to the given tasks to know who was best fit. An assessment of workload and priority was taken to quantify the amount of time needed for each task to be completed.

- Problem Formulation: The objectives of the following task are

  Objective:
  To formulate the current problem and identify the current need for product optimization
  Deliverables:
  - A list of current unsatisfactory conditions that will be approached by the proposed design
  - Person(s) Responsible: (David T.)
  - Estimated Time: 2 days

  Objective:
  To find who will be a potential end user of the product and to determine the reason why the client needs the product
  Deliverables:
  - A list of 5 potential clients and structured statement that defines the overall project goal and the scope of the goal
  - Person(s) Responsible: (Demetrious S.)
  - Estimated Time: 2 days

  Objective:
  To develop a goal statement and define measurable performance characteristics of design
  Deliverables:
  - A well labelled objective tree showing hierarchical relationships between objectives based on their performance characteristics.
  - Person(s) Responsible:(Ximena C.)
  - Estimated Time: 4 days

  Objective:
  To identify the different permissible ranges of the product design and recognizing the product working environment

  Deliverable:
  - A list of permissible range for the design parameters, description of the environment in which the design will operate
  - Person(s) Responsible: (Caleb R.)
  - Estimated Time: 2 days

- Project Planning: The objectives of the following task are
  Objective:
  To identify the different tasks that will need to be completed during the project
  Deliverable:

- A list of all the tasks that need to be completed for the project and their main subtasks
- Person(s) Responsible: (Group work)
- Estimated Time: 2 days

Objective:
To develop a detailed timeline for each one of the tasks listed in the task identification section

Deliverable:
- An effective timeline table
- Person(s) Responsible:(Group work)
- Estimated Time: 4 days

Objective:
Effectively organize the tasks and subtasks in a Gantt chart for timely completion.

Deliverable:
- A Gantt chart that has multiple features for project tracking.
- Person(s) Responsible: (David T.)
- Estimated Time: 5 days

- Literature Review: The objectives of the following task are

Objective:
To identify information relevant to project

Deliverable:
- A comprehensive list of relevant information
- responsible group member (Group work)
- Estimated Time: 1 day

Objective:
To establish a list of credible sources for the Information provided

Deliverable:
- A list of credible cited sources
- Person(s) Responsible: (Daniel)
- Estimated Time: 1 day

Objective:
To study relevant information on Oleophilic skimmers

Deliverable:
- A thorough research paper on oleophilic skimmers
- Person(s) Responsible: (Caleb R)
- Estimated Time: 1 day

Objective:
To create a detailed research on Non-oleophilic skimmers

Deliverable:
- A thorough research paper on Non-oleophilic skimmers
- Person(s) Responsible: (Ximena)
- Estimated Time: 1 day

Objective:
To Review information on Weir skimmers

Deliverable:

- Type a thorough research paper done on Weir Skimmers
- Person(s) Responsible: (Amna)
- Estimated Time: 2 days

Objective:

To Inquire into operational environment of skimmers

Deliverable:

- List of inquiries made into operational environment of skimmers
- Person(s) Responsible: (Daniel)
- Estimated Time: 2 days

- Functional Decomposition: The objectives for the following task are

Objective:

To study functional decomposition and generate concepts

Deliverable:

- An overall function statement
- responsible group member (Group work)
- Estimated time: 2 days

Objective:

To establish a strategy that define functions and subfunctions

Deliverable:

- A list of overall functions, a level 1 subfunction, a level 2 subfunction, a level 3 subfunction
- Responsible group member (Ximena C, Amna A, Amna J, Caleb R)
- Estimated time: 3 days

Objective:

To create a morphology table that identifies functional analysis

Deliverable:

- A morphology table for the functional decompositions, and a report that summarizes all the functions
- Responsible group member (Demetrious S, Daniel A)
- Estimated time: 2 days

- Concepts Generation: The objectives of the following task are

Objective:

To review the concepts

Deliverable:

- A list of customer needs and specifications
- Person(s) Responsible: (Group work)
- Estimated time: 2 days

Objective:

To modify the concepts

Deliverable:

- Finalized list of customer needs and specifications to generate a concept for all functions

- Person(s) Responsible: (Demetrious S, David T, Daniel A)
- Estimated time: 3 days

- Concept Evaluation: The objectives of the following task are

Objective:

To develop a list of generated criteria to begin the design analysis

Deliverable:

- A list of criteria that will be used to determine the preliminary concept design
- Person(s) Responsible: (Group)
- Estimated Time: 3 days

Objective:

Reorganize the created list into a manageable table

Deliverable:

- A Criteria Table
- Person(s) Responsible: (Ximena, David)
- Estimated time: 4 days

Objective:

Utilize the Go-no-go method and decision matrix to evaluate the list

Deliverable:

- Final result of the Go-No-Go method of the given criteria
- Person(s) Responsible: (Group)
- Estimated time: 4 days

Objective:

Develop a final preliminary concept for the design

Deliverable:

- Final result of the decision matrix determined and the evaluation of the preliminary design
- Person(s) Responsible: (Group)
- Estimated time: 4 day

- Preliminary Design: The objectives of the following task are

Objective:

To Explore the advantages and disadvantages of existing designs

Deliverable:

- The most effective outcome to improve the design process
- Person(s) Responsible: (Group)
- Estimated Time: 7 days

Objective:

To Prepare for the design to be subject to change if applicable

Deliverable:

- Plan to allow the preliminary design construct to be flexible
- Person(s) Responsible: (Amna J, Amna A)
- Estimated Time: 7 days

Objective:

To Meet the initial constraints requirements

Deliverable:

- Final preliminary design adheres to the constraint guidelines
- Person(s) Responsible: (Group)
- Estimated time: 7 days

- Detailed Design: The objectives of the following task are

  Objective:
  To get a realistic idea of the type of functional skimmer to create
  Deliverable:
  - Idea for skimmer design
  - Person(s) Responsible: (Group)
  - Estimated Time: 3 days

  Objective:
  To have a finalized image of skimmer design
  Deliverable:
  - Drawings on paper
  - Person(s) Responsible: (Aamna J)
  - Estimated Time: 6 days

  Objective:
  To make design come to life virtually in Fusion 360 software
  Deliverable:
  - A blueprint of skimmer in Fusion 360
  - Person(s) Responsible: (Aamna J)
  - Estimated Time: 4-5 days

  Objective:
  To run experimental testing of skimmer
  Deliverable:
  - A simulation on design and recorded data overtime
  - Person(s) Responsible: (Aamna J)
  - Estimated time: 6-7 days

- Detailed Parts Specifications: The objectives of the following task are

  Objective:
  To apply standards and design constraints to generate realistic models.
  Deliverable:
  - A model with correct measurements of each component, and assuring all components are scaled properly
  - Person(s) Responsible: (Aamna J and Amna A)
  - Estimated time: 6 days

  Objective:
  To identify the permissible range of the design and performance parameters
  Deliverable:
  - A list of permissible ranges for the design parameters and applying it to the model
  - Person(s) Responsible: (Aamna J)
  - Estimated Time: 4 days

Objective:
To ensure all parts meet parameter criteria.
Deliverable:

- Drawing standards when generating drawings of the parts, making sure it's well labeled and has all components.
- Person(s) Responsible: (Group)
- Estimated Time: 4-5 days

Objective:
To create design with all separate parts merged together for one finalized skimmer
Deliverable:

- Finalized Fusion 360 drawing that is realistic, meets industry needs, and will function when fabricated.
- Person(s) Responsible: (Group)
- Estimated Time: 7 days

- Budget & Project Cost (Economic Analysis): The objectives of the following task are

Objective:
Generate potential list of customer need
Deliverable:

- A list of customer needs and specifications
- Person(s) Responsible: (Demetrious S, David T, Daniel A)
- Estimated time: 2 days

Objective:
Finalized list of customer needs and specification
Deliverable:

- Evaluate the list of customer needs and specifications to generate a concept for all functions
- Person(s) Responsible: (Demetrious S, David T, Daniel A)
- Estimated time: 3 days

- Purchasing: The objectives of the following task are

Objective:
Generate a report that identifies all the parts that need to be purchased
Deliverable:

- A detailed technical report that identifies all the necessary parts
- Responsible person (Group work)
- Estimated time: 4 days (2/05 - 2/09)

Objective:
Purchase parts
Deliverables:

- A detailed technical report that identifies all the necessary parts
- Responsible person (Group work)
- Estimated time: 8 days (2/11 - 2/19)

- Fabrication & Testing: The objectives of the following task are

Objective:
A plan for manufacturing and assembly of Automated skimmer
Deliverable:
- A detailed plan on how to go about the production of the skimmer
- Responsible Person(s): (Group Work)
- Estimated Time: 1 day (2/26 - 02/27)

Objective:
A detailed schedule for machine shop work rotation
Deliverable:
- A finalized schedule for workshop rotations
- Responsible Person(s): (Group Work)
- Estimated Time: 4 days (02/28 - 03/10)

Objective:
Final testing and inspections on the Automated skimmer
Deliverable:
- A fully functional Automated Skimmer
- Responsible Person(s): (Group Work)
- Estimated Time: 2 days (03/10 - 03/20)

- Final Report & Presentation: The objectives of the following task are

Objective:
Construct a report that reveals the entire design process of the project
Deliverable:
- A compilation of revised reports
- Person(s) Responsible: (Group work)
- Estimated Time: 7 days

Objective:
A well-prepared presentation of the project
Deliverable:
- Create a well-developed PowerPoint presentation
- Person(s) Responsible: (Group work)
- Estimated Time: 2 days

3. The list below includes the estimated times for each one of the tasks to be performed during the project. The estimated time for each task was determined based on the reflection of the current time spent on the previous reports. In addition, the list includes the approximated start and end dates for the task.

1. Problem Formulation

   - Identify project scope and problem statement
     - Start/End Dates: 9/3 to 9/5
     - Estimated Duration: 3 hrs
   - Define clients and recognition of need
     - Start/End Dates: 9/3 to 9/5
     - Estimated Duration: 2 hrs
   - Display project goals and objectives

        - Start/End Dates: 9/4 to 9/8
        - Estimated Duration: 6 hrs
    - Point out initial project constraints
        - Start/End Dates: 9/4 to 9/6
        - Estimated Duration: 2 hrs

1. Project Planning

    - Identify tasks to be completed
        - Start/End Dates: 9/10 to 9/12
        - Estimated Duration:2 hrs
    - Generate a project timeline
        - Start/End Dates: 9/11 to 9/15
        - Estimated Duration:4 hrs
    - Create a Gantt chart
        - Start/End Dates: 9/11 to 9/16
        - Estimated Duration:7 hrs

2. Literature Review

    - Identify relevant Information to project
        - Start/End Dates: 9/16 to 9/17
        - Estimated Duration: 2 hours
    - Establish sources of relevant information
        - Start/End Dates: 9/17 to 9/18
        - Estimated Duration: 4 hrs
    - Research Oleophilic Skimmers
        - Start/End Dates: 9/18 to 9/19
        - Estimated Duration: 4 hrs
    - Analyze Non-Oleophilic Skimmers
        - Start/End Dates: 9/20 to 9/21
        - Estimated Duration: 4 hrs
    - Analyze Weir Skimmers
        - Start/End Dates: 9/20 to 9/22
        - Estimated Duration: 4 hrs
    - Make Inquiries into Operational Environment of skimmers
        - Start/End Dates: 9/22 to 9/24
        - Estimated Duration: 2 hrs

3. Functional Decomposition

    - Define functional decomposition concept
        - Start/End Dates: 9/23 to 9/25
        - Estimated Duration: 4hrs
    - Develop a strategy for the functions and subfunction
        - Start/End Dates: 9/23 to 9/26
        - Estimated Duration: 6hrs

- Identify material
  - Start/End Dates: 9/26 to 9/28
  - Estimated Duration: 4hrs
- Generate a morphology table
  - Start/End Dates: 9/28 to 9/30
  - Estimated Duration: 4hrs

5. Concepts Generation

   - To review the Concepts
     - Start/End Dates: 9/30 - 10/2
     - Estimated time: 8 hrs
   - To Modify the Concepts
     - Start/End Dates: 10/7 - 10/9
     - Estimated time: 4 hrs

6. Concept Evaluation

   - Identifying criteria
     - Start/End Dates: 10/14 to 10/17
     - Estimated Duration:4hrs
   - Organizing Criteria
     - Start/End Dates: 10/14 to 10/17
     - Estimated Duration: 4hrs
   - Go-no-go method
     - Start/End Dates: 10/16 to 10/20
     - Estimated Duration: 8hrs hrs
   - Decision matrix
     - Start/End Dates: 10/16 to 10/20
     - Estimated Duration: 8-10 hrs
   - Preliminary Design
     - Start/End Dates: 10/14 to 10/22
     - Estimated Duration: 8-10 hrs
7. Preliminary Design

   - Rehabilitate existing design
     - Start/End Dates:10/22 to 10/28
     - Estimated Duration: 10-12hrs
   - Identify options for flexibility
     - Start/End Dates: 10/28 to 11/04
     - Estimated Duration: 10-12hrs
   - Approximate dimensions
     - Start/End Dates: 10/28 to 11/04
     - Estimated Duration: 4-6 hrs

8. Detailed Design

- Identify and plan for types of analysis needed for the design
  - Start/End Dates: 11/04 to 11/07
  - Estimated Duration: 6 hrs
- Draw rough draft on paper
  - Start/End Dates: 11/04 to 11/10
  - Estimated Duration: 4 hrs
- Produce real life blueprint of design in Fusion 360
  - Start/End Dates: 11/10 to 11/14
  - Estimated Duration: 15-20 hrs
- Run simulation in Fusion 360
  - Start/End Dates: 11/14 to 11/19
  - Estimated Duration: 10-15 hrs

9. Detailed Parts Specifications

   - Create specifications of each component
     - Start/End Dates: 11/04 to 11/08
     - Estimated Duration: 12 hrs
   - Identify constraints of design
     - Start/End Dates: 11/08 to 11/12
     - Estimated Duration: 4 hrs
   - Design Evaluations/Modifications
     - Start/End Dates: 11/13 to 11/19
     - Estimated Duration: 15-20 hrs

10. Budget & Project Cost (Economic Analysis)

    - List of suppliers
      - Start/End Dates: 1/15 to 1/20
      - Estimated Duration: 7 hrs
    - Budget Generation
      - Start/End Dates: 1/20 to 1/25
      - Estimated Duration: 2 hrs
    - Approval of Budget Agreement
      - Start/End Dates: 1/25 to 2/02
      - Estimated Duration: 3 hrs

11. Purchasing

    - Technical report
      - Start/End Dates: 2/05 to 2/09
      - Estimated Duration: 6hrs
    - Purchases
      - Start/End Dates: 2/11 to 2/19
      - Estimated Duration: 8hrs

12. Fabrication & Testing

- Manufacture and Assembly
  - Start/End Dates: 2/26 to 2/28
  - Estimated Duration: 12 hrs
- Machine Shop Work
  - Start/End Dates: 2/28 to 3/02
  - Estimated Duration: 10-15 hrs
- Product Testing
  - Start/End Dates: 3/03 to 3/05
  - Estimated Duration: 8-10 hrs

13. Final Report & Presentation

- Finalize report
  - Start/End Dates: 4/22 to 4/29
  - Estimated Duration: 10 hrs
- Prepare presentation
  - Start/End Dates: TBA
  - Estimated Duration: 3 hrs

The arrangement of the timeline was determined appropriately and accurately in order to effectively and efficiently complete the different tasks and objectives in a timely manner. To accomplish this, a step by step analysis was performed to prioritize which tasks needed to be completed before others. This allows for smooth transitions between tasks and provides certainties for objectives to be completed to reach deliverables. To regulate the time constraints for each task, the project manual and syllabus was observed in order to settle suitable time frames for every objective and piece of work needed to be achieved.

Table 2.1 Detailed Project Tasks, Objectives, Deliverables, Task Duration & Responsible Personnel

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
Problem Formulation	1.1 Problem statement	To formulate the current problem and identify the current need for product optimization	Full description of the current unsatisfactory conditions that will be approached by the proposed design	2	9/3	9/5	David T.
	1.2 Client Identification and recognition of need	To find who will be a potential end user of the product and to determine the reason why the client needs the product	A list of 5 potential clients and structured statement that defines the overall project goal and the scope of the goal	2	9/3	9/5	Demetrious S.
	1.3 Project goals and objectives	To develop a goal statement and define measurable performance characteristics of design	A labelled objective tree showing hierarchical relationships between objectives based on their performance characteristics.	4	9/4	9/8	Ximena C.
	1.4 initial project constraints and operating environment	To identify the different permissible ranges of the product design and recognizing the product working environment	A list of permissible range for the design parameters, description of the environment in which the design will operate.	2	9/4	9/6	Caleb R.
Project Planning	2.1 Task identification	To identify the different tasks that will need to be completed during the project	A list of all the tasks that need to be completed for the project and their main subtasks	2	9/10	9/12	Group Work
	2.2 Timeline	To develop a detailed timeline for each one of the tasks listed in the task identification section	An effective timeline table	4	9/11	9/15	Group Work
	2.3 Gantt Chart	Effectively organize the tasks and subtasks in a gantt chart for timely completion.	A gantt chart that has multiple features for project tracking.	5	9/11	9/16	David T.

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
Literature Review	3.1 Identify relevant information to project	To identify information relevant to the project	A list of relevant Information for the project	1	9/16	9/17	Group Work
	3.2 Establish sources of relevant information	To establish a list of credible sources for the information provided	A list of credible cited sources	1	9/17	9/18	Caleb R.
	3.3 Research Oleophilic skimmers	To study relevant information on Oleophilic skimmers	A thorough research paper done on Oleophilic skimmers	1	9/18	9/19	DanielA.
	3.4 Analyze Non-Oleophilic skimmers	Detailed research on Non-oleophilic skimmers	A thorough research paper done on Non-oleophilic skimmers	1	9/19	9/20	Demetrious S.
	3.5 000Analyze Weir Skimmers	Review information on weir skimmers	A thorough research paper done on Weir Skimmers	2	9/20	9/22	David T.
	3.6 Make Inquiries into operational environment of skimmers	Inquire into operational environment of skimmers	list of inquiries made into operations environment of skimmers	2	9/22	9/24	Group Work
Functional Decomposition	4.1. Define functional decomposition concept	To study functional decomposition and generate concepts	Create an overall function statement	2	9/23	9/25	Group work
			A list of overall functions	3	9/23	9/26	Ximena C.
	4.2 Develop a strategy for the functions and subfunctions.	To establish a strategy that define functions and subfunctions	A Level 1 subfunction,				Amna A.
			A Level 2 subfunction,				Caleb R.
			A Level 3 subfunction				
	4.3 Generate a morphology table	To create a morphology table that identifies Functional analysis.	A morphology table for the functional decomposition	2	9/28	9/30	Demetrious S.
							Daniel A.

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
Concepts Generation	5.1 Develop a strategy to assign members to generate concepts	Generate concepts using well established concepts generation techniques for each of the functions.	A list of generated concepts	2	9/30	10/2	Demetrious S. Daniel A,
	5.2 Each member generates concept sketches individually			3	10/7	10/9	David T
	5.3Combine concepts from all members into morphology table	Generate sketches into team concepts for each function.	Sketches that present concept of function	2	10/7	10/14	David T
		Assimilate individual concepts into a morphology	A morphology table				
Concept Evaluation	6.1 Identifying Criteria	Develop a list of generated criteria to begin the design analysis	A list of criteria that will be used to determine the preliminary concept design	3	10/14	10/17	Group work
	6.2 Organizing Criteria	Reorganize the create list into a manageable table	A criteria table	3	10/14	10/17	Ximen C. David T.
	6.3 Go-no-go method	Use the Go-No-Go and decision matrix to evaluate the list	Final result of the Go-No-Go method of the given criteria	4	10/16	10/20	Group Work
	6.4 Decision matrix	Use the Go-No-Go and decision matrix to evaluate the list	Final result of the Go-No-Go method of the given criteria	4	10/16	10/20	Group Work
	6.5 Preliminary Design	Develop a final preliminary concept for the design	Final result of the decision matrix determined	4	10/14	10/22	Group Work
			The evaluation of the preliminary design	4	10/14	10/22	Group work
Preliminary Design	7.1 Rehabilitate existing designs 7.2 Identify options for flexibility	Explore the advantages and disadvantages of existing designs	Most effective ways to improve the design process	7	10/22	10/28	Group Work Amna J, Amna A
	7.3 Approximate Dimensions	Prepare for the design to have room for changes if needed	Flexible options	7	10/28	11/04	Group Work
		Meet the initial constraints requirements	Final preliminary design should follow the constraint guidelines	7	10/28	11/04	

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
Detailed Design	8.1 Identify and plan for types of analysis needed for the design	To get a realistic idea of the type of functional skimmer to create	A design idea created by working with all group members to produce ideas of skimmers that have never been on the market before.	4	11/04	11/07	Group Work
	8.2 Draw rough draft on paper	To have a finalized image of skimmer design	A drawing of rough draft on paper based on group ideas.	7	11/04	11/10	Amna A. Amna J.
	8.3 Produce real life blueprint of design in Fusion 360	To make design come to life virtually in Fusion 360 software.	A prototype in Fusion 360 software that has all aspects of design with correct parameters to resemble what the skimmer would look like once fabricated.	4	11/10	11/14	Group work Amna J.
	8.4 Run Simulation in Fusion 360	To run experimental testing of skimmer.	A simulation run that replicates tests, i.e. stress analysis and skimmer capabilities before doing real time experimentation.	5	11/14	11/19	Amna A. Amna J.
	8.5 Perform Detailed analysis	To perform thorough analysis of the skimmer design	A comprehensive analysis is established for the skimmer that will establish all components	5	11/14	11/19	Amna J
Detailed Parts Specifications	9.1 Identify constraints of design	To apply standards and design constraints to generate realistic models.	A model in Fusion 360 that shows the correct measurements of each component, and assuring all components are scaled properly.	4	11/04	11/08	Group work Amna J
	9.2 Generate specifications of each component	To identify the permissible range of the design and performance parameters	A list of permissible ranges for the design parameters, and applying it to the model.	4	11/08	11/12	Group Work
	9.3 Design Evaluation/Modifications	To ensure all parts meet parameter criteria.	A finalized drawing with all labels and dimensions	3	11/13	11/16	Group work
	9.4 Final CAD drawing	To create design with all separate parts merged for one finalized skimmer	A finalized Fusion 360 drawing that is realistic, meets industry needs, and will function when fabricated.	3	11/16	11/19	Group Work

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
10. Budget & Project Cost (Economic Analysis)	10.1 1 List of suppliers	To Compare prices and quality with those from different suppliers	a list parts that are necessary for purchase	20	11/05	11/25	David Trevino
	10.2 Budget Generation	To generate budgets for all the parts	a budget that is reasonable	5	1/20	1/25	Group Work
	10.3 Approval of Budget Agreement	To get budget approval from the Mechanical Engineering department to review the budget	Cost Comparison	8	1/25	2/02	Group Work
Purchasing	11.1 Technical report	Generate a report that identifies all the parts that need to be purchased.	A detailed technical report that identifies all the necessary parts. finalize purchases	4	2/05	2/09	Group work
	11.2 purchases	Purchase parts.	a final report that identifies all the parts that have been purchased.	8	2/11	2/19	Group work
Fabrication & Testing	12.1 Manufacture & Assembly	A plan for manufacturing and assembly of Automated Skimmer	A detailed plan on how to go about the manufacturing of the skimmer	1	2/26	2/27	Group Work
	12.2 Machine shop work	To create a detailed schedule for machine shop work rotation	Finalized schedule for workshop rotations	7	2/26	03/03	Group Work
	12.3 Product Testing	To conduct final testing and inspections for the automated skimmer	Fully Functional Automated Skimmer	7	03/03	03/09	Group Work
Final Report & Presentation	13.1Finalize report	To construct a final report that reveals the entire design process of the project.	Compilation of revised reports and a table of contents and figure list	7	4/22	4/29	Group work
	13.2 Prepare presentation	To organize all project elements into a presentation	A final presentation	2	TBA		Group presentation
		To present a well prepared presentation of the project	A well-developed PowerPoint presentation	2	TBA		

2.3 Gantt Chart

Gantt charts are a key tool for successful planning when executing a project. They are effective in projecting the duration of tasks and planning the order of milestone achievement. In this section, a Gantt chart was created to show a visual representation of the planning and scheduling of the tasks to be performed in Fall 2020 and Spring 2021. The program used to develop the planning of this project was Gantter Google.

Didn't make correction

In the figures 2.1 a visual representation of the planning for the Fall 2020 semester is displayed. In addition, the diamond shapes located above the bars indicate project milestones.

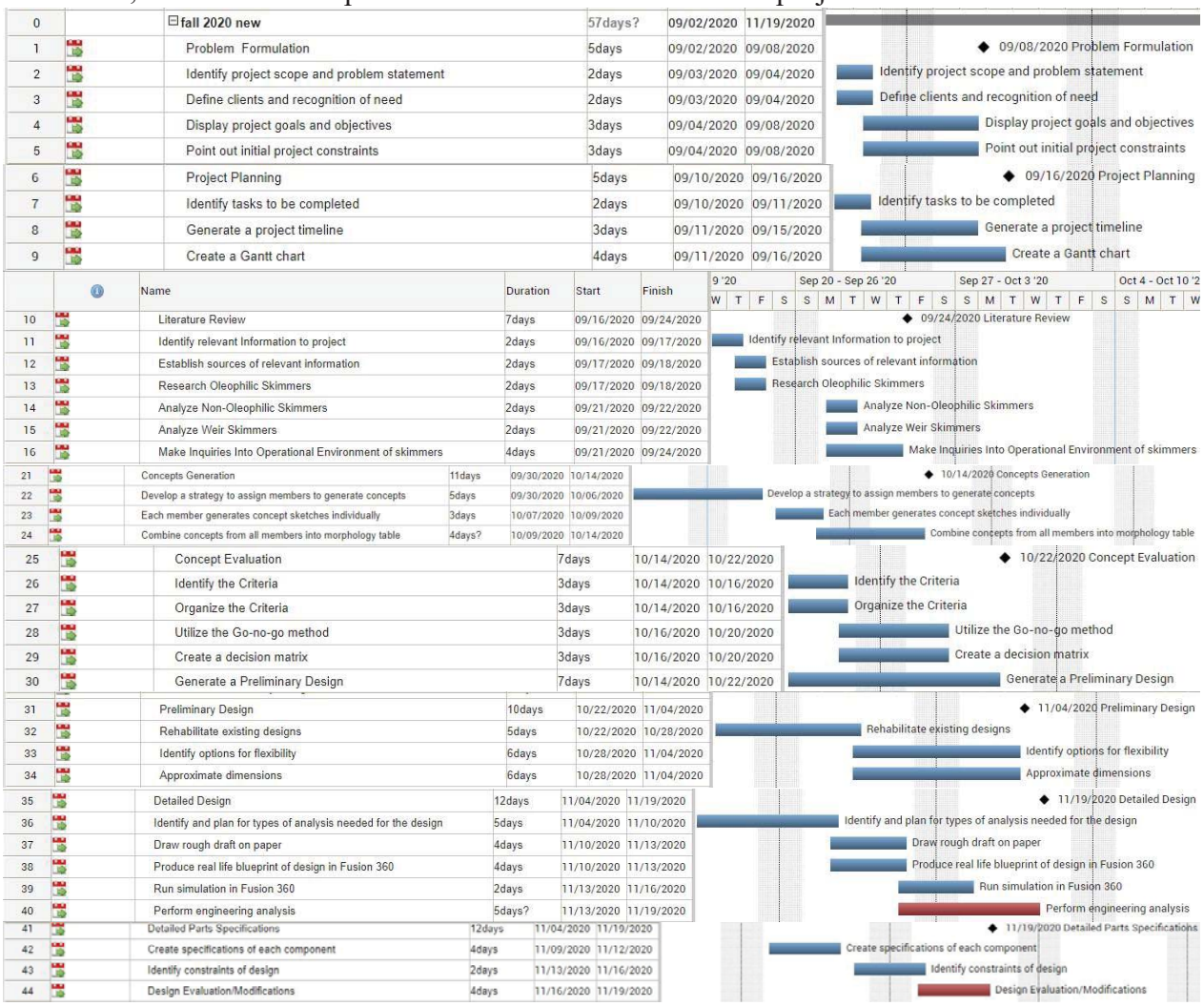


Figure 2.1 Gantt Chart Fall 2020

Didn't make correction

In Figure 2.1 a visual representation of the planning for the Spring 2021 semester is displayed. In addition, the green bar indicates the spring break week.

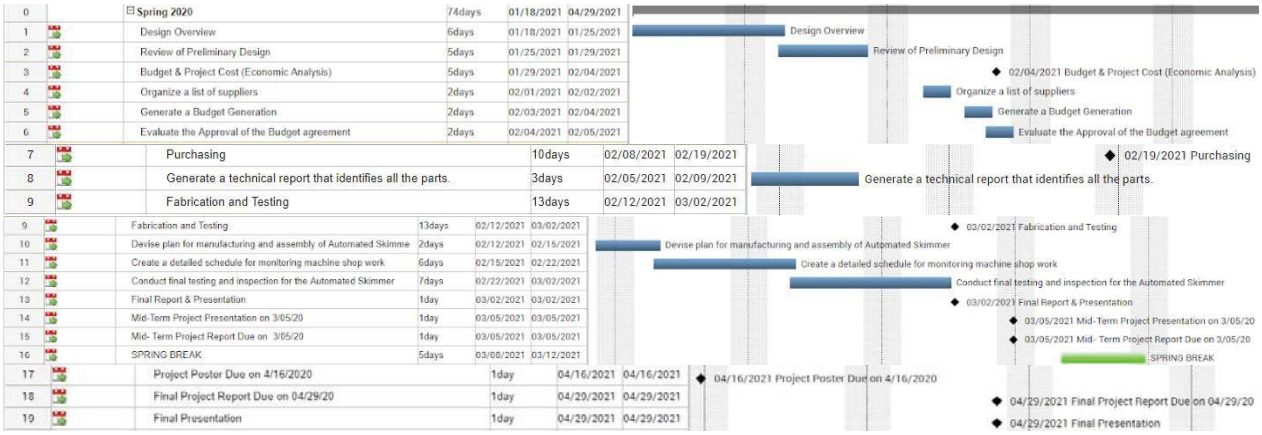


Figure 2.2. Gantt Chart Spring 2021

The use of the Gantt chart consists in strictly tracking the completion of the milestones and following the plan during the course of the school year. Strict use of the Gantt chart will ensure successful completion of the project. Currently, the team has reached the completion of the second milestone (Status Report on Project Planning) and are working on completing the third milestone (Status Report on Literature Review) of the Fall 2020 Gantt chart.

3. LITERATURE REVIEW

This chapter discusses different types of oil skimmers covered in our project. The oleophilic skimmers focused on include the disk-type, belt-type, drum-type and rope mop-type which all have different and unique ways to extract oil from water. The Non-Oleophilic skimmer types include Vacuum and Suction types, and Belt Mop-type. The topics for Weir skimmers include specific gravity and operational environment, as well as weir skimming operations. The last section covered the operational environment of skimmers including weathering and oil spill classifications.

3.1 Identification of Information Relevant to the Project

Research was done by each group member on the various types of skimmers currently in the market. Gaining a better understanding of the information needed to complete this project was carried out by identifying the relevant subject areas, and then analyzing previous skimmers that are currently in the market. The advantages and disadvantages of the existing designs were listed. Understanding the mechanics behind the different designs of existing skimmers was executed. Design analysis research was explored to aid with sizing and specifications for the current project.

Below is a list of main topics and their respective subtopics. Throughout the report every topic will be discussed in detail and the figures will give a visual representation of each topic.

- Oleophilic Skimmers
  - Disk-Type Skimmers
  - Belt-Type Skimmers
  - Drum-Type Skimmers
  - Rope Mop Skimmer

- Non-Oleophilic Skimmers
  - Vacuum and Suction Skimmers
  - Belt Mop Oil Skimmer

- Weir Skimmers
  - Specific gravity and operational environment
  - Weir skimming operation

- Operational Environment of Skimmers
  - Weathering
  - Oil Spill Classification

- Major Skimmer Components

- Relevant Analysis

- Codes and Standards
  - Oil Pollution Regulation Programs

3.2 Potential Sources of Information for Project

Sources have been gathered from using online scholarly databases such google scholars, University library, books, or any other online articles that have reliable secondary sources. Websites that allow multiple editors such as Wikipedia have been avoided to ensure information accuracy. In the list below you will find the different sources that were used in each section of the literature review.

- Oleophilic Skimmers
    - [1] Grill,P. Linde, F, Oil Skimming**,** Business Potential and Strategic Options Facing a Marginalised Business Segment at Sandvik Process Systems, Master of Science Thesis KTH School of Industrial Engineering and Management Energy Technology EGI-2013-077MSC SE-100 44 STOCKHOLM, pp 27-28
    - [2] Robert Governale, inventor; Miller Environmental Group, Inc., assignee. Oil Skimming Apparatus, United States patent US 5,685,979, 1997 Nov 11.
    - [3] Ray Ayers,Kenneth L. Bickham inventors; Shell Oil Company, assignee. Fibrous Disc Oil Skimmer, United States patent US 4,264,450, 1981 Apr 28.
    - [4] Agnew, R.W., *Free floating endless belt oil skimmer* United States Environmental and protection agency, 1972
    - [5] Philip C. Lewan, inventor; Camshaft Machine Company assignee. Belt Type Oil Skimmer with Horizontal Rotors, United States patent US 5,062,953, 1991 Nov 5.
    - [6] Philip C. Lewan, inventor; Miller Environmental Group, Inc., assignee. Belt Oil Skimmer Apparatus, United States patent US 5,015,378, 1991 May 14.
    - [7] Gregory A. Ettelt, Alfred L. Cohen, inventor; Tenco Hydro/Aero ScienceS, Inc., assignee. Belt Type Oil Removal Unit, United States patent US 4,089,784, 1978 May 16.
    - [8] INC., Elastec. “Drum Oil Skimmers: Oleophilic Skimmer.” *Elastec*, 17 Sept. 2020, www.elastec.com/products/oil-spill-skimmers/drum-oilskimmers/.
    - [9] Donald L. Wilson, Jerry C. Trippe, inventors; Elastec Inc., assignee. Device for skimming oil from water. United States patent US 4,957,636, 1990 Sep 18.
    - [10] J. S. Shum and M. Borst Mason & Hanger-Silas (*2015*) OHMSETT TESTS OF A ROPE-MOP SKIMMER IN ICE-INFESTED WATERS.

      International Oil Spill Conference Proceedings: February 2015, Vol. 2015, No. 1, pp. 31-34.

- [11] Alves, Tiago M et al. 2015. “Modelling of Oil Spills in Confined Maritime Basins: The Case for Early Response in the Eastern Mediterranean Sea.” Environmental Pollution 206: 390–99

- Non-Oleophilic Skimmers
  - [12] Al-Majed et al., 2012 A.A. Al-Majed, A.R. Adebayo, E.M. Hossain A sustainable approach to controlling oil spills J. Environ. Manag., 113 (2012).
  - [13] Anh Tuan Hoang & Minh Quang Chau, 2018. "A Mini Review of Using Oleophilic Skimmers For Oil Spill Recovery," Journal of Mechanical Engineering Research & Developments (JMERD), Zibeline International Publishing, vol. 41(2), pages 92-96, July.
  - [14] ITOPF. (2012). The Fate of Marine Oil Spills. London, UK: The International Tanker Owners Pollution Federation.
  - [15] NOAA. (2010). Fact Sheet: Skimmers. Mobile, AL: National Oceanic and Atmospheric Administration.
  - [16] Ortega AE, Walker JT, Whitfield WW, Bostwick J (2011) Materials and methods for removing oil from bodies of water Google Patents.
- Weir Skimmers
  - [17] Grill, P., Linde, F., *Oil Skimming Business Potential and Strategic Options Facing a Marginalised Business Segment at Sandvik Process Systems,* EGI-2013-077MS, The Royal Institute of Technology Stockholm, 2013, pp 24-90
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Environment preservation is a topic often overlooked by society. throughout the years the human population has had to jeopardize the well being of the earth to be able to fulfil the population needs. therefore, the world has reached a level where immediate action to preserve the environment needs to be taken and this literature review will focus on the preservation of the earth's bodies of water using different types of skimmers.

Industries that develop and enable the population to have access to sources derived from the oil exploitation have experienced major failures in their systems. These failures have open room for multiple and critical oil spills in the ocean. As a result, the quality of these bodies of water has been negatively affected and marine life is suffering major consequences. As a consequence, immediate need for an effective oil recovery system has grown and the development of new oil recovery technologies has been requested.

To further the discussion of oil recovery, it is extremely important to recognize that the recovery operation is broken into two different categories. One of the categories is the ability to immediately and effectively contain oil spills. On the other side, the other category is based on the different types of oil recovery methods and devices. This literature report will focus on the different types of skimmers and the oil behavior on the skimmer's operational environment.

In this literature report, there are two main types of skimmers that are discussed. The first type of skimmer consists of an oleophilic skimmer that utilizes a belt, disc, drum, tube, brush, grooved disc, smooth drum, and grooved drum to safely remove oil from water. The second type is called a non-oleophilic skimmer that employs a weir, belt mop or suction components in order to separate the oil. Each variant of skimmer

has its advantages, and some may contain more than one component in order to improve the efficiency of the skimmer.

3.3 Oleophilic Skimmers

In this section, the different types of oleophilic skimmers will be discussed in detail. Oleophilic skimmers are the type of skimmers that use disks, belts, drums or rob mop chains composed of oleophilic materials to catch the oil from the water surface.

3.3.1 Disk-Type Skimmers

Disk skimmers operate by mounting to the top of the tank and running a large diameter disk into the coolant surface. The disk itself is made of either plastic or stainless steel. As the disk passes through the coolant surface, oil is captured and cleaned with a set of wiper blades as the disk passes between them. The recovered oil may be stored in a container or pumped directly into a reservoir. This description can apply to the generic form of any disk skimmer, but what will be assessed are the different functionalities and flexible designs that today's oil skimmer has to offer as well as the advantages and disadvantages.

The Disk-Type oil skimmer offers flexible design options that allow versatility as well as cost efficient production options. Disk skimmers, although dependent upon the number and size of the operational discs; are most effective in medium viscosity oils. Compared to other oleophilic skimmer types, the disk skimmers are smaller, more cost efficient and have a slightly higher pickup rate than their counterparts. Grooved disks, studies have shown, result in higher recovery rates than of disks with smoother surfaced disks. The skimmers can also be operational in a stationary setting or float within polluted waters. Some drawbacks are that the disk skimmer requires a larger operating space due to the accommodation of the disks. Also, the skimmer typically cannot sustain efficient operation if debris is present. The skimmer may also require additional ancillaries to operate. These include separate power packs, hydraulic or discharge hoses and storage containment. [1] Industrial skimmers can be quite large in weight and volume due to the size and number of rotating disks. The final disadvantage is that the disk-skimmer cannot handle oil that has been emulsified, or chemically broken up into small droplets.

Didn't make correction

The designs of most disk-skimmers contain a single disk or a multiplicity of disks that rotate along a common axis. The tops of the disks rotate away from the skimmer enclosure while the bottom of the disk(s) rotates towards the skimmer. Materials for these disks are usually smooth unmalleable and rigid metals or plastic and plate like structures. Some designs also include disks that have sorbent materials that provide extra efficiency to oil recovery rate. Figure 3.1, A United States patent [2] developed in 1981 incorporated fibrous bristles that can attach to the disks. The design features 32 disks with absorbent fibers attached that provide a large surface area to which oil can adhere. The bristles have a thickness of .005-.100 inches and a length of .25-2 inches. Possible bristle materials were nylon, polyesters, and polyamides. An experiment conducted through this patent included a test of two types of oil with and without the presence of the oil absorbent bristles. Figure 3.2 is a side profile of US patent 5,685,979 that demonstrates the process of how the oil processes through the skimmer design using the fibrous disks. Results concluded that the presence of the fibrous bristles substantially increased the oil recovery for both

oil types due to the increased surface area they provided. This patent experiment expresses that simple disk design can be easily altered to increase the overall recovery efficiency of the skimmer.

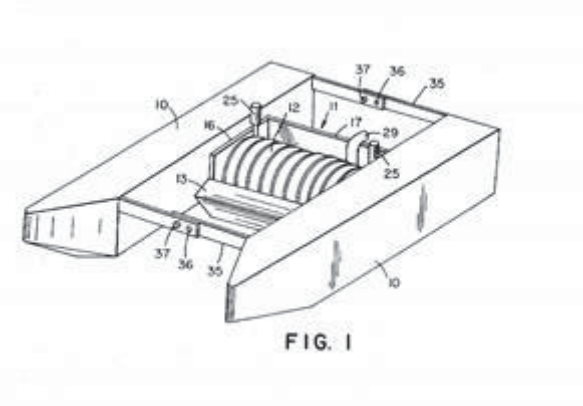


Figure 3.1 US Patent 5,685,979

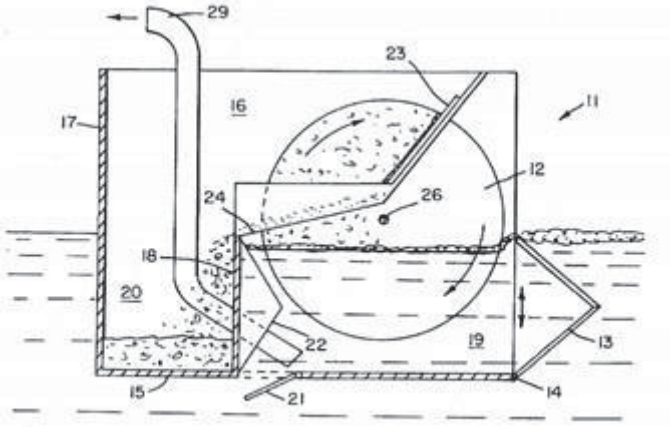


Figure 3.2 US Patent 5,685,979

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Another United States Patent presented in figure 3.1 is a [3] design that was developed in 1997 that features a detachable skimmer system that is suspended within two hulls. The open Ushaped design allows for water to flow inwards to a plurality of oleophilic disks along the same shaft. Like the previous mentioned patent, disks rotate away from the skimmer and alternatively collect oil while rubber scrapers are then used to remove the oil into a drainage area and into the hulls for storage. In many disk-designs like this one, hydraulic actuators can be used to compensate for the weight of the collected oil to maintain deployment of the skimmer device on the surface of the water. Keels and bows were also used to allow directional stability. The patent claims also express that the design was not limited to just the two hulls included. This helps to expand the design options for future oil skimmer developments.

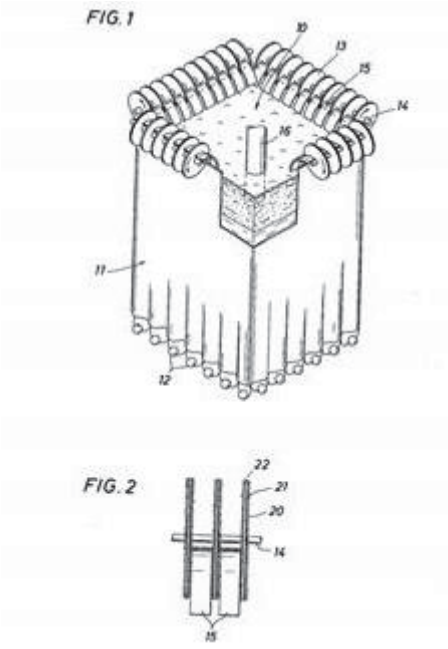


Figure 3.3 US Patent 4,264,450

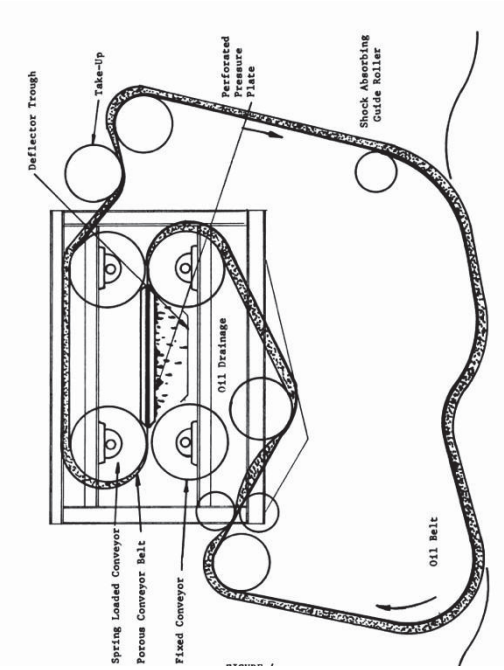
Automation within design serves as a key advantage to disk skimmers. Power packs are utilized for disk designs to allow the disk to rotate which can serve as a motor for the disk shaft. These can be hydro-electric or possibly just a standard industrial DC volt battery.

3.3.2 Belt-Type Skimmer

In this section, we will discuss an oleophilic oil skimmer which utilizes a belt system. This type of apparatus is commonly used in the oil recovery field alongside disc, drum, tube, brush, grooved disc, smooth drum, and grooved drum. A belt-type oil skimmer uses an endless belt of corrosion resistant steel or synthetic medium, which is lowered into the tank or vessel to be skimmed. The belt passes through resilient wiper blades where the oil is removed from both sides of the medium. The advantage of a belt type skimmer is that it is the most reliable and economical type of skimmer design that is able to remove various thickness of oil layers.

In the research paper “A free floating endless belt skimmer” an experiment was conducted using a free-floating endless belt skimmer. Another patent explored was developed in 1990 in which ”The belt is threaded over the upper portion of a primary drive roller having a horizontal axis and pressure rollers mounted upon linkage sets are biased towards opposite sides of the primary roller in engagement with the belt to squeeze the collected oil from the belt permitting the oil to flow to a collector located below the rollers”[5]. “The skimmer utilized a unique high efficiency conveyor wringer to power and wring the belt. The belt is designed to float on the water surface and responds rapidly to the shape of the waves, thereby maximizing oil-sorbent contact time” [4]. This experiment was conducted in a 60-foot diameter annular test tank and demonstrated the effectiveness of a belt type oil skimmer. The results of this experiment showed that the oil pick up rates would vary depending on the belt speed, oil slick thickness and porosities. In addition, “oil pick-up rates of 8.3 and 3.7 gpm per foot of belt width were

obtained for #2 Fuel Oil and Bunker C oil respectively at a slick thickness of 0.10 inches. The recovered liquid contained approximately 50-70% oil at 0.10-inch slick thickness."[4] This research was conducted in 1972, however it demonstrates the effectiveness of a belt type skimmer and provides experimental data and a design that can be improved upon. Another similar design explored was developed in 1990 in which "The belt is threaded over the upper portion of a primary drive roller having a horizontal axis and pressure rollers mounted upon linkage sets are biased towards opposite sides of the primary roller in engagement with the belt to squeeze the collected oil from the belt permitting the oil to flow to a collector located below the rollers"[5].



Didn't make correction

Figure 3.4 Free Floating Endless Belt Skimmer

In the patent 5,015,378, it illustrates an "apparatus for removing oil from the surface of a liquid using an endless belt partially submerged in the liquid, the belt passes over a primary roller having a vertical axis and pressure rollers squeeze the belt which flows by gravity to a collection receptacle mounted upon the frame supporting the primary roller and its driven structure. The belt twists whereby its lower portion submerged in the liquid defines a reversing loop whose configuration is maintained by a weight roller having a horizontal axis of rotation."[4] Using a combination of belt and rollers, this design is able to produce high efficiency oil removal and requires minimum maintenance and servicing.

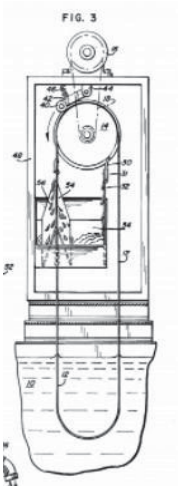


Figure 3.5 U.S Patent 5,017,378

In Figure 3.5 the patent 5,062,953 depicts an oil skimmer where "The belt is threaded over the upper portion of a primary drive roller having a horizontal axis and pressure rollers mounted upon linkage sets are biased towards opposite sides of the primary roller in engagement with the belt to squeeze the collected oil from the belt permitting the oil to flow to a collector located below the rollers. The linkage sets include reversing rollers, and the apparatus is constructed to readily permit belt replacement" [5]. Similarly, to the last patent, it uses a combination of belt and rollers in order to successfully remove oil from water. These patents exhibit similar goals and objectives, however, take various steps into achieving them. In Figure 3.6 the patent 4,089,784 portrays a design where "An endless belt for carrying oil is partially submerged in the basin and is driven and supported by a rotary drum. The rotary drum has an irregular surface for frictional cooperation with the belt and a spring biased roller urges the belt against the irregular surface. The oil is scraped from the belt and directed away from the belt and basin" [6].

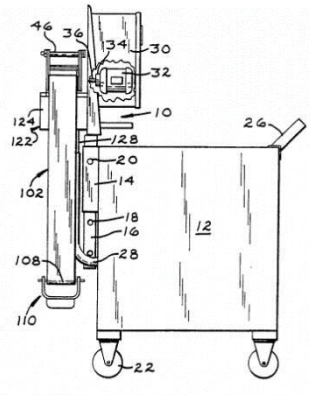


Figure 3.6 U.S Patent 4,089,784

Unlike these last two patents, this one utilizes a rotary drum in addition to a belt and roller system. The addition of a drum indicates that most oil skimmers will utilize a combination of designs in order to maximize efficiency of oil removal.

3.3.3 Drum Skimmers

The oleophilic drum skimmer shown in Figure 3.7 was pioneered in 1990 by Elastec and was regarded as one of the most efficient oil recovery skimmers for shallow waters [8]. This type of skimmer uses materials like aluminum, steel, or general-use plastics since these materials attract oil and repel water. This allows for oleophilic skimmers to be very efficient in not picking up substantial amounts of water even when there is little to no oil present. This is one of the most crucial elements of its design because this is what determines its rate of efficiency of oil recovery.

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Figure 3.7 Elastec Drum oil Skimmer

Drum skimmers typically have one or more large drums that rotate while slightly submerged in water. The oil attaches to the surface of the drum while the drum rotates in the oil-water interface. The oil is then squeezed or scraped off the drums into the recovery tank. The oil is passed to a reservoir trough, which forms the back of the frame, through channels between the two drums and at the drum ends. The reservoir trough and the drums are sized to provide all of the buoyancy necessary to float the device and are proportioned so as to position the skimmer in an effective, oil gathering attitude.

The drum skimmer consists of three main items in the development stage, a smooth or grooved drum skimmer, a pump, and a power unit. Just as there are also many factors to consider during configuration. For starters, the location of the oil must be known in order to choose the sizing of the model. Knowing if the oil is very light, light, moderate, or heavy as well as knowing what condition the oil is in due to the weather will affect the viscosity of the oil. For example, cold weather will cause more viscous oil which will be harder to pump. The volume of the oil is a big factor as well as the timeframe. When time is a factor, skimmers with a larger trough are not ideal since the large trough skimmers are used for a more paced scenario. Lastly, being aware of the surrounding area and resources will help depict the best power source (pneumatic skimmer system, electric power pack, or a diesel hydraulic power unit). Figure 3.8

and Figure 3.9 show the patient's design features; "polyolefins including polyethylene and polypropylene since they are among the preferred plastics due to the fact that they have desirable properties including light weight, oil wettability, and corrosion resistance [9].

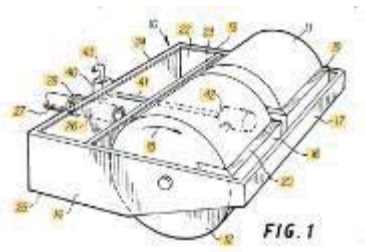


Figure 3.8 US Patent 4,957,636

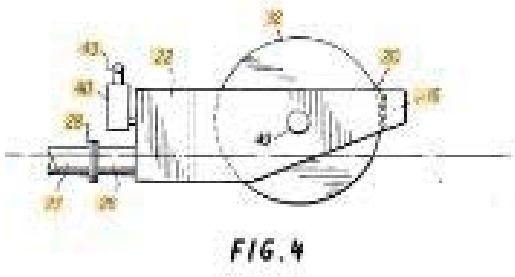


Figure 3.9 US Patent 4,957,636

The collection trough is open-topped, has two rear wall portions, each adjacent to and extending along the length of one of the drums and topped with scraper or doctor blades which bear against the cylindrical wall surface of the drums respectively. The total power required to drive the drums is modest; less than 1 horsepower, so a very light weight air motor is adequate" [9].

3.3.4 Rope Mop Skimmer

The rope mop oil skimmers or rope mop wringers are about the oldest technology out there for oil skimming or getting oil off water. Like all hard-mounted oil skimmers, the Rope Mop Oil Skimmer can be set to run continuously and run unattended. These rope mops run an endless or looped rope or belted material (looks like a squirrel tail) with oil attracting (oleophilic) fibers woven or sewn into it, out across the water or down vertically (as in a pit). The oil sticks to the outside of the fibers and the rope goes back into the wringer machine where either 2 or 3 rubber coated rollers squeeze the oil out and off of the rope and gravity drains it into a tank [10]. For higher viscosity oils, this medium tends to mat down and lose effectiveness. Generally, a decantation system must be used with these Units, as water pickup can be quite high. Also, replacement mops tend to be more expensive than its counterpart (Belt type skimmer).



Figure 3.10 Rope Mop Skimmer Didn't make correction

Rope mop skimmer can be used in a variety of configurations and they are listed as follows.

Vertical mop skimmers can be deployed down boreholes, drains, separators and sumps. Horizontal mop skimmers can be deployed across lakes and rivers, settlement bonds, balancing tanks or fat traps. They can also be Retrofitted to existing industrial water treatment facilities. Rope mop skimmers are efficient during early responses to oil spills while offering long durations of operations. 'Rope mop skimmer systems typically incorporate an oil/water separator which allows any free water pick up to be returned to the effluent water allowing only oil to be gravity drained or pumped to the waste oil storage tanks nearby. This means the system can effectively operate 24 hours per day 7 days per week without any manual assistance ensuring peace of mind clearing all visible surface oil contamination'[11].

The skimmers can be powered either by an electric drive, air, hydraulic or diesel options are available if required.

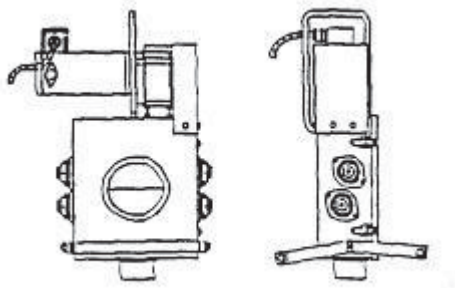


Figure 3.11 Rope Mop Skimmer Apparatus Didn't make correction

The mops are manufactured from a special polypropylene fabric which is stitched to form a continuous loop. Oil skim ropes are made from fibrillated polypropylene which has a large surface area and ensures excellent oil recovery rates. The mops are available in varying widths in black (For heavy sticky oils) and white (for light oils). They are available in lengths form 2m long to 120m long depending on the application. In addition to that, they recover up to 2000L an hour of floating oil.

The Rope Mop recovery rate is dependent on the number and velocity of the ropes, it is generally low throughput. It can be used in both medium to high oil spills, but it is most effective when used on medium spills. The design of the mop skimmer makes it operable in choppy waters, and it is also able to tolerate significant debris, ice and other obstructions.

3.4 Non-Oleophilic Skimmers

Non-oleophilic skimmers carry out the same function as other skimmers, to separate oil from water. The distinguishing component between non-oleophilic vs. oleophilic is that the latter uses oleophilic material. Oleophilic material is oil attracting, by adding oleophilic material onto the skimmer, oil adheres to the surface. In certain situations, such as hot alkaline aqueous parts washer, oleophilic material is inappropriate [12]. In such cases, non-oleophilic skimmers are necessary. Non-oleophilic techniques include weir skimmers, suction systems, and mechanical skimmers. Non-oleophilic skimmers are not as prevalent due to the many restrictions they have. They are usually only used in environments where oleophilic skimmers are inappropriate. They are not as efficient in differentiating between oil and water and aren't as versatile in the types of water they can be used in [13].

3.4.1 Suction Skimmers

Suction skimmers include vacuum skimmers, whereby oil is recovered directly from the water surface by air suction systems. Other vacuum skimmers use a hose directly connected to a vacuum truck, which can easily be carried out in rivers. Vacuum trucks are generally self contained with necessary power supply, pump and storage [14]. Due to the sensitivity to waves, vacuum skimmers are often restricted for use in calm waters. Furthermore, suction skimmers are ideally suited for recovery of oil on or near the shoreline [15]. Another disadvantage of suction mechanisms are the unchanging capabilities of a suction device which can result in high proportions of water being collected and are easily clogged by large debris.

3.4.2 Belt Mop Oil Skimmer

A belt mop oil skimmer is a non-oleophilic mechanism employed to skim oil from coolant and wastewater. The belt is used in applications where an oleophilic material, such as a rope, drum, or disc, is inappropriate. The skimmer works on the difference in surface tension of oil and water allowing the rotating continuous belt to attract waste oil and reject water. Since belt mop oil skimmers are used in harsh conditions, the skimmer is generally turned off whenever there is no oil to skim to minimize the amount of water collected. It is most effective in heavy oils and is capable of removing a high volume of oil [16].

3.5 Weir Skimmers

Weir skimmers are used for effective oil recovery all around the globe. This type of skimmer uses the difference in specific gravity from the oil and water to their advantage for effective draining of spilled oil from the surface of a body of water. The skimmers are usually released using a crane from a moving vessel into an oil containment area to proceed with the recovery of the oil.

The weir skimmers are either remote controlled by compressed air or by self-adjusting.

[17][18][19]Moreover, according to a study of the enhanced oil spill recovery rate using the weir skimmers made by A.H. Hammoud from the Mechanical Engineering Department of the Beirut Arab University, “Weir skimmers play an important role in oil spill recovery.” [20] In addition, the study emphasized that improving the performance of weir skimmers will allow spilled oil to be recovered more efficiently, which will result in the reduction of environmental harm [20]. However, weir skimmers’ recovery effectiveness lies on several factors that will be discussed in detail in the following paragraphs

3.5.1 Specific gravity and operational environment

In order to start developing a fundamental understanding of how the weir skimmer works, it is necessary to understand the role that specific gravity plays in the overall effectiveness of the skimmer. According to the book “Fluid Mechanics Fundamentals and Applications,” specific gravity is defined to be the ratio of the density of a liquid to the density of a standard liquid such as water at a specific temperature. Therefore, for many applications the specific gravity of a liquid is calculated based on the specific gravity of water at 4°C, 1000 kg/m3 [21]. As mentioned in the beginning of this section, the difference in specific gravity between the oil and water allows the oil to create layers on top of the surface of the water. The higher the difference in specific gravity between them, the higher chance for effective containment and recovery of the oil.

When an oil spill is experienced, one of the most important operations that leads to effective oil recovery, is the effective containment of the oil. Therefore, most of the oil recovery operations begin by using oil containment booms. Although the booms difference in size and form, what affects their effectiveness is the operational environment and the specific gravity difference between the oil and the water. These two factors go hand by hand and directly affect each other. For example, if the difference in specific gravity of the oil and the water is significant, then the oil will be more accessible in the recovery process as it will form a thick layer on top of the water surface. In addition, the thick layer of oil will be more likely to withstand higher wave pressure and increased wind. On the other hand, if the specific gravity of the oil is very close or equal to the specific gravity of the water, then the waves and higher winds are likely to easily move the oil. Harsh movement of the oil whose specific gravity is close to the water’s specific gravity, causes the oil to sink under the boom and resurface around 100 ft away from where it sank. As a consequence, the weir skimmer will not be able to recover the amount of oil when it experiences that level of turbulence and buoyancy [22].

3.5.2 Weir skimming operation

Weir skimmers drain are known to be floating devices. The edges of the weir skimmers are positioned at the interface between water and the oil layer on top of it or right below the upper oil slick surface. This allows the oil to successfully flow right over the weir edges into the containment area within the skimmer. Once the oil is recovered and placed in the containment area the Oil is then pumped into external storage tanks. The weird skimmers are the skimmers most used due to their portability and easy assembly [18][19]. Conclusively, these skimmers effectiveness increases when there is effective containment of the oil by using a boom like the one shown in Figure 3.12 and again depending on the

specific gravity of the oil over the water as stated in the specific gravity and environment subsection. In addition, weir skimming operations can be improved by developing a mechanism that will increase oil recovery rate with less amount of water recovered and becoming independent of the oil-water gravitational force effects.

Figure 3.12 displays an oil recovery operation by using a weir skimmer and a boom containment unit.



Figure 3.12 SpillPro on 1 November 2017

3.6 Operational Environment of Skimmers

Operational environment can be described as a condition that influences the behavior and efficiency of an object to do a certain function. Operational environment on booms, skimmers, absorbent materials or any other physical oil recovery method is the primary process that affects the nature of an oil spill. Boom is a barrier used to prevent oil spill or slick from spreading, however the efficiency of this operation can heavily depend on the characteristics of the current, wind, or wave behavior [24]. When the wind or current velocity is at a certain point or the height of the wave is above 1 meter then the oil will spill underneath the barrier. This will limit the booms efficiency recovery which leads to using a skimmer as the next step of the water cleanup process. An oil skimmer is a device used to remove oil from a body of water, however an operational environment can heavily influence the productivity of this product. These negative consequences can happen because of weathering, which is the case of spreading, evaporating, dispersion, dissolution, and emulsification of an oil [25]. The final step of water rehabilitation is using adsorbent materials, which is the use of sorbent materials to clean oil spills.

3.6.1 Weathering

The effect of weathering on the productivity and efficiency of the oil recovering process can occur in various ways. one of the weathering aspects is spreading, which can be described as the reduction of bulk

quantity of oil and increasing spatial area [24]. Thus, oil in a high current system can be less concentrated as opposed to a well contained system. Evaporation is another characteristic of weathering that can affect the recovery of an oil spill. Evaporation is the mechanism of losing the light molecules into the air which leaves the oil to be denser, heavier, and more viscous. Dispersion can be described as the action of distributing the oil into the water which can damage the skimmer or booms physical impact on oil recovering. Dispersion can be a result of having a high-water turbulence. Dissolution of oil occurs when the water-soluble component of oil may dissolve into the water surrounding. This type of weather characteristics is one of the primary toxic reasons of an oil spill. The process of dissolution may occur frequently when temperature rises, molecular weight decreases, salinity decreases, and when there is an increase in the dissolved concentrations of organic matter [25]. Lastly, emulsification is opposite to dispersion, it is when water dissolves and incorporates oil. This is a product of the wave behavior into the oil and water, the high energy of the wave emulsifies the oil. Heavier oil is more likely to emulsify rapidly as opposed to lighter oil. This condition is often referred to as "mousse". Figure 3.13 showcases some of the different alteration processes that an oil spill faces on water [26].

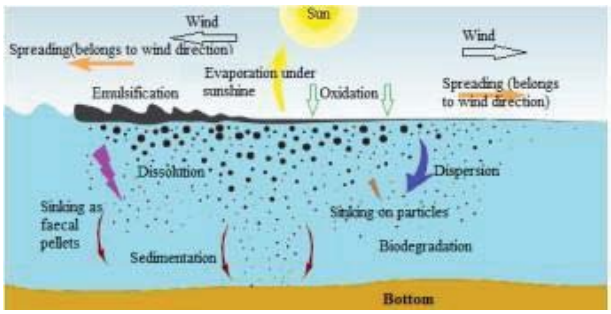


Figure 3.13: Various Weathering Conversations of Oil Spills

3.6.2 Oil Spill Classification

Oil spills unquestionably damages marine environments and causes severe impact to the water. Therefore, oil spills have been classified into three categories.

- First class: The following classification is for small oil spills that are related to machinery discharge of oil water mixture. It can also be a result of operational vessels/ships in port, or berth line [25].
- Second class: The following classification is for oil spills that are related to ship incidents such as fires, collisions, or any other damages that are associated with ships. This can result in contaminating large water areas and can result in damaging the ocean environment [25].
- Third class: The following oil spill classification is for any intentional oil spill, someone who jeopardizes the water quality and marine life just to save money. This can be classified as a criminal act [25].

3.7 Major Components of Skimmers

This section focuses on the main and vital components of many different skimmer designs. Through extensive research the team was able to accumulate a list of major components that current skimmer designs have. Below, a list of some of the different components identified is provided with their respective functions.

- Pump/hose: Extension of skimmer design used to extract collected oil to be relocated to an outside container source.
- Container - Used to store the collected oil from the skimmer. This prevents the oil from mixing with the water after it is collected.
- Draining system - A system designed to drain the collected oil from the container after it is separated from the water. The collected oil is then removed and stored to keep the container empty to restart the skimming process.
- Filter system - Oil and water separator that detects the density of collected liquids and also catches small particles to keep oil purified for reuse. After liquid is filtered, it is then moved to the container.
- Power supply - A power supply would be needed for skimmer mobility. Examples consist of an Electric motor, Diesel hydraulic power unit, or a DC volt battery.
- Sensor: A sensor will be needed to determine the distances the skimmer will fluctuate within. These sensors will also manage the START and STOP control for the skimmer during skimming operations. Finally, the sensor will be able to detect oil thicknesses.
- Actuators: Hydraulic actuators are components used to control the intake of a system. Since the skimmer is mechanically driven by water, the actuator can “control” how the system reacts to the environment using a control signal, usually a valve.

3.8 Relevant Analysis

This section covers the relevant analysis needed to understand the methods and mathematics for proper fabrication of a working skimmer. The skimmer will need to have realistic rates of recovery to meet general standards. The materials will need to be cost effective, meet the specifications for mechanical properties, have corrosion resistance, and the ability to withstand various types of weathering. Using the proper materials is vital to the lifetime of the skimmer. Below, a list of chemical properties, calculations, and material standards can be observed.

- Oil and grease always on the water surface. They do not mix with water. Separation of it is based on the surface tension, specific gravity and viscosity of them

- properties determining if oil can skim surfaces involve floatation, viscosity and the time the oil stays on the surface of the water.
- Specific gravity can be calculated to determine if oil will float on water, if the specific gravity is lower than the surrounding water is(which depends on if it's pure or sea water) then it will float. API equation can be used to measure specific gravity of oil

$$^{\circ}API = \frac{141.5}{specific\ gravity\ at\ 15.6\ ^{\circ}C} - 131.5 \qquad \text{(Equation 3.8)}$$

- Besides specific gravity, pour point, is another method used to categorize oils. The pour point is the temperature below which an oil can no longer float [27].
- The speed of oil spreading depends on the viscosity of the oil as well as external factors like wind. Low viscosity oil spreads easily while high viscosity oils do not
- The rate of evaporation depends on the ambient temperature as well as the wind speed, but in temperate climates all hydrocarbons with a boiling point below 200°C will evaporate within 24 hours [27].
- Oil dispersions mainly occur at sea, at the location of breaking waves. Dispersion usually affects low viscosity oils as high viscosity oils are more protected of dispersion as the particles are more tightly attached to each other thus requiring more force to break the oil particles apart.
- Various factors need to be taken into account during the selection skimmers but the most important aspects to consider are the viscosity and the adhesive properties of the oil within the skimming process
- The second most important factor to assess is the skimmer's intended use and expected operational conditions.
- Recovery rate (RR): The rate at which pure oil is recovered
- Recovery efficiency (RE): The relation between recovered oil and recovered fluids (oil water mixture)
- Throughput efficiency: The relation between encountered oil and recovered oil

3.8.1 Relevant Equations

Theoretical calculation that can potentially be used to identify the amount of oil that can be recovered using disc type oil skimmer:

$$Amount\ of\ recovered\ oil\ spill = A\ x\ \mathrm{R}\ x\ \mathrm{Ti}\ x\ \mathrm{T} \qquad \text{(Equation 3.8.1)}$$

where A is the area of the dipped disc(m2). R is the disc rotation speed (RPM). Ti is the time/duration taken(s). T is the oil thickness (cm).

When oil spill is recovered by a rotating drum skimmer, the following variables are involved:

$$f_1(Q, d, L, \omega, h, t, \rho, \mu, \sigma) = 0 \qquad \text{(Equation 3.8.2)}$$

where Q is the oil recovery rate (m3/s), d is drum outer diameter (m), L is drum length (m), o is rotational speed (rad/s), h is height of the drum centre above the oil/water interface surface (m), t is oil film thickness (m), r is oil density (kg/m3), m is dynamic viscosity of oil (Pas), and s is oil surface tension (N/m).

The volume rate of oil recovered per turn when shaft is rotating for the belt type skimmer:

$$V=T \times W \times \pi \times d \times N \qquad \text{(Equation 3.8.3)}$$

where T is the thickness of film on the belt in (mm). W is the width of the belt in (m). D is the diameter of the shaft in (m). N is the speed of rotation of the shaft in (rpm).

3.8.2 Relevant Materials

The proper selection of material for different parts of a machine will depend on the following factors:

- The cost of materials.
    - The cost of the materials used will need to be within means to appeal to buyers.
- Physical and chemical properties of materials.
    - Weather, water, and corrosion resistant materials such as stainless steel, rubber, aluminum and polypropylene.
- Mechanical property of material.
    - Factors include: Strength, Stress, Stiffness, Elasticity, Plasticity, Brittleness, and Hardness.

3.9 Codes and Standards

This section covers some of the acts, programs, and testing regulations that are relevant to Oil skimmers and oil recovery.

The oil pollution act was passed in 1990. This act was an amendment to the Clear Water Act in which some oil storage facilities were required to develop facility response plans for spills. The lead federal response agency EPA is the agency for oil spills occurring in inland waters. Some of EPA's top priorities are to prevent, prepare for, and respond to oil spills that occur in and around inland waters of the United

States. EPA's oil spill prevention program includes the Spill Prevention, Control, and Countermeasure (SPCC) and the Facility Response Plan (FRP) rules [27].

On the other hand, the Bureau of Safety and Environmental Enforcement, the Oil Spill Preparedness Division, and the Response Research Branch manages the OSRR Program. This research program has focused on improving the spill response countermeasures. The program opens a path that helps develop decision making strategies for oil spill responses in the offshore environment.

In addition, testing optimization from ASTM-2709-08 requires performance data to be the result of three measurements that produce results within 20% of the arithmetic mean. The skimmer optimization process requires that a skimmer should operate to provide the maximum ORR while also meeting 70%.

Discussion:

The supporting articles and references above help to establish the credibility and procurement of today's advances within the efforts of efficiently conducting oil removal from open water sources. The abundance of resources pertaining to these advances allow for comparisons of the advantages and disadvantages that the industrial oil skimmers have to offer today. By examining the many key differences between oleophilic, non-oleophilic, and weir skimmers, an analysis can be conducted to determine which design can be further altered to increase the efficiency of today's oil recovery. Key aspects of understanding the efforts of increasing the efficiency include the characterization of each skimmer type as well as their operational environments. Patterns and characteristics of oil behavior are also examined to comprehend the "oil life" during its duration on the water's surface. This guides the sense of urgency for the effectiveness of the oil removal process. All references gathered guided for a general understanding of the oil skimmer industry.

4. PRELIMINARY DESIGN

This chapter discusses the process in which the skimmer main functions were identified. Throughout the chapter descriptions and images related to the functional decomposition of prospective skimmer design can be found. Note that as some of the figures in the chapters are perceived as repetitive it is important to observe closely and effectively real the descriptions to better understand the process.

4.1 Functional Decomposition

In this section, the team worked both individually and in conjunction to come up with the best overall skimmer function for the prospective design. In addition, the team further decomposed the overall function in level 1, level 2, and level 3 sub-functions. This section allowed each team member to freely express their individual ideas and it encouraged each team member to research and get familiar with existing skimmer designs.

Identifying the most important function that the prospective skimmer design should achieve, was not an easy task. The process of narrowing down from the many functions available for skimmers to one overall function was found to be interesting and it will be considered for future project assignments.

To begin the identification of the overall function, each team member individually came up with 3 main functionalities that the prospective design should be able to perform. Once each member was ready to share their ideas, a sticky note splashguard was made available on a Google slides document. Team members were given approximately 4 minutes to input their ideas on the google sticky note splashguard as shown in Figure 4.1. After all the team members' ideas were posted, the team joined a Zoom meeting to discuss each one of the functionalities provided by the team and make an effective decision on an overall function. As shown in Figure 4.2, it was determined that the overall function of the prospective skimmer design was identified to be the ability to recover at least 25~50% of oil in 1-inch oil slick. In addition, the Figure 4.2 indicates the appropriate inputs related to the overall function and its expected outcomes.

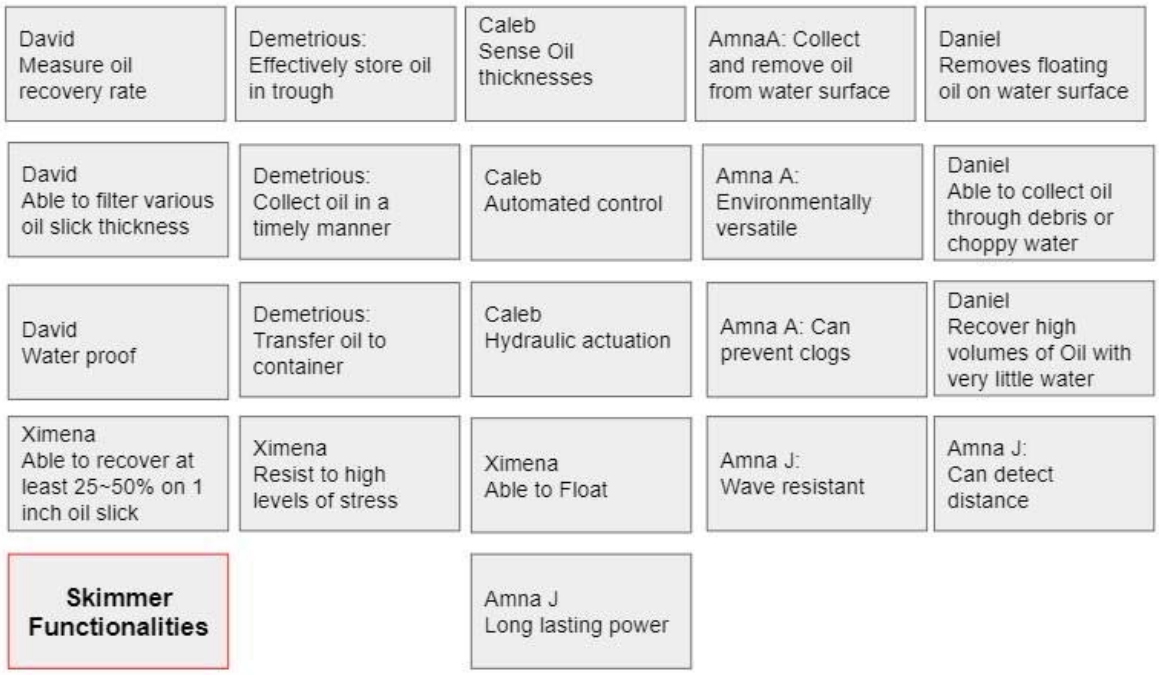
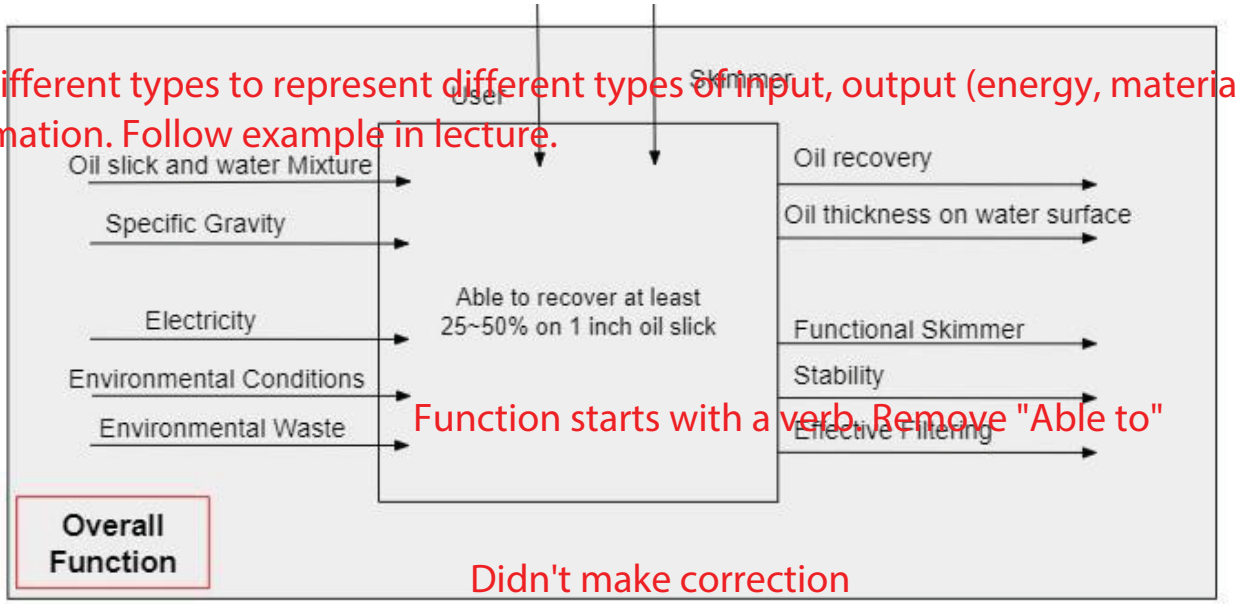


Figure 4.1 Skimmer Functions - Level 0

Use different types to represent different types of input, output (energy, materials, information. Follow example in lecture.



Function starts with a verb. Remove "Able to"

Didn't make correction

Figure 4.2 Overall Function Inputs and Outputs

In this section, each team member was asked to come up with three different level 1 sub-functions based on the identified overall function of the prospective skimmer. Once each Team member was ready to share their level 1 sub-function ideas, a sticky note splashguard was made available to each member on another Google slides document. Then, each team member was given another 4 minutes to input their ideas on the new google sticky note splash guard as shown on Figure 4.3. After all the group members shared their ideas, the team joined a Zoom meeting to further discuss each sub-function. Subsequently to

the analysis, the team selected six main level one subfunctions. As expressed in Figure 4.4, the team concluded that in order for the prospective skimmer design to be able to recover at least 25~50% of oil in 1 inch oil slick, the skimmer should be able to measure oil recovery rate, filter various oil slick thickness, separate oil from water, collect oil through debris or choppy water, have effective skimmer mobility, and limit water intake.

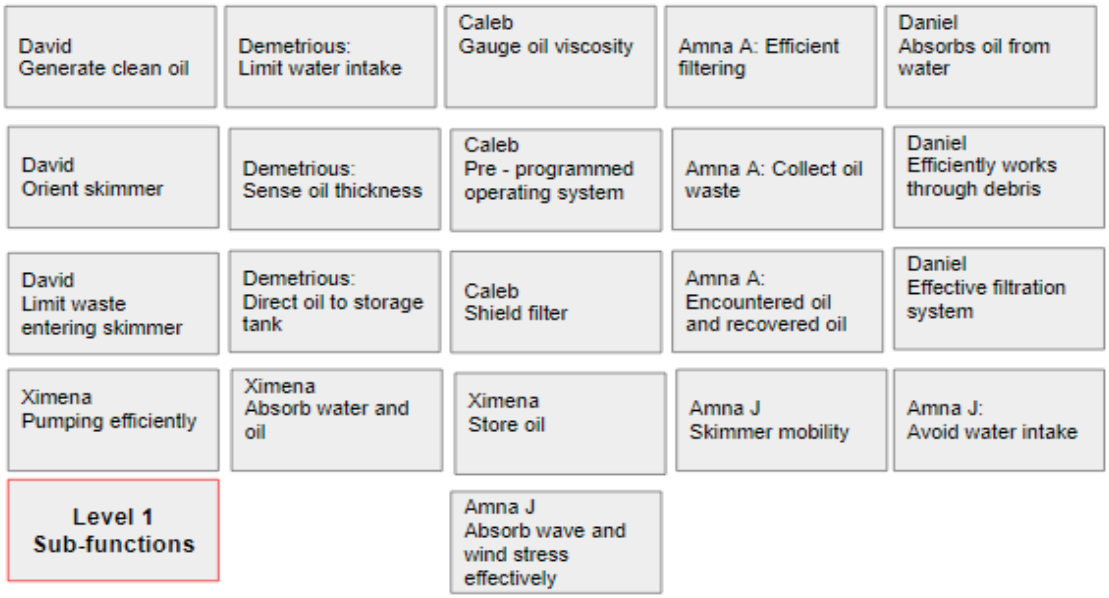


Figure 4.3 Skimmer Ideas - Level 1 Sub-functions

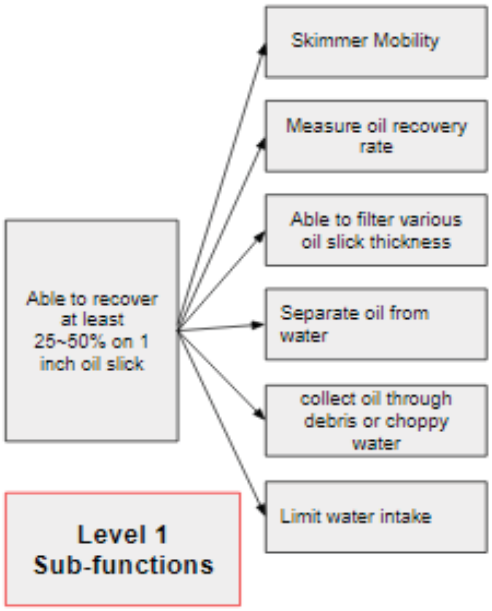


Figure 4.4 Level 1 Sub-functions Tree

In this section, each team member was asked to generate three different level 2 sub-functions for each one of the five level 1 sub-functions selected in the previous section. Once each team member was ready to share their 15 level 2 sub-function ideas, a sticky note splashguard was made available to each member for each one of the level 1 subfunctions. Then, each team member was given 12 minutes to input their ideas on the google sticky note splash guards as shown on Figures 4.5 - 4.10. After all the group members shared their ideas, the team joined another Zoom meeting to further discuss each level 2 sub-function. Next, the team selected 10 out of 105 level 2 sub-function ideas provided based on the level 1 sub-functions. In figure 4.11 a display of the 10 level 2 sub-functions selected was made available.
During the analysis of the level 2 functions, the team concluded that for the prospective skimmer design the skimmer mobility should be considered to perform flotation stabilization. In addition, it was determined that the skimmer needed to be able to measure oil recovery rate, the skimmer should be able to measure the amount of oil recovered per second and control rate of recovery. It was also concluded that for the skimmer to be able to filter various oil slick thickness, the skimmer must be able to distinguish between viscosities, detect type of oil, and self-adjust to different types of oil. In addition, the team decided that to successfully separate the oil from the water, the prospective skimmer must be able to filter water out of the oil and Contain the oil (Filter water out of the oil). Moreover, it was determined that for the skimmer to be able to avoid debris collection. Finally, the team agreed that to limit the water intake, the skimmer design should be able control water intake with actuators.

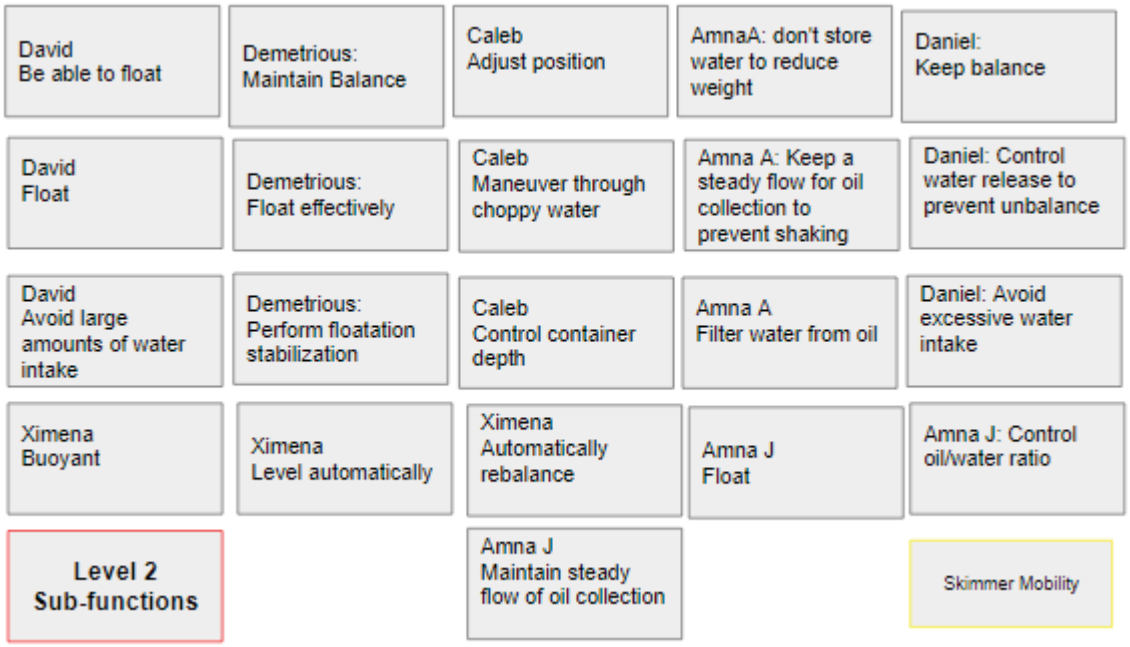


Figure 4.5 Skimmer mobility - Level 2 Sub-functions

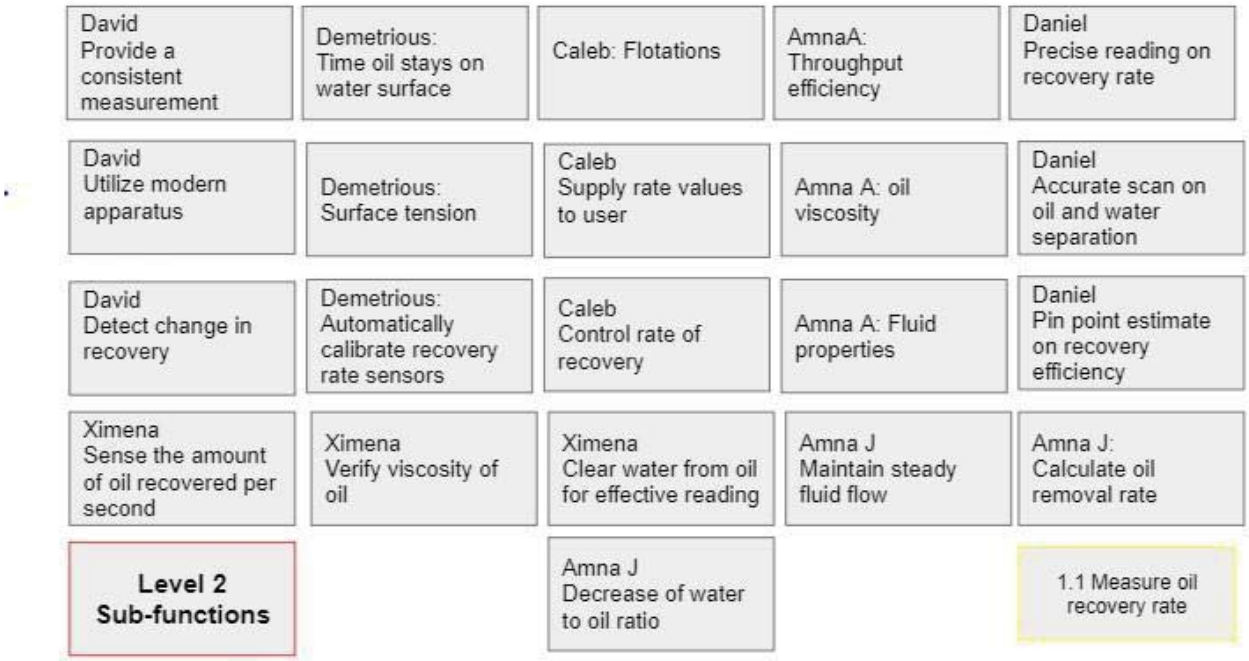


Figure 4.6 Measure Oil Recovery Rate - Level 2 Sub-functions

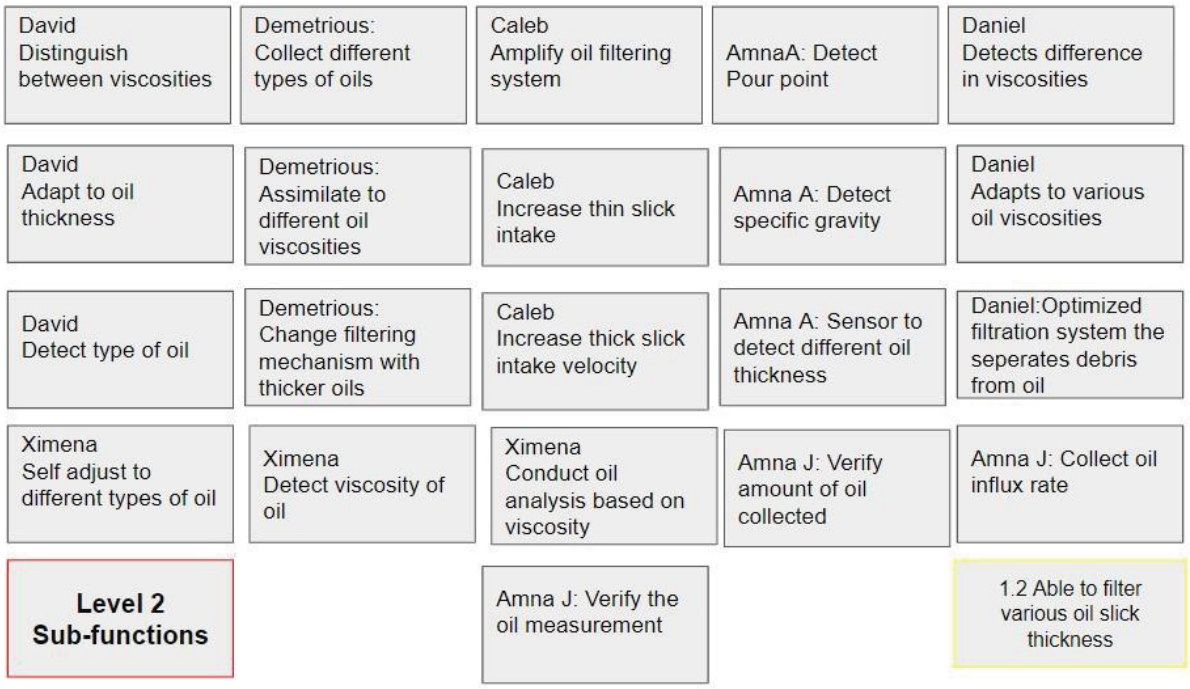


Figure 4.7 Filter various oil slick thickness - Level 2 Sub-functions

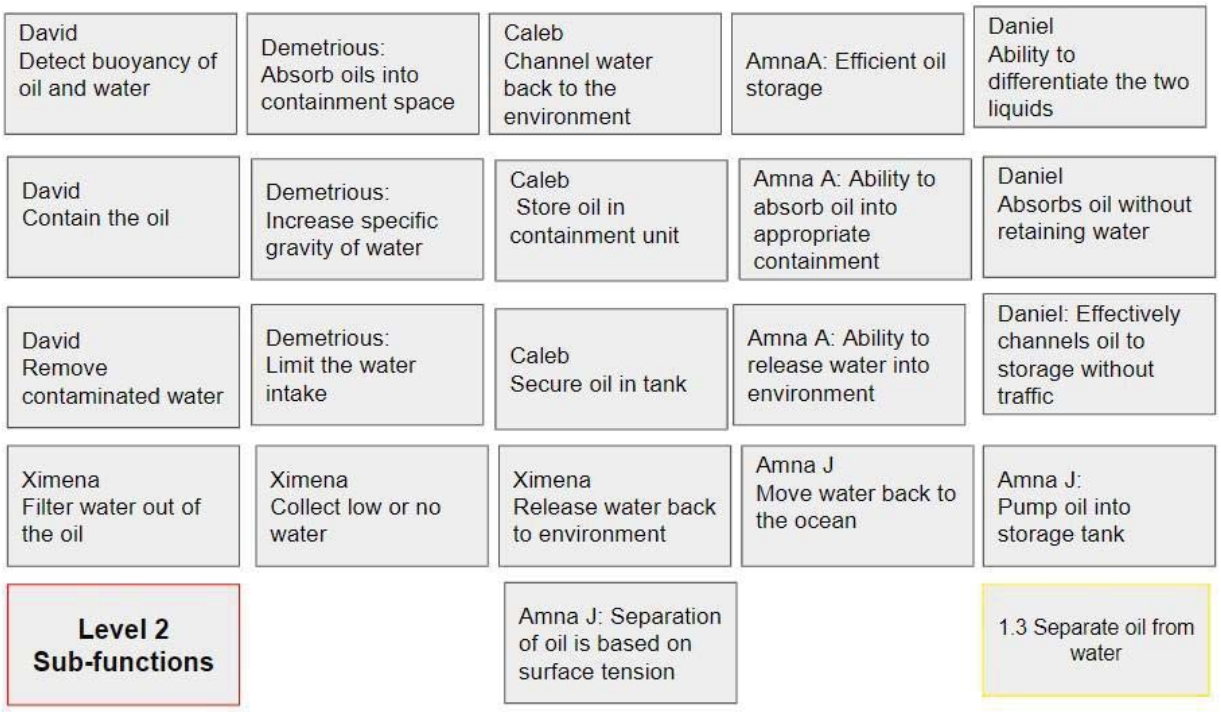


Figure 4.8 Separate Oil from Water - Level 2 Sub-functions

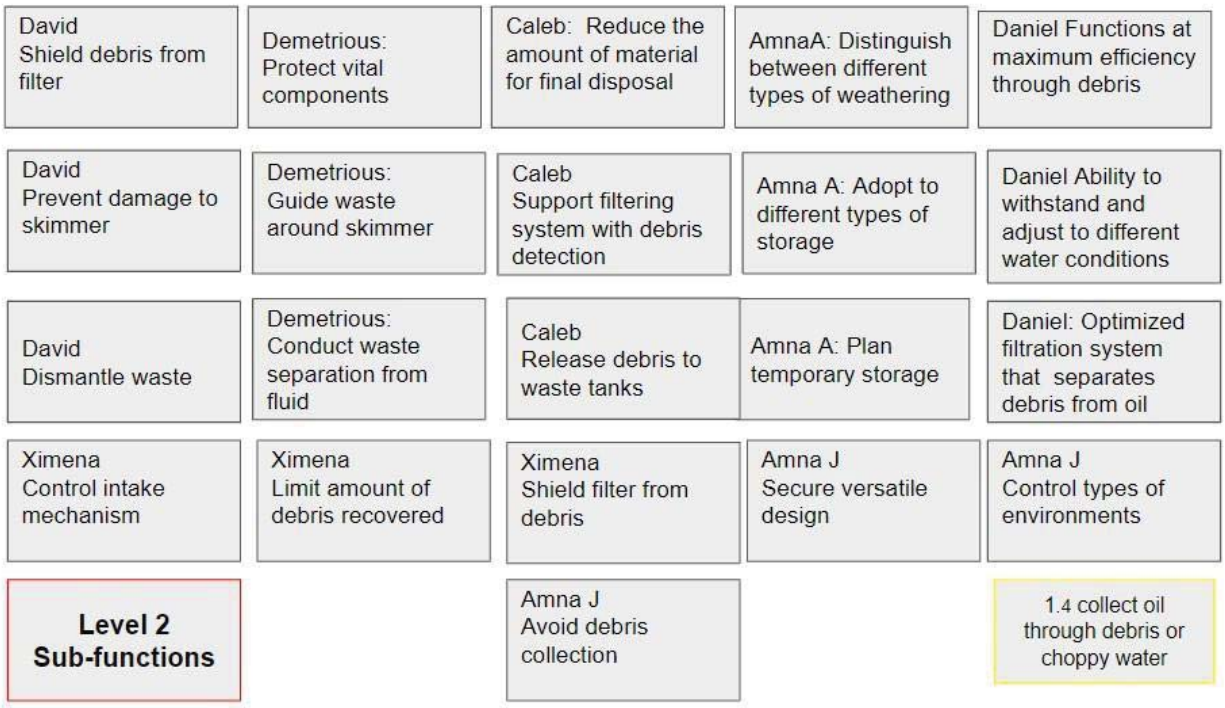


Figure 4.9 Collect Oil Through Debris or Choppy Water - Level 2 Sub-functions

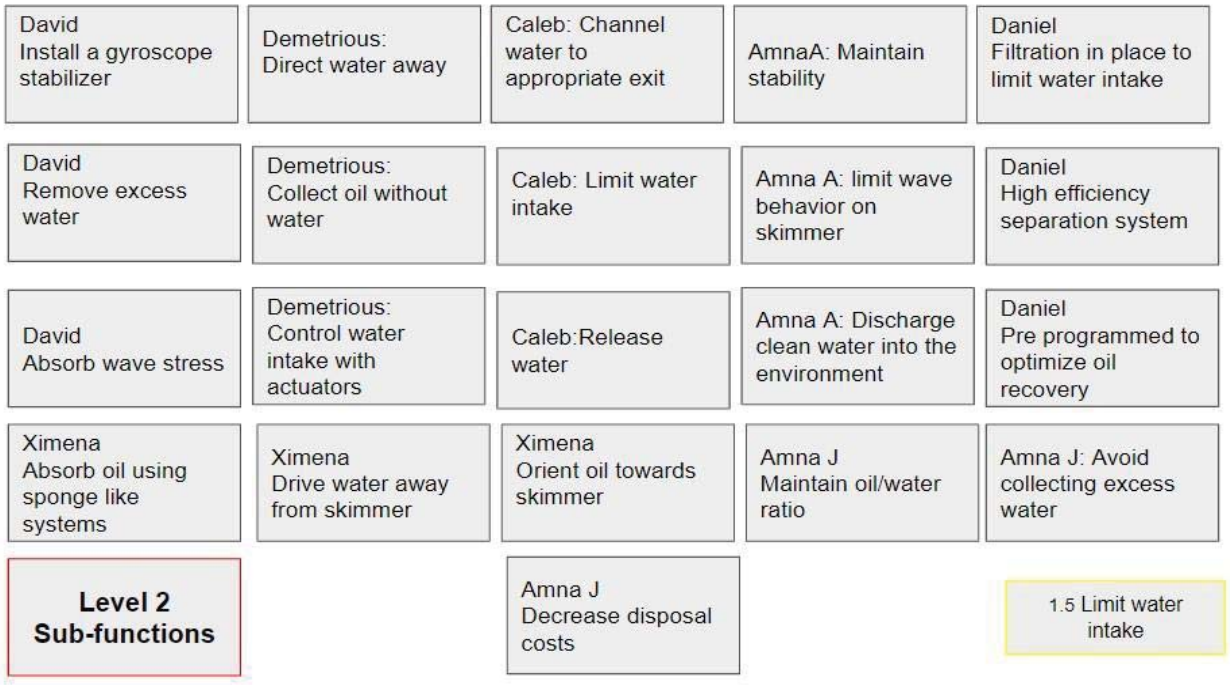


Figure 4.10 Limit Water Intake - Level 2 Sub- functions

Fill the empty space.

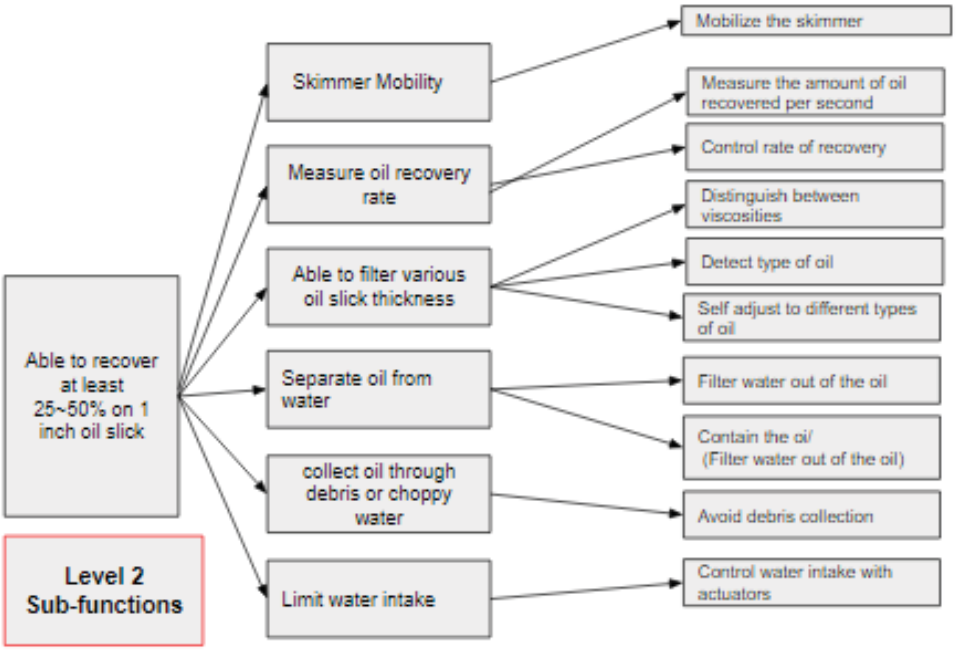


Figure 4.11 Level 2 Sub-functions Tree

In this section, each individual generated three different level 3 sub-functions for five of the level 2 sub-functions selected in the previous section. Once each team member was ready to share their 15 level 3 sub-function ideas, a sticky note splashguard was made available to each member for each one of the level 2 subfunctions to repeat the same process done in the previous sections. At that point each team member was given around 12 minutes to input their ideas on the google sticky note splash guards as shown on Figures 4.12 - 4.16. Next, all the group members were able to discuss the level 3 sub-functions in a Zoom meeting. Subsequently, the team selected 15 out of 105 level 3 sub-function ideas based on the level 2 sub-functions identified in the previous section. In figure 4.17 the full functionality decomposition for the prospective skimmer design is displayed.

Through the analysis of the level 3 functions, it was concluded that for the design to be able to have effective skimmer mobility, the skimmer should be able to perform flotation stabilization. Moreover, for the design to be able to sense the amount of oil recovered per second, the skimmer should be able to transform rate readings, calculate amount of oil intake, and accurately detect through sensors. It was also concluded that for the skimmer to be able to distinguish between viscosities, the design must be able to verify oil thickness, measure oil resistance to flow, and detect surface tension. In addition, the team decided that to successfully filter water out of the oil, the prospective skimmer must be able to dissipate excess water, increase filtration rate, and avoid water contamination.

Furthermore, it was determined that for the skimmer to be able to avoid debris collection, the design must successfully limit debris entering skimmer, divert debris using its filtration system, and remove debris through aversion technology Finally, the team decided that to control the water intake with actuators, the

skimmer design should be able use specific gravity differential to limit water intake, perform floatation stabilization, collect optimal level of oil.

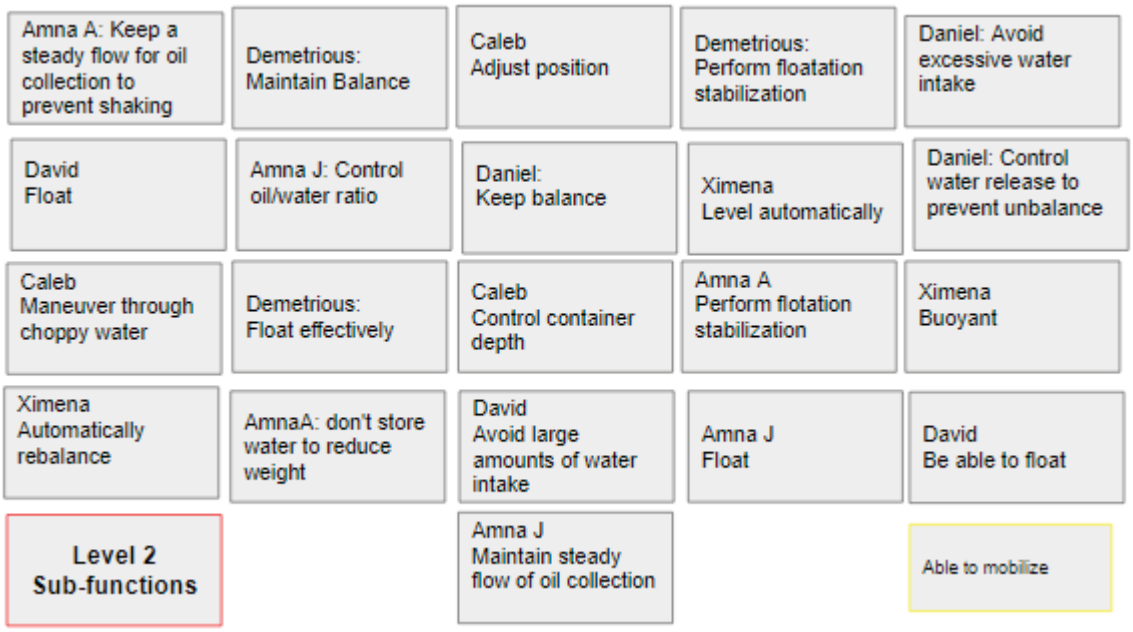


Figure 4.12 Able to mobilize - Level 3 Sub-functions

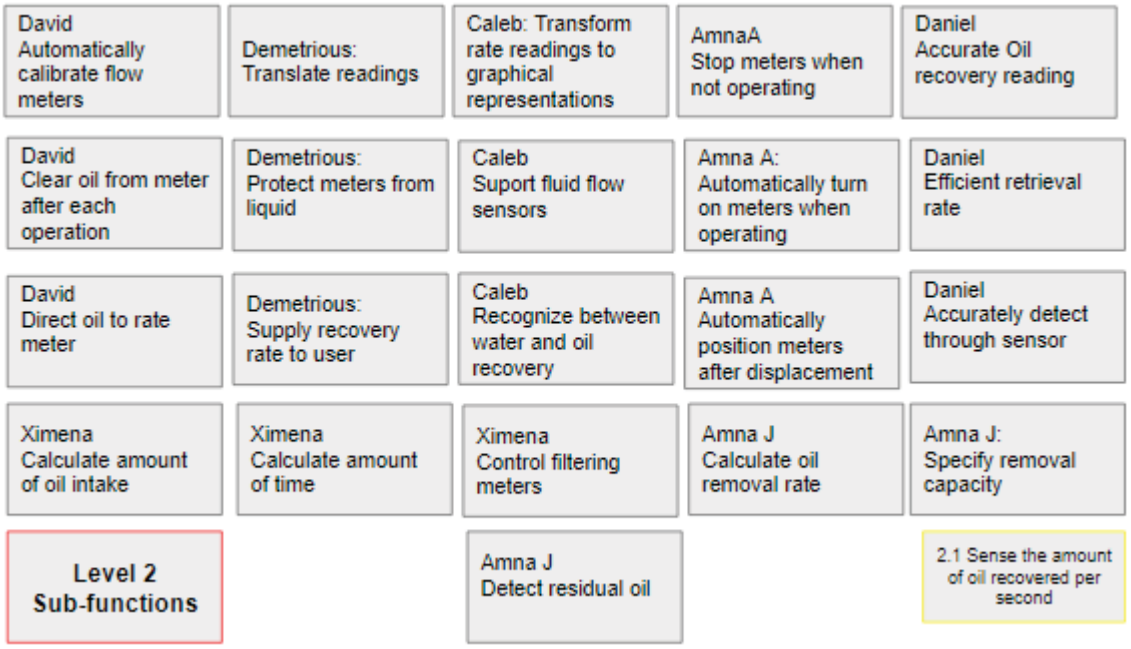


Figure 4.13 Sense the amount of oil recovered per second - Level 3 Sub-functions

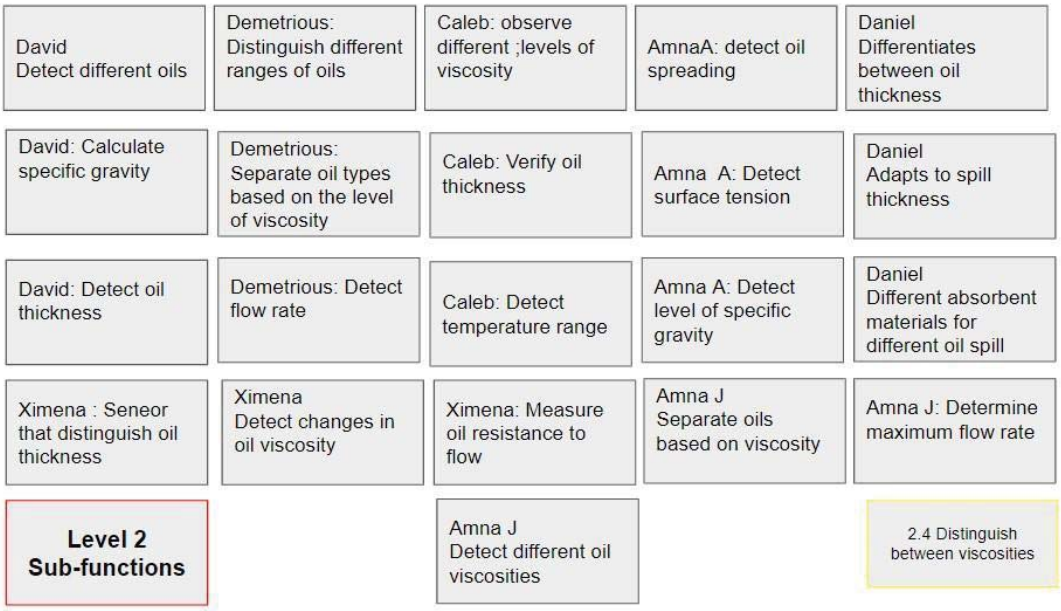


Figure 4.14 Distinguish Between Viscosities - Level 3 Sub-functions

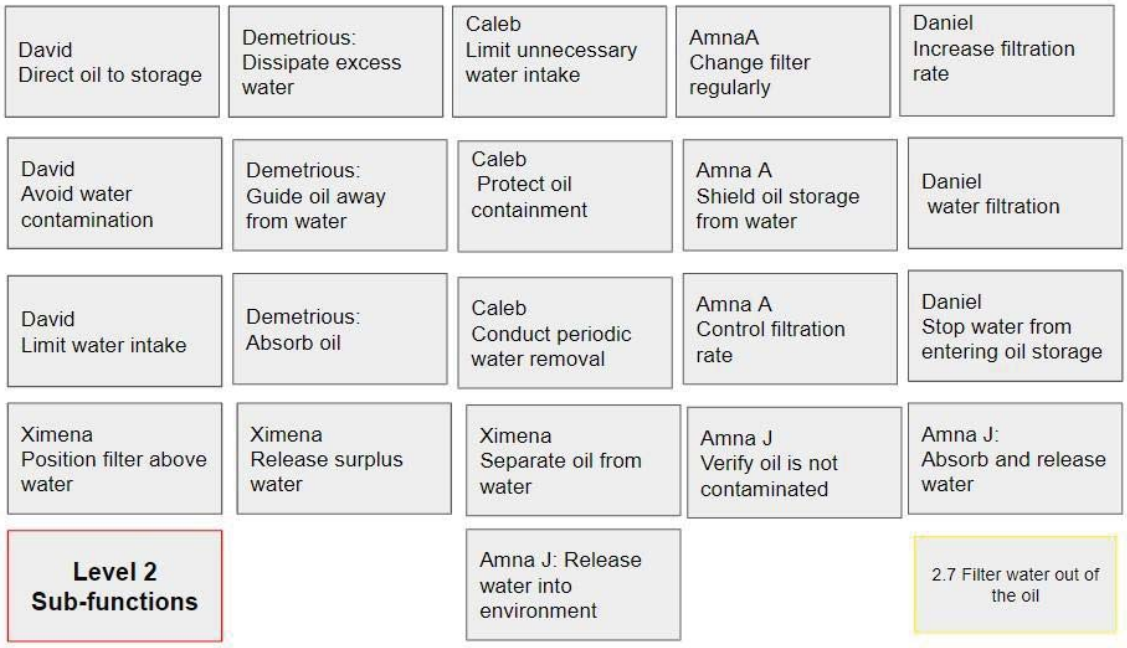


Figure 4.15 Filter Water Out of Oil - Level 3 Sub-functions

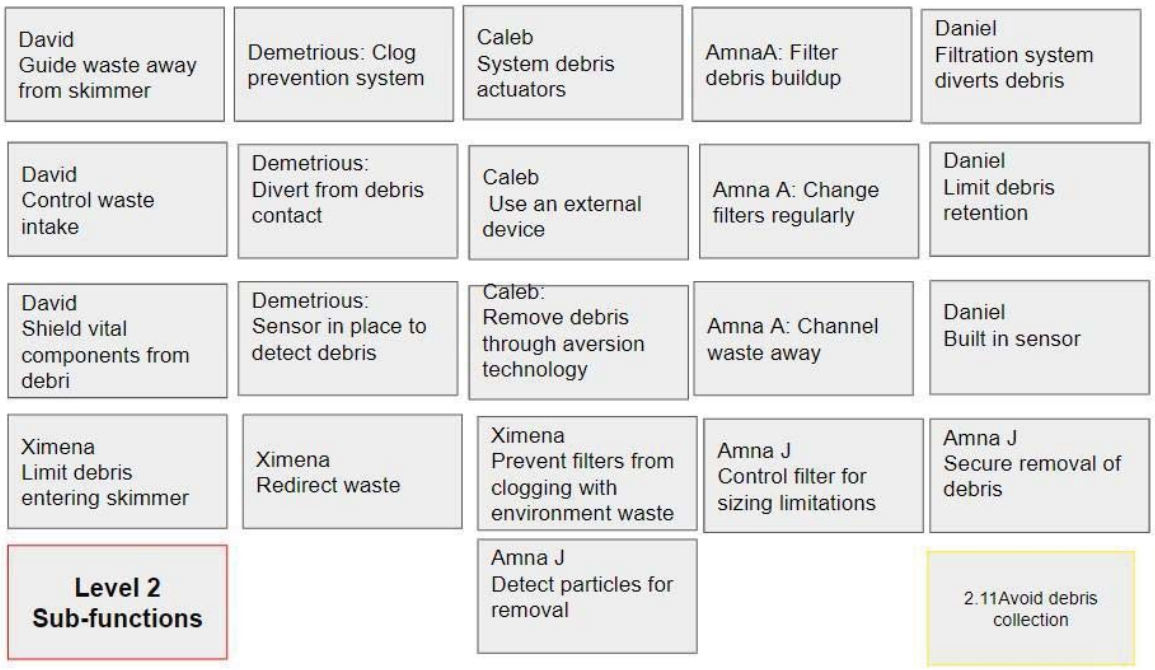


Figure 4.16 Avoid Debris Collection - Level 3 Sub-functions

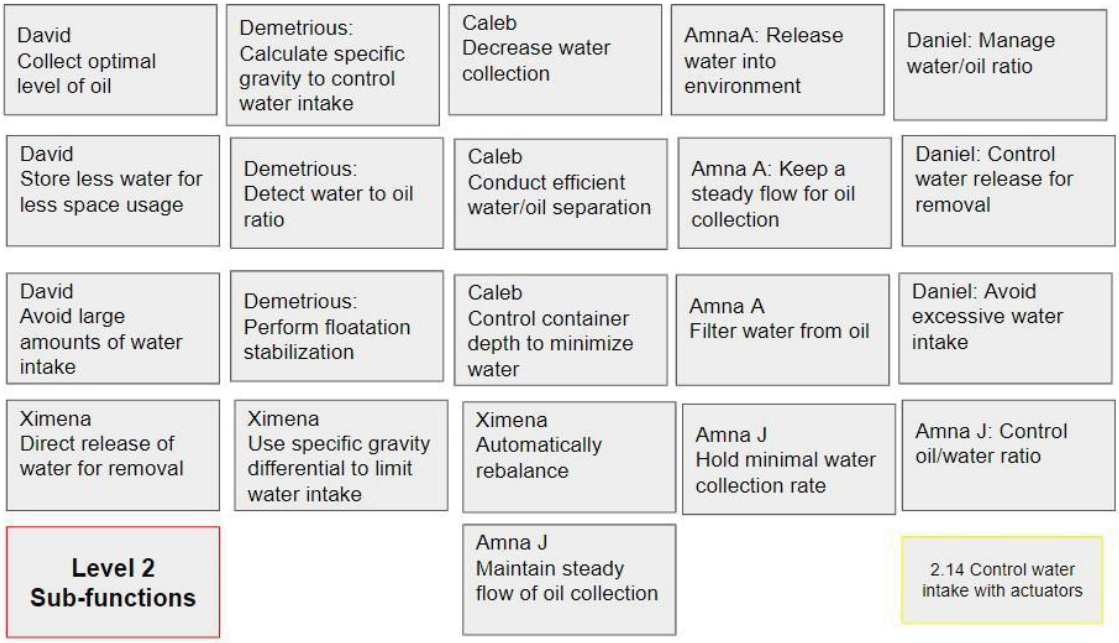


Figure 4.17 Control Water Intake with Actuators - Level 3 Sub-functions

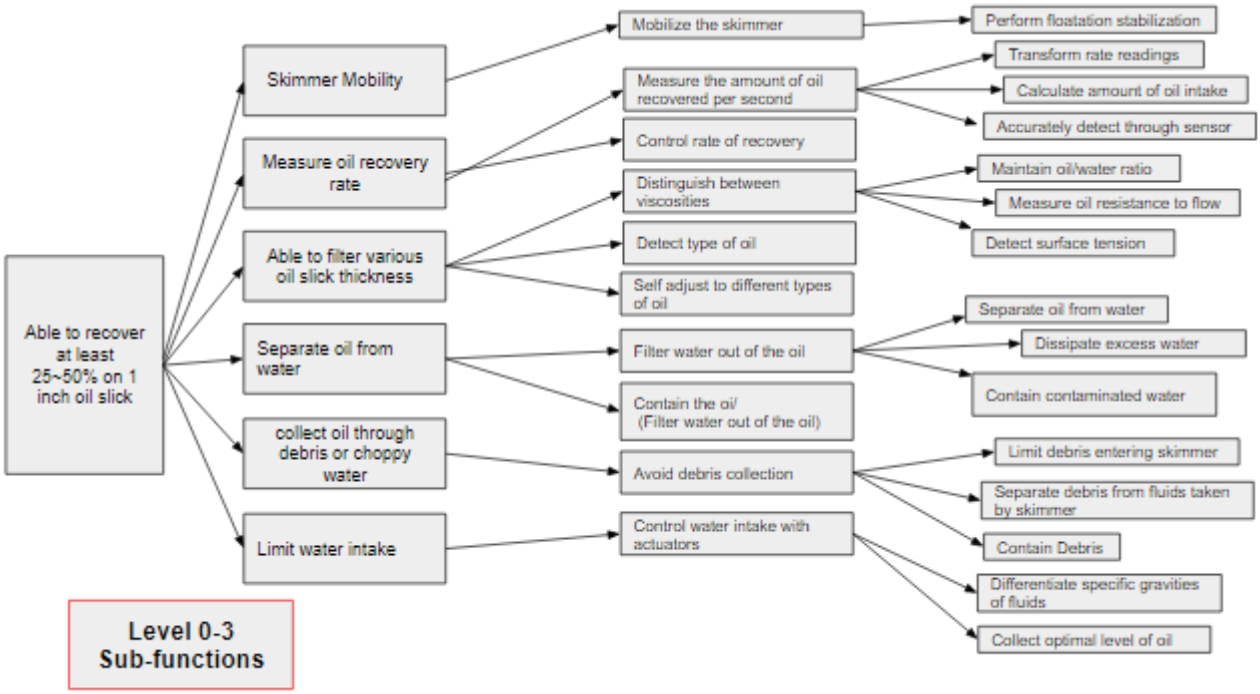


Figure 4.18 Level 3 Sub-functions Tree

Table 4.1, given below, is a morphology table that represents the current status of the generated subfunctions levels 1-3 created through adaptations of the overall function of the skimmer being able to recover at least 25~50% on 1 inch oil slick. The table is organized in levels of sequential order from sub-function 1 to 2 to 3. As shown below, some of sub-level 2 functions do break down into a third sublevel. These breaks help to express which sub-functions were further chosen to be expanded based upon their vitality and functionality.

Table 4.1 Morphology (Functional Decomposition and Concepts) Table

Overall Function	Level 1 Sub-functions	Level 2 Sub-functions	Level 3 Sub-functions	Concept 1	Concept 2	Concept 3	Concept 4
Recover at least 25~50 % on 1-inch oil slick	Skimmer Mobility	Mobilize the skimmer	Perform Floatation Stabilization				
	Collect oil through debris or choppy water	Avoid debris collection	Limit debris entering skimmer				
			Separate debris from fluids taken by skimmer				
			contain debris				
	Measure oil recovery rate	Measure the amount of oil recovered per second	Transform rate readings				
			Calculate amount of oil intake				
			Accurately detect flow rate				
		Control rate of recovery					
	Able to filter various oil slick thickness	Distinguish between oil viscosities	Maintain oil/water ratio				
			Measure oil resistance to flow				
			Detect surface tension				
		Detect type of oil					
		Self-adjust separation method to different types of oil					
	Limit water intake	Control water intake	Differentiate specific gravities of fluids				
			Collect optimal level of fluids				
	Separate oil from water	Filter water out of the oil	Separate oil from water				
			Dissipate excess water				
			contain contaminated water				
		Contain the oil(filter water out of the oil)					

4.2 Concept Generation

In this section, the team developed and executed a plan to effectively generate concepts for the level 2 and level 3 functions identified during the functional decomposition stage. Members were designated to generate 4 concepts for each of 10 to 11 functions that were assigned per member. During this stage each team member developed an individual report that displayed around 44 concepts. Then, the team worked together to generate a group report where a total of 100 concepts out of the 300 concepts were selected. In Table 4.2 the level 0,1,2,3 functions can be found. In addition, the table shows the functions assigned to the student for the concept generation stage. The student will be required to develop 4 concepts per function assigned. Once the student generates the concepts, the student will be required to use Table 4.3 to list the figure numbers for each concept generated and a brief description of the figure.

Table 4.2 Individual Assignment for Concept Generation

Overall Function	Level 1 Sub-functions	Level 2 Sub-functions	Level 3 Sub-functions	Name	Name	Name
Recover at least 25~50% on 1-inch oil slick	Skimmer Mobility	Mobilize the skimmer	Perform Floatation Stabilization	Aamna J	Ximena	Daniel
	Collect oil through debris or choppy water	Avoid debris collection	Limit debris entering skimmer	Demetrious	David	Caleb
			Separate debris from fluids taken by skimmer	Ximena	Daniel	Amna A
			contain debris	Aamna J	Caleb	Demetrious
	Measure oil recovery rate	Measure the amount of oil recovered per second	Transform rate readings	Demetrious	Aamna J	Daniel
			Calculate amount of oil intake	Ximena	David	Caleb
			Accurately detect flow rate	Aamna J	Daniel	Amna A
		Control rate of recovery		Daniel	Amna A	Ximena
	Able to filter various oil slick thickness	Distinguish between oil viscosities	Maintain oil/water ratio	Demetrious	Aamna J	Amna A
			Measure oil resistance to flow	Ximena	Aamna J	Demetrious
			Detect surface tension	Demetrious	Daniel	Ximena
		Detect type of oil		David	Caleb	Aamna J
		Self-adjust separation method to different types of oil		Daniel	Amna A	David
	Limit water intake	Control water intake	Differentiate specific gravities of fluids	Amna J	David	Caleb
			Collect optimal level of fluids	David	Caleb	Demetrious
	Separate oil from water	Filter water out of the oil	Separate oil from water	Demetrious	Caleb	Ximena
			Dissipate excess water	Daniel	Demetrious	Caleb
			contain contaminated water	Aamna J	David	Amna A
		Contain the oil(filter water out of the oil)		David	Aamna J	Amna A

Table 4.3 Morphology Functional Decomposition and Concepts Table

Overall Function	Level 1 Sub-functions	Level 2 Sub-functions	Level 3 Sub-functions	Concept 1		Concept 2		Concept 3		Concept 4		Concept 5		Concepts 6		Concept 7		Concept 8	
				Description	Sketch	Description	Sketch	Description	Sketch	Description	Sketch	Description	Sketch	Description	Sketch	Description	Sketch	Description	Sketch
Recover at least 25~50% on 1-inch oil slick	Skimmer Mobility	Mobilize the Skimmer	Perform Floatation Stabilization	Floatation foam container	Figure 4.1 (A)	Foam Filled Buoys	Figure 4.1 (B)	Buoyant Body	Figure 4.1 (C)	Foam filled modular chain buoys	Figure 4.1 (D)	Tri-float skimmer	Figure 4.1 (E)	Floating Drum Skimmer	Figure 4.1(F)	Skimmer material	Figure 4.1(G)		
	Collect oil through debris or choppy water	Avoid debris collection	Limit debris entering skimmer	Monitoring sensor	Figure 4.2 (A)	Debris Net	Figure 4.2 (B)	Perimeter appendage	Figure 4.2 (C)	Repeller Grate	Figure 4.2 (D)	Debris shield	Figure 4.2(E)	Skimmer guard	Figure 4.2(F)	Flow Transmitter	Figure 4.2(G)		Figure 4.2(H)
			Separate debris from fluid taken by skimmer	Debris protection net	Figure 4.3(A)	Floating Skimmer Fence	Figure 4.3(B)	Self Filtration	Figure 4.3(C)	Commercial Screened Shield	Figure 4.3 (D)	Filters	Figure 4.3(E)						
			Contain debris	Return-line filter	Figure 4.4(A)	Waste Basket	Figure 4.4(B)	Hydraulic system	Figure 4.4(C)	Bandalong Litter Trap	Figure 4.4 (D)	m system	Figure 4.4(E)	bag float	Figure 4.4(F)				
	Measure Oil Recovery Rate	Measure the amount of oil recovered per second	Calculate amount of oil intake	Flow meter	Figure 4.5 (A)	Flow Monitor	Figure 4.5 (B)	Signa Magmeter	Figure 4.5 (C)	Electromagnetic Meter	Figure 4.5 (D)	Flow switch	Figure 4.5(E)	Flow meter	Figure 4.5(F)	Ultrasonic clamp meter			
			Transform rate readings	Digital Transmitter	Figure 4.6 (A)	Detector Array	Figure 4.6 (B)	Control panel	Figure 4.6 (C)	Electrical panel	FIgure 4.6 (D)	Oil Monitor	Figure 4.6(E)	Flow Meter	Figure 4.6(F)				
			Accurately detect flow rate	Oil/Water Separator	Figure 4.7 (A)	Pressure Transducer	Figure 4.7 (B)	Oil smart alarm system	Figure 4.7 (C)	Waterproof 24-hr timer	FIgure 4.7 (D)	frequency transceiver	Figure 4.7(E)	Sensor	Figure 4.7(F)				
		Control rate of recovery		Fixed orifice model	Figure 4.8 (A)	Flow Monitor	Figure 4.8 (B)	Pressure Switch	Figure 4.8 (C)	DataFlo Remote controller	FIgure 4.8 (D)	oil traffic controller	Figure 4.8(E)	Actuator	Figure 4.8(F)				
	Able to filter various oil slick thickness	Distinguish between oil viscosities	Maintain oil/water ratio	Microwave signal generator	Figure 4.9 (A)	DMS Thickness Gauge	Figure 4.9 (B)	Ultrasonic thickness gauge	Figure 4.9 (C)	Ultrasound Ultrasonic Testing	Figure 4.9 (D)	Line transducer	Figure 4.9 (E)	Flow transmitter	Figure 4.9 (F)	Digital flow meter	Figure 4.9 (G)		Figure 4.9 ()
			Measure oil resistance to flow	Viscometer fork	Figure 4.10 (A)	Oval Gear Flow Meter	Figure 4.10 (B	Flow meter	Figure 4.10 (C)	Flow Meter DulcoFlow	Figure 4.10 (D)	Hand viscosity meter	Figure 4.10(E)		Figure 4.10(F)		Figure 4.10(G)		Figure 4.10(H)
			Detect surface tension	Surface tension meter	Figure 4.11(A)	Tension Meter	Figure4 4.11(B)	Grease Grabber	Figure 4.11(C)	Portable Tensiometer	Figure 4.11(D)	Surface tension detector	Figure 4.11(E)	Tensiometer	Figure 4.11 (F)		Figure 4.11 (G)		Figure 4.11 (H)
		Detect type of oil		Digital viscometer	Figure 4.12(A)	Viscometer	Figure 4.12(B)	Compact density meter	Figure 4.12(C)	Viscosities and Densities Detector	Figure 4.12(D)	Viscosity tester	Figure 4.12(E)	Detection system	Figure 4.12 (F)		Figure 4.12 (G)		Figure 4.12 (H)
		Self-adjust separation method to different types of oil		Viscometer	Figure 4.13(A)	Compact Density Meter	Figure 4.13(B)	Flow gauge	Figure 4.13(C)	Vibration Viscometer	Figure 4.13(D)	Mass flow meter	Figure 4.13 (E)	Density meter	Figure 4.13 (F)	Analog recorder	Figure 4.12 (G)		Figure 4.12(H)
	Limit water intake	Control water intake	Differentiate between specific gravities	Hydrometer	Figure 4.14(A)	Liquid Level Transmitter	FIgure 4.14(B)	Point level sensor	FIgure 4.14(C)	TriSKimmer (TSK) weir skimmer	Figure 4.14(D)	Oil grabber	Figure 4.14(E)		Figure 4.14 (F)		Figure 4.14 (G)		
			Collect optimal level of fluids	Grooved disk	Figure 4.15(A)	Groove Formation	Figure 4.15(B)	Ultrasonic transmission	Figure 4.15(C	Druck 180	Figure4 4.15(D)	Grooved disk	Figure 4.15(E)	Filtration Plate	Figure 4.15(F)	Level transmitter	Figure 4.15 (G)		
	Separate oil from water	Filter water out of the oil	Separate oil from water	Grooved disk	Figure 4.16(A)	Grooved Disk	Figure 4.16(B)	Oil Water Filter	Figure 4.16(C)	Mini Polypropylene T-Strainer	Figure 4.16(D)	Increased width of canal fingers	Figure 4.16(E)	Oil filter	Figure 4.16 (F)				
			Dissipate excess water	Transmitter	Figure 4.17(A)	Liquid Level Sensor	Figure 4.17(B)	Oil Water Separator	Figure 4.17(C)	Frothy	Figure 4.17(D)		Figure 4.17(E)		Figure 4.17 (F)		Figure 4.19(G)		Figure 4.19 (H)
			Contain contaminated water	Filter cart	Figure 4.18(A)	Oil Separator System	Figure 4.18B	Filtration system	Figure 4.18(C	Fluid Separator	Figure 4.18(D)	regulating valve	Figure 4.18(E)	Ball Valve	Figure 4.18 (F)	Flow switch	Figure 4.18 (G)	Oil transmitte	Figure 4.18 (H)
		Contain the oil		Storage tank	Figure 4.19(A)	Oil Retainer	Figure 4.19(B)	Oil Container	Figure 4.19(C	Floating Boom sock	Figure 4.19(D)	oil containment	Figure 4.19(E)	Oil skimmer tan	Figure 4.19 (F)		Figure 4.19 (G)		Figure 4.19 (H)

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4.2.1 Concepts for the function “Perform floatation stabilization”

In Figure 4.19 the concepts generated for the function “Perform flotation stabilization” can be observed. Figure 4.19A includes an image of a flotation foam container. This material can be applied under the skimmer bottom surface to increase the skimmer flotation [29]. Figure 4.19B displays spherical foam filled buoys that can be installed on the outside of the skimmer to improve skimmer flotation [30]. Another concept, Figure 4.19C includes a buoyant body for floating on the water surface having a front and rear portion. A debris collecting channel passes between the front and rear portions, the skimmer device also including a propulsion system for moving the buoyant body through the body of water in the direction of the front portion [31]. Figure 4.19D contains a display of several foam filled modular chain buoys that can help maintain flotation and stabilization of the skimmer device [32]. Figure 4.19E is a Tri-float skimmer. All 3 sides have flotation devices within them. All 4 concepts could assist in the floatation stabilization of skimmer [33]. Another concept is Figure 4.19F Floating Drum Skimmer (FDS) they float on the surface, and sealed flotation makes them unsinkable [34]. Finally, Figure 4.19G is a device that floats on the water surface. It is made of corrosion-resistant glass fiber reinforced plastics, stainless steel or marine grade aluminum alloy [35]. It can be used for recovery of spilled oil on the surface of seawater or fresh water and its robust and durable structure is best suited for applications on open seas were rough sea state may occur.

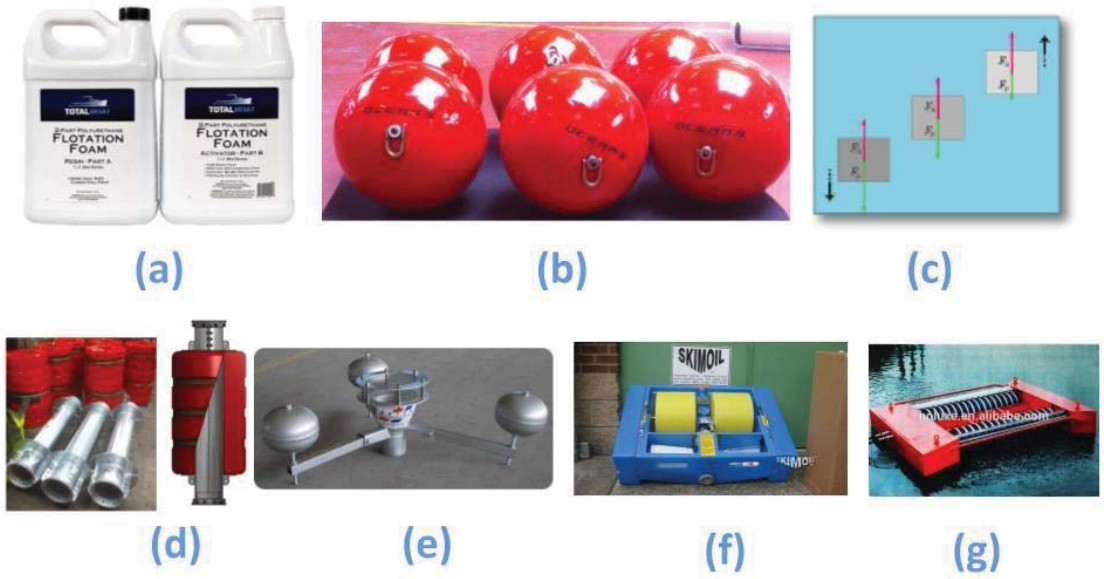


Figure 4.19 Concept Sketches for “Perform flotation stabilization”

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4.2.2 Concepts for the function “Limit debris entering skimmer”

In Figure 4.20 the concepts generated for the function “Limit debris entering skimmer” can be observed. Figure 4.20A is a Condition Monitoring Sensor that provides continuous real-time monitoring for cases of large particle build-up preventing unexpected downtime in the process [36]. Figure 4.20B is an InCord enviroNet is a debris net that offers total containment of both solid and liquid contaminants. Developed for use under bridges spanning sensitive waterways, enviroNet has the debris containment power of our RocBloc family of nets, with the added benefit of liquid and fine particle control [37]. Figure 4.20C The bracket could be used to swipe debris away from the skimmer as a perimeter appendage [38]. Finally Figure 4.20D contains the Repeller Grate inhibits the accumulation of weeds and debris on the intake grate, which may interfere with the performance of the watercraft. Commonly used on jet skis, the design can be modified to fit an oil skimmer and prevent debris from entering the skimmer [39]. Figure 4.20E is a debris shield that can be used as a perimeter appendage to block out entering debris during skimmer movement.
The concept could be incorporated around the entire skimmer to increase debris limitation [40]. Additionally, Figure 4.20F is a standard skimmer guard used in modern day swimming pools. The guard concept could also be imagined within the skimmer design as another way to block out unwanted debris [41]. Finally, Figure 4.20G displays a RT-30 Flow Transmitter provides protection from moisture and debris from environmental factors [42].

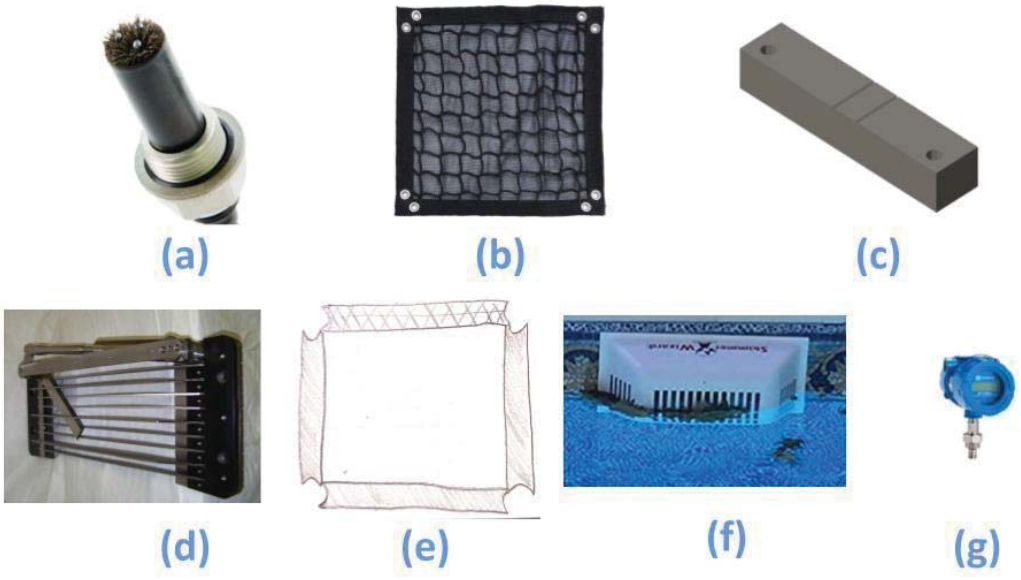


Figure 4.20 Concept Sketches for “Limit debris entering skimmer”

4.2.3 Concepts for the function "Separate debris from fluids taken by the skimmer”

In Figure 4.21 the concepts generated for the function “Filtration system diverts that debris” can be observed. Figure 4.21A shows an enclosed debris protection net that contains anchors at the bottom end

[43]. The anchors will allow the bottom of the net to sink. On the other hand, the net will be fixed to the skimmer outer fence to prevent debris from entering the skimming area. Figure 4.21B includes a sketch of an outer floating skimmer fence that contains pores on its surface [44]. This allows water and oil to flow through the pores and prevent debris from reaching the skimming area. Figure 4.21C is a self filtration debris filter that can divert any unwanted material out of the system [45]. Figure 4.21D displays a Commercial screened Shield head to prevent leaves and debris from blocking downspouts and entering your skimmer tank. Shield heads are ideally installed on each downpipe as they protect the skimmer and improve your tank's water quality [46]. Finally, Figure 4.21E filters have rigid and durable V-SLOT filter cartridges, with uniform surface crack width, single large filter area, precision filtration features, and high reliability features. It applies to the filtration of dirty water containing oil sludge type impurities, soft and viscous impurities, high content impurities, small amount of hairs and fibers [47].

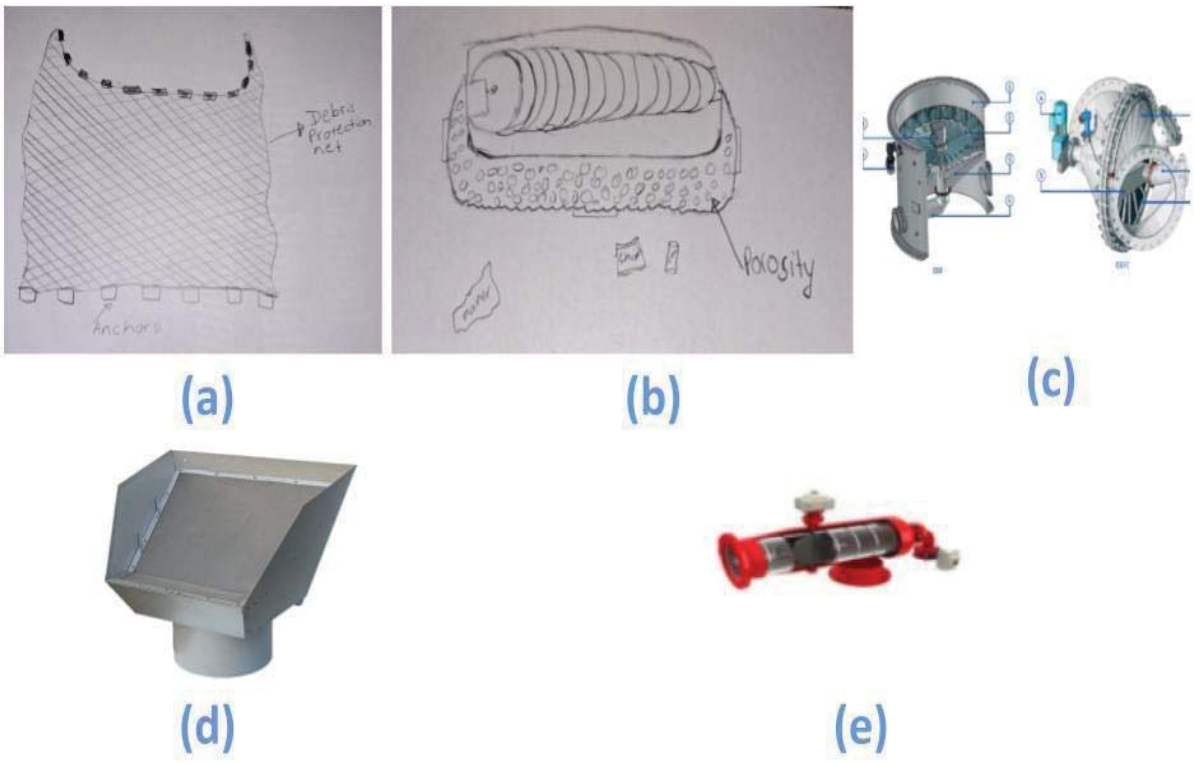


Figure 4.21 Concept Sketches for "Separate debris from fluids taken by the skimmer"

4.2.4 Concepts for the function "Contain debris"

In figure 4.22 the concepts generated for the function "Remove debris" can be observed. Figure 4.22A displays a return-line hydraulic filter, also known as a spin-on filter, which is used to clean hydraulic oil or fluid in pressurized hydraulic systems [48]. This filter has multiple openings for debris filtration. Inline hydraulic filters are installed on the low-pressure, return line side of a hydraulic system to clean the fluid before it returns to the reservoir. Figure 4.22B shows a waste basket that's used for collecting larger amounts of debris that can be removed when full [49]. This filter allows for debris accumulation that can be easily cleaned once max debris is collected. On the other side, Figure 4.22C is a single-head filter

assembly for return lines on hydraulic systems that clean hydraulic fluid by passing it through one filter before returning it to the reservoir [50]. Finally Figure 4.22D contains a Bandalong litter trap designed to float in waterways in order to capture litter before it flows farther downstream by using the current to guide debris into the trap [51]. Additionally, Figure 4.22E is the Bandalong Boom Systems, which act as a barrier to collect or deflect debris. The floating boom sections are coupled together and spanned across a weir, waterway or dam to capture litter and prevent it from floating farther downstream [52]. Finally, Figure 4.22F displays a Hayward TVX6009EA where this bag float is used to pick up the debris [53].

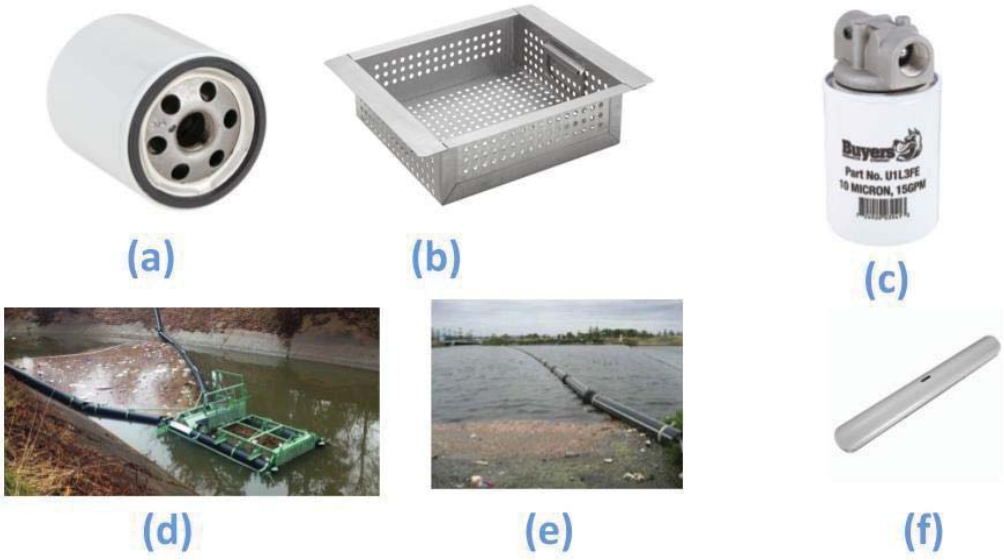


Figure 4.22 Concept Sketches for "Contain Debris"

4.2.5 Concepts for the function "Calculate amount of oil intake"

In figure 4.23 the concepts generated for the function "Calculate amount of oil intake" can be observed. Figure 4.23A shows a mass flow meter is a large diameter developed to meet the demanding custody transfer requirements of the oil and gas industry. The high performance of the OPTIMASS 2000 also makes it a suitable flow meter for the bulk measurement of petroleum and oil as well as products like syrup, molasses, and raw chemicals [54]. Figure 4.23B Greyline Instruments SLT 5.0 Level and Flow monitor [55]. This device can be used to monitor flow levels and totalize a quantity within a channel of flow. This can be incorporated to help calculate the total amount of oil collected in GPM.on the other side, Figure 4.23C is a GF Signet 2551 Magmeter that is corrosion resistant with digital readings of liquid

flow within a channel [56]. The corrosive resistance would allow for increased lifespan as well as optimal calculation of oil intake for the oil skimmer. Figure 4.23D contains a Badger Meter M1000 Electromagnetic Flow Meter. Electromagnetic flow meters have inherent advantages over other flow technologies and can accurately meter liquids that are highly corrosive, very viscous, contain a moderate number of solids or require special handling [57]. This device can be used in most industries and can be incorporated in wastewater management. Another concept, Figure 4.23E includes a series flow switch that can be utilized to amplify the flow rates of the skimmer [58]. Figure 4.23F demonstrates a durable lightweight flow meter that is able to measure flow rates from 1-10 GPM to 60-600 GPM. With a basic accuracy of ±3%, the TM Series is well suited for sub-metering facility water usage and small wastewater treatment equipment [59]. Finally, the last concept is Figure 4.23G, which contains an ultrasonic clamp flow meter that can also be used to measure the flow rate with water entering the system. The clamp flow meter can be conveniently installed as it easily clamps on the skimmer [60].



Figure 4.23 Concept Sketches for "Calculate amount of oil intake"

4.2.6 Concepts for the function “Transform Rate Readings”

In figure 4.24 the concepts generated for the function “Transform rate readings” can be observed. Figure 4.24A Digital moisture transmitter designed for transforming rate readings and measuring water content in oil [61]. Figure 4.24B utilizes the “SmartCell" Detector Array Technology, the OCM analyses all three oil types simultaneously without the need for recalibration [62]. On the other side, Figure 4.24C is Control panel that will show all the rate readings and will have the switches and controls for the skimmer [63]. Figure 4.24D contains an electrical panel. This enclosure contains the brains and it runs and monitors all the components continuously, it transforms the data collected into readable values for data analysis [64]. Figure 4.24E is a device for real time sampling and measuring the oil content in a moving stream of water [65]. Finally, Figure 4.24F is a Compact Orifice Flow Meter that is ideal for volumetric measurement of relatively clean liquids. Meaning it can transform the readings of the clean water [66].

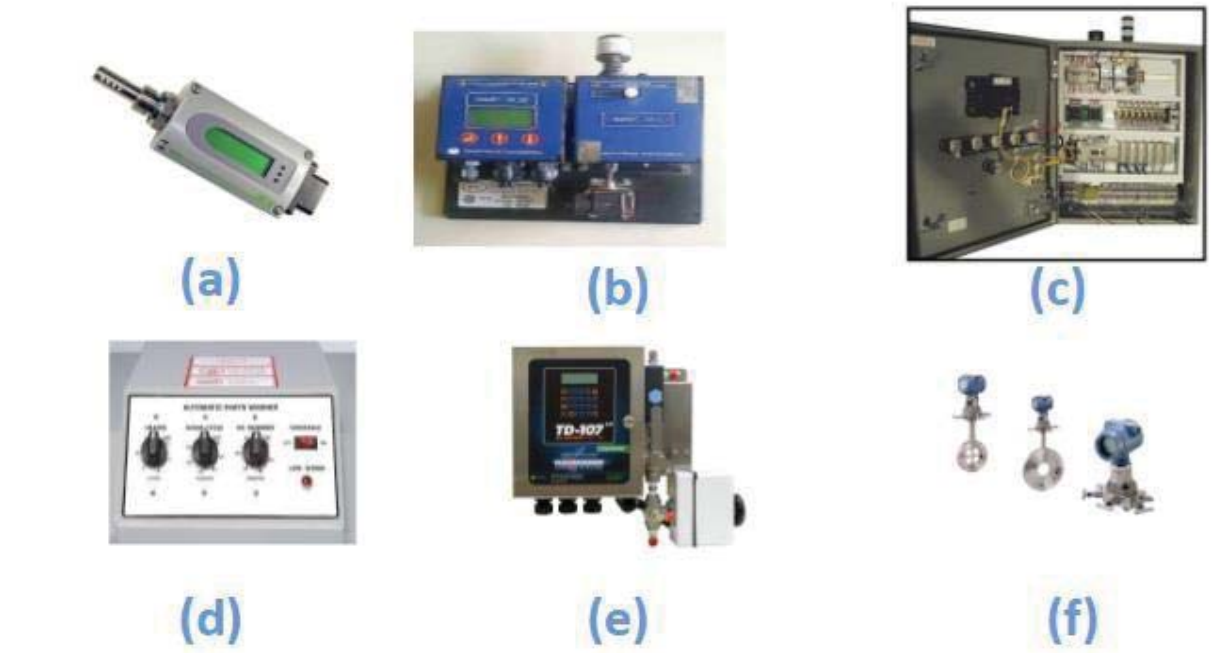


Figure 4.24 Concept Sketches for “Transform rate readings”

4.2.7 Concepts for the function “Accurately detect flow rate”

In figure 4.25 the concepts generated for the function “Accurately detect through sensor” can be observed. Figure 4.25A is an Oil Water Separator High/Low Level

Alarm, Rings when accumulated oil would reach a predetermined level. Signals when maintenance is needed [67]. Figure 4.25B is a Core Sensors CS80, a versatile pressure transducer that is designed to operate under the harshest conditions [68]. On the other side, Figure 4.25C is a Oil Smart Alarm System, a plug and play alarm that differentiates between oil and water, it will activate with the detection of any liquid and will identify if oil or water is present [69]. Figure 4.25D contains a Waterproof 24-hr timer, 110V easy to set up, and high efficiency [70]. Figure 4.25E is GE Leakwise ID-227, which is a high frequency transceiver with two antenna elements. One antenna is located at the water interface and the other is located underwater [71]. Finally, Figure 4.25F is the Leakwise ID-225 sensor measures the thickness and monitors the buildup of hydrocarbons in water. Many petroleum and power companies use it for monitoring and control of oil layers in remediation control and skim tanks [72].

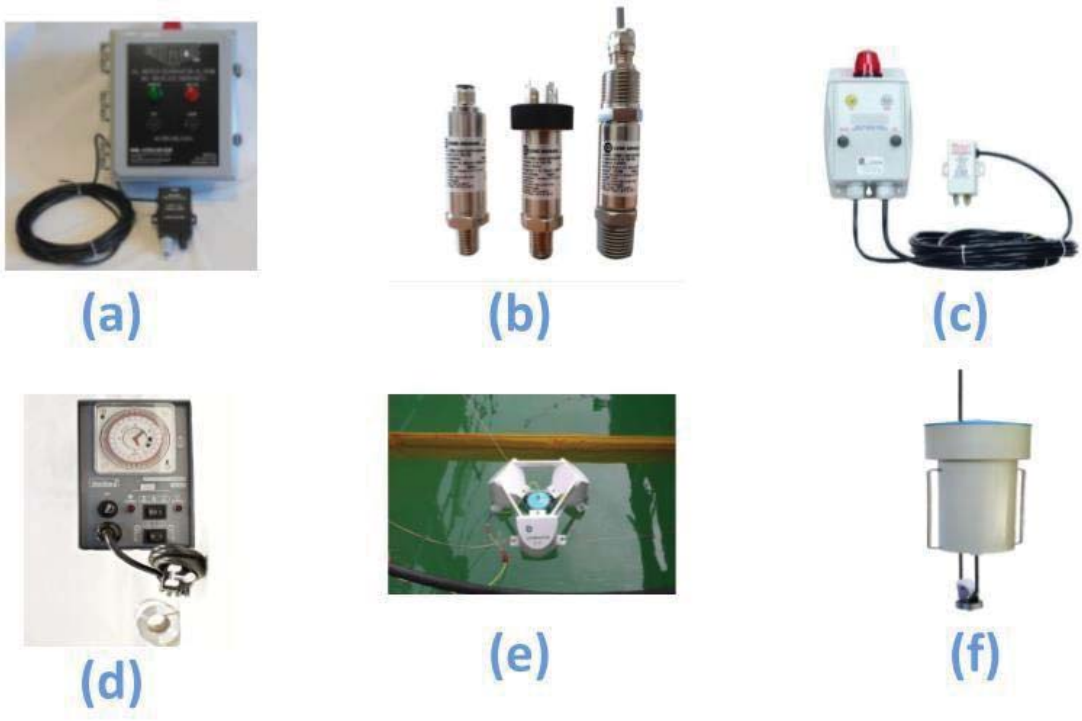


Figure 4.25 Concept Sketches for "Accurately detect flow rate"

4.2.8 Concepts for the function "Control rate of recovery"

In figure 4.26 the concepts generated for the function "Control rate of recovery" can be observed. Figure 4.26A is a Sketch of a fixed orifice within a system. The fixed orifice is one of the most elemental methods for controlling flow and can help maintain steady recovery flow rate within the skimmer [73]. Figure 4.26B Blancett B2900 Flow Monitor, a flow meter that calculates flow rate and total flow simultaneously with 10-point linearization for improved accuracy [74].On the other side, Figure 4.26C Ashcroft B400 Series Pressure Switch, a pressure switch that can control the oil rate recovery [75]. Figure 4.26D contains a DataFlo Remote controller that can help control the rate of oil recovery within the skimmer [76]. Figure 4.26E is an oil traffic controller that is used with skimmer to reduce skimmings to oil only and save coolant. When the oil is removed from the tank, the coolant removed by your skimmer will be returned right

back to the tank [77]. Finally, Figure 4.26F is an actuator that controls the intake of oil being recovered and automatically shuts down or recalibrates if debris was picked up [78].

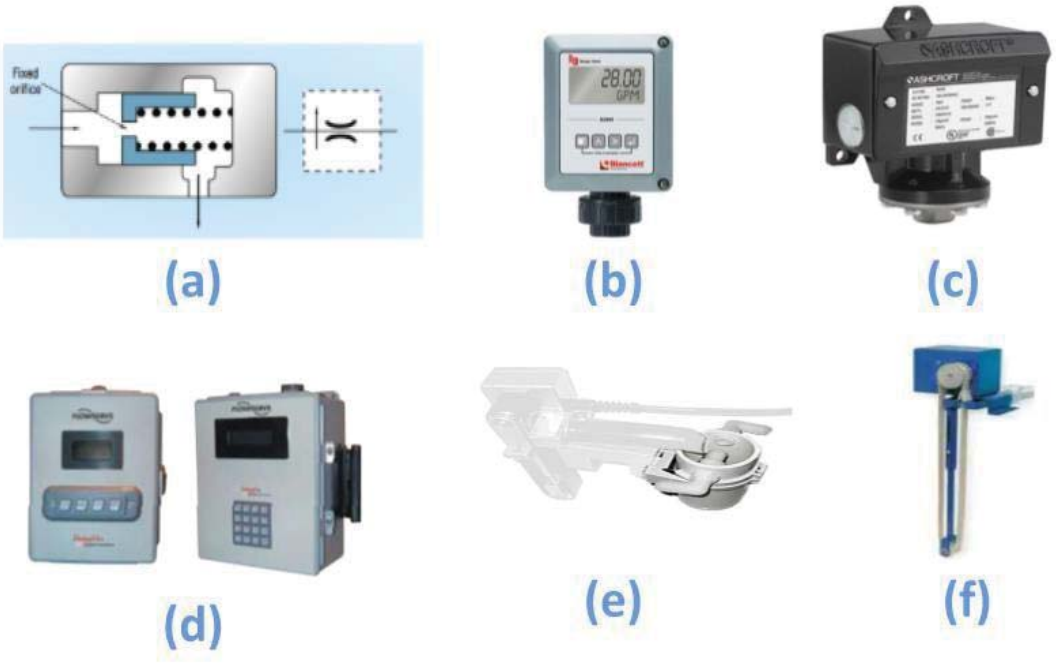


Figure 4.26 Concept Sketches for "Control rate of recovery"

4.2.9 Concepts for the function "Maintain Oil/Water Ratio"

In figure 4.27 the concepts generated for the function "Verify oil thickness" can be observed. Figure 4.27A is a Berkeley Nucleonics' Model 845 RF Microwave Signal Generator, a low-noise and fast-switching microwave signal generator. The natural microwave radiation encountering this oil layer causes its surface brightness to increase as a function of the oil layer thickness [79]. Figure 4.27B is a BDMS Go+ Thickness Gauge that has the ability to provide accurate, reliable and comprehensive thickness inspection data [80]. On the other side, Figure 4.27C also presents an ultrasonic thickness gage that is called CL5 Ultrasonic Thickness Gauge [81]. Figure 4.27D contains an Ultrasound Ultrasonic Testing which can measure thick oil slicks on water. Workers in the oil spill field have also used this technique from below the water surface. This is possible because there are sonic reflections from the oil–water interface and from the air– oil interface. All these can be used to detect oil thickness in water [82]. Figure 4.27E displays a Delay Line Transducer that incorporates a short delay between the element and the test piece [83]. Additionally, 4.27F is a Ultrasonic Flow Transmitter which utilizes a state-of-the-art flow measurement capability with a low cost transmitter package [84]. Finally, Figure 4.27G is a Parametric DigitalFlow, which is an ultrasonic flow meter that can measure oil thickness by calculating other parameters such as velocity, volumetric and energy flow rates using transit time technology [85].

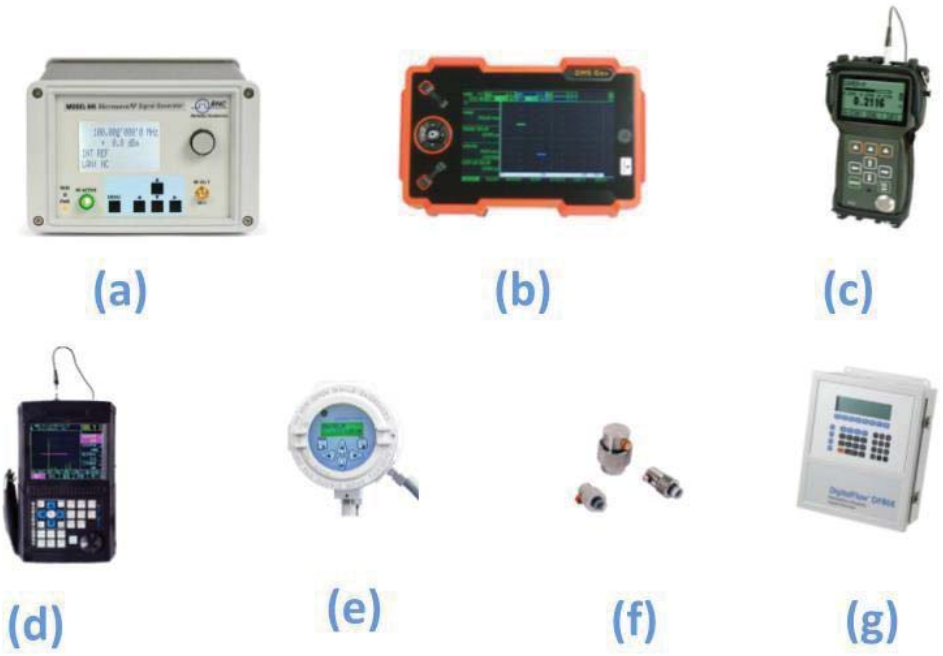


Figure 4.27 Concept Sketches for "Maintain Oil/Water Ratio"

4.2.10 Concepts for the function "Measure oil resistance to flow"

In figure 4.28 the concepts generated for the function "Measure oil resistance to flow" can be observed. Figure 4.28A is a device featuring a level of 1% of reading, a tuning fork vibration viscometer delivers a high level of accuracy [86]. This measures viscosity by detecting the driving electric current needed to resonate two sensor plates at a constant frequency. Figure 4.28B is an Oval Gear Flow Meter which measures the low flow rate of highly viscous oils, a tool that can measure oil resistance to flow [87]. On the other side, Figure 4.28C is a E+H Proline Promass I 300 Coriolis Flow Meter that Provides an in-line viscosity measurement in addition to mass flow, density and temperature measurement and utilizes one side access, remote display and improved connectivity options [88]. Figure 4.28D contains the Flow Meter DulcoFlow, this device works on the ultrasound measuring principle. It was developed specifically for measuring small pulsating volumetric flows. All liquids that conduct ultrasound waves can be measured [89]. All these measurement tools can be used to measure oil resistance flow. Finally, Figure 4.28E displays a hand viscosity meter that can be installed in the skimmer prototype to measure the viscosity level of the oil to be recovered [90].



Figure 4.28 Concept Sketches for "Measure oil resistance to flow"

4.2.11 Concepts for the function "Detect surface tension"

In figure 4.29 the concepts generated for the function "Detect surface tension" can be observed. Figure 4.29A is a Sensodyne fluid surface tension meter that can be used to measure the static and dynamic surface tension of the fluid recovered with the skimmer [91]. Figure 4.29B is a Tension meter that is cost effective for various force measurements [92]. On the other side, Figure 4.29C is a Grease grabber is able to tell the difference in surface tension between oil and water, making an efficient skimmer, with little to no water recovery [93]. Figure 4.29D contains a portable tensiometer that can be installed in the skimmer for accurate surface tension measurements [94]. Another concept, Figure 4.29E is a device that performs high-precision, automatic and reliable measurements of surface tension and Interfacial tension, CMC and contact angle on solids, fibers and powders. With high-quality components and a uniquely wide range of methods, the instrument carries out many tasks in the field of surfactant analysis and wetting measurement for your quality assurance or research [95]. Finally, Figure 4.29F displays a Tensiometer Classic that is used to measure suction tension [96].

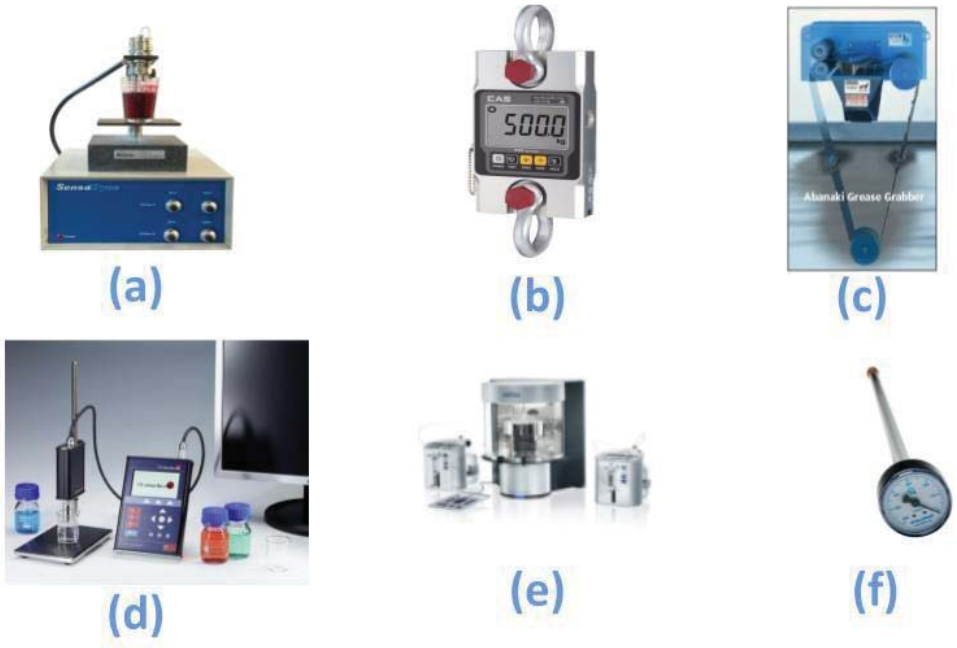


Figure 4.29 Concept Sketches for "Detect surface tension"

4.2.12 Concepts for the function "Detect type of oil"

In Figure 4.30 the concepts generated for the function "Detect type of oil" can be observed. Figure 4.30A is a Digital Viscometer 15~100,000 mPa.s, a rotary viscosity meter. The screen can directly display the viscosity, rotation speed, rotor number, percentage torque and other information. It can detect the type of oil by means of viscosity [97]. Figure 4.30B is a concept in which a viscometer can be mounted onto the skimmer much like in a tank to detect viscous properties of the oil to determine the type presented [98]. On the other side Figure 4.30C The Micro Motion CDM100 compact density meter uses dual curved-tube meter technology to measure density and Coriolis to indicate (velocity/volume) flow rate. This device can be used to distinguish between different types of oils through the use of density [99]. Figure 4.30D contains different oils containing different viscosities and densities. Within a storage tank, the oil can be detected by visualization of the way it floats on the water. There are 5 types of oil groups which include gasoline products (group 1), Diesel-Like Products/Light Crude Oils (group 2), Medium Crude Oils/Intermediate Products (group 3), Heavy Crude Oils/Residual Products (group 4) and Non-floating Oils (group 5) [100]. Figure 4.30E is a viscosity test, this test is a measurement of a lubricant's resistance to flow at a specific temperature. The single most important property of a lubricant is its viscosity [101]. Finally, Figure 4.30F is a concept sketch that serves as a mountable detection system. A probe is inserted into the oil slick and through the meniscus effect is absorbed through a pipette and into a detection tube that can then display onto a digital reading [102].

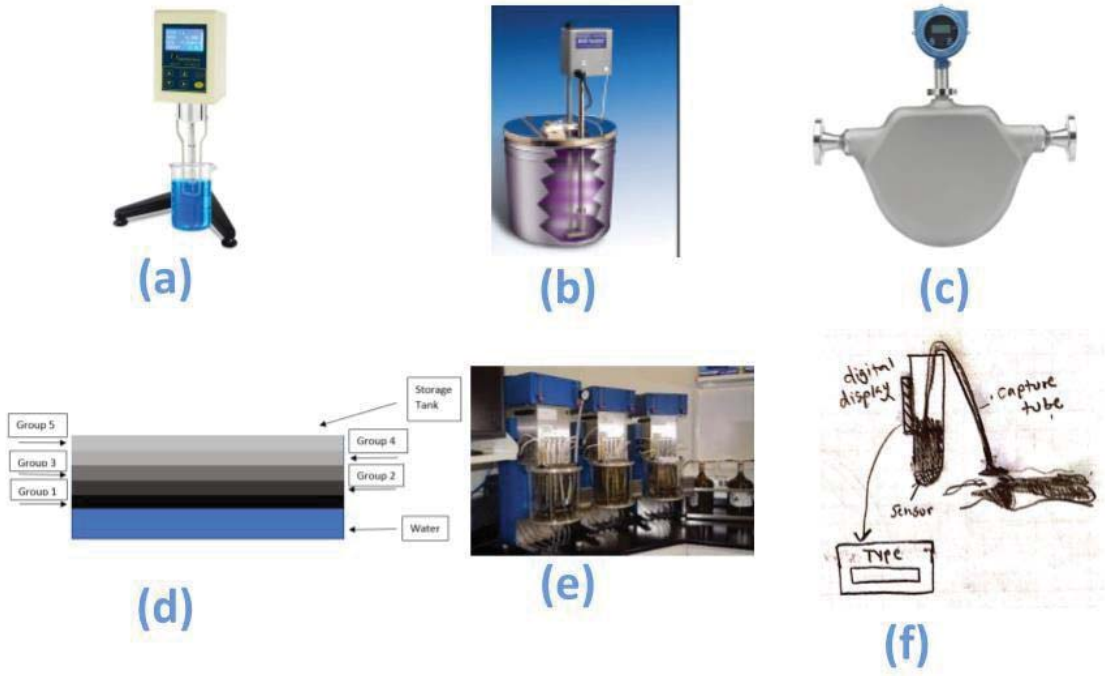


Figure 4.30 Concept Sketches for "Detect type of oil"

4.2.13 Concepts for the function "Self-adjust Separation method to different types of oil"

In Figure 4.31 the concepts generated for the function "Self-adjust to different types of oil" can be observed. Figure 4.13A evaluates fluidity and thickness of various fluid materials. This viscometer has microcomputer control technology and comes with a LED screen to evaluate your readings instantly [103]. Figure 4.31B demonstrates a compact density meter that uses dual curved-tube meter technology to measure density Coriolis to indicate velocity and volume flow rate. This device can be used to distinguish between different types of oils through the use of density [104]. On the other side, Figure 4.31C displays a series flow switch that is adjustable to an infinite number of flow settings at pressures up to 1000 psig [105]. Figure 4.31D contains a device features a level of 1% of reading, a tuning fork vibration viscometer delivers a high level of accuracy. This measures viscosity by detecting the driving electric current needed to resonate two sensor plates at a constant frequency [86]. Another concept, Figure 4.31E KROHNE OPTIMASS 1000 Coriolis Mass Flow Meter that can measure volume, temperature, volume concentration or solid content [106]. Another concept is Figure 4.31F is a handheld density meter that can adjust to different types of oil [107]. The last concept is Figure 4.31G, which is a device with multiple uses for both industry and the research field. The PAR 99X-MA analog recorder can be connected to different sensors via the 4-20 mA inputs. The PAR 99X-MA analog recorder can identify individually diverse oils with their viscosity, and they can also be digitally scaled. Therefore, the PAR 99X-MA analog recorder is able to be used in small and medium measurement/adjustment systems, as well as it allows to register simultaneously 8 signal processes. [108].

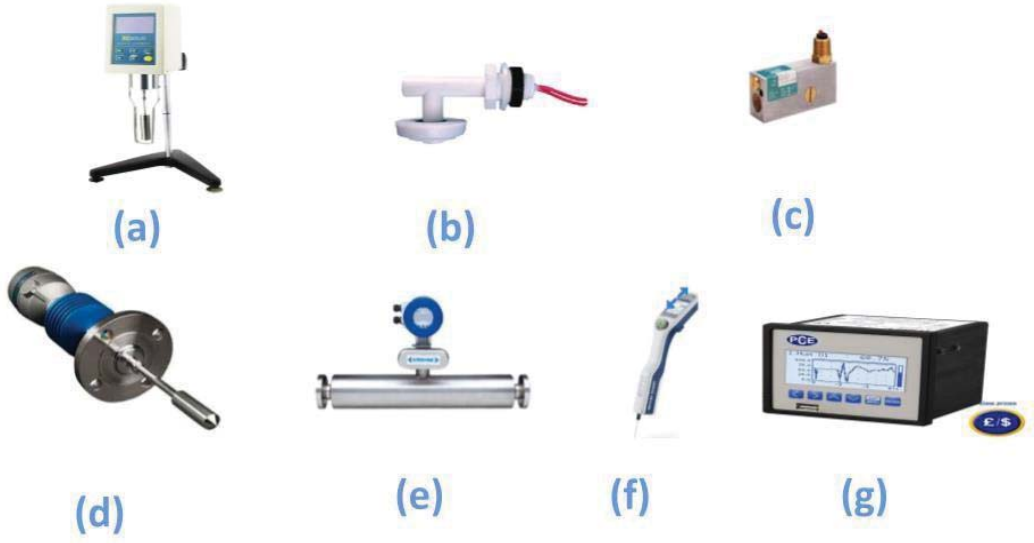


Figure 4.31 Concept Sketches for "Self-adjust Separation method to different types of oil"

4.2.14 Concepts for the function "Differentiate between specific gravities"

In Figure 4.32 the concepts generated for the function "Differentiate between specific gravities" can be observed. Figure 4.14A is a simple hydrometer that is the most standard form of a hydrometer that can easily be incorporated into the skimmer design to help specify specific gravities of the oil or water [109]. Figure 4.32B is a Rosemount 2051L Liquid Level Transmitter that is a more modern type of instrument that can be flange mounted to any device to measure specific gravities up to 300psi [110]. Similarly, Figure 4.32C is a LMT110 point level sensor. Its compact sensor tip allows integration even in small pipes [111]. The factory setting to different fluid types eliminates the need for an adjustment and is automatic. The sensor allows for measurement of specific gravity based upon point level detection and is optimal for uses in storage tanks. Figure 4.32D is a TriSKimmer (TSK) weir skimmer that uses specifically the gravity differential between water and oil to effectively recover the oil [112]. Figure 4.32E is The Abanaki Model 8 Oil Grabber the belt skimmer allows to attract oil and other hydrocarbon liquids from the surface of the fluid. The Model 8 can be used in tanks with depths as shallow as one foot, or as deep as 100 feet [113]. Figure 4.32F is the PetroXtractor Skimmer, which makes use of the differences in specific gravity and surface tension between oil and water. These physical characteristics allow the unit's continuous belt to attract floating oil in the well. After picking up the oil, the belt travels over the head pulley on the drive unit and through tandem wiper blades. All these concepts exist today to differentiate between specific gravities [114]. Finally, Figure 4.32G demonstrates a tuning fork density meter that allows accurate reading of specific gravity and density within a pipe while being placed on the outside of the pipe [115].

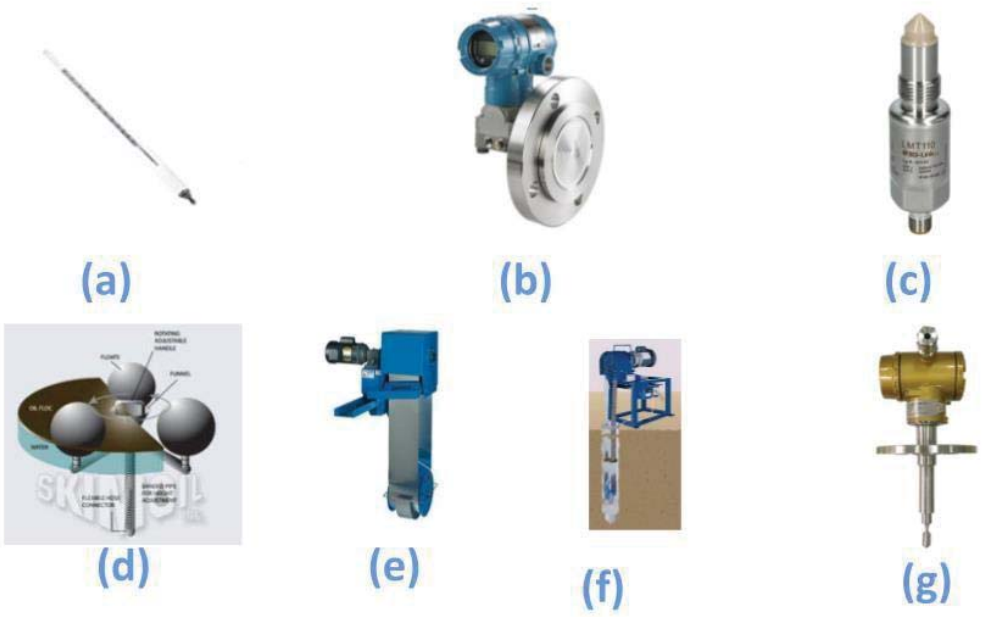


Figure 4.32 Concept Sketches for "Differentiate between specific gravities"

4.2.15 Concepts for the function "Collect optimal level of fluids"

In figure 4.33 the concepts generated for the function "Collect optimal level of oil" can be observed. Figure 4.33A presents a disk used in order to improve oil recovery, the disk is put into an offset angle [116]. The change of orientation will cause the disk to filtrate a greater amount of oil. The orientation can be manually controlled by an actuator to adjust to various oil thickness. Figure 4.33B shows how the amount grooves can be increased or decreased depending on the oil thickness that is being filtered. Additionally, an oleophilic coating can be applied to ensure that oils are successfully extracted through the grooves [117]. On the other side, Figure 4.33C is a polycarbonate design that offers measurement of liquids based on ultrasonic transmissions [118]. If utilized in this design, this concept would allow for accurate measurement of oil intake.Figure 4.33D contains Druck 180 series submersible pressure transmitters [119]. These transmitters are fully submersible and can detect hydrostatic liquid levels. This concept could be used within the storage tank. Figure 4.33E displays a Spinning Grooved Disks that pulls the oily water upward, where metal skimmers strain the oil away, separating the oil from the water and leaving the water to fall back down [120]. Figure 4.33F shows the filtration plate with the grooves evenly placed out. The distance between the grooves can be increased or decreased to accommodate the oil thickness that is being filtered. Similarly, to the last figure, an oleophilic coating can be applied to the grooves to increase the rate of oil collected [121].Finally, Figure 4.33G displays a Keller Acculevel Submersible Level Transmitter that incorporates microprocessor-controlled signal conditioning for providing outstanding accuracy in the monitoring of oil collection [122].

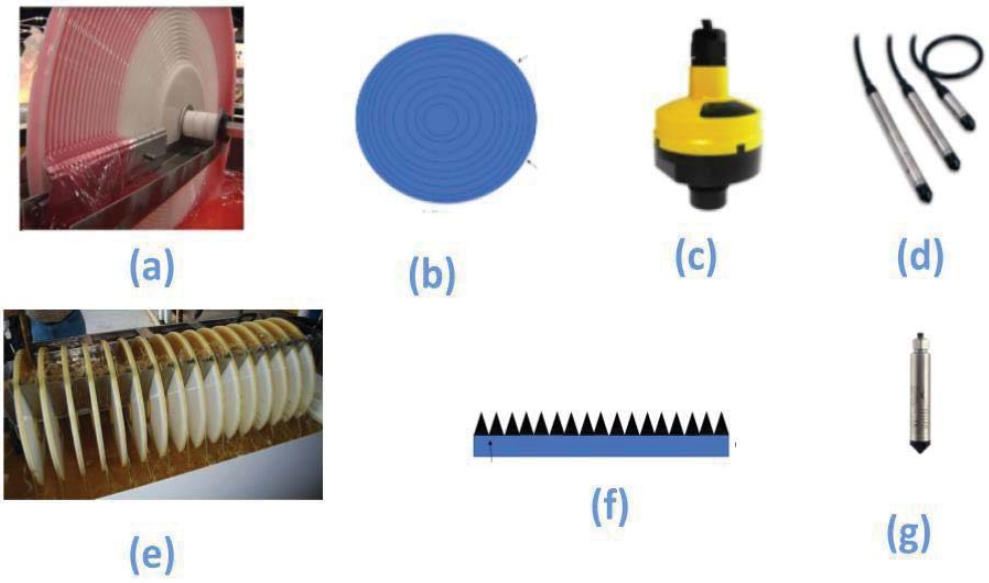


Figure 4.33 Concept Sketches for "Collect optimal level of fluids"

4.2.16 Concepts for the function "Separate oil from water"

In Figure 4.34 the concepts generated for the function "Separate oil from water" can be observed. Figure 4.34A is a Grooved Drum, the grooved surface of this drum skimmer is designed so that it is more efficient in oil collection [123]. When scraping off the oil, the plate has the same grooved pattern so that the oil can be scraped off the drum surface and between the grooves. The greater the width of the grooves the greater the amount of oil picked up by the skimmer. Figure 4.34B displays a grooved disk that will increase the oil filtration rate as the oil sticks in the oleophilic material as the excess water drops before making it to the recovery canal. The disk displayed has an increased groove width and depth which will provide more contact surface area for the oil to stick [124]. Figure 4.34C is an oil and water separator that filters and separates oil and water during the filtration process [125]. This is vital to this function because the need for the collection of the oil is based upon the filtering of oil of water molecules to be returned to the water source. Figure 4.34D contains a Mini Polypropylene T-Strainer w/ Clear Bowl that has an advantage in material due to the properties of the device [126]. It also would help to improve filtration rate through separation of oil and water separation. Figure 4.34E displays the increased width of the recovery canal fingers. This allows the recovery canal to match the increased thickness of the disk grooves [127]. Finally, Figure 4.34F includes a Diesel Bypass Oil Filter that draws approximately 10 percent of the oil pump's capacity at any one time [128].

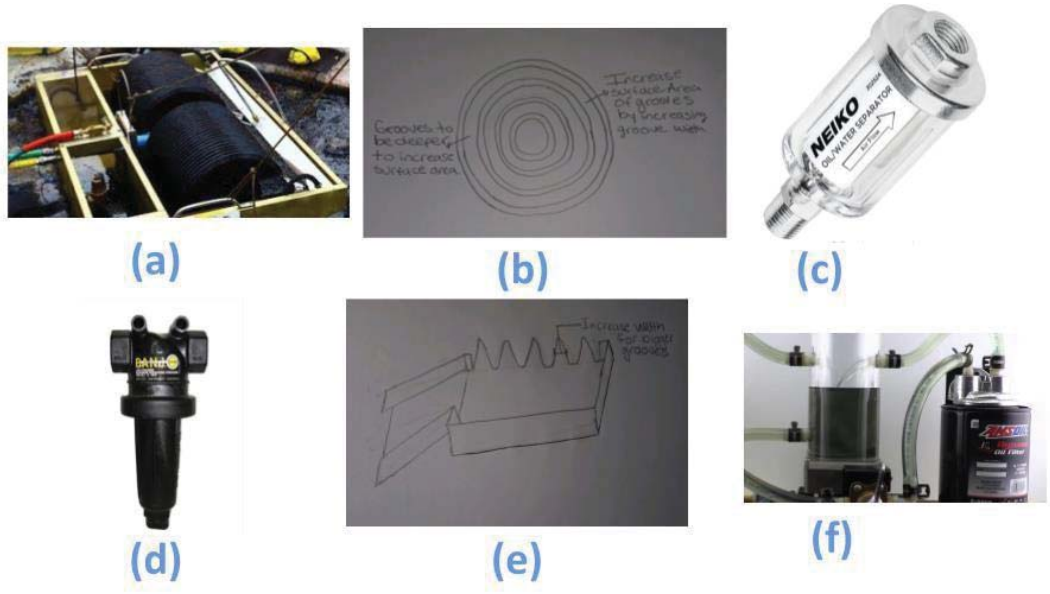


Figure 4.34 Concept Sketches for "Separate oil from water"

4.2.17 Concepts for the function "Dissipate excess water"

In Figure 4.35 the concepts generated for the function "Dissipate excess water" can be observed. Figure 4.17A is a HUMICAP ® Moisture and Temperature Transmitter series that enables fast and reliable detection of moisture/water in oil [129]. This would allow for fast detection of excess water within the oil source to be extracted. Figure 4.35B is a FS20 High Pressure Liquid Level Sensor, it is a stainless steel, buoyant and vertical oriented sensor that operates in high pressure environments but allows functionality in open and closed systems [130]. On the other side, Figure 4.35C is an Oil Water (Baffle) Separation, Oil water separators are based on gravity and since the specific gravity of oil is less than that of water, it floats to the water's surface. As the oil rises the cleaned water passes through to the next container until you are left with just the cleaned water [131]. Figure 4.35D contains the skimmed oil is frothy, such as that found in machine tool coolant, cold rolling mill coolant, or parts washing solutions The decanter gives any water collected a chance to further separate from the removed oil and be returned to the solution reservoir. This helps to conserve solution loss, decreasing the need for new solution purchases [132]. Another concept, Figure 4.35E the Oil Smart Pump Switch, when combined with a nonauto pump, will allow excess water to be pumped without the risk of pumping oil out of the system [133]. Figure 4.15F is a device that is attached to a 1/2" air diaphragm pump by a 3/4" hose, the suction from the pump and floating skimmer pulls the oil/water mixture into the intake of the skimmer, then to a Oil/Water Separator where the oil is removed from the wastewater and stored for recycling [134]. The water is sent back to the storage tank or sent directly to the Sewer. Finally, Figure 4.15G displays a Flange-Mounted Rosemount 2051L Liquid Level Transmitter that provides precise level and specific gravity measurement [135].

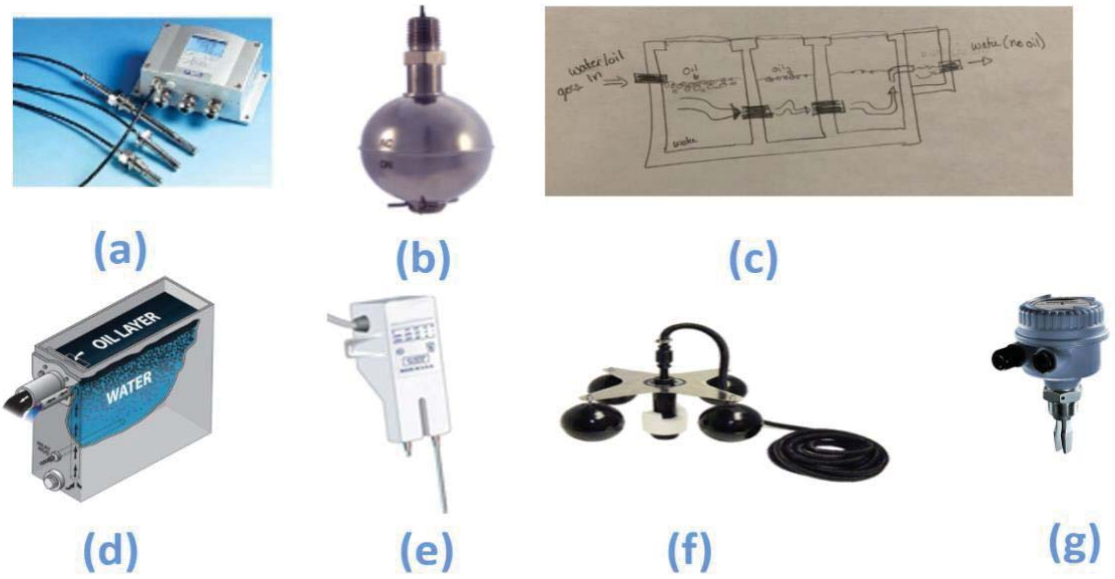


Figure 4.35 Concept Sketches for "Dissipate excess water"

4.2.18 Concepts for the function "Contain contaminated water"

In Figure 4.36 the concepts generated for the function "Avoid contaminating water" can be observed. Figure 4.36A is the Contaminant Removal Filter Cart is a portable oil filter cart. These carts use multipass filtration to remove water and contaminants from the liquids [136]. Figure 4.36B is the SmartSkim Oil Separator System that sets the industry standard for skimming and separating floating oil and solids from industrial fluids [137]. Figure 4.36C is the Kidney Loop Filtration System, an oil filtration system feature BETA 1000 Absolute rated micro-glass filter elements or adsorptive cellulose media filters in a variety of micron retention ratings to meet the target ISO 4406 Cleanliness Code requirements for any industrial system [138]. Figure 4.36D demonstrates a fluid separator that automatically separates the water and oil through the use of a sensor that detects density of the fluid to their respective storage tank [139]. Figure 4.36E contains an automatic flow regulating valve that keeps the flow constant by decreasing the cross-section of an orifice proportionally as the pressure increases [140]. Additionally, figure 14.36F exhibits a type 127 ball valve allowing the separation of water and oil through an open and close operation [141]. Figure 4.36G is a Gems FS-400 Series Flow Switch, which is a switch that can be used to separate the oil [142]. Finally Figure 4.36H present Moisture in Oil Transmitter, it offers highly accurate measurement of water activity and temperature; it uses those values to calculate the absolute water content [143].



Figure 4.36 Concept Sketches for "Contain contaminated water"

4.2.19 Concepts for the function "Contain the oil"

In Figure 4.37 the concepts generated for the function "Contain the oil" can be observed. Figure 4.37A is an Oil Storage Tank, the oil spill is drawn into the vacuum storage tank through the opening of the oil head. After the oil-water separation tank is filled with oily sewage, the liquid level controller automatically cuts off the vacuum pump current, and the vacuum pump stops pumping the oil spill on the water surface [144]. Figure 4.37B is the Oil Retainer, where Oil is wiped off and discharged into a collection container in a manner similar to belt oil skimmers [145]. Figure 4.37C is an oil container for an oil skimmer which serves as a designated oil reservoir from the collection process [146]. Figure 4.37D shows a floating boom sock that is able to contain and absorb oil spills on the surface of water [147]. Figure 4.37E illustrates an oil containment tank where only successfully extracted oil is sent and ensures that the oil stored in the tank is water free [148]. Finally, Figure 4.37F presents the reader can observe that an Oil skimmer tank is presented, this tank can be used to contain the oil [149].

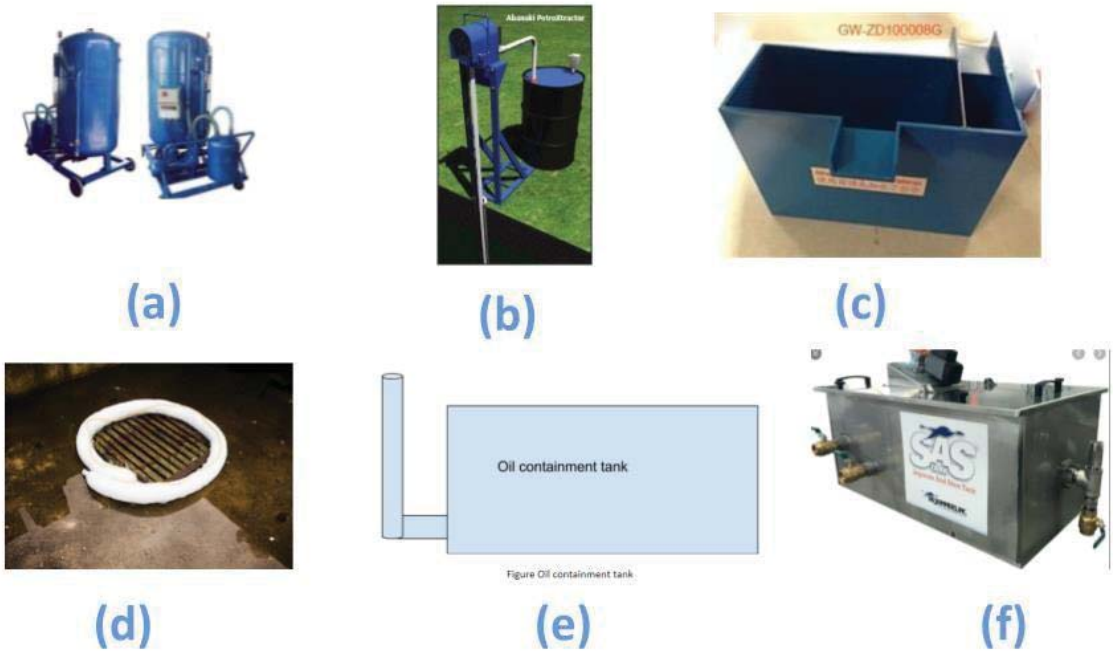


Figure 4.37 Concept Sketches for "Contain the oil"

4.3 Concepts Evaluation

In this section, the team developed and executed a plan to evaluate the concepts generated during the concept's generation phase of the project. In the concept's evaluation section, the team was able to identify the different criteria that affects each one of the skimmer functions identified during the functional decomposition phase of the project. Then, the team was able to evaluate each one of the concepts generated by using a GO-NO-GO method and a decision matrix. Towards the end of the section, detailed sketches based on the concepts that were identified to be the best in meeting the relevant requirements/criteria of the project can be observed. Finally, the team was able to evaluate the final sketches and decide on a final preliminary design.

4.3.1 Requirements/criteria

In this subsection, the team was able to analyze the different requirements related to the project, the operating environment of the design, constraints that directly affect the project development, the different technology that is relevant to the design development, the design manufacturing requirements, the project objectives, the need for analysis and testing, the functions needed to be achieved, and the safety and failure modes of the design. Once the team analyzed the mentioned points, the team developed a list of requirements/criteria needed to achieve a successful design. Then, the team was able to develop a table where each function was assigned criteria that directly affects each one of the concepts generated for each specific function.

- What customer requirements are related to the project? Make a list of all customer requirements

1. Be able to recover oil in at least one ½ inch of oil slick at 25%-50%
2. Easy assembly
3. Easy to operate
4. Eco friendly
5. Cost effective
6. High oil storage capacity
7. Long skimmer life
8. Waterproof
9. Marketable
10. Detachable parts
11. Removable storage container
12. Lightweight and compact design

- What operating environments are related to the project? Look at all your operating environments.

13. Operational in all calm waters

14. Corrosion resistance
15. Debris proof
16. Operational in various oil thickness

- What constraints can affect the project? List all of your project constraints.

17. Satisfy size constraint (Over all 5ft x 5ft)
18. Small components
19. Buoyancy
20. Easy to transport
21. Easy to maneuver

- Is current technology available for the functions of the project

22. Easily designed with CAD software
23. High water pump capacity system

- Can the technology/concept be manufactured with known processes?

24. Easy to manufacture

- What are the project objectives? Look at your list of objectives

25. High oil/ water separation
26. Fast oil recovery

- Is there a need for experimentation to ascertain how well certain project functions can be achieved?

27. ANSYS analysis

How do you use this as criterion? Needs more description.

- Are critical parameters that control the functions of the project identified?

28. Accurate Oil Thickness Detection
29. Capability of Viscosity Sensibility
30. Utilizes Cohesion/Surface Tension
31. Apply Specific Gravity

- Are the safe operating latitude and sensitivity of the parameters known?

32. Design should meet all federal and state regulations
33. Accurate fluid sensibility

- Have all the failure modes been identified for the project?

34. Prevent accidental oil release
35. Prevent accidental contaminated water release

In Table 1, the level 0,1,2,3 functions can be observed. In addition, the table displays the assigned requirements/criteria that affects each one of the subfunctions.

A few criteria listed above were not used in Table 4.4, such as 7, 21, 32. If you don't need the criteria, remove them from the list above.

Table 4.4. Requirements/Criteria Affecting Sub-function Didn't make correction

Overall Function	Level 1 Sub-functions	Level 2 Sub-functions	Level 3 Sub-functions	Requirements/Criteria Affecting Sub-Function								
				1	2	3	4	5	6	7	8	9
Recover at least 25~50% on 1-inch oil slick	Skimmer Mobility	Mobilize the skimmer	Perform Floatation Stabilization	18	16	11	2	8	9	5		
	Collect oil through debris or choppy water	Avoid debris collection	Limit debris entering skimmer	4	11	15	25	27	34	35		
			Separate debris from fluids taken by skimmer	4	14	15	17	25	34	35		
			contain debris	4	11	15	34	35				
	Measure oil recovery rate	Measure the amount of oil recovered per second	Transform rate readings	1	33	12	22	18	13	10	25	199
			Calculate amount of oil intake	1	33	12	22	18	13	10	25	2
			Accurately detect flow rate	1	33	12	22	18	13	10		
		Control rate of recovery		1	33	15	35	26	12	5		
	Able to filter various oil slick thickness	Distinguish between oil viscosities	Maintain oil/water ratio	33	25	1	12	10	18	5		
			Measure oil resistance to flow	33	1	16	3	10	18	5		
			Detect surface tension	33	31	26	30	1				
		Detect type of oil		28	29	1						
		Self-adjust separation method to different types of oil		18	16	22	28	24				
	Limit water intake	Control water intake	Differentiate specific gravities of fluids	1	2	9	13	16	18	19		
			Collect optimal level of fluids	1	2	6	13	14	18	20		
	Separate oil from water	Filter water out of the oil	Separate oil from water	18	6	1	4	14	30	17		
			Dissipate excess water	1	2	10	12	13	15	25		
			contain contaminated water	4	17	35	11	14	15	23		
		Contain the oil(filter water out of the oil)		17	6	34	25	11	14	15		

4.3.2 GO-NO-GO and Decision Matrix

In this subsection, the team evaluated each concept generated for the functions identified during the functional decomposition assignment. The team generated tables where concepts were evaluated based on the relevant criteria identified in section 4.3.1. Each concept was evaluated using the GO-NO-GO method and each concept received a score from 1 to 10. The team decided that a score of 5 and below was considered a NO-GO decision and any number above 5 was considered a Go. The concepts were scored based on the concept's ability to meet each criterion assigned for the concept's function. In addition, the concepts that scored GO for most of their criteria were able to move to the next evaluation phase.

Tables 4-5 to 4.23- represent the GO-NO-GO Evaluations for each one of the concepts. These concepts were identified in the concept's generation phase, and they were based on the functions identified in the functional decomposition phase.

Table 4.5 Concepts GO-NO-GO Evaluation of the function "Perform Floatation Stabilization"

	Concept 1		Concept 2		Concept 3		Concept 4		Concept 5		Concept 6		Concept 7	
	Floatation foam		Foam Filled Buoys		Buoyant Body		Foam filled modular chain buoys		Tri-float skimmer		Floating drum skimmer		Skimmer material	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Lightweight and compact design	7	GO	5	NO_GO	5	NO GO	2	NO GO	9	GO	9	GO	4	NO GO
Maneuverable	5	NO_GO	1	NO-GO	10	GO	3	NO GO	8	GO	8	GO	6	GO
Satisfy size constraint	2	NO_GO	3	NO_GO	8	GO	3	NO GO	7	GO	9	GO	6	GO
Waterproof	10	GO	10	GO	10	GO	10	GO	8	GO	10	GO	10	GO
Buoyant	10	GO	10	GO	10	GO	10	GO	10	GO	10	GO	10	GO
Easy to operate	3	NO_GO	8	GO	4	NO GO	4	NO GO	5	NO GO	7	GO	7	GO
Marketable	2	NO_GO	7	GO	9	GO	3	NO GO	6	GO	8	GO	7	GO
Overall Decision		NO_GO		GO		GO		NO GO		GO		GO		GO

Do not use all criteria in Go-NO-Go Table. Use fewer most important criteria.

Didn't make corrections.

Table 4.6 GO NO-GO for Evaluating Concepts for the function "Limit Debris Entering Skimmer"

Concepts	Monitoring sensor		Debris Net		Perimeter appendage		Repeller Grate		Debris shield		Skimmer guard		Flow Transmitter	
Requirements/Criteria	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go
Eco friendly	8	GO	6	GO	6	GO	7	GO	8	GO	7	GO	5	GO
Long skimmer life	4	NO-GO	8	GO	4	NO-GO	6	GO	8	GO	5	GO	6	GO
Prevent accidental oil release	1	NO-GO	9	GO	3	NO-GO	8	GO	9	GO	8	GO	3	NO-GO
Prevent accidental contaminated water release	1	NO-GO	9	GO	3	NO-GO	8	GO	9	GO	8	GO	3	NO-GO
small components	8	GO	8	NO-GO	8	GO	3	NO-GO	7	GO	5	GO	8	GO
ANSYS analysis	3	NO-GO	8	GO	5	GO	7	GO	8	GO	8	GO	4	NO-GO
Debris proof	4	NO-GO	9	GO	6	GO	8	GO	8	GO	9	GO	2	NO-GO
Overall Decision		NO-GO		GO		NO-GO		GO		GO		GO		NO-GO

Table 4.7 GO-NO-GO for Evaluating Concepts for the function "Separate debris from fluids taken by skimmer"

Concepts	Debris protection net		Floating Skimmer Fence		Self Filtration		Commercial Screened Shield		Filters		Concept 6		Concept 7		Concept 8	
Requirements/ Criteria	**Score**	**Go-No-Go**	**Score**	**Go-No-Go**	**Score**	**Go-No-Go**	**Score**	**Go-No-Go**	**Score**	**Go-No-Go**	**Score**	**Go-No-Go**	**Score**	**Go-No-Go**	**Score**	**Go-No-Go**
Eco friendly	5	GO	6	GO	7	GO	8	GO	5	NOGO						
Prevent accidental oil release	7	GO	7	GO	9	GO	9	GO	8	GO						
Prevent accidental contaminated water release	7	GO	7	GO	9	GO	9	GO	8	GO						
High oil/ water separation	2	GO	7	GO	9	GO	8	GO	9	GO						
Remove storage container	8	GO	8	GO	8	GO	8	GO	4	NOGO						
ANSYS analysis	5	GO	5	GO	8	GO	7	GO	5	NOGO						
Debris proof	8	GO	8	GO	8	GO	8	GO	5	GO						
Overall Decision		GO		GO		go		GO		NO GO						

Delete empty columns.

Didn't make correction.

Table 4.8 GO-NO-GO Table for Evaluating Concepts for the function "Contain the Debris"

Concepts	Returnline filter		Waste Basket		Hydraulic system		Bandaloong Litter Trap		Bom system		Bag float		Concept 7		Concept 8	
Requirements/ Criteria	**Score**	**Go-No-Go**	**Score**	**Go-No-Go**	**Score**	**Go-No-Go**	**Score**	**Go-No-Go**	**Score**	**Go-No-Go**	**Score**	**Go-No-Go**	**Score**	**Go-No-Go**	**Score**	**Go-No-Go**
Eco friendly	5	GO	7	GO	6	GO	8	GO	6	GO	4	NO-GO				
Prevent accidental oil release	4	NO-GO	8	GO	4	NO-GO	9	GO	8	GO	7	GO				
Prevent accidental contaminated water release	4	NO-GO	8	GO	4	NO-GO	9	GO	7	GO	7	GO				
Removable storage container	4	NO-GO	9	GO	3	NO-GO	8	GO	4	NO-GO	8	GO				
Debris proof	6	GO	8	GO	4	NO-GO	8	GO	8	GO	5	GO				
Overall Decision		NO-GO		GO		NO-GO		GO		GO		GO				

Delete empty columns.

Didn't make correction.

Table 4.9 Concepts GO-NO-GO Evaluation of the function "Transform Rate Readings"

	Concept 1		Concept 2		Concept 3		Concept 4		Concept 5		Concept 6	
	Transmitter		Detector Array		Control panel		Electrical panel		Oil Monitor		Flow Meter	
Requirements/Criteria	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go
Oil recovery efficiency of 25%-	8	GO	10	GO	6	GO	1	NO-GO	3	NO-GO	4	NO-GO
Accurate Fluid Sensibility	7	GO	9	GO	1	NO-GO	2	NO-GO	8	GO	3	NO-GO
Lightweight and compact	10	GO	8	GO	1	NO-GO	2	NO-GO	4	NO-GO	10	GO
High oil/water separation	2	GO	5	GO	1	NO-GO	1	NO-GO	1	NO-GO	5	GO
Small Components	10	GO	4	GO	1	NO-GO	1	NO	4	NO	10	GO
Operational in all calm waters	10	GO	8	GO	3	NO-GO	3	NO-GO	3	NO-GO	10	GO
Detachable	10	GO	8	GO	1	NO-GO	2	NO-GO	4	NO-GO	10	GO
Easily designable with CAD	9	GO	4	GO	1	NO-GO	4	GO	3	NO-GO	7	GO
Easy to Operate	8	GO	7	GO	4	NO-GO	6	NO-GO	4	NO-GO	10	GO
Overall Decisio		GO		GO		Go or not Go?						GO

Didn't make correction.

Table 4.10 Concepts GO-NO-GO Evaluation of the function "Calculate Amount of Oil Intake"

	Concept 1		Concept 2		Concept 3		Concept 4		Concept 5		Concept 6		Concept 7	
	Mass Flow Meter		Flow Monitor		Magmeter		Badge Meter		Series Flow Switch		Lightweight Flow Meter		Clamp Flow Meter	
Requirements/Criteria	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go
Oil recovery efficiency of 25%-50% on ½ in oil	9	GO	7	GO	8	GO	5	No-Go	6	No-Go	7	GO	6	No-Go
Accurate Fluid Sensibility	7	GO	6	No-Go	8	GO	7	GO	5	No-Go	7	GO	9	GO
Lightweight and compact design	7	No-Go	5	No-Go	8	GO	3	No-Go	9	GO	9	GO	6	No-Go
High oil/water separation	9	GO	5	No-Go	7	GO	5	No-Go	5	No-Go	5	No-Go	7	GO
Small Components	7	No-Go	8	No-Go	9	GO	5	No-Go	9	GO	9	GO	5	No-Go
Operational in all calm waters	10	GO	10	GO	10	GO	10	GO	10	GO	10	GO	10	GO
Detachable parts	8	GO	6	No-Go	10	GO	2	No-Go	10	GO	8	GO	5	No-Go
Easily designable with CAD	10	GO	5	No-Go	6	No-Go	3	No-Go	10	GO	8	GO	3	No-Go
Fast Oil Recovery	7	GO	8	GO	6	No-Go	5	No-Go	8	GO	6	No-Go	6	No-Go
Overall		GO		Go?		GO		Go?		Go?		GO		GO or no Go?

Didn't make correction.

Table 4.11 Concepts GO-NO-GO Evaluation of the function "Accurately Detect Flow Sensor"

	Concept 1		Concept 2		Concept 3		Concept 4		Concept 5		Concept 6		Concept 7	
	Mass Flow Meter		Flow Monitor		Magmeter		Badge Meter		Series Flow Switch		Lightweight Flow Meter		Clamp Flow Meter	
Requirements/Criteria	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go
Oil recovery efficiency of 25%-50% on ½ in oil	9	GO	7	GO	8	GO	5	No-Go	6	No-Go	7	GO	6	No-Go
Accurate Fluid Sensibility	7	GO	6	No-Go	8	GO	7	GO	5	No-Go	7	GO	9	GO
Lightweight and compact design	7	No-Go	5	No-Go	8	GO	3	No-Go	9	GO	9	GO	6	No-Go
High oil/water separation	9	GO	5	No-Go	7	GO	5	No-Go	5	No-Go	5	No-Go	7	GO
Small Components	7	No-Go	8	No-Go	9	GO	5	No-Go	9	GO	9	GO	5	No-Go
Operational in all calm waters	10	GO	10	GO	10	GO	10	GO	10	GO	10	GO	10	GO
Detachable parts	8	GO	6	No-Go	10	GO	2	No-Go	10	GO	8	GO	5	No-Go
Easily designable with CAD	10	GO	5	No-Go	6	No-Go	3	No-Go	10	GO	8	GO	3	No-Go
Fast Oil Recover	7	GO	8	GO	6	No-Go	5	No-Go	8	GO	6	No-Go	6	No-Go
Overall		GO				GO						GO		

Table 4.12 Concepts GO-NO-GO Evaluation of the function "Control rate of recovery"

	Concept 1		Concept 2		Concept 3		Concept 4		Concept 5		Concept 6	
	Fixed orifice model		Flow Monitor		Pressure Switch		DataFlo Remote controller		oil traffic controller		Actuator	
Criteria/Requirements	Score	GO NO GO	Score	GO NO GO	Score	GO NO GO	Score	GO NO GO	Score	GO NO GO	Score	GO NO GO
Oil recovery efficiency of 25%-50% on ½ in oil slick	4	NO GO	3	NO GO	5	NO GO	5	NO GO	4	NO GO	6	GO
Accurate fluid sensibility	6	GO	7	GO	7	GO	6	GO	6	GO	6	GO
debris prof	8	GO	2	NO GO	4	NO GO	3	NO GO	4	NO GO	7	GO
Prevent accidental contaminated water release	6	GO	2	NO GO	7	GO	5	NO GO	8	GO	6	GO
Fast oil recovery	3	NO GO	6	GO	6	GO	3	NO GO	4	NO GO	3	NO GO
Lightweight and compact design	7	GO	7	GO	7	GO	6	GO	6	GO	5	NO GO
Cost Effective	10	GO	3	NO GO	9	GO	3	NO GO	6	GO	5	NO GO
Overall Decision		GO		NO GO		GO		NO GO		GO		GO

Table 4.13 Concepts GO-NO-GO Evaluation of the function "Maintain oil/water ratio"

	Concept 1		Concept 2		Concept 3		Concept 4		Concept 5		Concept 6		Concept 7	
	Microwave signal generator		DMS Thickness Gauge		Ultrasonic thickness gauge		Ultrasound Ultrasonic Testing		Line transducer		Flow transmitter		Digital flow meter	
Criteria/Requirements	Score	GO NO GO	Score	GO NO GO	Score	GO NO GO	Score	GO NO GO	Score	GO NO GO	Score	GO NO GO	Score	GO NO GO
Accurate fluid sensibility	6	GO	7	GO	6	GO	5	NO GO	8	GO	7	GO	6	GO
high oil/water separation	6	GO	5	NO GO	4	NO GO	3	NO GO	4	NO GO	5	NO GO	5	NO GO
Oil recovery efficiency of 25%-50% on ½ in oil slick	5	NO GO	3	NO GO	4	NO GO	3	NO GO	6	GO	5	NO GO	6	GO
Light weight and compact design	4	NO GO	7	GO	9	GO	6	GO	7	GO	9	GO	4	NO GO
Detachable part	6	GO	8	GO	8	GO	6	GO	5	NO GO	7	GO	0	NO GO
Small Component	5	NO GO	6	GO	8	GO	6	GO	8	GO	8	GO	3	NO GO
Cost effective	3	NO GO	0	NO GO	0	NO GO	2	NO GO	0	NO GO	6	NO GO	0	NO GO
Overall Decision		NO GO		GO		GO		NO GO		GO		GO		NO GO

Table 4.14 Concepts GO-NO-GO Evaluation of the function "Measure oil resistance to flow"

	Concept 1		Concept 2		Concept 3		Concept 4		Concept 5	
	Viscometer fork		Oval Gear Flow Meter		Flow meter		Flow Meter DulcoFlow		Hand viscosity meter	
Criteria/Requirements	Score	GO NO GO	Score	GO NO GO	Score	GO NO GO	Score	GO NO GO	Score	GO NO GO
Accurate fluid sensibility	8	GO	8	GO	8	GO	7	GO	7	GO
Oil recovery efficiency of 25%-50% on ½ in oil slick	4	NO GO	7	GO	5	NO GO	5	NO GO	4	NO GO
Lightweight and compact design	8	GO	4	NO GO	7	GO	5	NO GO	5	NO GO
Easy to operate	7	GO	6	GO	8	GO	7	GO	8	GO
Detachable part	8	GO	5	NO GO	4	NO GO	5	NO GO	8	GO
Small Component	7	GO	6	GO	6	GO	7	GO	5	NO GO
Cost effective	5	NO GO	5	NO GO	0	NO GO	4	NO GO	5	NO GO
Overall Decision		GO		GO		GO		NO GO		NO GO

Table 4.15 Concepts GO-NO-GO Evaluation of the function "Detect Surface Tension"

	Concept 1		Concept 2		Concept 3		Concept 4		Concept 5		Concept 6	
	Surface tension meter		Tension Meter		Grease Grabber		Portable Tensiometer		Surface tension detector		Tensiometer	
Criteria/Requirements	Score	GO NO GO	Score	GO NO GO	Score	GO NO GO	Score	GO NO GO	Score	GO NO GO	Score	GO NO GO
Accurate fluid sensibility	6	GO	5	NO_GO	5	NO GO	2	NO GO	3	NO GO	7	GO
Applies Specific Gravity	7	GO	1	GO	10	GO	3	NO GO	6	GO	6	GO
Fast oil recovery	2	NO_GO	3	NO_GO	8	GO	3	NO GO	4	NO GO	4	NO GO
Utilizes Cohesion/Surface Tension of Oil	10	GO	10	GO	10	GO	8	GO	8	GO	10	GO
Oil recovery efficiency	3	NO_GO	8	NO_GO	4	NO GO	2	NO GO	5	NO GO	4	NO GO
Overall Decision		GO		NO GO		GO		NO GO		NO GO		GO

Table 4.16 Concepts GO-NO-GO Evaluation of the function "Detect Type of Oil"

	Concept 1		Concept 2		Concept 3		Concept 4		Concept 5		Concept 6	
	Digital viscometer		Viscometer		Compact density meter		Viscosities and Densities Detector		Viscosity tester		Detection system	
Criteria/Requirements	Score	GO NO GO	Score	GO NO GO	Score	GO NO GO	Score	GO NO GO	Score	GO NO GO	Score	GO NO GO
Accurate Oil Detection Thickness	7	GO	5	NO_GO	5	NO GO	6	GO	6	GO	10	GO
Capability of Viscosity Sensibility	6	GO	10	GO	8	GO	7	GO	8	GO	7	GO
Oil Recovery efficiency	3	NO_GO	4	NO GO	4	NO GO	4	NO GO	4	NO GO	6	GO
Overall Decision		GO		NO_GO		NO_GO		NO GO		GO		GO

Table 4.17 Concepts GO-NO-GO Evaluation of the function «Self-adjust separation method to different types of oil»

	Concept 1		Concept 2		Concept 3		Concept 4		Concept 5		Concept 6		Concept 7	
	Viscometer		Compact Density Meter		Flow gauge		Vibration Viscometer		Mass flow meter		Density meter		Analog recorder	
Criteria/Requirements	Score	GO NO GO	Score	GO NO GO	Score	GO NO GO	Score	GO NO GO	Score	GO NO GO	Score	GO NO GO	Score	GO NO GO
Small components	6	GO	6	GO	6	GO	6	GO	9	GO	7	GO	7	GO
Operational in various Oil Thickness	4	NO GO	1	NO-GO	4	NO GO	3	NO GO	8	GO	4	NO GO	6	GO
Easily designable with CAD software	2	NO_GO	3	NO_GO	8	GO	3	NO GO	3	NO GO	3	NO GO	4	NO GO
Accurate Oil Detection Thickness	6	GO	10	GO	6	GO	7	GO	2	NO GO	8	GO	3	NO GO
Easy to manufacture	3	NO_GO	5	NO GO	7	GO	4	NO GO	5	NO GO	6	GO	7	GO
Overall Decision		NO_GO		NO GO		GO		NO GO		NO GO		GO		GO

Table 5.18 Concepts GO-NO-GO Evaluation of the function "Differentiate specific gravities of fluids"

Concepts	Simple Hydrometer		Liquid level transmitter		Point Level Sensor		Weir skimmer		Model 8 oil grabber		PetroXtractor Skimmer		Tuning fork density meter	
Requirements/Criteria	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go
Eco friendly	9	GO	8	GO	9	GO	5	NO GO	6	GO	8	GO	9	GO
Satisfy size constraint	9	GO	8	GO	8	GO	3	NO GO	3	NO GO	4	NO GO	9	GO
Buoyant	6	GO	4	NO GO	6	GO	8	GO	5	NO GO	3	NO GO	5	NO GO
Accurate fluid Sensibility	8	GO	9	GO	8	GO	3	NO-GO	6	GO	5	NO GO	8	GO
Lightweight and compact design	9	GO	8	GO	5	NO GO	4	NO GO	5	NO GO	3	NO GO	9	GO
Easy to operate	9	GO	7	GO	6	GO	8	GO	5	NO GO	5	NO GO	2	NO-GO
Easy to assemble	9	GO	4	NO GO	8	GO	4	NO GO	2	NO GO	3	NO GO	7	GO
Overall Decision	59	GO	44	GO	50	GO	35	NO GO	32	NO GO	28	NO GO	49	GO

Table 4.19 Concepts GO-NO-GO Evaluation of the function "Collect optimal level of fluids"

Concepts	Disk		Grooves		polycarbonate Ultrasonic Transmission		Submersible Pressure transmitters		Spinning grooves disk		Filtration Plate		Submersible level transmitter	
Requirements/Criteria	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go
Eco friendly	9	GO	8	GO	7	GO	7	GO	8	GO	8	GO	8	GO
Satisfy size constraint	9	GO	8	GO	7	GO	7	GO	5	NO GO	5	NO GO	9	GO
Oil recovery efficiency of 25% - 50% on ½ in oil slick	9	GO	7	GO	8	GO	8	GO	9	GO	8	GO	8	GO
Accurate fluid sensibility	8	GO	7	GO	8	GO	8	GO	7	GO	8	GO	9	GO
Prevent accidental oil release	7	GO	8	GO	8	GO	7	GO	8	GO	8	GO	8	GO
Easy to operate	9	GO	8	GO	7	GO	8	GO	8	GO	7	GO	9	GO
Easy oil recovery	9	GO	7	GO	8	GO	8	GO	9	GO	9	GO	8	GO
Overall Decision		GO		GO		GO		GO		GO		GO		GO

Table 4.20 Concepts GO-NO-GO Evaluation of the function "Separate Oil from Water"

	Concept 1		Concept 2		Concept 3		Concept 4		Concept 5		Concept 6	
	Grooved drum		Grooved disk		Oil Water Filter		Strainer		fingers		Oil filter	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Oil recovery efficiency of 25%-50% on ½ in oil slick	10	GO	10	NO_GO	6	GO	7	GO	9	GO	9	GO
Prevent accidental oil release	8	GO	7	NO-GO	8	GO	8	GO	2	NO-GO	6	GO
High oil storage capacity	9	GO	8	NO-GO	5	NO-GO	3	NO-GO	5	NO-GO	4	GO
High oil/ water separation	10	GO	10	GO	10	GO	10	GO	8	GO	10	GO
Debris proof	3	NO-GO	5	NO-GO	2	NO-GO	3	NO-GO	3	GO	4	GO
Easy to operate	7	GO	8	GO	3	NO-GO	3	NO GO	6	NO GO	3	GO
Eco friendly	7	GO	7	GO	7	GO	8	GO	5	NO-GO	1	NO-GO
Overall Decision		GO		GO		GO		GO		NO-GO		NO-GO

Table 4.21 Concepts GO-NO-GO Evaluation of the function "Dissipate Excess water"

Concepts	Moisture & temperature transmission series		High pressure liquid level sensor		Baffle		Decanter		Oil smart pump switch		Hose		Liquid level transmitter	
Requirements/Criteria	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go	Score	Go-No-Go
Eco Friendly	8	GO	8	GO	6	GO	8	GO	8	GO	8	GO	5	NO GO
Satisfy size constraint	8	GO	6	GO	4	NO-GO	6	GO	7	GO	6	GO	7	GO
Easy to manufacture	6	GO	7	GO	5	NO-GO	6	GO	5	NO GO	7	GO	4	NO-GO
High water pump capacity	7	GO	6	GO	8	GO	7	GO	8	GO	6	GO	7	GO
Accurate fluid sensibility	8	GO	9	GO	5	NO GO	7	GO	8	GO	8	GO	8	GO
Prevent accidental contaminated water release	4	NO-GO	6	GO	8	GO	8	GO	3	NO GO	7	GO	4	NO-GO
Removable storage container	2	NO GO	2	NO GO	7	GO	5	NO GO	3	NO GO	4	NO GO	3	NO GO
Overall Decision		GO		GO		NO-GO		GO		NO GO		GO		NO GO

Table 4.22 Concepts GO-NO-GO Evaluation of the function "Contain contaminated water"

	Concept 1		Concept 2		Concept 3		Concept 4		Concept 5		Concept 6		Concept 7		Concept 8	
	Contaminant removal filter cart (portable)		Oil separator from industrial fluids System		Kidney loop filtration system		Oil/water separator using density sensor		Automatic flow regulating valve		Ball valve that separates oil and water		Series flow switch		Moisture in oil transmitter	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
1.Eco friendly	7	GO	6	GO	7	GO	9	GO	10	GO	9	GO	7	GO	8	GO
2. Satisfy size constraint	6	GO	4	NO-GO	6	GO	9	GO	10	GO	10	GO	10	GO	10	GO
15. Prevent accidental contaminated water release	6	GO	7	GO	5	NO-GO	4	NO-GO	4	NO-GO	4	NO-GO	1	NO-GO	6	GO
25. Removable storage container	9	NO-GO	1	NO-GO	1	NO-GO	6	GO	4	NO-GO	1	GO	1	NO-GO	1	NO-GO
27. Corrosion resistance	7	GO	6	GO	4	NO-GO	9	GO	8	GO	5	NO-GO	4	NO-GO	9	GO
30. Debris proof	5	NO-GO	4	NO-GO	6	GO	5	NO-GO	1	NO-GO	5	NO-GO	1	NO-GO	4	NO-GO
12. High water pump capacity	5	NO-GO	5	NO-GO	1	NO-GO	5	NO-GO	1	NO-GO	5	NO-GO	1	NO-GO	4	NO-GO
Overall Decision		GO		NO-GO		NO-GO		GO		NO-GO		GO		NO-GO		GO

Table 4.23 Concepts GO-NO-GO Evaluation of the function "Contain the oil (filter water out of the oil)"

	Concept 1		Concept 2		Concept 3		Concept 4		Concept 5		Concept 6	
	Oil Storage tank		Oil retainer where oil is whiped off before containtment		Oil container for oil skimmer		Floating boom sock		Oil containtment tank for storage		Large oil skimmer tank	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
2. Satisfy size constraint	8	GO	8	GO	7	GO	10	GO	8	GO	2	NO-GO
4. High oil storage capacity	7	GO	10	GO	10	GO	2	NO-GO	10	GO	10	GO
14. Prevent accidental oil release	6	GO	7	GO	4	NO-GO	2	NO-GO	8	GO	5	NO-GO
17. High oil/ water separation	4	NO-GO	8	GO	4	NO-GO	5	NO-GO	9	GO	3	NO-GO
25. Removable storage container	7	GO	8	GO	5	NO-GO	9	GO	8	GO	3	NO-GO
27. Corrosion resistance	9	GO	7	GO	7	GO	5	NO-GO	8	GO	7	GO
30. Debris Proof	4	NO-GO	2	NO-GO	5	NO-GO	5	NO-GO	4	NO-GO	6	GO
Overall Decision		GO		GO		NO-GO		NO-GO		GO		NO-GO

The second evaluation phase consisted in a decision matrix, where all of the remainder concepts were evaluated. In this phase each criterion was assigned a specific weight from 1 to 10. Then the scores for each concept were transferred from the GO-NO-GO phase and were multiplied by the weight assigned for each criterion. Then the total amount of points for each concept was calculated and the two concepts per function that had the highest score, were selected to move into the final design evaluation stage. Tables 21-39 display the matrix decision method to evaluate the concepts that passed the GO-NO-GO test.

Table 4.24 Concepts Decision Matrix Evaluation of the function "Perform Floatation Stabilization"

		Concept 2		Concept 3		Concept 5		Concept 6		Concept 7	
		Foam Filled Buoys		Buoyant Body		Tri-float skimmer		Floating drum skimmer		Skimmer material	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Lightweight and compact design	10	5	50	8	80	9	90	9	90	4	40
Maneuverable	6	1	6	9	56	8	48	8	48	6	36
Satisfy size constraint	8	3	24	8	64	7	56	9	72	6	48
Waterproof	10	10	100	10	100	8	80	10	100	10	100
Buoyant	10	10	100	10	100	10	100	10	100	10	100
Easy to operate	6	8	48	7	42	5	30	7	42	7	42
Marketable	6	7	35	9	63	6	36	8	48	7	42
Overall Decision			363		505		440		500		408

Table 4-25 Decision Matrix Table for the Function "Limit Debris Entering Skimmer"

		Concept 2		Concept 4		Concept 5		Concept 6	
		Debris Net		Repeller Grate		Debris shield		Skimmer guard	
Requirements/Criteria	**Weight**	**Score**	**Weighted Score**	**Score**	**Weighted Score**	**Score**	**Weighted Score**	**Score**	**Weighted Score**
Eco friendly	5	6	30	7	35	8	40	7	35
Long skimmer life	7	8	56	6	42	8	56	5	35
Prevent accidental oil release	9	9	81	8	72	9	81	8	72
Prevent accidental contaminated water release	9	9	81	8	72	9	81	8	72
small components	3	8	24	3	9	7	24	5	15
ANSYS analysis	6	8	48	7	42	8	48	8	48
Debris proof	10	9	90	8	80	8	80	9	90
Total Weighted Score			**410**		**352**		**410**		**367**

Table 4-26 Decision Matrix Table for the Function "Separate debris from fluids taken by skimmer"

		Concept 1		Concept 2		Concept 3		Concept 6	
		Debris protection net		Floating Skimmer Fence		Self Filtration		Commercial Screened Shield	
Requirements/Criteria	**Weight**	**Score**	**Weighted Score**	**Score**	**Weighted Score**	**Score**	**Weighted Score**	**Score**	**Weighted Score**
Eco friendly	6	5	30	6	36	7	42	8	48
Long skimmer life	6	7	42	7	42	9	54	9	54
Prevent accidental oil release	10	7	70	7	70	9	90	9	90
Prevent accidental contaminated water release	10	2	20	7	70	9	90	8	80
small components	4	8	32	8	32	8	32	8	32
ANSYS analysis	8	5	40	5	40	8	64	7	56
Debris proof	7	8	56	8	56	8	56	8	56
Total Weighted Score			290		346		428		416

Table 4-27 Decision Matrix Table for the Function "Contain the Debris"

		Concept 2		Concept 4		Concept 5		Concept 6	
		Waste basket		Bandalong Litter Trap		Bom system		Bag float	
Requirements/Criteria	**Weight**	**Score**	**Weighted Score**		**Weighted Score**	**Score**	**Weighted Score**	**Score**	**Weighted Score**
Eco friendly	7	7	42	8	56	6	42	4	28
Long skimmer life	7	8	56	9	63	8	56	7	42
Prevent accidental oil release	10	8	80	9	90	7	70	7	70
Prevent accidental contaminated water release	10	9	90	8	80	4	40	8	80
small components	5	8	40	8	40	8	40	5	25
Total Weighted Score			308		329		248		245

Table 4-28 Concepts Decision Matrix Evaluation of the function "Separate Oil from Water"

		Concept 2		Concept 3		Concept 5		Concept 6	
		Grooved drum		Grooved disk		Oil Water Filter		Strainer	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Oil recovery efficiency of 25%-50% on ½ in oil slick	10	10	100	10	100	6	60	7	70
Prevent accidental oil release	10	8	80	7	70	8	80	8	80
High oil storage capacity	8	9	72	8	64	5	40	3	24
High oil/ water separation	10	10	100	10	100	10	100	10	24
Debris proof	6	3	18	5	30	2	12	3	18
Easy to operate	7	7	49	8	56	3	21	3	21
Eco friendly	10	7	70	7	70	7	70	8	80
Overall Decision			489		490		383		317

Table 4-29 Concepts Decision Matrix Evaluation of the function "Transform Rate Readings"

		Concept 1		Concept 2		Concept 6	
		Digital Transmitter		Detector Array		Flow Meter	
Requirements/Criteria	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Oil recoverg efficiency of 25%-50% on ½ in oil	10	8	80	10	100	4	40
Accurate Fluid Sensibility	9	7	63	9	81	3	27
Lightweight and compact design	6	10	60	8	48	10	60
High oil/water separation	9	2	18	5	40	5	40
Small Components	3	10	30	4	12	10	30
Operational in all calm waters	5	10	50	8	40	10	50
Detachable	1	10	10	8	8	10	10
Easily designable with CAD software	7	9	63	4	28	7	49
Easy to Operate	8	8	64	7	56	10	80
Total Weighted Score			**438**		**413**		**386**

Table 4-30 Concepts Decision Matrix Evaluation of the function "Calculate Amount of Oil Intake"

		Concept 1		Concept 3		Concept 6	
		Mass Flow Meter		Magmeter		Lightweight Flow Meter	
Requirements/Criteria	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Oil recovery efficiency of 25%-50% on ¾ in oil	10	9	90	8	80	7	70
Accurate Fluid Sensibility	9	7	63	8	72	7	63
Lightweight and compact design	6	7	42	8	48	9	54
High oil/water separation	9	9	81	7	63	5	45
Small Components	3	7	21	9	27	9	27
Operational in all calm waters	5	10	50	10	50	10	50
Detachable	1	8	8	10	10	8	8
Easily designable with CAD software	7	10	70	6	42	8	56
Past Oil Recover	8	7	56	6	48	6	48
Total Weighted Score			481		440		421

Table 4-31 Concepts Decision Matrix Evaluation of the function "Accurately Detect Flow Sensor"

		Concept 2		Concept 5		Concept 6	
		Pressure Transducer		Transceiver		Sensor	
Requirements/Criteria	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Oil recovery efficiency of 25%-50% on ¼ in oil	10	6	60	7	70	7	70
Accurate Fluid Sensibility	9	7	63	7	63	9	81
Lightweight and compact design	6	9	54	8	48	9	54
Small Components	3	9	27	7	21	9	27
Operational in all calm waters	5	10	50	10	50	10	50
Detachable	1	9	9	7	7	9	9
Easily designable with CAD software	7	8	56	6	42	7	49
Total Weighted Score			319		301		340

Table 4-32 Concepts Decision Matrix Evaluation of the function "Differentiate specific gravities of fluids"

		Concept 1		Concept 2		Concept 3		Concept 7	
		Simple Hydrometer		Liquid level Transmitter		Point level Sensor		Tuning Fork density meter	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Eco Friendly	5	9	45	8	40	9	45	9	45
Satisfy size constraint	7	9	63	8	56	8	56	9	63
Buoyant	7	6	42	4	28	6	42	5	35
Accurate fluid sensibility	9	8	72	9	81	8	72	8	72
Lightweight and compact design	8	9	72	8	64	5	40	9	72
Easy to Operate	9	9	81	7	63	6	54	2	18
Easy to assemble	8	9	72	4	32	8	64	7	56
Overall Decision			447		364		373		361

Table 4-33 Concepts Decision Matrix Evaluation of the function "Collect optimal level of fluids"

		Concept 1		Concept 2		Concept 3		Concept 4		Concept 5		Concept 6		Concept 7	
		Disk		Grooves		Polycarbonate Ultrasonic Transmission		Submersible pressure transmitter		Spinning grooves disk		Filtration plate		Submersible level transmitter	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Eco friendly	7	9	63	8	56	7	49	7	49	8	56	8	56	8	56
Satisfy size constraint	7	9	63	8	56	7	49	7	49	5	35	5	35	9	63
Oil recovery efficiency of 25%-50% on ½ in oil slick	10	9	90	7	70	8	80	8	80	9	90	8	80	8	80
Accurate fluid sensibility	10	8	80	7	70	8	80	8	80	7	70	8	80	9	90
Prevent accidental oil release	7	7	49	8	56	8	56	7	49	8	56	8	56	8	56
Easy to operate	7	9	63	8	56	7	49	8	56	8	56	7	49	9	63
Easy oil recovery	8	9	72	7	56	8	64	8	64	9	72	9	72	8	64
Overall Decision			480		420		427		427		435		428		472

Table 4-34 Concepts Decision Matrix Evaluation of the function "Dissipate excess water"

		Concept 1		Concept 2		Concept 4		Concept 6	
		Moisture and temperature tranamission series		High pressure liquid sensor		Decanter		Hose	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Eco Friendly	8	8	64	8	64	8	64	8	64
Satisfy size constraint	7	8	56	6	42	6	42	6	42
Easy to manufacture	7	6	42	7	49	6	42	7	49
High water pump capacity	6	7	42	6	36	7	42	6	36
Accurate fluid sensibility	8	8	64	9	72	7	56	8	64
Prevent accidental contaminated water release	8	4	32	6	48	8	64	7	56
Removable storage container	9	2	18	2	18	5	45	4	36
Overall Decision			318		329		355		347

Table 4-35 Concepts Decision Matrix Evaluation of the function "Detect Surface Tension"

		Concept 1		Concept 5		Concept 6	
		Surface tension meter		Grease Grabber		Tensiometer	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Accurate fluid sensibility	7	6	60	5	78	7	68
Applies Specific Gravity	6	7	75	10	89	6	57
Fast oil recovery	8	2	20	8	82	4	34
Utilizes Cohesion/Surface Tension of Oil	10	10	100	10	100	10	90
Oil recovery efficiency	10	3	24	4	65	4	35
Overall Decision			279		414		284

Table 4-36 Concepts Decision Matrix Evaluation of the function "Detect Type of Oil"

		Concept 1		Concept 5		Concept 6	
		Digital Viscometer		Viscosity Tester		Detection System	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Accurate Oil Detection Thickness	10	7	65	6	58	10	100
Capability of Viscosity Sensibility	7	6	53	8	75	7	80
Oil recovery efficiency	10	3	35	4	35	6	65
Overall Decision			153		168		245

Table 4-37 Concepts Decision Matrix Evaluation of the function "Self-adjust separation method to different types of oil"

		Concept 3		Concept 6		Concept 7	
		Flow gauge		Density meter		Analog recorder	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Small components	8	6	77	7	80	7	80
Operational in various Oil Thickness	10	4	89	4	56	6	68
Easily designable with CAD software	7	8	45	3	35	4	46
Accurate Oil Detection Thickness	10	6	65	8	85	3	30
Easy to manufacture	10	7	100	6	90	7	70
Overall Decision			376		346		294

Table 4-38 Concepts Decision Matrix Evaluation of the function "Control Rate of recovery"

		Concept 1		Concept 3		Concept 5		Concept 6	
		Fixed orifice mode		Pressure Switch		oil traffic controller		Actuator	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Oil recovery efficiency of 25%-50% on ½ in oil slick	10	4	40	5	50	4	40	6	60
Accurate fluid sensibility	10	6	60	7	70	6	60	6	60
debris prof	5	8	40	4	20	4	20	7	35
Prevent accidental contaminated water release	9	6	54	7	63	8	72	6	54
Fast oil recovery	7	3	21	6	42	4	28	3	21
Lightweight and compact design	7	7	49	7	49	6	42	5	35
Cost effective	8	10	80	9	72	6	48	5	40
Overall Decision			344		366		310		305

Words are blurry in the table. Do not use pictures for tables.

Table 4-39 Decision Matrix Evaluation of the function "Maintain oil/water ratio"

		Concept 2		Concept 3		Concept 5		Concept 6	
		DMS Thickness Gauge		Ultrasonic thickness gauge		Line transducer		Flow transmitter	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Accurate fluid sensibility	9	7	63	6	54	8	72	7	63
high oil/water separation	9	5	45	4	36	4	36	5	45
Oil recovery efficiency of 25%-50% on ½ in oil slick	10	3	30	4	40	6	60	5	50
Light weight and compact design	7	7	49	9	63	7	49	9	63
Detachable part	6	8	48	8	48	5	30	7	42
Small Component	7	6	42	8	56	8	56	8	56
Cost effective	8	0	0	0	0	0	0	6	48
Overall Decision			277		297		303		367

Table 4-40 Concepts Decision Matrix Evaluation of the function "Measure oil resistance to flow"

		Concept 1		Concept 2		Concept 3	
		Viscometer fork		Oval Gear Flow Meter		Flow meter	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Accurate fluid sensibility	10	8	80	8	80	8	80
Oil recovery efficiency of 25%-50% on ½ in oil slick	10	4	40	7	70	5	50
Lightweight and compact design	7	8	56	4	28	7	49
Easy to operate	8	7	56	6	48	8	64
Detachable part	5	8	40	5	25	4	20
Small Component	7	7	49	6	42	6	42
Cost effective	8	5	40	5	40	0	0
Overall Decision			361		333		305

Table 4-41 Concepts Decision Matrix Evaluation of the function "Contain contaminated water"

		Concept 1		Concept 4		Concept 8	
		Contaminant removal filter cart (portable)		Oil/water separator using density sensor		Moisture in oil transmitter	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
1.Eco friendly	8	7	56	9	72	8	64
2. Satisfy size constraint	10	6	60	9	90	10	100
15. Prevent accidental contaminated water release	7	6	42	4	28	6	42
25. Removable storage container	4	9	36	6	24	1	4
27. Corrosion resistance	9	7	63	9	81	9	81
30. Debris proof	5	5	25	5	25	4	20
12. High water pump capacity	6	5	30	5	30	4	24
Total Weighted Score			312		350		335

Table 4-42 Concepts Decision Matrix Evaluation of the function "Contain the oil (filter water out of the oil)"

		Concept 1		Concept 2		Concept 5	
		Oil Storage tank		Oil retainer where oil is wiped off before containment		Oil containment tank for storage	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
2. Satisfy size constraint	10	8	80	8	80	8	80
4. High oil storage capacity	7	7	49	10	70	10	70
14. Prevent accidental oil release	10	6	60	7	70	8	80
17. High oil/ water separation	10	4	40	8	80	9	90
25. Removable storage container	4	7	28	8	32	8	32
27. Corrosion resistance	9	9	81	7	63	8	72
30. Debris Proof	5	4	20	2	10	4	20
Total Weighted Score			358		405		444

4.4 System Sketches and Description for Two Final Design

In this subsection, the team compiled all the concepts that were selected from the matrix decision phase of the design evaluation. Once the concepts were compiled the team generated two detailed sketches using the concepts that were identified to best meet the important criteria of the project. Then, both systems were evaluated, and the team made a decision of a finalized preliminary design.

In Figure 4-37 the sketch of the higher score components is displayed.

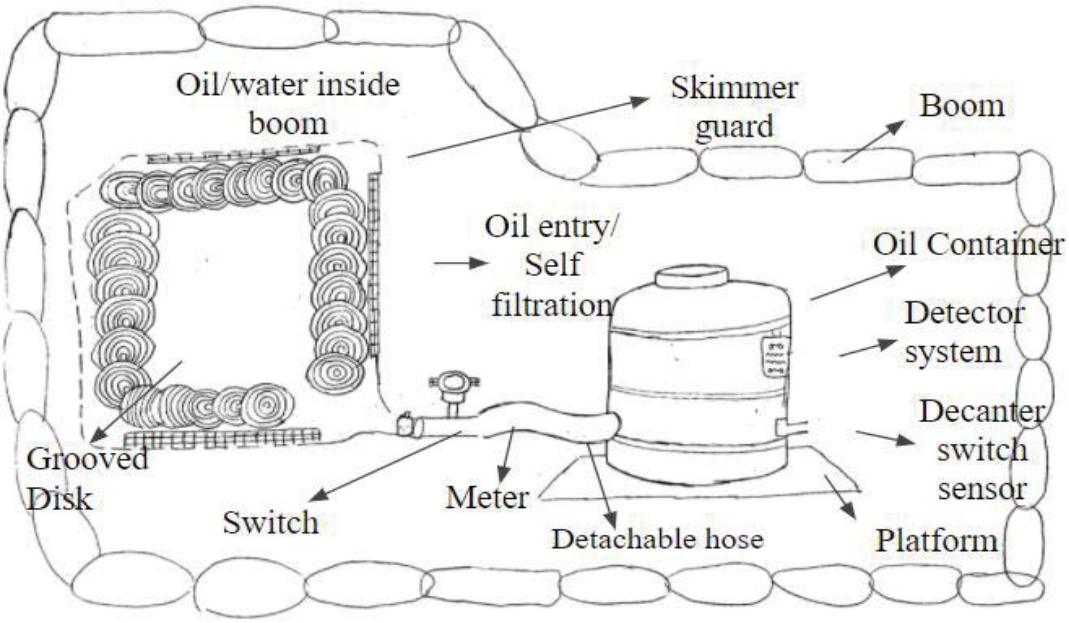


Figure 4.37 Skimmer Sketch 1

In Figure 4-38, the sketch that contains the components with the second highest score in the decision matrix is displayed.

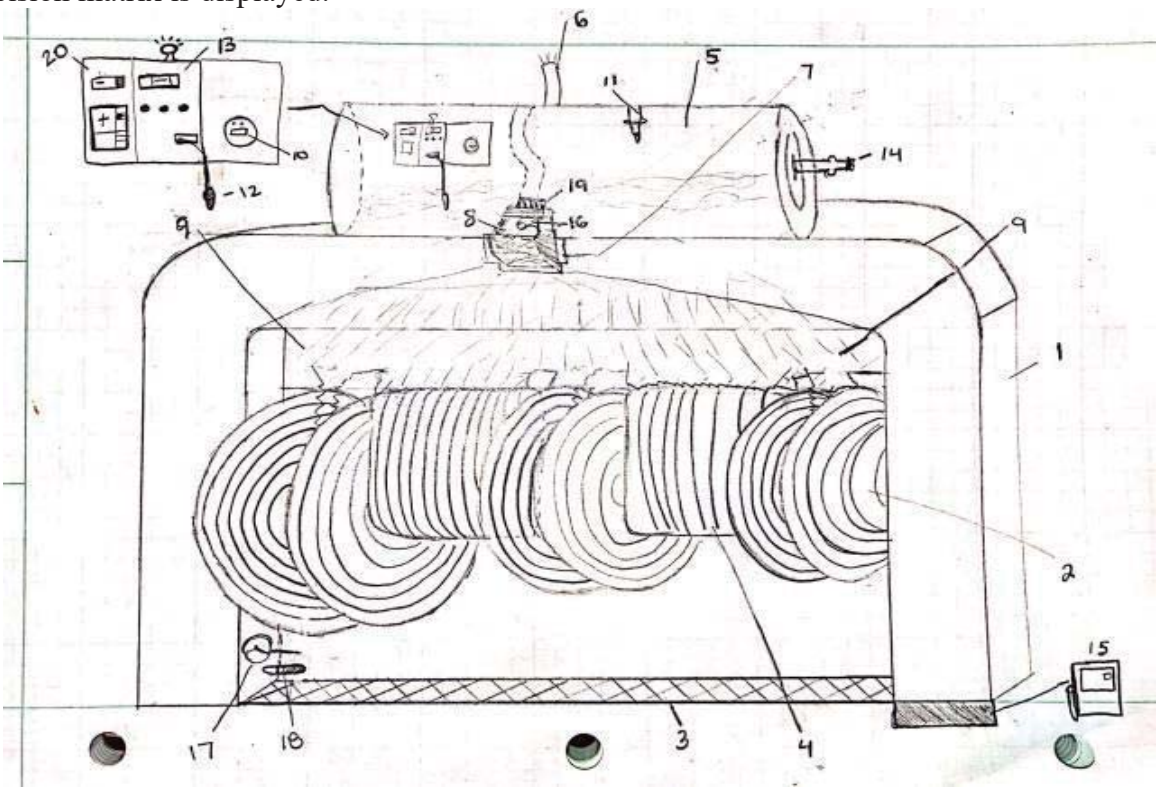


Figure 4- 38 Skimmer Sketch 2

In Figure 4-39 a legend for figure 2 is displayed.

Sketch 2 Legend
1. U-shaped body
2. Grooved disk
3. Debris shield
4. Floating Drum skimmer
5. Oil retainer
6. Hose
7. Waste Basket
8. Commercial screen shield
9. Oil ramp
10. Magmeter
11. Point level sensor
12. Submersible level transmitter
13. Detector array
14. Pressure Transducer
15. Line transducer
16. Oval gear flow meter
17. Tensiometer
18. Density meter
19. Fixed Orifice system
20. Moisture oil transmitter

Figure 4-39 Legend of Figure 4-38

First you need to explain how the two systems will work. Then, you compare the two systems.

The second sketch featuring the second tier of concepts from the decision matrix was chosen to be the favorite over the first sketch. Due to the complexities of some of the concepts within the first tier, the design for the first sketch was more difficult to imagine as a fully functional and apprehensive model. The first sketch had too many moving parts that could become a size constraint issue if not properly designed. The second tier of concepts flowed more fluidly when meshed together while also being able to add a few small components to make the functions of the concepts coincide with one another. Although the first sketch presented better concepts overall, the assembly of the second sketch is more comprehensive and also more reliable in terms of a compact and lightweight design.

Didn't make corrections.

Missing 4.5 Design Constraints and Applicable Codes and Standards Used in the Design

5. DETAILED SYSTEM DESIGN

This chapter identifies and displays a plan for the different types of analysis needed to effectively design the skimmer. In addition, this chapter details the engineering analysis and simulation for designing. Also, the chapter identifies the sizing specification and the selection of parts for the design. Moreover, the chapter displays the full engineering analysis and simulation of the design and the layout of detailed drawings and the Equipment selection with specifications. Finally, the chapter makes available the list of the application of engineering codes and standards in design, the economic analysis, fabrication and testing of the skimmer design.

5.1 Identification and Plans for Types of Analysis Needed for the Design

This section includes a list of the different types of analysis needed for the skimmer design. The list can be observed in Table 5.1 where the specific analysis identified is linked with a specific component, subject area, and the reference from which the information was obtained. To generate Table 5.1, the team reviewed each one of the concepts selected in the concept's evaluation phase of the project. As each concept was reviewed, the team generated a list of different types of analysis required to successfully complete each one of the functions each concept was required to fulfill.

Table 5.1 contains the main components of the skimmer design along with a list of different analyses that were performed to ensure the most effective part selection.

Table 5.1 Summary of System Components, Types of Analysis needed, Subject Areas and Reference Sources used for the Design Analysis of the Components

Item #	System Component or part description	Description of analysis needed for the design, sizing, specifying or selecting component	Subject Area	Reference Source for Analysis
5.2.1	Disk	Determining ORR AND RE of various oil slick with a grooved disk to determine the best in the market	ORR(Oil recovery rate), RE (Recovery Efficiency)	Fluids Mechanics
5.2.2	Pump	Calculate the flow rate of a pump	Fluid Mechanics	Fluid Mechanics Fundamentals and Applications
5.2.3	Shaft	For the shaft analysis, diameter and length were calculated to meet dimension criteria that fits the skimmer, the rotational speed was calculated to determine how fast the discs can rotate without failure.	Shaft Analysis, Mechanics and dynamics of cylindrical rod.	Mechanical Engineering Design
5.2.4	Components size	Calculate the oil skimmer major component Dimension; skimmer shell, oil container, grooved discs and, grooved drums	Dimensional analysis	
5.2.5	Motor	Calculated torque and power	Machine Design	Shigley's Mechanical Engineering Design
5.2.6	Floating mechanism Skimmer shell	Buoyancy	Physics Fluids	Fluids Mechanics Book

Approval by Project owner: Jaejong Park Signature _____

5.2 Detailed Engineering Analysis and Simulation for Designing, Sizing, Specifying and Selecting Parts for the Design.

This section has been identified as the breakdown of each one of the relevant analyses identified in section 5.1 of the chapter. In each subsection of section 5.2, the free body diagrams that show all of the known and unknown forces acting on the part analyzed are displayed. In addition, the subsections will include process diagrams when applicable. These diagrams display all the input and output variables relevant to the analysis and are vital to the development of the design. Moreover, the following subsections will include the set of equations needed for each analysis along with each variable description located under the equations. Also, each analysis section will include the values of all of the known variables and its computational methods. These will include the final computed variables and the parts specification if the part was selected for the final skimmer design.

5.2.1 Analysis for determining ORR (Oil recovery rate) and RE (Recovery Efficiency) through various oil slick with grooved disk

In this section, the analysis for determining oil recovery rate and recovery efficiency is discussed. One disadvantage of the traditional smooth surface disk skimmers led to the development of innovative surface geometries targeting enhanced oil recovery performance. One of the most effective surface geometry enhancements was the addition of grooves to the disk. Disk skimmers with grooves, showed up to 200% increase in the recovery efficiency (RE) and an increase in the oil recovery rate (ORR).

a. Process diagram

The process diagram shown in figure 5.1 displays how the disk collects oil from water based on the test that's going to be performed below.

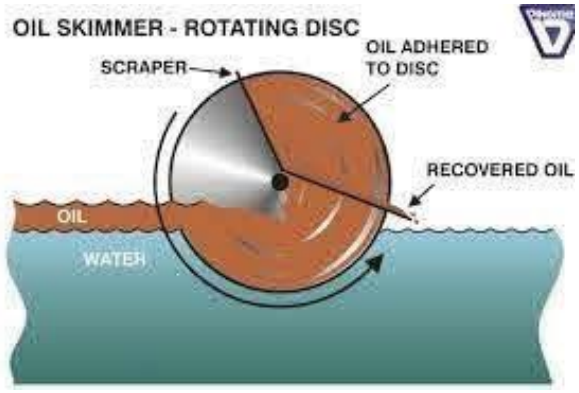


Figure 5.1 Process diagram of disk in action.

Refer to my comments in Status report 9 to improve this section.

b. Equations needed for the analysis (with all variables defined under the equations)

To analyze the ORR (Oil Recovery Rate) and RE (Recovery Efficiency) at various oil slick, consider the slick thickness, disc speed and collection time. We can apply the general equation below:

$$ORR = \frac{Voil}{T}$$

Where:

Voil = Volume of oil recovered, liter or gallon
T= Elapsed time of recovery, minutes

And: $RE = Voil\ Vtotal\ fluid \times 100$ R

Where: Vtotal fluid = Volume of total fluid (Water and oil) recovered

Theoretical calculation will be used to identify the amount of oil can be recovered and efficiency using grooved disc type oil skimmer. This calculation consists of several components, disc rotation, test duration, and slick thickness. Thus, such components can be expressed in form of following formula:

$$Amount\ of\ recovered\ oil\ spill = rotation\ speed \times time \times slick\ thickness$$
(3)

Where:

Rotation speed: Disc rotation (rpm)

Time: Duration taken during each test (s)

Thickness: Oil thickness (mm)

c. Values of all known variables

The values attached to the rpm, are the various speeds the skimmer can operate on. The values attached that come with time, are the duration each test was performed. The values attached to the slick, are different oil thickness the test was performed. These values are standard ASTM F2709 for oil skimmer testing.

Rotational speed (rpm): 5.5, 6, 10, 25, 34, 36

Collection times (s): 60, 63, 69, 70

Slick thickness (mm): 6, 12, 25, 50,

75

d. Method of computation and final values of computed variables.

Results and the specification of the specific disk is shown in Table 5.2.(Numbers in blue are the averages)

Using the computer software EES and expanding equation (3) Table 5.2 includes the analysis result:

Table 5.2 Analysis Results

Slick Thickness (mm)	DISC Speed (rpm)	Collection Time (s)	Oil Recovery Rate (L/min)/(gpm)	Recovery Efficiency (%)
75-50	36	69	284/75	77
75-50	36	63	322/85	85
75-50	34	70	307/81	87
			307/81	**83**
50	25	60	242/64	85
50	25	60	227/60	84
50	25	60	238/63	84
			235/62	**85**
25	10	60	68/18	72
25	10	60	76/20	75
25	10	60	72/19	80
			72/19	**76**
12	6	60	38/10	84
12	6	60	42/11	68
12	6	60	30/8	75
			38/10	**76**
6	6	60	26/7	62
6	5.5	60	19/5	68
6	5.5	60	23/6	65
			23/6	**65**

e. Specification of part if part is selected

Figure 5.2 shows the disk that best represents the groove depth and scrapper in which the disk skimmer and should possess. The X30 skimming system uses the latest patented grooved disc technology for recovering oil from the surface of water. The system recovered 4,670 gallons per minute (1,060 cubic meters per hour) at an average 90 percent efficiency while being officially and independently tested at the Ohmsett facility in New Jersey.



Figure 5.2 Elastec grooved disc X-30 skimmer

5.2.2 Analysis for determining the flow rate of a Pump

A pump is essential in our design to pump the excess amounts of water out of the skimmer system. The flow rate of the pump, also known as the capacity, measures the volume of liquid that travels through the pump with respect to time. With a low desire of the water intake, the pump will help lower the collection rate by pushing the excess water out.

Refer to my comments in Status report 9 to improve this section.

a. Process Diagram

Figure 5.3 is a free-body diagram of the pump system, showcasing how the pump works

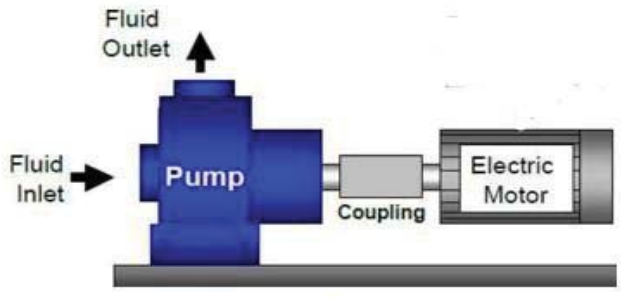


Figure 5.3 Pump and Electric Motor

b. Equation Analysis

The equation to find the flow rate is shown below

$$Q = \frac{V}{T}$$

Where,
Q= Volume Flow Rate or Capacity (gpm) or (L/min)
V= Flow (Gallons) or (Liters)
T= Time (minutes)

c. Values of known variables

Utilizing the known variables,and assuming the body of water contains over 27.5 gallons of water
(1 Gallon = 3.785 Liters), and time given is 2 min,

V_total= 27.5 gal
T= 2 min

d. Values of computed variables

By plugging the values above into the following equation
Flow Rate, Q = 13.75 gpm
Flow Rate, Q = 52 L/min

e. Specification of part if part is selected

Figure 5.4 displays a Xylem Magnetic coupling water pump. The pump will be used to assist with the skimmer operations. In addition, Table 5.3 contains the specifications of the pump in figure 5.4 which directly aligns with the functions of the skimmer.



Figure 5.4 Xylem, 230 V Magnetic Coupling Water Pump 52L/min

Table 5.3 specifications for figure 5.4

Specifications	
Input connection	.5 in BSP
Maximum flow rate	52 L/min
Brand	Xylem
Input Power	.06 kW
IP Rating	IPX5
Body material	Polypropylene
Coupling type	Magnetic
Supply Voltage	230 V
Maximum head	6.8m

5.2.3 Shaft analysis to calculate the best material and rotational speed of the shaft.

In this subsection, the horizontal shaft in which the rotating discs are mounted will be displayed. First, a diagram displaying the location of the shaft along with the forces acting upon it is shown. Secondly, the equations used for determining torque and shaft rotation speed were determined. In addition, the values of all known and computed variables are displayed. Finally, a good material for use in building the shaft is chosen.

a. Process Diagram & Free Body Diagram (FBD)

The diagram showing the rotation and direction of motion is shown in Figure 5.5. In this figure, the placement of the horizontal shafts is shown along with a rotation powered by the motor. On the horizontal shaft multiple discs are mounted, one end is connected to the DC motor to power the rotation at 45 rpm.

Refer to my comments in Status report 9 to improve this section.

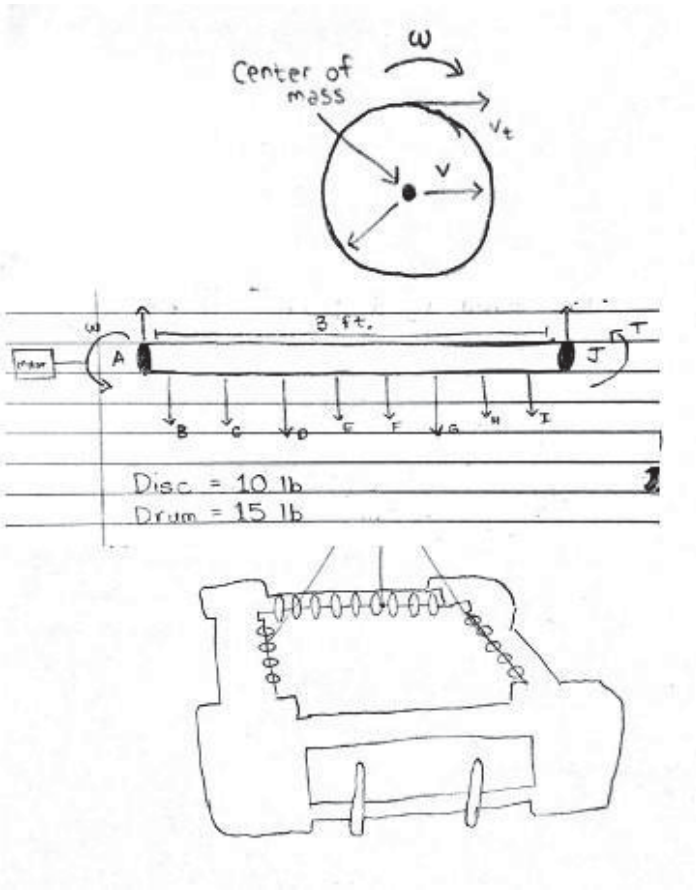


Figure 5.5 Process/FBD of shaft

b. Analysis Equations

Using shaft analysis, equations were derived to find the torque and rotational velocity. Then, from knowing the power coming from the motor, the rotational speed of the shaft was determined.

$$T = \frac{63025H}{n} \quad (1)$$

equation is not formatted correctly.

H= Power in hp
n = Speed of rotation of shaft in rpm

$$\tau = Tr/J = (16T)/(\pi d^3)$$

τ= Allowable stress lbf
T= Torque in lbf*in

$$d = (16T)/(\pi \tau)$$

d = Diameter of shaft in inches. πdn

$$V = (\pi dn)/(12)$$

V= velocity in feet/sec^2

$$\omega = v/(2\pi r)$$

r= Radius of shaft in inches

ω = Rotational speed in RPM

c. Values of known variables

d.Method of computation and final values of compute variables.

With known values, the torque was computed using equation (1)to be **T=4726 lbf*in**

The diameter for the shaft was calculated from equation (3) to be **D= 2.5 inches (0.21 ft)**

With known values, the velocity was computed using equation (4) to be **V=13.09 ft/s^2**

The rotational speed was computed using equation (5) to be **ω =1.65 RPM**

e. Specification of part if part is selected

Stainless steel, 3 ft in length and 2.5 inches in diameter. Figure 5.6 shows the images of the shafts that will need to be purchased [1]. Stainless steel is used as the material because it does not rust or corrode when exposed to water.



Figure 5.6 Stainless Steel Shaft

5.2.4 Analysis for determining the appropriate motor for the skimmer proposed design

A motor must be used in the design to power the shaft and rotate the disc. An analysis to determine the torque is necessary to yield the ability to perform work. Using similar disc motors, the torque was analyzed and calculated. Additionally, using the value obtained from the torque, the power was calculated.

Refer to my comments in Status report 9 to improve this section.

The calculation of the torque is provided below and the figure 5.7 shows the rpm and torque acting upon an electric motor

a. Process Diagram

Figure 5.7 displays a free body diagram demonstrating the rpm and torque acting upon an electric motor.

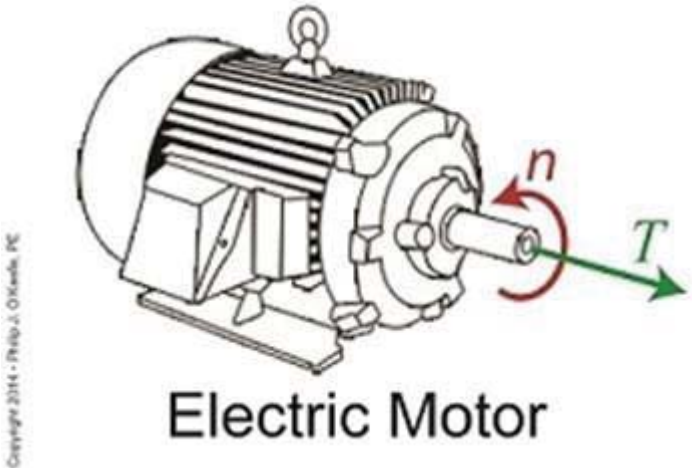


Figure 5.7 Calculating Torque of an Electric Motor

b. Analysis equations

$$Tinlb = \frac{Php * 63025}{n}$$

Where

$$Tinlb = torque, lbf$$
$$Php = Horsepower\ delivered\ by\ the\ electric\ motor, hp$$
$$n = Revolution\ per\ minute, rpm$$

$$Power\,(Kw) = \frac{2\pi * n * T(nm)}{60}$$

Where

$$Power = Product\ of\ a\ torque\ of\ the\ shaft, Kw$$
$$n = Revolution\ per\ minute, rpm$$
$$T = torque, nm$$

For motor MG07A1

$$Php = 0.068hp$$
$$n = 7\ rpm$$

$$T = 1.3558\, nm\ (Converted\ from\ 585.23\ lbf)$$

c. Values of non-variables

The known variables were taken from similar motors on current oil skimmers. Table 5.4 displays the motor specifications.

Table 5.4 Various motors specification

Motor Number	Volts	Hz	LRA	RPM	Watts	HP	Fan
MG07A1	115	60	0.43	7	49	0.065	Y
MG02A1	115	60	0.43	2	49	0.065	Y
MG06E1	220	50	0.22	6	48	0.064	Y

For motor MG07A1

Php = 0.065 hp

n = 7 rpm

Additionally in order to calculate the power we use the value obtained from the

torque Torque =1.3558 nm (Converted from 585.23 lbf)

d. Values of computed variables

By plugging these values into the equation above. We found the torque for a MG07A1 motor to be:

$$Tinlb = \frac{0.065 * 63025}{7}$$
$$Tinlb = 585.23\ lbf$$
$$Power\,(Kw) = \frac{2\pi * 7 * 1.3558}{60}$$
$$Power(Kw) = 0.993$$

e. Specification of part if part is selected

Figure 5.8 shows the selected electric motor that can give us 585.23 lbf.



Figure 5.8 Electric Motor

5.2.5 Analysis for determining the appropriate dimensions for the oil skimmer design.

In this subsection, the analysis of the skimmer's dimension is being proposed. This section includes a skimmer component diagram that displays a U-shaped Oleophilic skimmer with all its major design components dimensions. The free body diagram is followed with a table that presents all the proposed dimensions of the skimmer's components. In addition, this section presents equations that are needed for the dimension analysis of the skimmer. Also, the values for the unknown variables are being displayed along with the computed values. Finally, Parts specification are being displayed in the following subsection.

a. Skimmer components diagram

Figure 5.9 displays a u-shaped skimmer sketch body with an oil container that is attached to the back of the skimmer. The main components that are presented in figure 5.9 are the skimmer shell, oil container, 6 grooved discs, and two drum skimmers with grooved surface. Table 5.5 shows all of the proposed dimensions for the oil skimmer's components.

Refer to my comments in Status report 9 to improve this section.

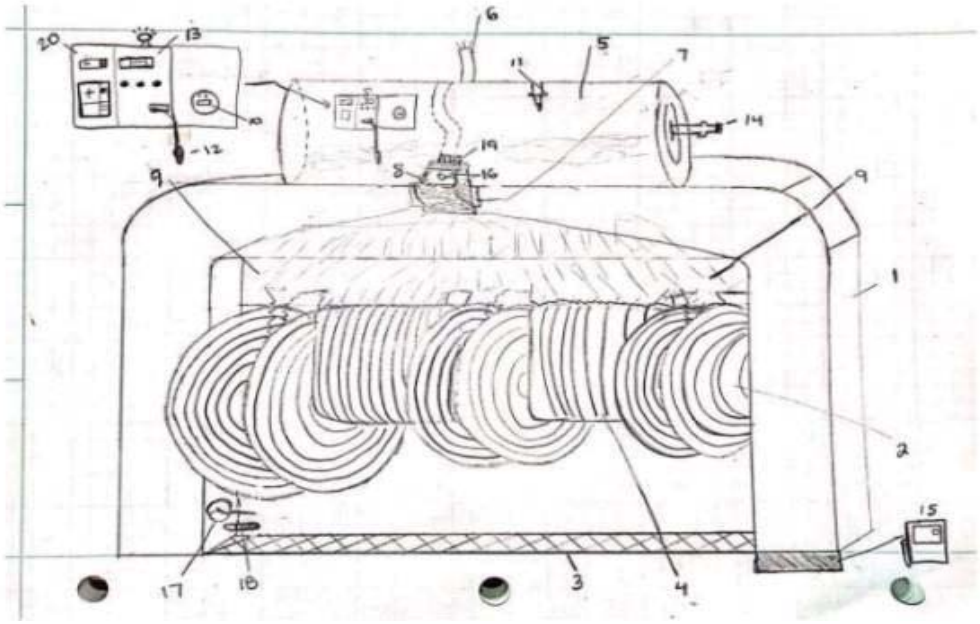


Figure 5.9 Skimmer Component Diagram

Table 5.5 Proposed Dimensions

	Skimmer Part	Dimension Specification
1	U shaped Body	Skimmer body = 40 x 20 x 15 (in) area removed = 20 x 10 x 15 (in)
2	Grooved disk	Disk diameter = 9 (in) Disk thickness = 1 (in) Number of Disks = 6 Groove depth = 0.75 (in) number of grooves = 15 Space between disk = 0.5 (inch)
3	Debris Shield	20 (in)
4	Floating Drum Skimmer	4.75 (in) D=9 (in) 2 drum
5	Oil container	Diameter = 15 (in) L = 30 (in)
6	Shaft	L = 36 (in) D = 2.5 (in)

b. Equations needed for the analysis (with all variables defined under the equations)

The dimensions of all the skimmer components must be within an operational domain of 5 ft by 5 ft (60 in by 60 in). The followings are basic formulas that have been used for the dimensional analysis of the skimmer.

- **Groove angle for the disc:**

$$Tan(theta)D = \frac{opposite}{adjacent}$$

- **Number of grooves per disc:**

$$Grooves\ width * 2D = disc\ diameter$$

- **Space between each groove:**

Same as grooves width

- **Space between discs, drums, and skimmer shell**:

$$Length\ of\ removed\ area = (disc\ thickness * number\ of\ discs) + (number\ of\ drums * drum\ length) + (number\ of\ spacing * S)$$

- **Groove angle for the drum skimmer:**

$$Tan(theta) = \frac{(opposite)}{adjacent}$$

- **Number of grooves per drum:**

$$Groove\ width * 2d = drum\ diameter$$

c. Values of all known variables

- Skimmer shell dimension = 40 x 20 x 15 (inches)
- Removed area to create U-shaped body = 20 x 10 x 15 (inches)
- Estimated disc diameter = 9 (inches)
- Estimated disc thickness = 1 (inches)
- Estimated number of discs= 6
- estimated number of drums = 2
- Estimated groove depth for both the disc and drum= 0.75(inches)
- Estimated groove width for the disc = 0.3 (inches)
- Estimated groove width for drum = 0.25
- Estimated oil container dimensions are length = 30 (inches) and diameter = 15 (inches)

d. Method of computation and final values of computed variables.

Groove angle for the disc:

Tan(theta) = (opposite)/adjacent
= ((disc groove width / 2) /(groove depth) = ((0.3/2) /(0.75)

Theta = inverse Tan (0.15 / 0.75)
= 11.31 degrees
= 11.31 * 2
= 22.62

Number of grooves per disc:

Grooves width * 2#D = disc diameter
0.3 * 2#D = 9
2#D = 9 / 0.3
2#D = 30
#D = 30 / 2
#D = 15

Space between discs, drums, and skimmer shell:

Length of removed area =(disc thickness * number of discs) + (number of drums * drum length) + (number of spacing * S)
20 = (1 * 6) + (2 * 4.75) + (9 * S)
20 = (6) + (9.5) + 9*S
20 - 15.5 = 9*S
4.5 = 9*S
S = 4.5 / 9
S = 0.5 (inches)

Groove angle for the drum skimmer:

Tan(theta) = (opposite) /(adjacent)
= ((drum groove width / 2) /(groove depth)
= ((0.25/2) /(0.75)
Theta = inverse Tan (0.125 / 0.75)
= 9.46 degrees
= 9.46 * 2
= 18.92

Number of grooves per drum:

grooves width * 2#d = drum length
0.25 * 2#D = 4.75
2#D = 4.75 / 0.25
2#D = 19
#D = 19 / 2

Refer to my comments in Status report 9 to improve this section.

#D = 9.5

= 9 grooves per drum

e. Specification of part if part is selected

Figure 5.10 displays a free body diagram of a U-shaped skimmer body with fillet edges, The proposed dimensions for the body are 40 inches by 20 inches with a 15 inches thickness. In addition, the sketch also presents all the components that will be attached to the skimmer body with its estimated dimension. The components that will be attached to the body of the skimmer are; debris shield, line transducer, tensiometer, and a density meter.

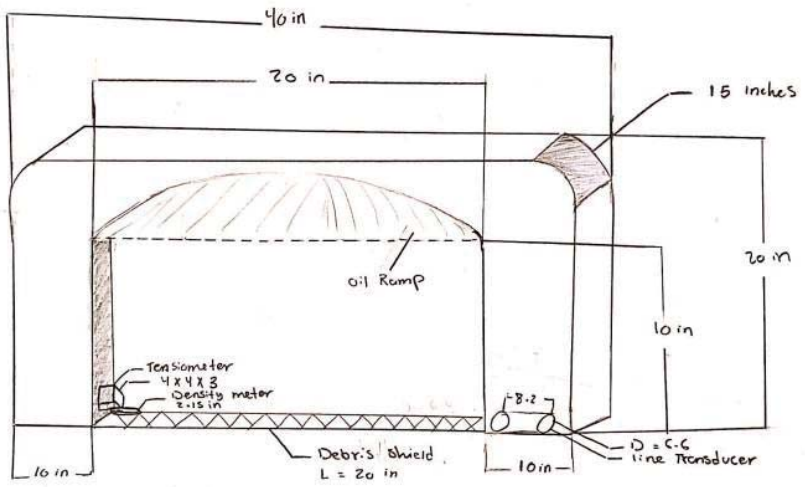
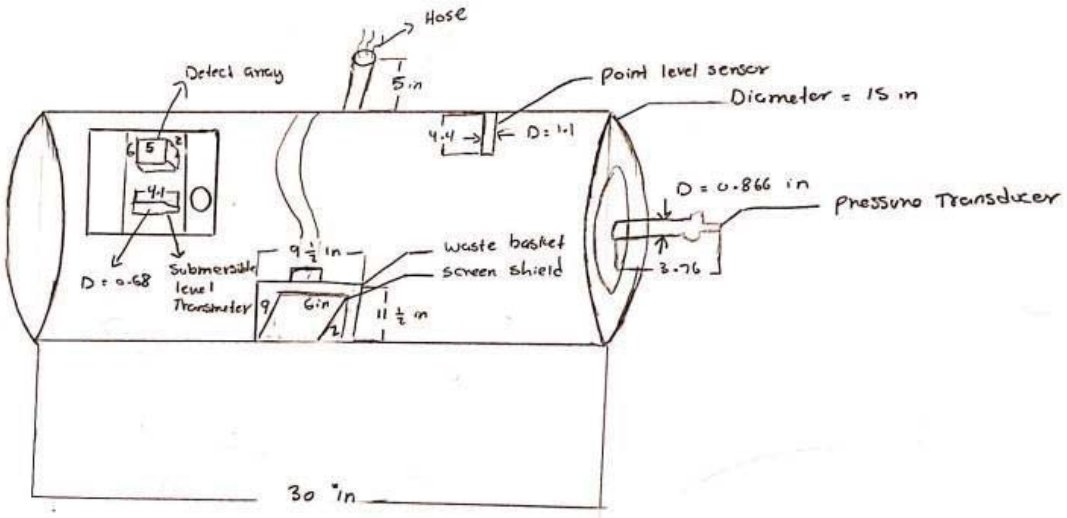


Figure 5.10 U-shaped skimmer body

Figure 5.11 displays a free body diagram of an oil retainer with the estimated appropriate dimensions. The sketch also contains the dimension of all the other components that will be attached to the oil retainer. The components that will be attached to the oil retainer are; hose, waste basket, point level sensor, pressure transducer, fixed orifice system, oval gear flow meter, submersible level transmitter, detect array, and a moisture oil transmitter.



Refer to my comments in Status report 9 to improve this section.

Figure 5.11 Oil Container

Figure 5.12 and 5.13 presents a grooved disk with its proposed dimension, the estimated dimensions of the skimmers are 9 inch diameter with a 1 inch thickness. The number of disks are estimated to be 6 grooved discs, each disc is going to have 15 V grooves with a width of 0.30 inches and an estimated groove depth of 0.75 inches. Also, between each disk there will be a space of 0.5 inches to allow for oil recovery.

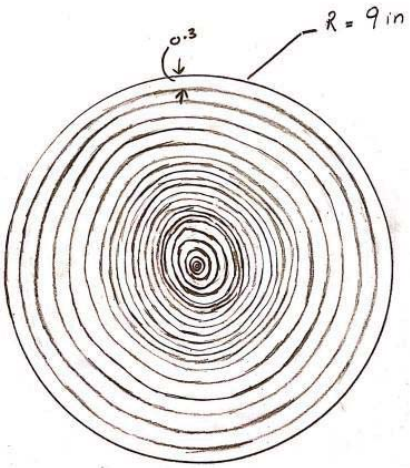


Figure 5.12 Grooved disk

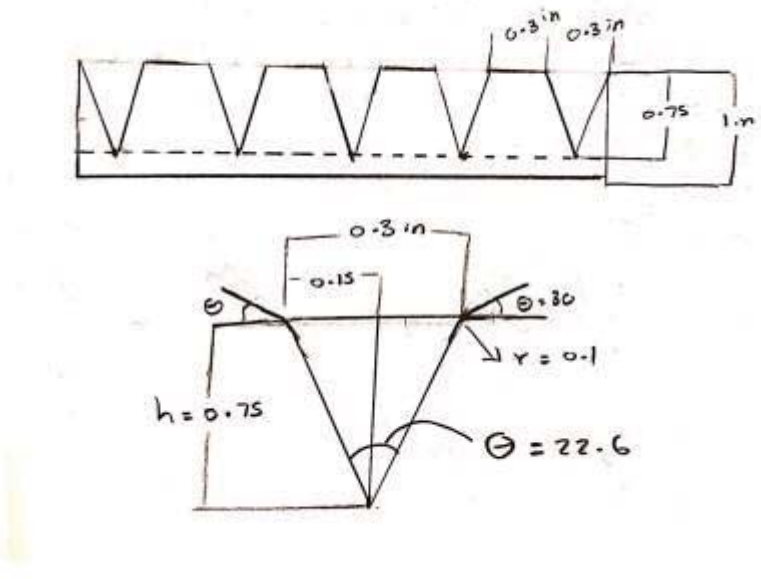


Figure 5.13 Grooved Dimensions

Figure 5.14 displays a drum skimmer with its proposed dimensional analysis. The simmer design is going to have two drum skimmers with an estimated width of 4.75 inches and a diameter of 9

inches. The surface of the drum skimmer is going to have 9 grooves with a width of 0.25 inches and a groove depth of 0.75 inches.

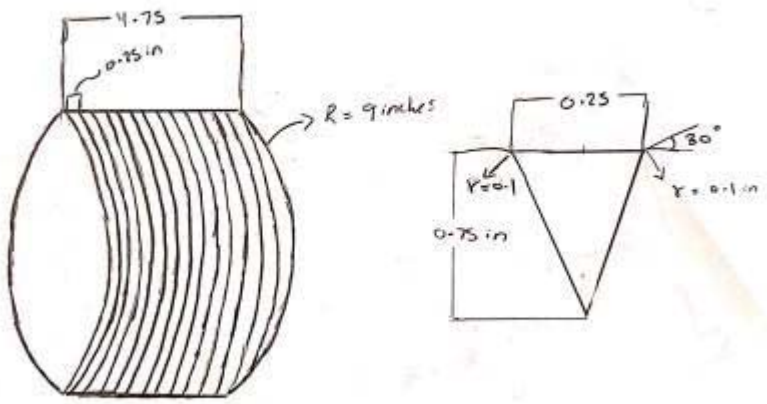


Figure 5.14 Drum Skimmer Dimensions

5.2.6 Analysis for determining the appropriate floating mechanism for the selected skimmer design. In this subsection, the analysis of the proposed skimmer floating mechanism is displayed. The section includes a free body diagram that provides a visual representation of buoyancy. In addition, the subsection includes the equations necessary to fully analyze the floating mechanism required for the skimmer. Furthermore, the values for all known variables are displayed along with the computed values. Finally, the subsection described system used to compute the unknown variables and added the part specifications for the floating mechanism selected.

a. Free body diagram

In figure 5.15 the force diagram used for the analysis of the skimmer floating mechanism displayed. The diagram shows the direction of the buoyant and weight forces that apply to the floating skimmer shell. In addition, the diagram shows the distance (h) which represents the distance between the bottom of the skimmer that is submerged and the surface of the water.

Refer to my comments in Status report 9 to improve this section.

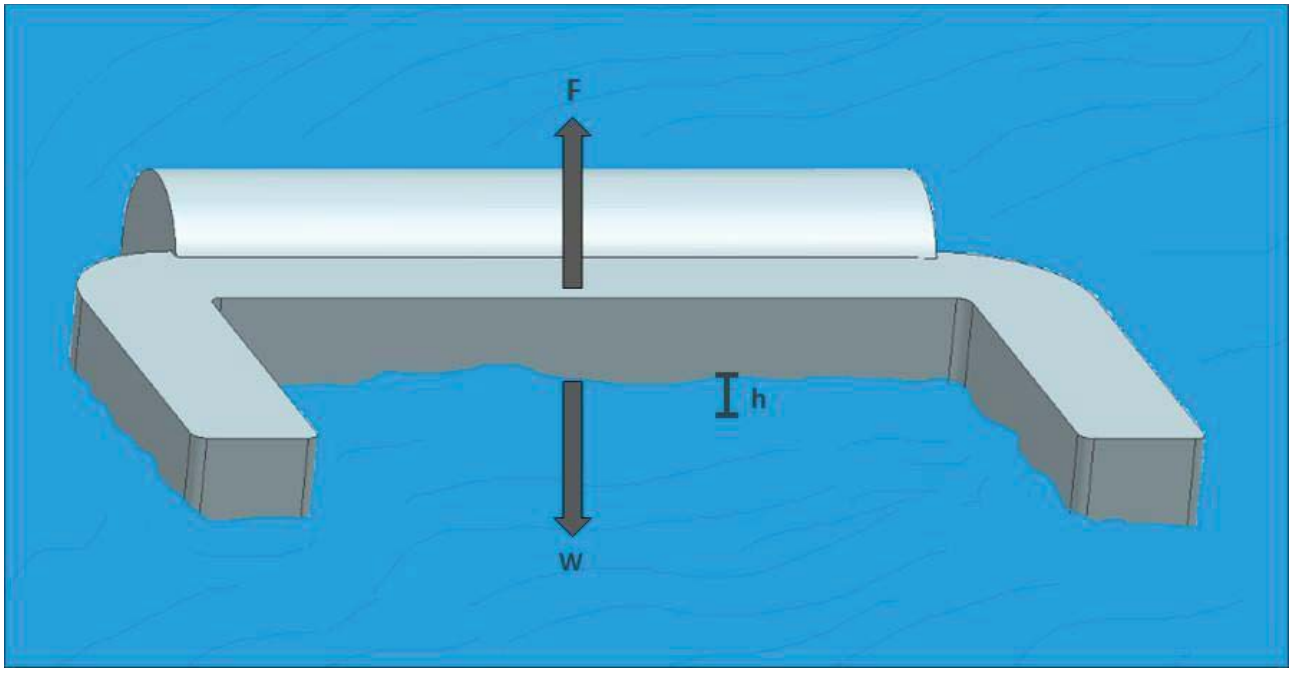


Figure 5.15 Floating Mechanism Force Diagram

b. Analysis equations

Buoyancy force in the oil recovery skimmer design project has been defined to be the force equal to the weight of the fluid (water/oil) that is displaced. Figure 5.15 provided a closer look to the role that buoyancy plays in the fabrication of the proposed skimmer design. Therefore, it was important to break down the forces using the appropriate equations as it is shown below.

To calculate the weight of the system the formula below can be utilized:

$$W = mg$$
$$m = mass\ of\ skimmer\ (kg)$$
$$g = gravity\ (ft/s\text{^}2)\ or\ (m/s\text{^}2)$$

To calculate the buoyant force of the system the formula below can be utilized:

$$Fb = \rho Vg = \rho Ahg = mg \textbf{ (lbf)}$$
$$V = Ah$$
$$m = \rho V$$

= density of water (lb/in^3)
A= area of the base of the object that is submerged (in^2)
Vs= volume of fluid displaced, also equals volume of portion submerged
(lb/in^3) h = height of object that is submerged in fluid (in) g = gravitational
acceleration (in/s^2) mw = mass of fluid displaced (lb)

c. Values of all known variables

For $W = mg$

Given the assumption for the use of polyethylene HDPE material (High density polyethylene) and observation of current designs: **m = 20.4 kg (45 lbs) g = 32.2 ft/s^2 (9.81 m/s^2)**

For the computational analysis of calculating the buoyant force:
= 62.4 lbs/ft^3 = (1000 kg/m^3) h (assumed) = 2 in = (.051 m) g = 32.2 ft/s^2 = (9.81 m/s^2)

d. Method of computation and final values of computed variables.

The figure below represents the assumed dimensions of the skimmer body. Figure (b) shows the area removed from (a) to complete the U-shaped body

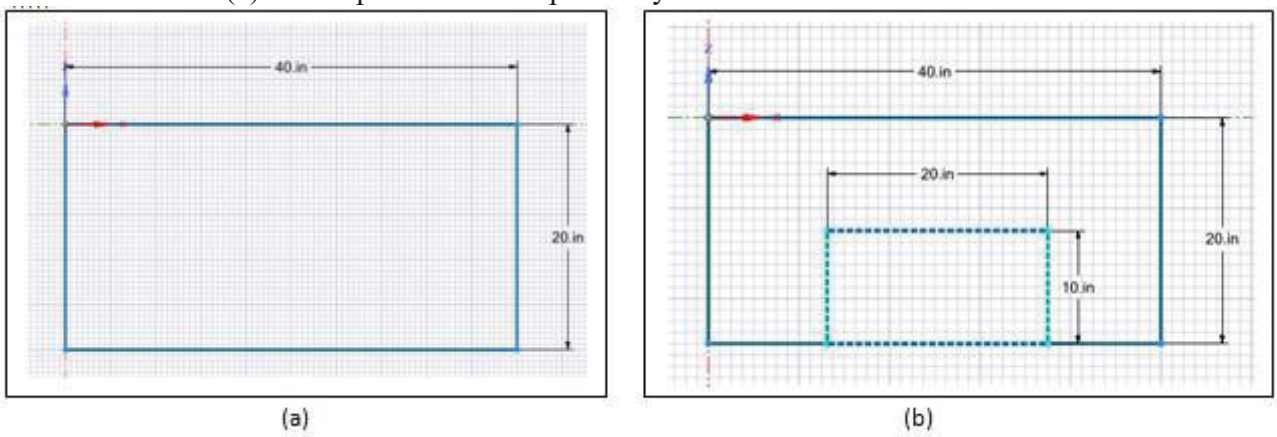


Figure 5.16 Skimmer Dimensions for Computational Analysis of Buoyant Force

Figure 5.7 Skimmer Dimensions for Computational Analysis of Buoyant Force
Procedure for calculating the buoyant force (values obtained using T-84 calculator):
1. Calculate the Area of the base by using geometric analysis

$$Area\ of\ the\ base, A_b = (40 * 20) - (20 * 10) = 600\ in^2$$

2. Calculate the Volume of the fluid displaced, which is also the volume of the submerged portion of the skimmer

$V_s = A_b h$ (h is an assumed height which represents the submerged portion of the skimmer)

$$V_s = 600\ in^2 * 2in = 1200 in^3$$

3. Calculate the buoyant force, F_b

Refer to my comments in Status report 9 to improve this section.

$F_b = w_{df} = mg = pV_s g,$ where w_{df} is the weight of the displaced fluid and m is the fluid mass

$F_b = \left(62.4\,\frac{lb}{ft^3}\right) * (1200in^3) * \left(32.2\frac{ft}{s^2}\right)$, convert the V_s to ft^3 to get units of lbf

$$1200\,\frac{1in^2\ 1ft^3}{1\ \ 1{,}789} = .694ft^3$$

$$F_b = \left(62.4\,\frac{lb}{ft^3}\right) * (.694ft^3) * \left(32.2\frac{ft}{s^2}\right) = 1{,}394\ lbf$$

From this, mass of the fluid displaced is **43.3 lb**

e. Specification of part if part is selected

Figure 5.17 shows the skimmer body that best represents the structure in which the skimmer body and material should possess.



Figure 5.17 SkimOil's FDS20RS SteelMAX FLoating Drum Skimmer

Results and the specification of this specific skimmer body is shown in Table 5.6, the only modification would be adjusted to the skimmer entryway which would be an open "U shape." These specifications were obtained for reference from SkimOIL Industrial Solutions inc [2].

Table 5.6 Skimmer Body Specifications

Specifications	
Oil recovery rate:	Up to 20gpm / 5cu.m per hour
Number of drums:	2 (Polyethylene HDPE)
Frame:	Polyethylene HDPE
Wiper blades	Self-adjusting (spring loaded).Spare wiper blades included.
Wiper retainer:	Mounted with stainless steel pins & springs
Handles:	Included
Dimensions:	42 x 28 x 14 inch / 1.07 x 0.71 x 0.36m
Weight:	50lbs / 23kg
Drive:	Pneumatic or hydraulic
Max operating temp:	54 C / 130 F (high temperature* version available)
Suction coupling:	2 inch female camlock

5.3 CAD Models, Detailed Drawings, Sub-assemblies, System Assembly and Equipment specifications and selection

In this section, the skimmer components CAD Models, detailed drawings, assembly, and equipment specifications and selections are displayed. Each component encloses a model shot and a blueprint draft with dimensional specifications. In addition, the codes and standards used for modeling each component are listed after all the drafting figures of this report. Finally, the section encloses a summary of the engineering analysis needed for proper sizing of each component.

In this section, the team was able to work together to identify the different components that needed to be modeled. Once the components were identified, each team member was able to contribute by modeling one component. During the modeling phase, each team member made the proper optimizations to the previously designed parts as shown in Figures 5.18 to 5.25.

Refer to my comments in Status report 10 to improve this section.

1. Skimmer Shell

In Figure 5.18, the 3D CAD model for the skimmer body is displayed.

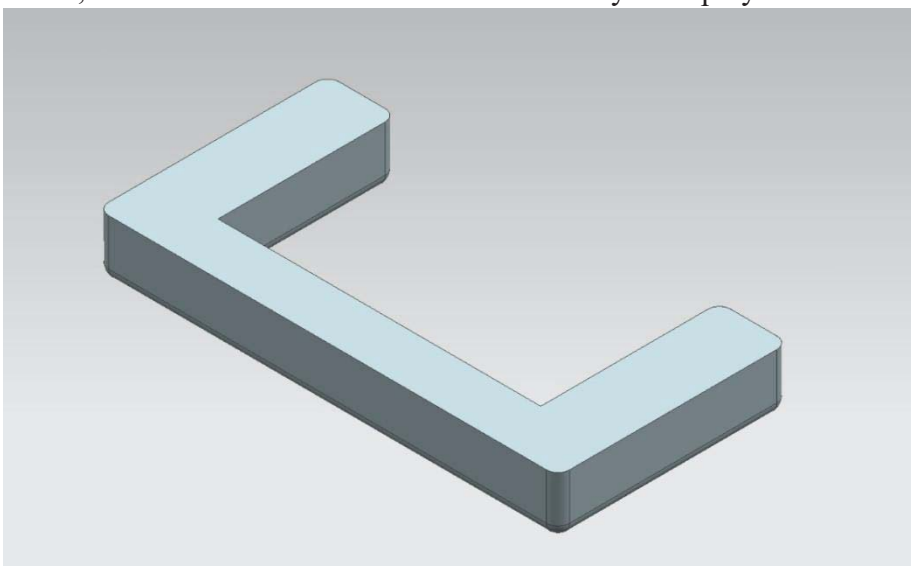


Figure 5.18 Skimmer Shell 3D Model

2. Tank

In Figure 5.19, the 3D CAD model for the oil containment tank is displayed.

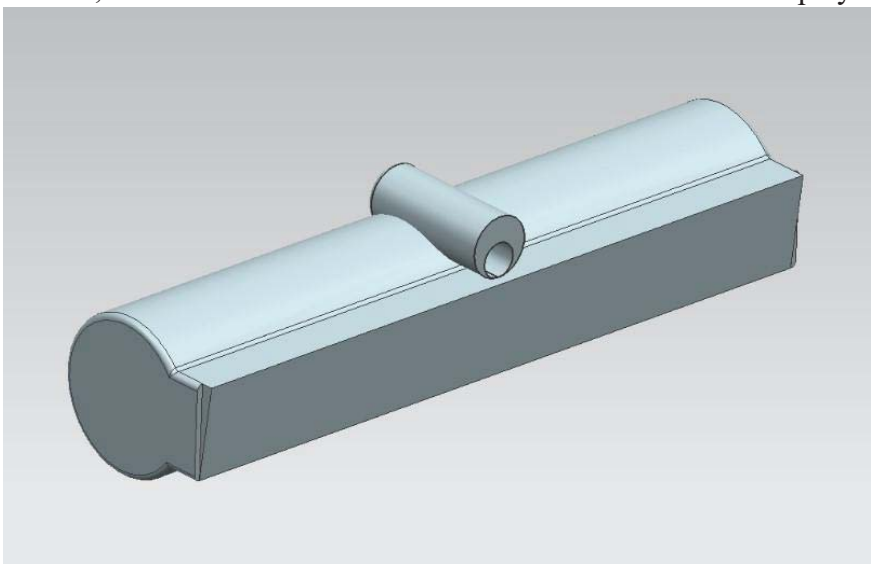


Figure 5.19 Oil Containment Tank 3D Model

3. Grooved Disk

In Figure 5.20, the 3D CAD model for one of the six grooved disks is displayed.

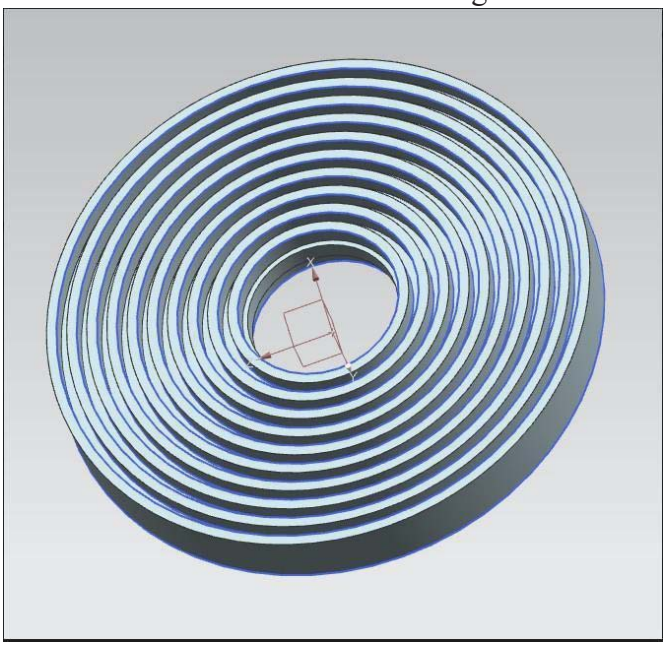


Figure 5.20 Grooved Disk 3D Model

4. Drum

In Figure 5.21, the 3D CAD model for one of the three grooved drums is displayed.

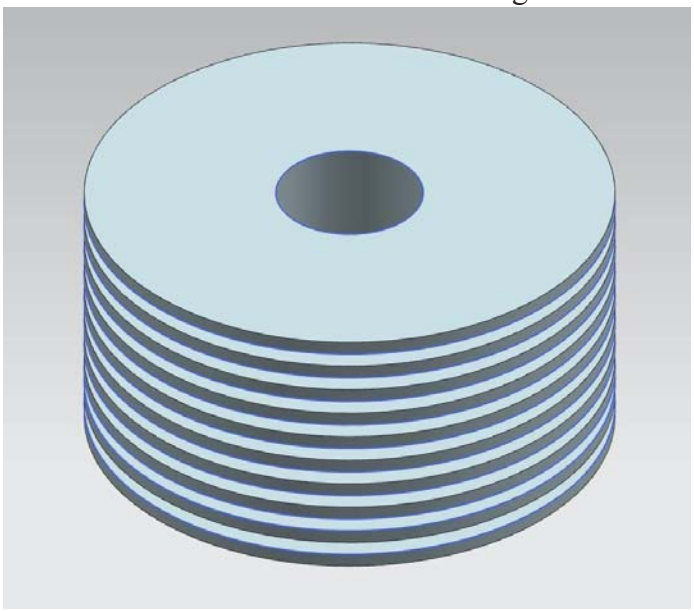


Figure 5.21 Drum 3D Model

5. Shaft

In Figure 5.22, the 3D CAD model for the skimmer's shaft is displayed.

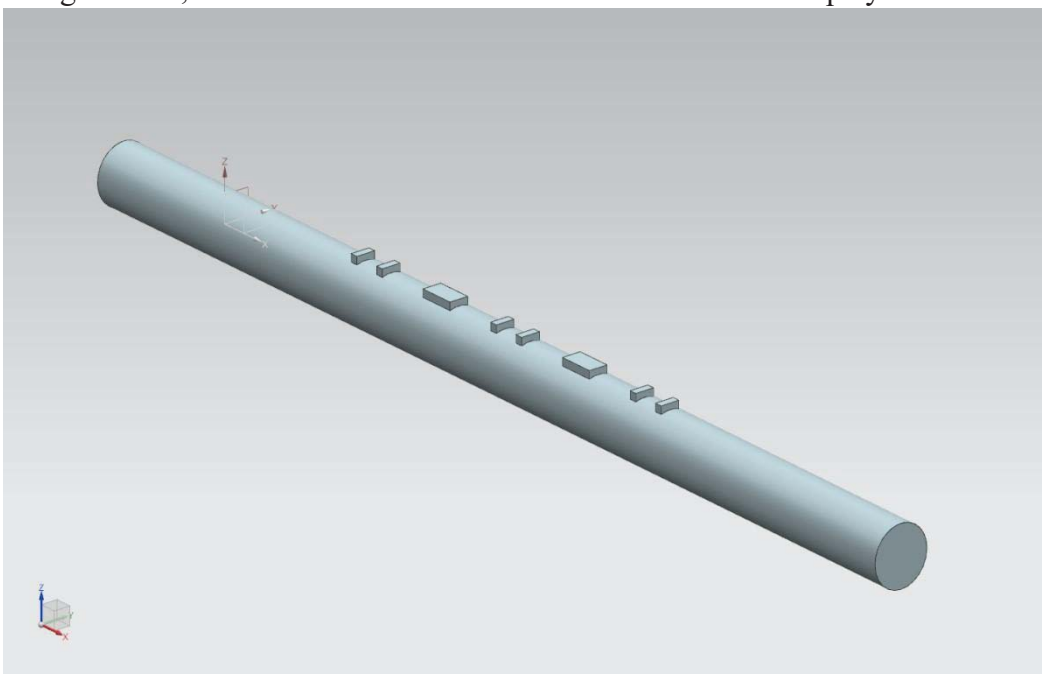


Figure 5.22 Shaft 3D Model

6. Pump

In Figure 5.23, the 3D CAD model for the pump is displayed.

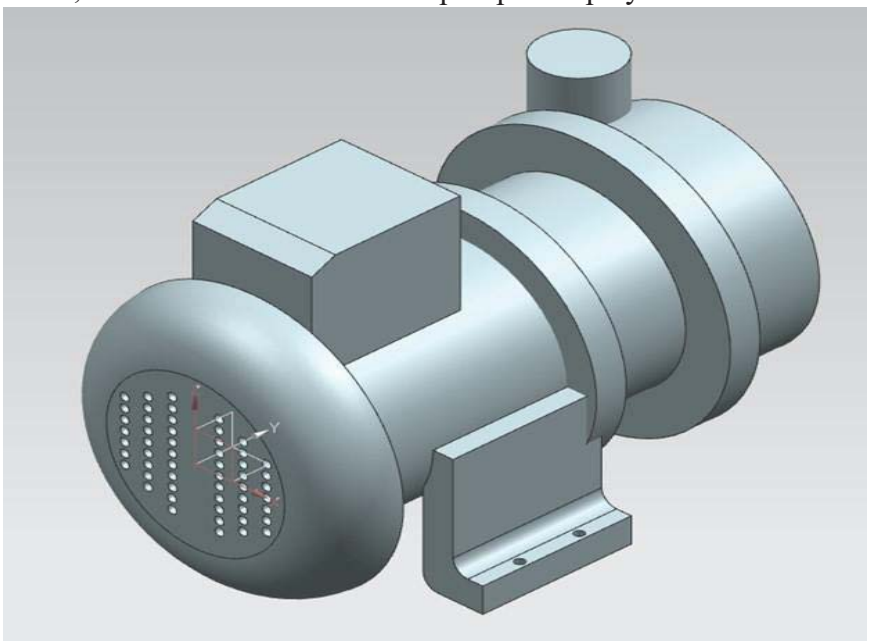


Figure 5.23 Pump 3D Model

7. Motor

In Figure 5.24, the 3D CAD model for the Motor is displayed.

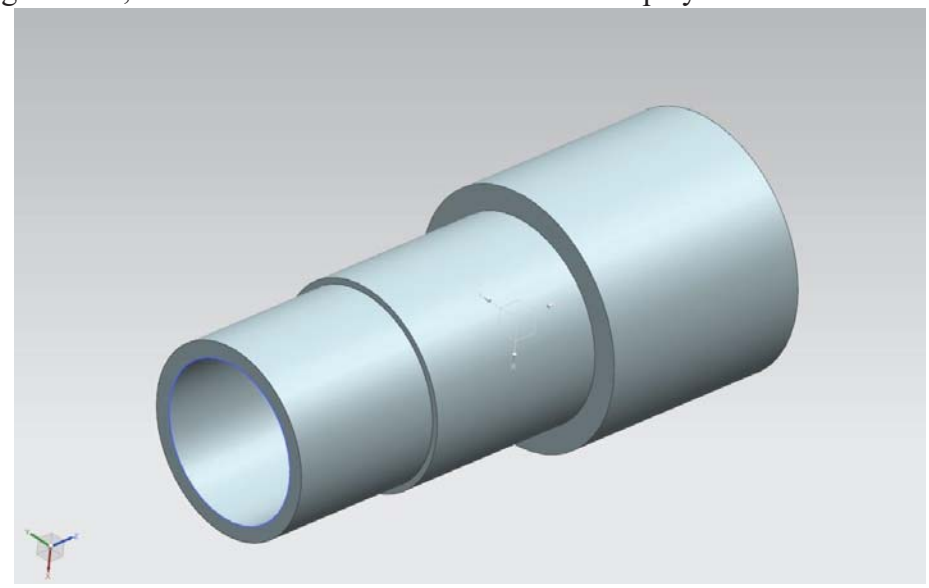


Figure 5.24 Motor 3D Model

8. Debris Shield

In Figure 5.25, the 3D CAD model for the debris shield is displayed.

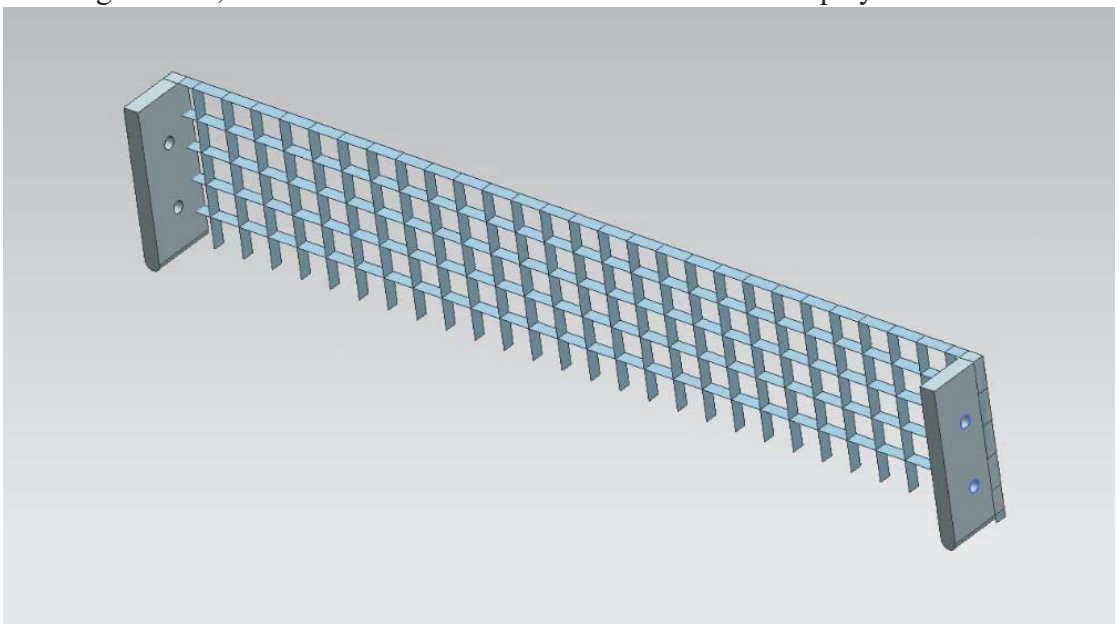


Figure 5.25 Motor 3D Model

Refer to my comments in Status report 10 to improve this section.

In this section, once all the models were presented, each team member went back to create a dimensional draft of each component as shown in Figures 5.26 to 5.33.

1. Skimmer Shell

In Figure 5.26, the Blueprint Drawing of the Skimmer shell is being displayed, using Siemens NX10 sheet.

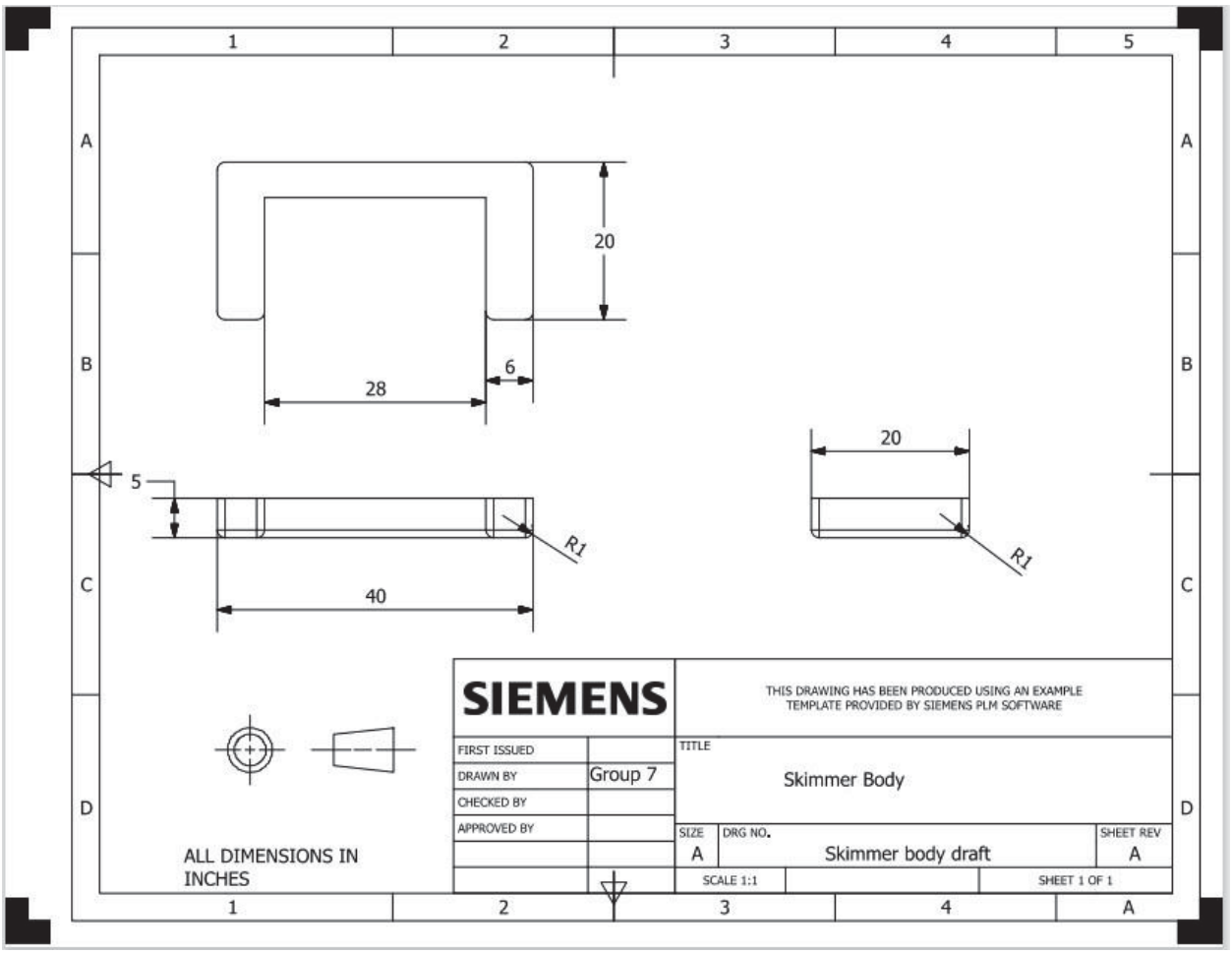


Figure 5.26 Skimmer Shell 2D Draft

2. Tank

In Figure 5.27, the Blueprint Drawing of the Containment Tank is being displayed, using Siemens NX10 sheet.

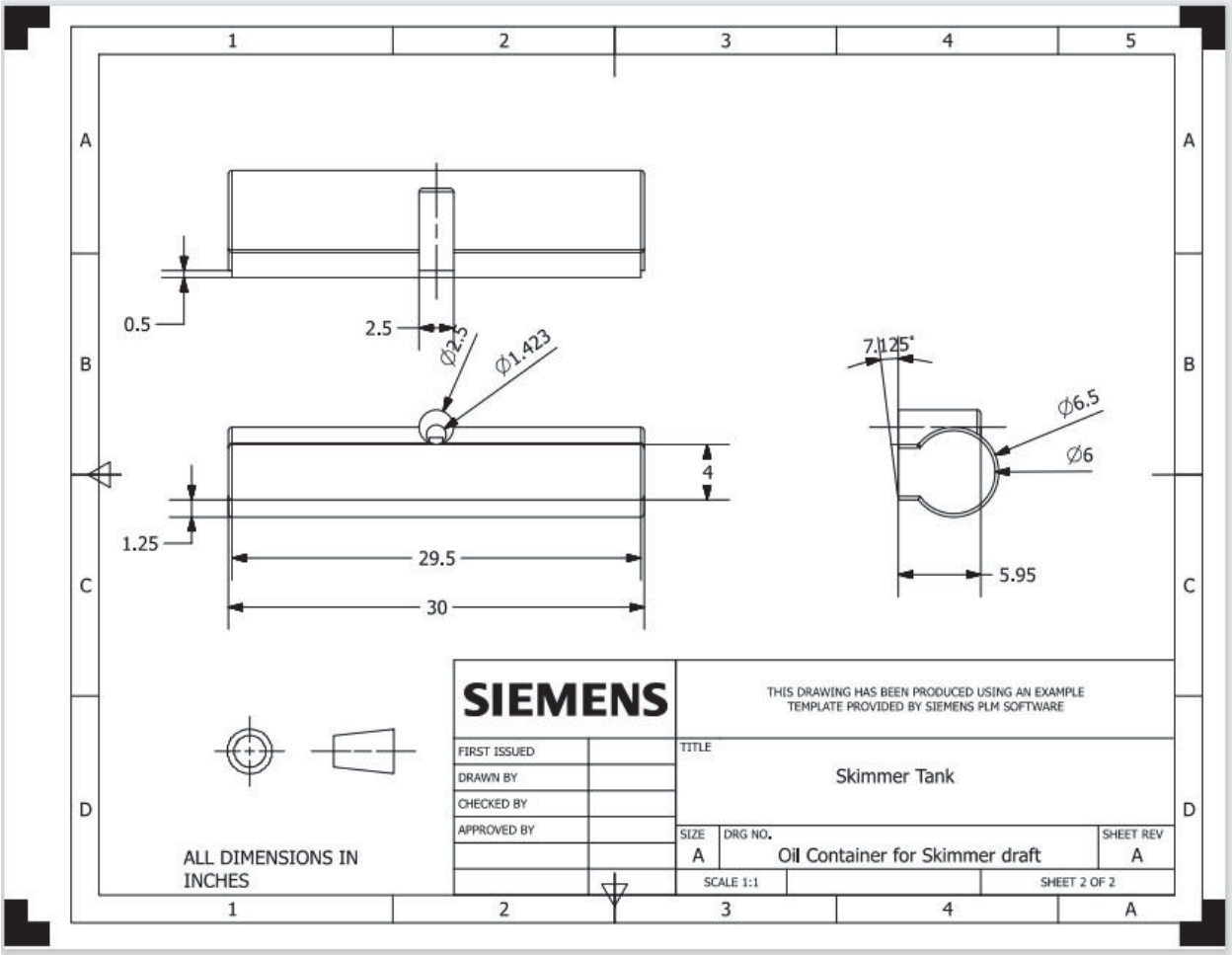


Figure 5.27 Oil Containment Tank 2D Draft

3. Disk

In Figure 5.28, the Blueprint Drawing of the Grooved Disk is being displayed, using Siemens NX10 sheet.

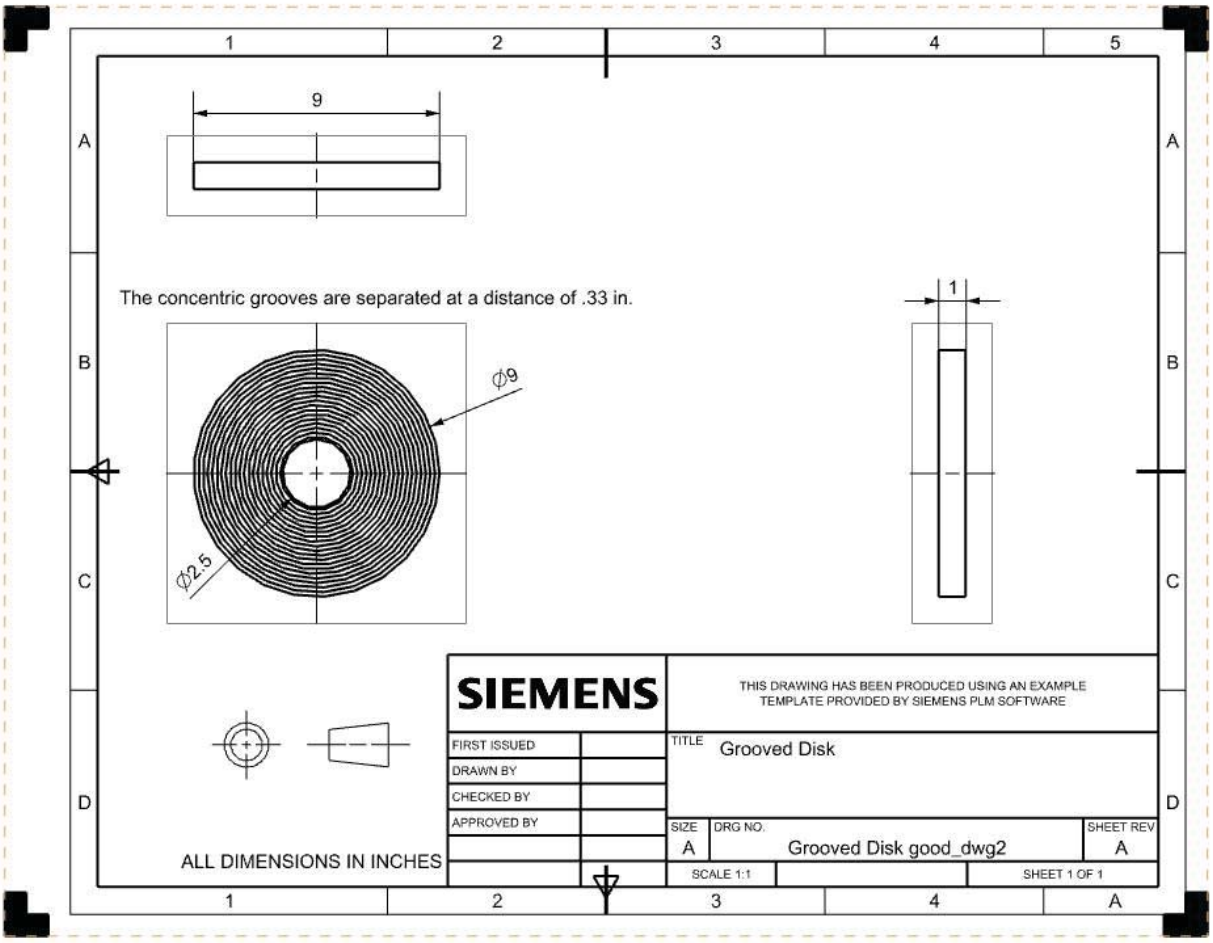


Figure 5.28 Grooved Disk 2D Draft

4. Drum

In Figure 5.29, the Blueprint Drawing of the Grooved drum is being displayed, using Siemens NX10 sheet.

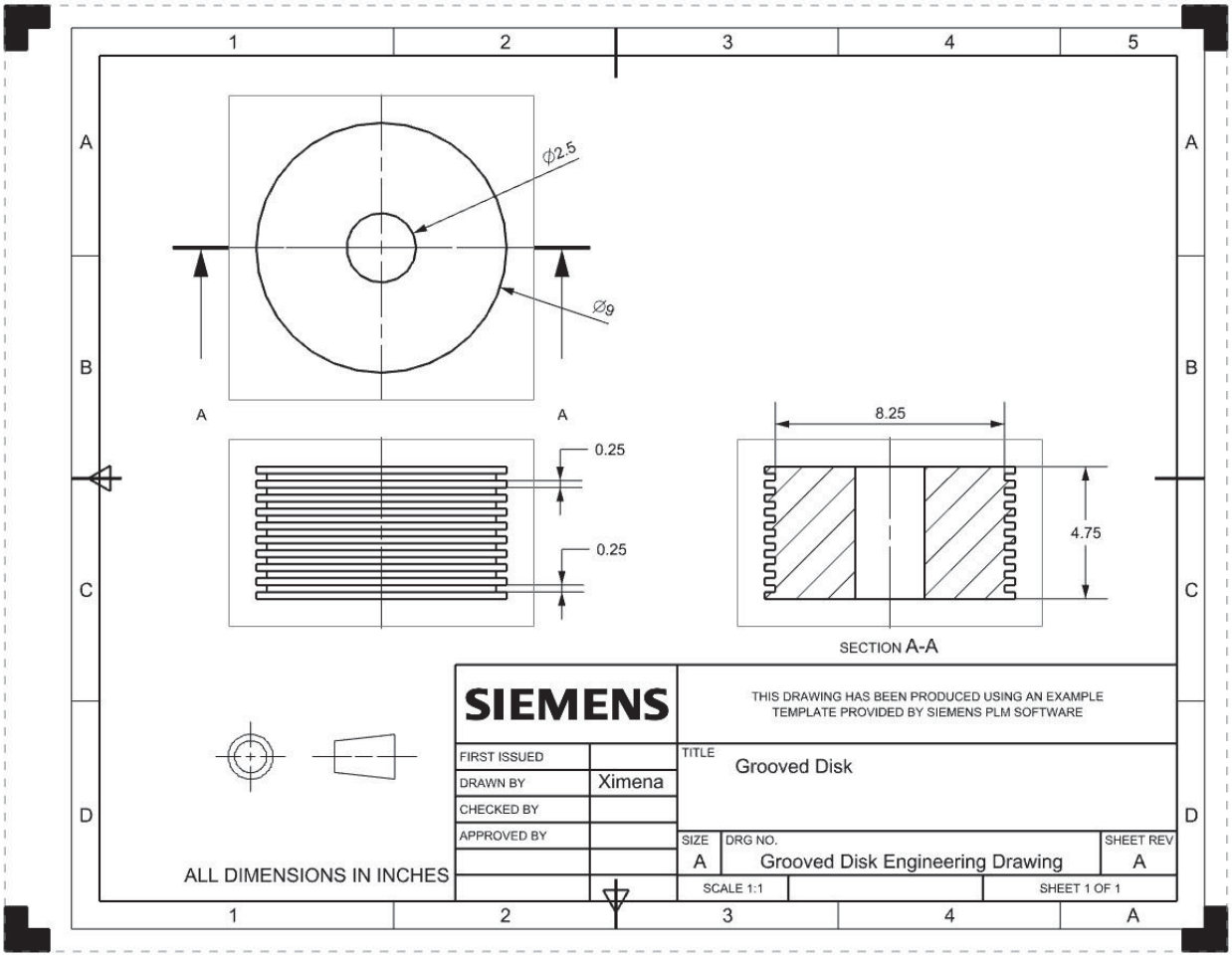


Figure 5.29 Grooved Drum 2D Draft

5. Shaft

In Figure 5.30, the Blueprint Drawing of the Shaft is being displayed, using Siemens NX10 sheet.

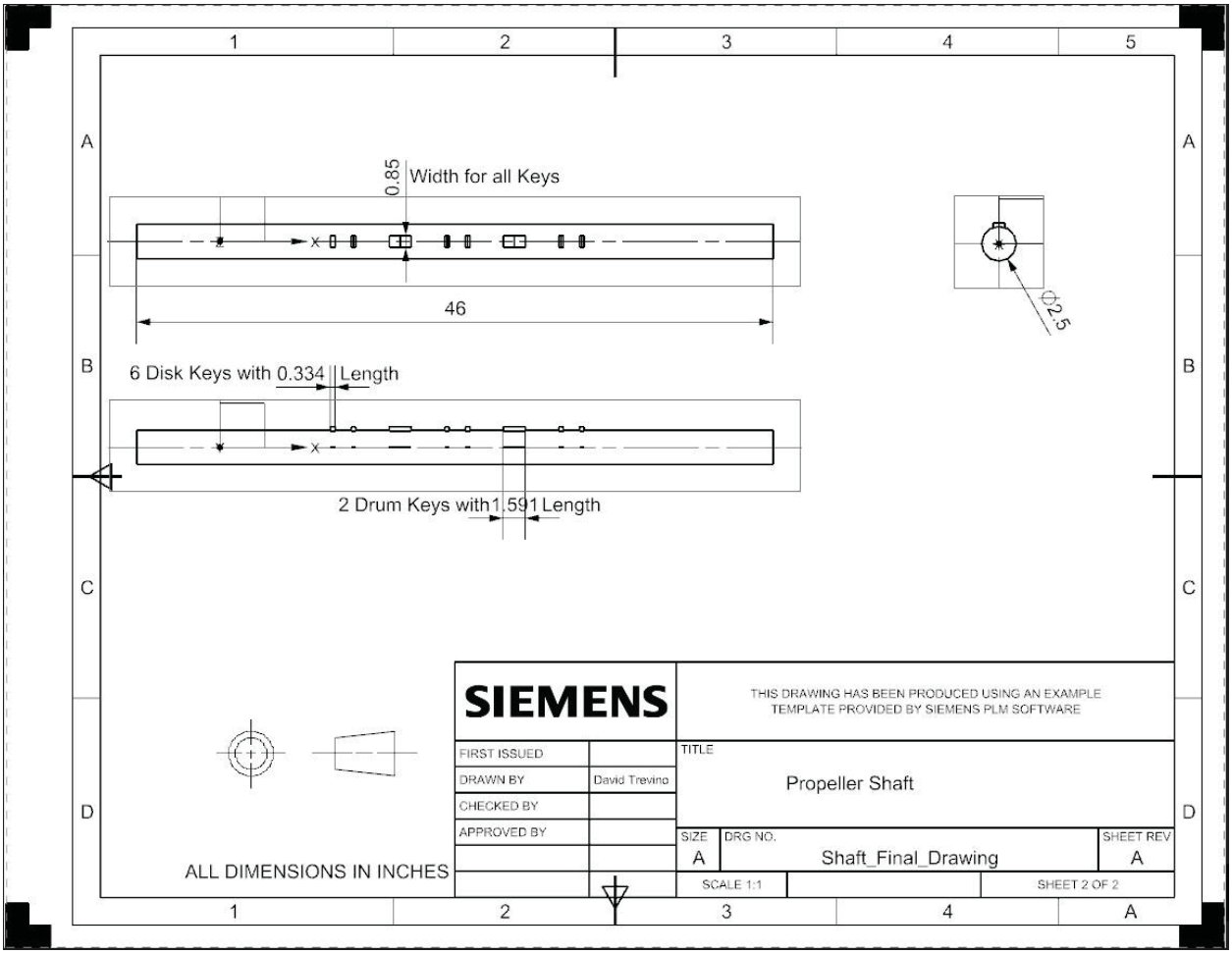


Figure 5.30 Shaft 2D Draft

6. Pump

In Figure 5.31, the Blueprint Drawing of the Pump is being displayed, using Siemens NX10 sheet.

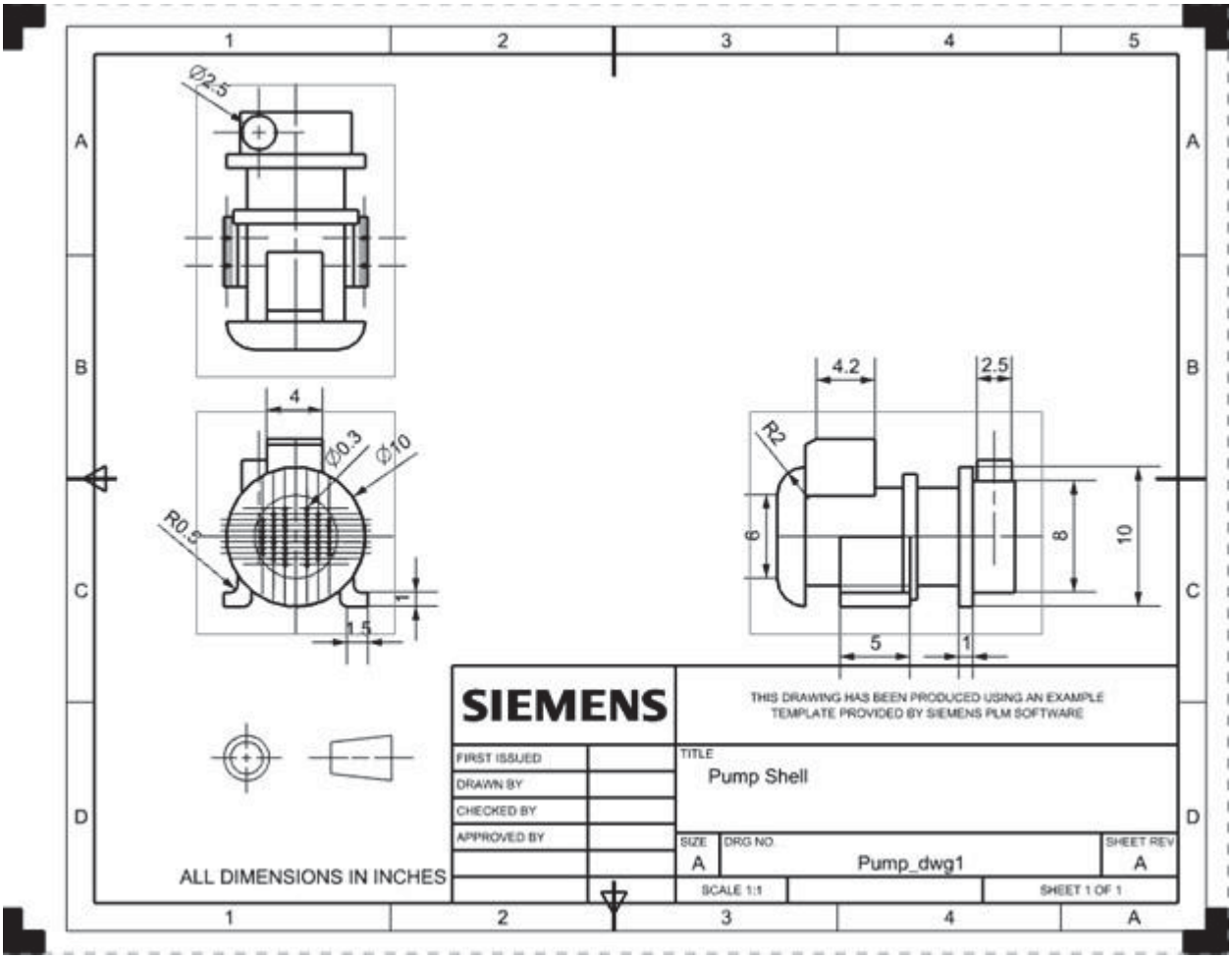


Figure 5.31 Pump 2D Draft

7. Motor

In Figure 5.32, the Blueprint Drawing of the Motor is being displayed, using Siemens NX10 sheet.

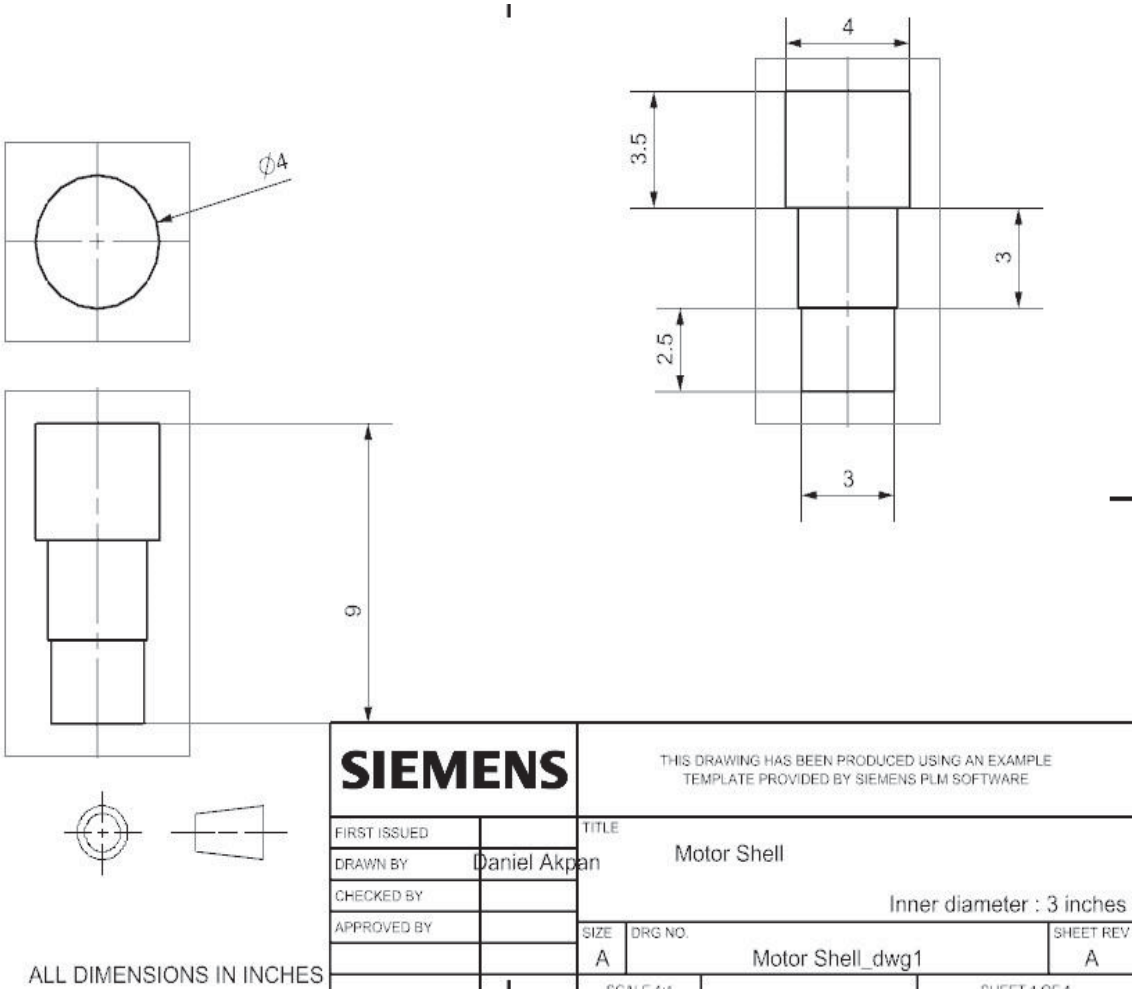


Figure 5.32 Motor 2D Draft

8. Debris Shield

In Figure 5.33, the Blueprint Drawing of the is being displayed, using Siemens NX10 sheet.

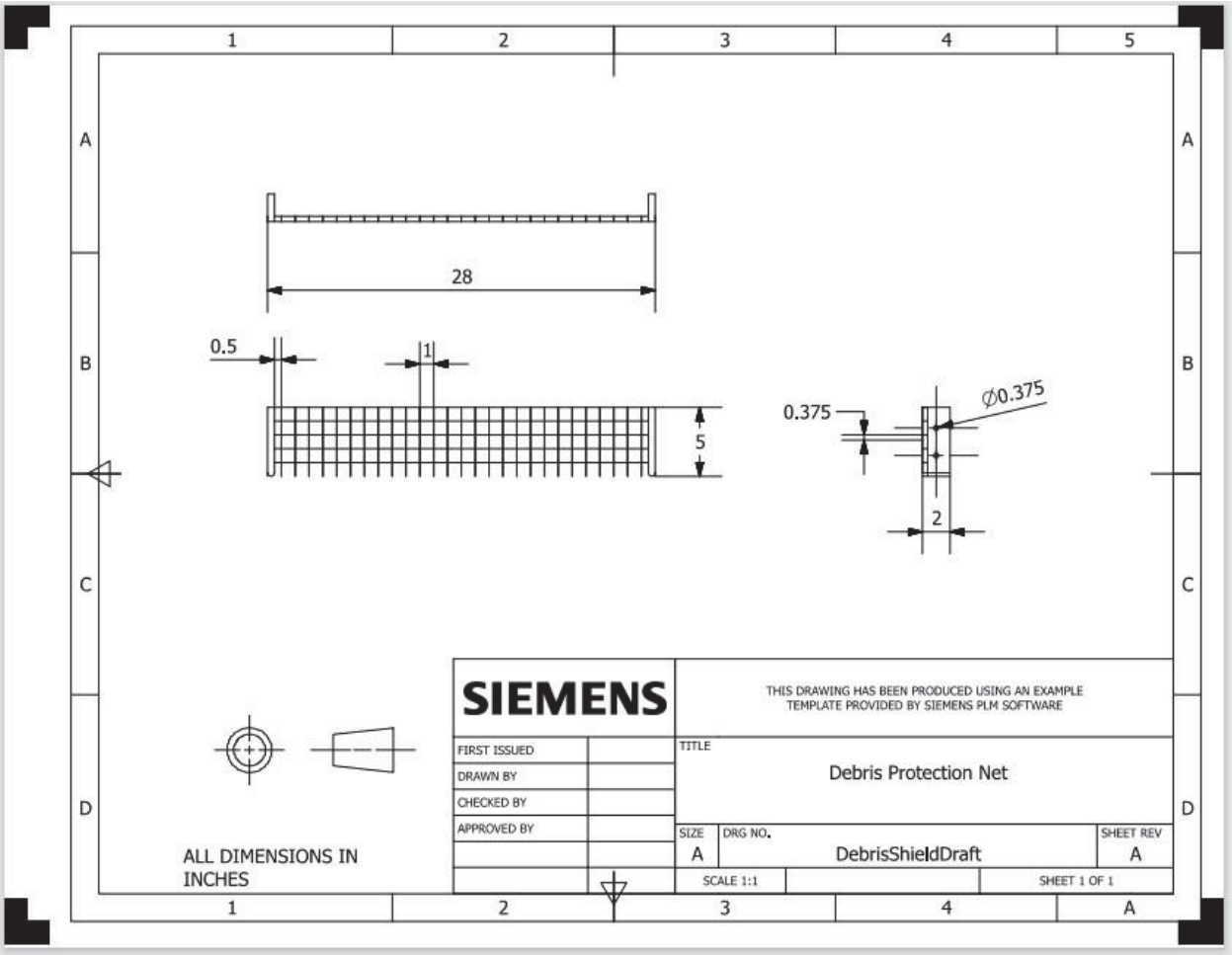


Figure 5.33 Debris Shield 2D Draft

Refer to my comments in Status report 10 to improve this section.

Finally, the team was able to come together and properly assemble all of the parts together as shown in Figure 5.34 and 5.35. Each part was assigned a specific part number. These part numbers were noted on both the model and engineering drawing to signalize each component. These numbers were also used in the other sections of the report to ensure the order of all the material discussed on the report.

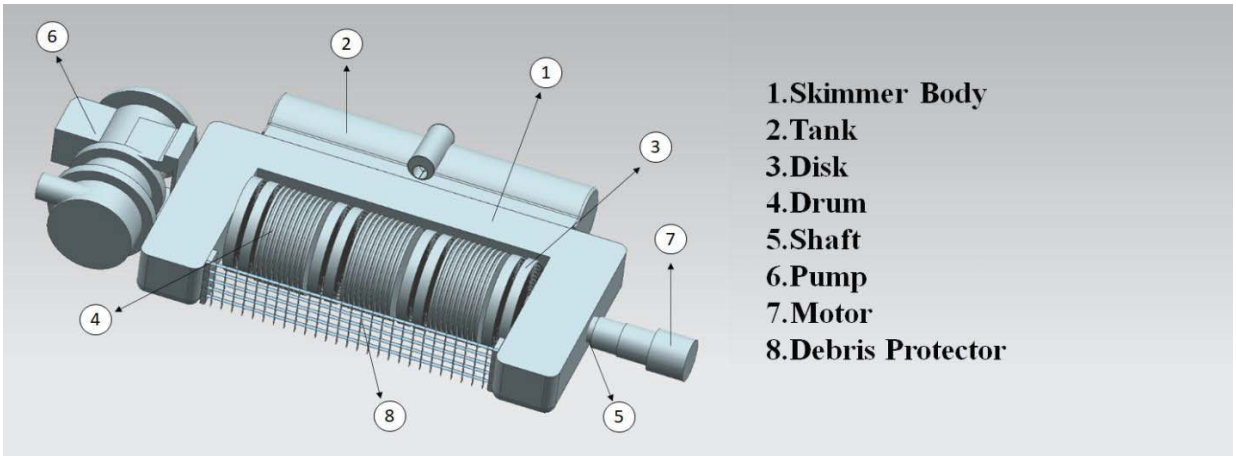


Figure 5.34 Skimmer Assembly 3D Draft

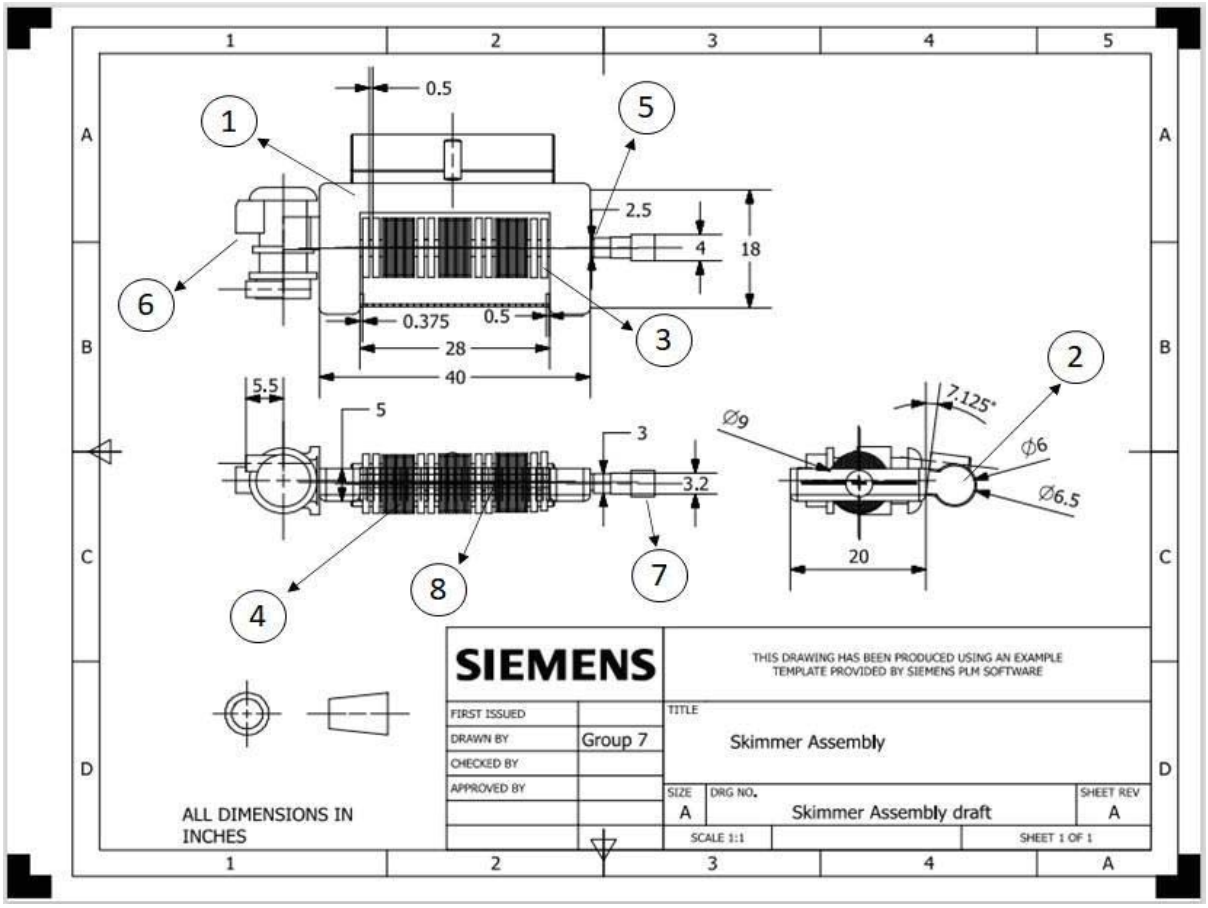


Figure 5.35 Skimmer Assembly 2D Draft

Remove this part from report.

In this section, the standards to generate the models, drawings, and assemblies are discussed. In the next few paragraphs, each one of the model's standards used are described in a list form. The information on each component is listed in the order of part number assigned in the previous section.

1. Skimmer Shell

To generate the 3-dimensional model for the skimmer shell (body), NX Modeling was utilized as well for the drawings and assemblies. The design was created in inches to match all the other parts of the skimmer. Also, the design was generated to fit the measurements constraints of the other parts of the oil skimmer as well as adhering to the 5ft by 5ft operating domain limitation. The 2-D drawing was utilized to display the blueprint of the skimmer shell.

2. Tank

The ISO (International Organization for Standardization) was applied to creations of models within NX 10 software. The designs display orthographic projections and cross-section views. Material type and thickness is also shown in the 3-D drawings. The dimensions were chosen based on the skimmer body size.

3. Disk

The creation of this model was generated using NX 10 software. 2-D drawing was utilized to define the overall blueprint for the design while also analyzing realistic dimensions for the skimmer disk based upon current designs and the design that we are constructing.

4. Drum

The standards used to design the proper drum for the skimmer include adhering to the size constraints identified in report 9. In addition, the manufacturability of the part was considered when making the design. Moreover, the part was designed to limit the friction between the inner diameter of the drum and the outer diameter of the shaft by creating keyways on the disk. To model the drum of the skimmer and generate the draft of the part, the software NX 10 was used.

5. Shaft

Utilizing Siemens NX 10, the shaft was generated for the automated oil skimmer. Within this shaft contains multiple keys in which the disks and drums will sit upon and prevent unnecessary rotation. The length of the shaft alongside the diameter was chosen based on the proposed design identified in the status report 9. Additionally, a 2-D drawing was generated in order to display the dimensions of the shaft and keys.

6. Shell of Pump

The three-dimensional design of the pump and the two dimensional drawing was generated using Siemens NX 10 Modeling software using inches as units. The design was created to fit the dimensions of the skimmer body all while staying within the 5ft by 5ft operating limitations.

7. Motor

To generate the 3-dimensional model for the Motor shell, Nx modeling was used for the drawings, dimensions and modeling. The design was chosen due to ASTM standards for parts and the ease of manufacturability. The sizing was chosen to fit the design constraint of the oil skimmer, which is not to exceed 5ft by 5ft. The power generated by the motor was also taken into account during the design process. The unit used for the dimensions of the motor are in "Inches".

8. Debris Shield

To generate the 3-dimensional model for the skimmer's debri shield, NX Modeling was utilized as well for the drawings and assemblies. The design was generated to fit the U-shaped body of the skimmer. The purpose of this component is to keep the debris away from the disks and the drum to ensure a more accurate oil recovery rate.

In the following section, the team was able to provide a summary of the engineering analysis and the calculations needed to effectively size the part. During the process of the skimmer assembly, some of the sizes for the parts were adjusted to ensure that the skimmer parts were proportional to each other and that they fit properly together. Once the changes were made to each part, each team member noted the new measurements in this section and modified each individual draft.

1. Skimmer Shell

The engineering analysis of the skimmer shell was based on the project initial constraints, that the oil skimmer cannot exceed an operating domain of 5ft by 5ft. The U-shaped body of the skimmer shell was assumed to be 40 inches in lengths and 20 inches in width, and the height of the skimmer was assumed to be 5 inches. The following measurements fit the project constraints and it is going to allow the skimmer to operate in a 5 ft by 5ft domain.

2. Tank

The main measurements of the tank were based on the skimmer shell, since the tank is vertically attached to the main skimmer shell, it was assumed to be the same length of 3 ft. This tank has the capability of holding 275 gallons of oil based on the volume. Prior research that consisted of current skimmer storage capabilities was also taken into consideration.

3. Disk

The orientation of the grooved disks was determined based upon literature review and current disk skimmer designs. A total of eight disks will be incorporated into the design. NX was used to construct a 9 in diameter disk with a grooved face created with .33 in thickness concentric circles. The depth and distance between the grooves were determined using geometric calculations as described in the previous chapter.

4. Drum

The drum dimensions were determined by the space between the arms of the skimmer body. In addition, the team considered the amount of disks desired in the design as well as the desired oil

recovery rate. It was determined that increasing the surface area of both the disks and the drums would significantly increase the oil recovery rate of the skimmer. Moreover, design contains a total of 3 drums. Finally, for the skimmer design it was determined that the drum size should be 4.5 in and should maintain a diameter of 9 in as shown in Figures 5.4 and 5.12.

5. Shaft

The dimensions for the shaft were determined by the length of the skimmer shell and the motor shell. Utilizing information gathered from status report 9, the shaft dimensions turned out to be 46 inches long with a diameter of 2.5 inches. Additionally, in order to prevent unnecessary rotation of the disks and drums, keys were added to the shaft. There is a total of 11 keys within the shaft, 8 keys were used for the disk which are 0.334 in by 0.85 in and 2 keys for the shaft with the dimensions of 1.591 in by 0.85 in. The material for the shaft was determined to be aluminum 6061-T6.

6. Pump

The size of the pump was designed based on the dimensions of the skimmer body. The pump will either fit on the right side of the skimmer body using screws to hold it in place or on the backside next to the container attached with more screws to ensure stability in a vertical position will. Its shape was made to resemble that of a pump from RS Components & Controls (I) Ltd..

7. Motor

The size and geometry of the motor shell was designed based on the dimensions of the motor shell in the analysis report. The motor will fit either on the left or right outer most part of the skimmer (extended parts of the shaft), where it will be attached to the protruded part of the shaft on either side. The motor will then produce power, causing the shaft to rotate, in turn making the disk and drums rotate, all of which leads to the disk and drums collecting oil. The total length of the motor was 9 in, with each individual component making up the total length measuring 3.5in, 3in and 2.5in respectively. The outer diameter of the motor measures 4in, while the inner diameter measures 2.7 in.

8. Debris shield

The size of the debris shield was based on the dimension of the skimmer shell, more specifically the removed area of the shell. The length of the debris shield is 28 inches with a 2 inches bracket to secure the debris shield on the sides of the skimmer shell.

5.5 Economic Analysis

In this section the economic analysis for the parts designed can be found in table 5.7. The table summarizes all the data obtained from suppliers. In addition, the supplier information can be found on the table. Moreover, the team was required to obtain at least 3 quotes from the suppliers for parts that were quoted to be more than $50. The values displayed on the table are those of the lowest price found. Finally, the team concluded that for some of the parts, 3D printing would be the most economical option. Note that some of the prices listed on the table are subject to change.

Table 5.7 Parts Specifications, Vendor Information and Cost Summary Table

Part #	Part Name	Part Specification/Description	Quantity Needed	Unit Price	Extended Price	Vendor Name	Vendor Phone #	Web-address
1	Skimmer Body	The skimmer frame is manufactured in Polyethylene HD, making it resistant to many chemicals found in industrial pits, sumps, separators, and tanks.	1	$13 32.0 0	$1332.0	Elastec	(618)3822525	https://www.elastec.com/products/oil-spillskimmers/drum-oil-skimmers/minimax/
2	Tank	Vertical oval oil storage tank that features heavy-duty steel construction and can hold up to 275 Gal. The tank includes a vent-fill cap and a tank gauge.	1	$1,3 70	$1,370.0	Liquid ynami cs	(281)2392777	https://www.homedepot.com/p/Liquidynamics-275-GalVertical-Oval-Oil-Storage-Tank-with-Vent-Fill-Cap-and-TankGauge-901060V-03/305613847
3	Disk	Rustlick - 4" Reach 12" Wheel Diam Oil Skimmer Disk - For Use with Disk Oil Skimmers	8	$57. 72	$461.76	Strong Toolin g	(888)-9888820	https://strongtooling.com/products/99045775?variant=34566419153045&currency=USD&utm_source=google&utm_medium=cpc&utm_campaign=google+shopping&gclid=Cj0KCQiAzZL-BRDnARIsAPCJs71URRBzQONjnhZrd79m_T85sPunFLIbXGTFofMOh5FeUvGn-4eDzMIaAj-yEALw_wcB
4	Drum	Price for a circus skimmer drum with 4.75 inches in length and a diameter of 9 in	3	$1,5 40.0	$4,620.0	Elastec	618-3822525	https://www.elastec.com/products/oil-spill-skimmers/drum-oilskimmers/
5	Shaft	Price for a 46 inches shaft with a diameter of 2.5 inches in addition to the 8 keys within the design. Aluminum 6061-T6 was the material selected for the shaft.	1	$43 6.69	$436.69	Xomet ry	(859)-2174112	https://get.xometry.com/quote/2B1D7-15001?process=543ef1f380da5b0c476373a6
6	Pump	Ecologically friendly and energy-efficient pump that offers high performance and high flow rates.	1	$21 2.82	$212.82	Alpine Corpor ation	(281)4642080	https://www.homedepot.com/p/Alpine-Corporation-Eco-TwistPump-3000GPH-33-ft-Cord-PXX3000/300497451?

Part #	Part Name	Part Specification/Description	Quantity Needed	Unit Price	Extended Price	Vendor Name	Vendor Phone #	Web-address
7	Motor	115V 7RPM Motor enclosed inside a Steel housing.	1	$28 8.80	$288.80	John Henry Foster	(314)-.5931243	https://store.jhf.com/contact-us
8	Debris Shield	Custom 10 oz mesh tarp used to prevent waste debri from entering the skimmer. 5.5in x 39.98in or .458ft x 3.33ft.	1	$2.1 4	$2.14	Covers & All	(800)2602829	https://www.coversandall.com/cover-mesh-custom-tarps.html
9	Hose	Custom-Length 5/8-inch Polyurethane Garden Hose Assumed length of 54 inches.	1	$31. 21	$31.21	ELEY	(800)5234321	https://www.eleyhosereels.com/products/custom-length-5-8-polyurethane-garden-hose?variant=31844536320071&gclid=Cj0KCQiAk53BRD0ARIsAJuNhpvvPzlCMYBhjTrLL1_hrBOPGGza5T4oqdeuSoC82jaVnxyUVlUyjk4aAsKPEALw_wcB
10	Waste Basket	a simple waste basket for collecting a larger amount debris at that can be removed when full.	1	$10 5.30	$105.30	Advan ced Tabco	**help@webstaurantsto re.com**	https://www.webstaurantstore.com/advance-tabco-a-17-3-deepperforated-sink-basket-for-9-1-2-x-11-1-2-x-6bowls/109A17.html?utm_source=google&utm_medium=cpc&utm_campaign=GoogleShopping&gclid=Cj0KCQiAk53-BRD0ARIsAJuNhpsARD78HrAgGEHhHCQvyOqqiRqbaxue8tFzFQO9MaJmJQvrgY8P1igaAmTUEALw_wcB
11	Oil Recovery Plate	A plate that will be designed to hold oil until displaced into storage	1	TB D	TBD	Elastec	(618)-2687675	https://www.elastec.com/products/oil-spill-skimmers/
12	Magmeter	A measurement tool to record the flow of the oil collected, operated by using a magnetic field to generate and channel liquid flow through a pipe. A voltage signal is created when a conductive liquid flow through the flowmeter's magnetic field.	1	$606 .35	$606.35	Instrum art	(800)-8844967	https://www.instrumart.com/products/45963/ehpicomag-electromagnetic-flow-meter

Part #	Part Name	Part Specification/Description	Quantity Needed	Unit Price	Extended Price	Vendor Name	Vendor Phone #	Web-address
13	Point Level Sensor	Point level measurement sensors are used to mark liquid height. Signals an overfill condition by an alarm system	1	$285.00	$285.00	Flowline	(800)-6370405	https://www.automationdirect.com/adc/shopping/catalog/process_control_-a_measurement/level_sensors_-a-_controllers/flowline_level_sensors_(contact)
14	Submersible Level Transmitter	used for level measurement in containers, tanks, wells, flowing water, bore holes and wastewater plants	1	$349.00	$349.00	Automation direct	(800)-6330405	https://www.automationdirect.com/adc/shopping/catalog/process_control_-a_measurement/level_sensors_-a_controllers/submersible_level_sensors/
15	Detector Array	Provides visual indication for flow rates for water or petroleumbased fluids	1	$86.00	$86.00	Automationdirect	(800)-6330405	https://www.automationdirect.com/adc/shopping/catalog/process_control_-a-_measurement/flow_sensors/variable_area_mechanical_flow_meters/fg1w-75bp-7
16	Pressure Transducer	Pressure transducer/sender/sensor 150 psi stainless steel for oil,fuel,air,water	1	$25.98	$25.98	AUTEX	(888)-2156068	https://www.amazon.com/AUTEX-Pressure-Transducer-Stainless-Compatible/dp/B00NIK98O8/ref=sr_1_6?dchild=1&keywords=line+transducer&qid=1606941587&sr=8-6
17	Line Transducer	Higher frequency that improves resolution and small flaw detectability	1	$671.00	$671.00	Instrumart	(877)7526213	https://www.instrumart.com/products/39739/waygatetechnologies-delay-line-transducers
18	Density Meter	A device that is able to measure density such as a hydrometer. A 165 mm, NIST Standards Hydrometer was selected.	1	$42.50	$42.50	Grainger	1-(800)-GRAINGER	https://www.grainger.com/product/13K061?gclid=Cj0KCQiAk53-BRD0ARIsAJuNhpvgBelXJxQODas3elZ4vJmZU4Qq7_dRBCg7yxDV4Yhbs4OTPhxn0kwaAjwcEALw_wcB&cm_mmc=PPC:+Google+PLA&ef_id=Cj0KCQiAk53-BRD0ARIsAJuNhpvgBelXJxQODas3elZ4vJmZU4Qq7_dRBCg7yxDV4Yhbs4OTPhxn0kwaAjwcEALw_wcB:G:s&s_kwcid=AL!2966!3!264955916102!!!g!436597552742!&gucid=N:N:PS:Paid:GGL:CSM-2295:4P7A1P:20501231
19	Moisture Oil Transmitter	A sensor that is able to accurately measure moisture within oil. A 1/4 in MNPT Pressure Transmitter was selected.	1	$118.50	$118.50	Grainger	1-(800)-GRAINGER	https://www.grainger.com/product/2HLW2?gclid=Cj0KCQiAk53-BRD0ARIsAJuNhpud2rDLLdoEWrqaDu0IgKqFKQCl_4niHwk63zUbntr2SvfSHfv12acaAmxgEALw_wcB&cm_mmc=PPC:+Google+PLA&ef_id=Cj0KCQiAk53-BRD0ARIsAJuNhpud2rDLLdoEWrqaDu0IgKqFKQCl_4niHwk63zUbntr2SvfSHfv12acaAmxgEALw_wcB:G:s&s_kwcid=AL!2966!3!264955916540!!!g!436873882546!&gucid=N:N:PS:Paid:GGL:CSM-2295:4P7A1P:20501231
				Total	$11045.05			

This chapter is the same as in midterm report. You need to update with the new work you have done after midterm.

6. RESULTS & DISCUSSION

6.1 Summary of Goals and Objectives

This project's main goal is to design an automated oil skimmer that offers oil recovery rates greater than or equal to those of today's industrial skimmers. Within this goal, some major objectives needed to be fulfilled include establishment of identifying relevant topics of information to this project as well as potential sources for research. By doing this, the team can begin researching and observing current oil skimmers in order to address current deficiencies/limitations as well as current successes. The scope of this goal is to design a system that offers greater efficiencies of recovery rates for oil slicks that are less than 1/2-inch thickness. A goal that offers progression to this project is task identification. This goal allows the group to analyze and decide which actions and procedures need to be taken to advance. A timeline was the next objective implemented to sequence these tasks followed by a Gantt chart to create a visual chronological representation of the overall project memos. Finally, a literature review was performed to ascertain which skimmers are currently used today for oil spill recoveries and response. During the development of the design process, the team will aim to prioritize the responder safety, portability of technology, simplicity of use, and reduction of waste during recovery operations.

update this section

6.2 Discussion of Completed Work (Chapter by chapter for the three chapters above)

The completed work for this project is as follows: Within the first chapter, the first work objective completed was to determine and establish the project scope as well as the problem statement for the project. The completion of this allowed for the project to rely on a focus area. The area of focus from the problem statement then allowed for the determining of potential project client's and needs. From determining these key aspects, a clear-cut project goal statement as well as design objectives were developed in order to maintain and fulfill the success of meeting the clients' needs and interests. Finally, within the first chapter, after observing the client's needs as well creating design objectives, initial project constraints as well as operating environments were determined based on project scope and goal analysis.

The second chapter's work objectives helped to generate a structure for the process of the project completion. Project planning and task identification served as a basis for structural development of a timeline for the oil skimmer completion. The timeline helped to chronologically order the subtasks, objectives and deliverables in a way that will guide smooth transitions of project protocol. The timeline was then structured into a Gaant chart that visually represents all activities and checkpoints with respected dates that may be subject to change throughout the project.

The third chapter of this mid-term report required the generation and discussion of a literature review. The work in the literature review consisted of the procurement of potentially relevant information and sources that could be used to identify what guidelines and strategies should be

taken to successfully complete the project. Analysis of skimmer types, oleophilic and non-oleophilic as well as weir skimmers were researched and examined to obtain a better understanding of the current skimmer capabilities and functionalities. These literary sources were also used to examine which skimmers are better suited for different situations and environments. Observation of various skimmer patents served to help the guidance and relevancy of today's skimmer designs and how they have advanced over time based on technology advancement. A common theme of the literature reviews was the advantages and disadvantages of efficiencies of each kind as well as their major components of operation. Through all of the reviews, a decision of which skimmer of suitability can be developed in the future

The final chapter of this report involved the functional decomposition analysis. Within this chapter, developments of the skimmer functions were generated. Through individual brainstorming and evaluation, an overall function was determined to be further analyzed into three levels of subfunctions. The overall function is for the skimmer to be able to recover at least 25~50% on 1-inch oil slick. This is the level 0 of the decomposition. To further its subfunctions, each member created lists of possible subfunctions to be evaluated to determine the next new level of sub functionality. This process was repeated for 5 sub function levels at level 1. Furthermore, this process was again repeated to break these down into three second level sub functions at level 2. And finally, these three second level sub functions were then expanded into a final level 3 sub function in which not all level 2 subfunctions expanded. The entirety of this process allowed for the consistency of thought as well as the collaboration of vital functionalities needed for the skimmer design. This process will allow for the next step of concept design to begin.

update work completed in chapter 4.

What about chapter 5?

6.3 Summary of Constraints and Codes Identified for Project

The automated oil skimmer project will be based upon specifications given by The Bureau of Environmental Enforcement (BSEE). This is an agency that is within the United States Department of Interior and is the lead agency in charge of improving safety and environmental protection relating to offshore energy industries. Testing optimization within BSEE requires operations of oil skimmer efficiencies to be .25-.50 for oil thicknesses of 1 inch. The current disadvantages of today's oil skimmers create issues for oil recovery of thicknesses less than 1 inch. A summary of the initial project constraints are as follows: the skimmer must be waterproof as well as buoyant. Stated constraints include that the skimmer will be automatic and cannot exceed operation parameters of 5ft by 5ft. Based upon current skimmers, this skimmer must also be accustomed to oil slick thicknesses up to 3 inches and must be climate resistive. Additionally, the skimmer efficiency must be comparable to the efficiencies of current skimmers. Meaning that the skimmer must at least be within the same level of success as the industrial skimmers operating currently. Some other developed constraints featured are that the skimmer must be adaptable to recover different temperatures of oil slick as well as possess an oil containment device. Codes and regulations are based upon the Oil pollution act which was passed in 1990. The act was established as an amendment under the Clean Water Act in which some oil storage facilities were required to develop facility response plans for spills. The lead federal response

update this section

agency EPA is the agency for oil spills occurring in inland waters. Some of EPA's top priorities are to prevent, prepare for, and respond to oil spills that occur in and around inland waters of the United States. EPA's oil spill prevention program includes the Spill Prevention, Control, and Countermeasure (SPCC) and the Facility Response Plan (FRP) [17].

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

update this chapter.

The Automated Oil Skimmer Project is subject to many tasks, objectives and deliverables that serve to meet client needs as well as environmental needs. The lack of consistency of oil recovery response has led to environmental damage as well as unnecessary costs to environmental and oil industries. Although oil incidents are not always preventable, the quantity of damage they can cause can be. Through education and observation of current skimmer capabilities, advancements can be made, and technological implementation can wield a greater performance of skimmers and that can reverse the effects of human mistakes. The ethical gratitude of this project must also be taken into consideration. Although the main goal is to increase the performance of the skimmer, accountability for protecting the environment must also be simultaneously considered. As expressed within the fourth chapter the overall function of the skimmer design is for it to be able to recover at least 25~50% on 1-inch oil slick.

All decisions and actions that are to be performed will serve to not only successfully help improve skimmer performance, but also maintain ethical conduct within the field of Engineering.

7.2 Recommendations

The lack of consistency of oil recovery response has led to environmental damage as well as unnecessary costs to the environment and oil industries. Therefore, we seek to advance a current oleophilic skimmer design that abides by BSEE and EPA specifications. Therefore, we recommend further research on existing oil skimmers and find ways to improve upon their designs. In addition, while our design's constraint is 5 ft x 5 ft x ft, if preliminary tests are overwhelmingly positive, it is recommended to increase the size of the oil skimmer in order to be able to pick up and filtrate upon a larger surface.

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AVERAGE

"Experimental Design to Measure Heat Transfer Coefficient and Effective Thermal Conductivity in Nanofluids Under Different Boundary Conditions"

Senior Design & Professionalism I
~~Midterm~~ Report

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~~October 9, 2020~~

LETTER OF TRANSMITTAL

THE MEASUREMENT OF HEAT TRANSFER COEFFICIENT AND THERMAL CONDUCTIVITY OF NANOFLUIDS UNDER DIFFERENT BOUNDARY CONDITIONS

100 University Dr. Prairie View, TX. 77446 (512) 400-3333

~~October 9, 2020~~

Dr. Xiaobo Peng
Office: Room 102A
C. L. Wilson Engineering Building
Prairie View, TX 77446

Dear Dr. Peng:

The attached technical report contains the current and completed phases of the experiment to measure heat transfer coefficient and effective thermal conductivity in nanofluids under different boundary conditions. We used the solution criteria established by Dr. Shahin Shafiee current instructor and project owner at Prairie View A&M to evaluate the design:

- Heat transfer coefficient
- Effective thermal conductivity in nanofluids
- Different boundary conditions
- Heat convection
- Heat transfer rate with changes in boundary conditions

Dr. Shafiee recommends the use of the measurement design on campus for future engineering studies and research purposes. The experiment provides a detailed measurement of heat transfer coefficient under different boundary conditions, second is to study the effectiveness of thermal conductivity in nanofluids and finally to monitor the heat convection undergoing the process. This design best meets the needs of the project requirement.

Dr. Shafiee or one of our group members is available to answer any questions you may have concerning this report or the project in general. you can contact Dr. Shafiee by email at shshafiee@pvamu.edu

Sincerely,



Senior Design Group 3

Acknowledgment

We, the project team members, would like to express our deepest appreciation and gratitude to our project advisors, Dr. Shahin Shafiee and Dr. Xiaobo Peng, as their knowledge and guidance has made this research project possible. We are grateful for their constant support and dedicated involvement throughout the process, as well as their patience and willingness to instruct us on the proper procedures involved in this project. This would include their assistance and guidance on research, problem analysis and the writing of all conclusive reports. We would also like to express our gratitude to all of our respective course professors who have been detrimental to the success of our academic careers. Without them, our education level would not be at such a high level as it is today. We thank them for kindly sharing all of their understanding and wisdom, as well as their encouragement through these particularly difficult subjects. We also give a very special and kind appreciation to our families and their continuous support as we undertake the many challenges and learning experiences associated with academia.

Abstract

This project will address an issue that professors, scientists, engineers, and engineering students face when it comes to understanding nanofluids and their behaviors under different boundary conditions. The group is undergoing research on how to better measure heat transfer coefficient and effective thermal conductivity in nanofluids under those different boundary conditions by creating a system designed to conduct an experiment that will measure different nanofluids and their behaviors. The constraints that we face deal with inflexible boundary conditions, applicable techniques for such nanofluids, selecting the appropriate material, ensuring the nanofluid(s) has an ability to withstand high pressure, and the apparatus size. Although these constraints can make difficult this projects' experiment, the solution will be to establish set boundary conditions, research different techniques from past experiments, select the appropriate material, research which nanofluids can withstand high pressures, and ensure the apparatus size is applicable with the system and nanofluid(s). The results will be that the system that has been designed is successful in measuring the heat transfer of multiple nanofluids under different boundary conditions as well as its thermal conductivity. The conclusion drawn from this result is that there are more effective ways in measuring the behavior of different nanofluids that will help those who are under the study of heat transfer use to gain a better understanding of the overall function of nanofluids when placed in different boundary conditions.

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1.2	Client identification and recognition of need	Christian White
1.3	Project goals and objectives	Fanta Kaba
1.4	Potential impact of project on society	Fanta Kaba
1.5	Initial Project constraints	Yemboado Brayan Yonli
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3.5	Identifying Major Components	Abdullah EL Aker
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5.3	CAD Models, Detailed Drawings, Sub-assemblies, System Assembly and Equipment specifications and selection	Christian White and Abdullah EL Aker
5.5	Economic Analysis	Yemboaodo Brayan Yonli and Christian White and Abdullah EL Aker
6.1	Summary of Goals and Objectives	Yemboaodo Brayan Yonli
6.2	Discussion of Completed Work	Marcelo Epam Ona**,**
6.3	Summary of Constraints and Codes used and met by Design	Christian White
7.1	Conclusions	Yemboaodo Brayan Yonli
7.2	Recommendations	Marcelo
	Project Selection and Team Formation	Abdullah EL Aker
	Team Organization and Agreement	Abdullah EL Aker
	Record of Meeting Minutes	Fanta Kaba

1. PROJECT SCOPE

This chapter represents the project scope of the entire project. It will begin by defining the project through establishing the problem statement for clarity and understanding. The clients will be identified and a need for this project will be defined. It will be followed by goals and objectives aimed to further understand the scope of the project. Furthermore, this chapter will conclude with establishing some project constraints and defining the operating environment for this entire project.

1.1 Problem Statement

Measurement of heat transfer coefficient and thermal conductivity of nanofluids do not accommodate different boundary conditions; therefore, an effective measurement technique will be selected to adapt to the change of properties of the nanofluids.

This project is to select the proper measurement technique amongst the current methods used in the industry to measure the convection transfer coefficient for nanofluids. The technique will measure the heat transfer coefficient and thermal conductivity of the nanofluid while accommodating for changes in boundary conditions and common constraints. Experimental testing will be performed for comparison in order to study the effects of heat transfer rates under different boundary conditions. To ensure functionality in the measurement technique selected, measurements of the convection coefficient for some nanofluids will be compared to the results of the published values given.

1.2 Client identification and recognition of need

i. Identifying the client.

This project pertains to specific clients that have professional backgrounds in the study of heat transfer, thermal conductivity, and thermodynamics. This would include engineers, professors, scientists, and engineering firms, such as Koch Heat Transfer Company, who conduct research for industry use. An experiment will be conducted to measure thermal conductivity of nanofluids under different boundary conditions. Therefore, it is imperative that those who want to start or maintain a career in heat transfer have an effective system.

ii. Identify the need to be fulfilled

The suspended nanoparticles of conventional fluids have been the subject of intense study worldwide for many years by pioneering researchers due to their anomalous thermal behavior. Over time, existing theories cannot seem to explain the behavior of these fluids with small-particle concentrations. We know that the current methods do not adequately predict the order of magnitude of thermal conductivity. This is due to a driven argument that nanofluids carry an enhanced thermal conductivity, relative to the base fluid. This in turn makes them superior agents for heat transfer in a variety of circumstances. As a result, finding the right ratio of nanoparticles to base fluid is needed to attain the most effective thermal conductivity in research. Along with obtaining the lowest possible effective viscosity from the fabricated nanofluid to ensure the application of heat transfer is met. A proper measurement technique will then help to form an educated hypothesis on understanding how to manipulate the nanofluid and the environment to gain accurate readings. Without a proper thermal conductivity measuring technique, researchers, engineers, professors, and scientists will ultimately find difficulty in understanding the true function of nanofluids. Including, how to effectively manipulate them to achieve the desired outcomes.

In many industries fluids are used to cool down the machinery used. Nanofluids are thought to be having higher heat transfer coefficient and thermal conductivity than regular fluids like water due to the suspension of metal particles in them. However, boundary conditions change can significantly affect the performance of rate of heat transfer of the nanofluid which means that the heat transfer coefficient and

thermal conductivity of the nanofluid are influenced by the boundary conditions. For example, a magnetic field will definitely create a pull force that can disturb the agglomeration of the metal particles in the nanofluid. Finding a way to safely and accurately be able to measure the heat transfer coefficient and thermal conductivity of a nanofluid would be a great time and money saver for many industries.

1.3 Project goals and objectives

In this section, a well-defined goal will be established to further understand the scope of the project. It will include making a list of objectives that will be broken down into high level and low-level objectives. It will be followed by an objective tree to optimize the characteristics of the system in order to achieve the goal at hand.

Goal Statement:

The project goal is to design a proper setup with reliable and common results for convection heat transfer coefficient in nanofluids. The designed measurement technique establishes a system for data collection for the study of nanofluids under different boundary conditions.

Project Objective:

(i) List of Objectives

Objectives List

- Measurement technique
- Method for measurements
- Experimental Set-up

(ii) High-Level & Low-Level Objectives

High Level Objectives

- Proper equipment and testing setup
- Efficient measurements for transferring heat
- Ability to measure heat transfer under constraints

Low Level Objectives

- Proper apparatus and experimental setup
- Effective measurement of convection heat transfer coefficient
- Ability to measure heat transfer coefficient of nanofluids with changing boundary conditions

(iii) Figure 1.1 displays the objective tree for this experiment.

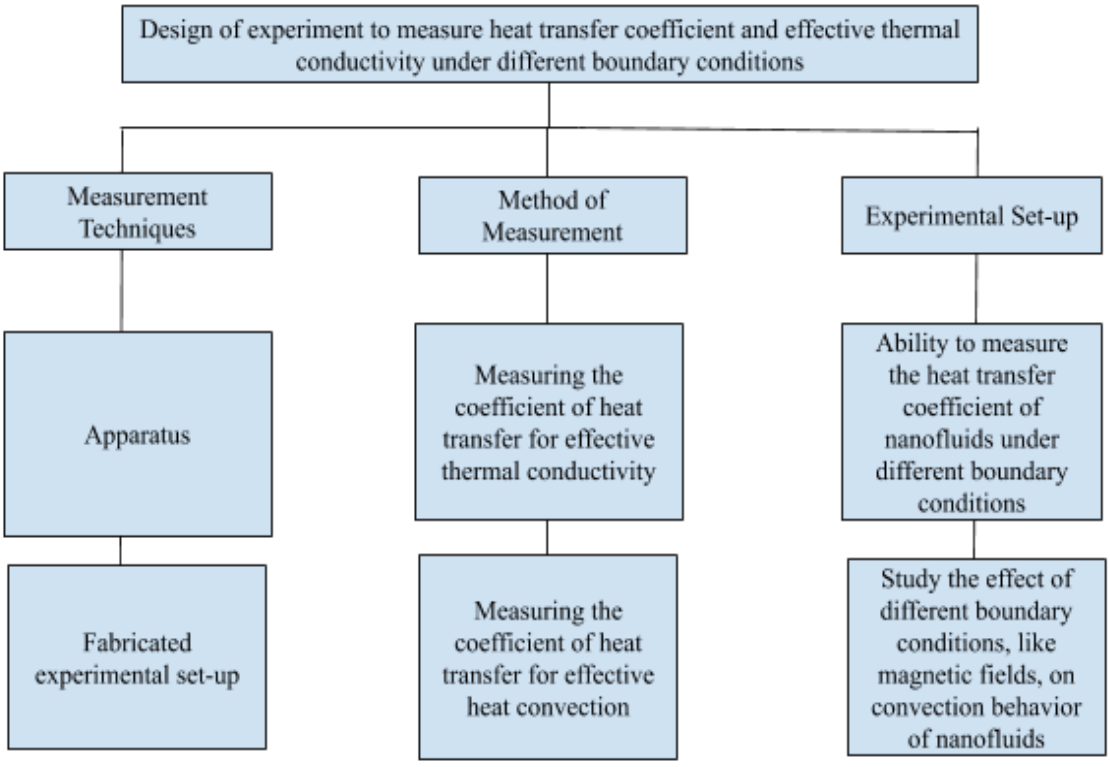


Figure 1.1 Objective Tree for the Measurement of Convection Heat Transfer

iv. In Table 1.1 a breakdown of objectives for measurements and units are shown.

Table 1.1 Basis for, and Units of, Measuring Objective

Objective	Measurement Basis	Criteria	Units
Accurate measurement of temperature	Accuracy & Consistency	Temperature Gauge	K or °C
Accurate measurement of pressure	Accuracy & Consistency	Pressure Gauge	J or kg·m2·s−2
Deliver consistent results	Accuracy	System Efficiency	W/(m·K)

1.4 Potential Impact of Project on Society

The twenty-first century is experiencing a wave of technologies and innovations making use of unique features of nanofluids, in applications such as industrial and process heating, air conditioning and refrigeration systems, heat pipes, solar energy, thermal storage systems, electronic cooling systems and others. Recent literature indicates that suspending solid nanoparticles in traditional working fluids can enhance heat transfer rates by increasing thermal conductivity and heat transfer coefficients. The knowledge and understanding of heat transfer are important for the design of a wide range of industrial, commercial and domestic processes and appliances, including chemical processing, air conditioning and refrigeration, solar energy production and conversion, oil and gas industries and electronics cooling. In practice, the usage of nanoparticles in heat transfer equipment still faces

a number of challenges arising from issues such as the lack of stability of the nanofluids, high variation on reported physical properties and heat transfer enhancement effects. Furthermore, the lack of understanding about the mechanisms and forces that act on the nanoparticles during and after suspension. These issues have slowed the process of standardization and formulation of nanofluid in technology today.

As society makes attempts to combat climate change and provide sustainable energy access for all, solar energy stands out as a primary means of reducing global carbon emissions to the Earth's atmosphere. Many solar capture devices suffer from relatively low collection efficiencies. Recent studies indicate that nanofluids can be used specifically in low optical and thermal performance solar energy conversion systems to boost their performance which seem promising. Research indicates that it seems likely that solar energy capture devices may be one of the first applications to have the widespread uptake of nanofluids technology, although the stability of nanofluids remains a significant barrier.

A further look into the nanoparticles in the nanofluid and its toxic and environmental effects show that there are no clear standards to determine their effects. The toxicity of nanoparticles is related to their small size, large surface area, and their ability to produce reactive oxygen species. Nanoparticles can pass through different cell membranes of mammalians and be absorbed in them. One of the places nanoparticles are stored in is the mitochondria, which can cause toxic reactions. Nanoparticles can cause inflammation and fibrosis in multicellular organisms, and their main impact in unicellular organisms is their antioxidant property and toxic cells. Workers that are in the gas, coal, and asphalt industry are exposed to diseases that are associated with air pollution due to nanoparticles, which can cause premature deaths. There is not much study that has been conducted on the effects of the exposure of such workers to nanoparticles. However, the limited research that is available suggests that such people are subject to increased risk of adverse health effects caused by their exposure to nanoparticles.

Despite the promising heat transfer enhancement potential observed by many researchers, there are several barriers to widespread implementation in industrial settings. Most studies on nanofluids largely rely on commercially available nanoparticles. Nanoparticles are not cheap and there is no standard price for these particles as at present. In addition, it seems that the properties of nanoparticles differ according to the manufacturer, which adds to the uncertainty of physical property data. Equally important, some nanomaterials are toxic and therefore extra measures taken in preparation increase production cost. Challenges such as the high cost of nanoparticles, instability and agglomeration, pumping power and pressure drop, erosion and corrosion of components make nanofluid usage commercially unattractive. However, they concluded that the general application of nanofluids is still in its infant stages and, therefore, future investigations will increase the potential applications of nanofluids.

1.5 Initial Project constraints and Operating Environment

A. Initial Constraints

Every Project has some limitations that the engineers have to be aware of. Those are called constraints and are a good indicator of things that need to be taken into consideration while going through designing and building. There are 3 different types of constraints that are the equality constraints, the inequality constraints and the "Yes or No" constraints.

Equality constraints

The results in these experiments must be comparable to the published values of the experiment with the same background providing a range of trustable values. This can be identified as an equality constraint. The material chosen for this experiment must be able to sustain high level temperatures. For example, if using glass in the apparatus it is to know that maximal thermal shock resistance for glass is 160 °C. Borosilicate glass can easily handle a temperature of 400 °C. Maximus Pressure that can be handled by the materials used is also listed as an equality constraint. Again with glass as an example the maximum pressure supported by lab glass is around 25 to 30 Psi. When it comes to accuracy the percentage error would be great at + or - 1%. However, the instruments

used during the experiment will help to set the accuracy. all this would be part of project budgeting as the more accurate the instrument the more expensive it is.

Inequality constraints

The flexible boundary conditions in which the experiments are supposed to be performed can be classified as an inequality constraint as the boundary conditions are not fixed to one condition but are varying. The apparatus and the experimental setup must be designed in order to be able to withstand different boundary conditions when performing experiments on nanofluids, such as adding or removing magnetic fields.

"Yes or No" constraints

Another constraint in the design of the experiment is to choose the appropriate convection measurement techniques for nanofluids. Therefore, to obtain reliable results, selecting the appropriate technique is necessary. This could be put as a Yes or No constraint, as it would answer the question "can the technique be used to measure the heat transfer coefficient and thermal conductivity in nanofluids?

B. List of Operating Environment

The operating environment for the experiment can vary from schools or to engineering workplaces. it is important that the experiment be conducted in a lab. the environment in which is conducted must be able to support:

- High Pressures (depending on the nanofluid used)
- High Temperature (depending on the nanofluid)
- A strong Magnetic field (1000 Gauss or more)

2. PROJECT PLANNING AND TASK DEFINITION

Every single project or design should be thought and planned out properly before starting. For example, it can be seen how architects first create and obtain the model of a particular building before getting into constructing such an establishment. In this chapter, the focus would be mainly on planning and having a schematic on how this senior design project is going to look like, taking into consideration the hours, days or months that it is going to take to carry out each major task. To do that, two main objectives were considered. First, project planning and task definition. This section was mainly focused on organizing and arranging the different tasks as well as understanding what those are and how to perform them. Since that is the only way groups can estimate the time might take to perform every single one of them. And second, the Gantt chart, which is where a series of horizontal lines shows the amount of work done or production completed in certain periods of time in relation to the amount planned for those periods.

2.1 Task Identification

The task identification is in detail, to convey what will be done currently and in the future for the project. The detailed task list is the focal point for the manufacturing, conceptual design, ASME code & standards, and CAD modeling aspect of the project. The resources used to create the detailed list was the senior design manual and the syllabus. We specified the technical and non-technical aspects that will be presented in the final presentation. The non-technical component includes the research and study behind the project. The technical component includes the step by step process on how to design and develop the experiment for the project. Beneath are the identified tasks and subtasks in detail.

Senior 1

Problem Formulation (from 09/02/2020 to 09/09/2020)

- ~~Identify~~ and Recognize the Need.
- Define Goals.
- Define the objectives.
- Identify the Constraints and Operating Environment.

Project Planning (from 09/10/2020 to 09/16/2020)

- Identify the task.
- Develop objectives of each task.
- Set up the Timeline.
- Create a Gantt Chart.

Literature Review (from 09/16/2020 to 09/22/2020)

- Identify Potential Sources and Relevant Information
- Study convection of nanofluids
- Study convection of nanofluids under different boundary conditions.
- Study of Different measurement techniques for convection and their advantages
- Identify and collect comparable results
- Conclude the literature review.

Functional Decomposition (from 09/23/2020 to 09/29/2020)

- Use strategies to develop Level 1 Sub functions.
- Use strategies to develop Level 2 Sub functions.
- Use strategies to develop level 3 Sub functions.
- Develop the Morphology Table.

Concepts Generation (from 09/30/2020 to 10/05/2020)

- Generate techniques for the Concepts from Functions.

- Develop a Conceptual Designs of the experimental set up that would base on the properties of nanofluid and the boundary conditions that would be applied

Concepts Evaluation (10/14/2020 to 10/20/2020)
- Evaluate based on go-no-go.
- Evaluate based on decision matrix.

Preliminary Design (10/21/20 to 11/05/20)
- Make the design sizing and components Analysis.
- Develop Methods for presenting design analysis.
- Apply ASME codes & Standards
- Consider public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors in Design.

Detailed Design (11/06/21 to 11/21/20)
- To develop CAD models of project parts & components.
- Develop Engineering Drawings from part models.
- Develop sub-system assembly and system assembly.

Detailed Parts Specification (11/22/20 to 11/29/20)
- Specify of parts
- Identify the use of each part.

Budget and Project Cost (11/30/20 to 12/06/20)
- Identify the material needed for the parts
- Identify parts that can directly be bought
- Identify the manufacturing cost
- Summarize into a budget that can cover up for all costs.

Purchasing (01/25/21 to 02/06/21)
- Research Vendors able to manufacture the needed parts based on the Design.
- Obtain Quotes Generation by vendor
- Generate a cost/quality Analysis
- Choose the vendor best suited for Project Budget.
- Purchase from the vendor

Manufacturing and Testing (02/07/21 to 04/16/21)
- Manufacture the parts based on the design.
- Assemble of the part
- Testing of the experiment and testing of the equipment

Final senior Design Presentation (04/17/21 to05/12/21)
- To come with a detailed Project Presentation of the Problem.
- To come with Detailed explanation on the project planning.
- To come with Detailed Presentation on the Literature Review.
- To come with Detailed Presentation of functional decomposition.
- To come with Detailed presentation on the concept generation.
- To come with Detailed presentation on the design analysis.
- Etiquette and laws applied to the project**.**

2.2 Project Timeline

To successfully undertake the design of this experiment in its entirety, it was important that the framework for this project was clearly outlined and defined. This was done by initially defining the major tasks. These tasks represent the basic building blocks of what it takes to complete this design experiment from start to finish. From this point, each task is followed by its objectives. These objectives give clear understanding to the purpose of the task associated with it. Once the objectives are clear, there is a specific deliverable for each objective. The deliverables define exactly what needs to be done to fulfill the assigned objective. These are awfully specific jobs that needed to be carried out for the task to be considered complete. Every deliverable was allotted a time frame that was estimated for its completion. This time frame was estimated depending on the difficulty and ease of the deliverable. More days were given to more difficult deliverables and fewer days to those that were considered less time consuming. Once the process was broken down to clear and precise deliverable associated with the task, it was assigned a specific person to carry out the deliverable. Each team member's knowledge and personal strengths were taken into consideration with this step. Some deliverables were given more than one person to accommodate time restrictions, a person's knowledge/strengths or for the importance of collaboration needed. A list of tasks, objectives, deliverables, responsible members, and time frame is shown below in the following format.

1. Problem Formulation

1.1 Identify clients and recognize needs.

-Objective: Identify the consumer.

-Deliverable: Specify at least 3 clients.

-Members: Marcelo Epam Ona/Christian White
-Timeline: 3 days

1.2 Define goals.
-Objective: Clear understanding of need.
-Deliverable: Define 3 specific needs.
-Members: Christian White
-Timeline: 3 days

1.3 Define objectives.
-Objective: Clarify objectives.
-Deliverable: List objectives for each task.
-Members: Yemboado Yonli
-Timeline: 2 days

1.4 Identify the constraints and operating environment.
-Objective: Understand limitations of design.
-Deliverable: List all constraints.
-Members: Marcelo Epam Ona/Abdullah El Aker
-Timeline: 5 days

2. Project Planning

2.1 Identify the tasks.
-Objective: Clear understanding of task.
-Deliverable: List of tasks.
-Members: Diana Morales
-Timeline: 2 days

2.2 Develop objectives for each task.
-Objective: Develop objectives.
-Deliverable: Specify all requirements to complete task.

-Members: Fanta Kaba
-Timeline: 2 days

2.3 Set up a timeline.
-Objective: Estimate timeline for completion.
-Deliverable: Estimate dates for tasks.
-Members: Fanta Kaba
-Timeline: 3 days

2.4 Create a Gantt chart.
-Objective: Visual representation of timeline.
-Deliverable: Create a Gantt Chart.
-Members: Abdullah El Aker
-Timeline: 2 days

3. Literature Review

3.1 Identify potential sources and relevant information.
-Objective: Understand the background of the project.
-Deliverable: List of research previously found on convection of nanofluids.
-Members: Marcelo Epam Ona/Christian White
-Timeline: 2 days

3.2 Study convection of nanofluids.
-Objective: Understand the mechanism.
-Deliverable: List of research on heat convection under different boundary conditions.
-Members: Diana Morales/Fanta Kaba
-Timeline: 2 days

3.3 Study convection of nanofluid under different boundary conditions.
-Objective: Understand change of boundary condition.
-Deliverable: List boundary conditions.
-Members: Yemboado Yonli
-Timeline: 2 days

3.4 Study measurement techniques of convection and their advantages.
-Objective: Identify different measurement techniques for convection.
-Deliverable: List 3 techniques.
-Members: Yemboado Yonli/Christian White
-Timeline: 2 days

3.5 Identify and collect of comparable results.
-Objective: Obtain a range of results that satisfy results.
-Deliverable: List comparable results.
-Members: Marcelo Epam Ona/Abdullah El Aker
-Timeline: 2 days

3.6 Conclude the literature review.
-Objective: To summarize research.
-Deliverable: Write paragraph on summary of research.
-Members: Christian White
-Timeline: 1 day

4. Functional Decomposition

4.1 Use strategies used to develop Level 1 Sub Functions.
-Objective: Define the general function of the experiment.
-Deliverable: Give definition of the major function based on the project statement.
-Members: Christian White/Marcelo Epam Ona/Abdullah El Aker
-Timeline: 1 day

4.2 Use strategies used to develop Level 2 Sub Functions.
-Objective: To define the main functions of what is to be accomplished.
-Deliverable: To break each second level function into sub functions.
-Members: All members
-Timeline: 3 days
4.3 Develop the Morphology Table.
-Objective: To break each second level function into sub function
-Deliverable: An assignment for each member to build up in order to complete the project.
-Members: All members
-Timeline: 2 days

5. Concept Generation
5.1 Generate techniques for concept.
-Objective: To Generate concepts using concept generation techniques.
-Deliverable: Brainstorm and generate 3 concepts for each function.
-Members: Christian/Fanta/Bryan/Marcelo/Diana/Abdullah
-Timeline: 2 days
5.2 Develop a conceptual design of the experimental.
-Objective: To consolidate individual concepts and sketches.
-Deliverable: Combine concepts/sketches.
-Members: Christian/Fanta/Bryan/Marcelo/Diana/Abdullah
-Timeline: 3 days

6. Concept Evaluation
6.1 Evaluate based on Go-No-Go.
-Objective: Select and acquire relevant information.
-Deliverable: Select 4 merits that may meet the needs of the customer.
-Members: Diana Morales/Cristian White/Abdullah El Aker
-Timeline: 6 days
6.2 Evaluate based on decision matrix.
-Objective: Decisions made based on a descriptive matrix evaluation method.
-Deliverable: Select the best choice from the matrix with an explanation on its selection
-Members: Yemboado Yonli/ Marcelo Epam Ona/Fanta Kaba
-Timeline: 1 day

7. Preliminary Design
7.1 Make the Design Sizing & Components Analysis.
-Objective: Analyze project and design from basic science.
-Deliverable: Select the proper tools needed for the experiment.
-Members: Diana Morales/Cristian White/Abdullah El Aker
-Timeline: 5 days
7.2 Develop methods for design analysis.
-Objective: Choose different methods used.
-Deliverable: Proper method is chosen for each respective part.
-Members: Yemboado Yonli/ Marcelo Epam Ona/Fanta Kaba
-Timeline: 4 days
7.3 Apply ASME Codes & Standard to experiment.
-Objective: Rules and ethics applied to obtain best results.
-Deliverable: Defining 5 rules that are necessary for this experiment to function with the most accurate results.
-Members: Diana Morales/Cristian White/Abdullah El Aker
-Timeline: 4 days

7.4 Consider public health, safety, and welfare factors into design.
-Objective: Assure experiment is safe.
-Deliverable: List at least 10 rules that would make this experiment safe for consumers and environment.
-Members: Yemboado Yonli/ Marcelo Epam Ona/Fanta Kaba
-Timeline: 4 days

8. Detailed Design
8.1 Design CAD models of project parts & components.
-Objective: Generating a design of the different parts needed with precise measurements.
-Deliverable: Parts with precise measurement.
-Members: White/Marcelo Epam Ona/Abdullah El Aker
-Timeline: 7 days
8.2 Develop Engineering Drawings from part models.
-Objective: Have perspective and schematic of project.
-Deliverable: Schematic of design experiment.
-Members: Yemboado Yonli/ Marcelo Epam Ona/Fanta Kaba
-Timeline: 7 days
8.3 Develop sub-system assembly and system assembly.
-Objective: Creating a simpler system.
-Deliverable: Part fit perfectly for a simple design.
-Members: Diana Morales/Cristian White/Abdullah El Aker
-Timeline: 5 days

9. Detailed Parts Specifications
9.1 Specify the parts.
-Objective: To be able to identify each part.
-Deliverable: Parts
-Members: White/Marcelo Epam Ona/Abdullah El Aker
-Timeline: 7 days
9.2 Identify the use of each part.
-Objective: To identify the utility of each part.
-Deliverable: Utility of part
-Members: Diana Morales/Cristian White/Abdullah El Aker
-Timeline: 5 days

10. Budget and Project Cost
10.1 Identify the material needed for the parts.
-Objective: Know what should be purchased.
-Deliverable: List of material needed and where it can be found.
-Members: Christian White.
-Timeline: 3 days

10.2 Identify parts that can directly be purchased.
-Objective: Identify what can be directly acquired.
-Deliverable: List of parts that can be directly purchased.
-Members: Fanta kaba/Diana Morales
-Timeline: 2 days
10.3 Identify manufacturing cost.
-Objective: Know how much it would cost to manufacture the part.
-Deliverable: Cost of the part that can be directly acquired.
-Members: Yemboado Yonli

-Timeline: 2 days

10.4 Summarize budget plan to cover all costs.

-Objective: Make sure that every dollar is properly spent.
-Deliverable: Estimated cost and final budget.
-Members: Marcelo Epam Ona/ Abdullah El Aker
-Timeline: 4 days

11. Purchasing

11.1 Research vendors that can provide manufactured parts.

-Objective: Know the companies or manufacturers that can build necessary parts.
-Deliverable: List of the parts specifications to be purchased and manufactured.
-Members: Yemboado Yonli
-Timeline: 13 days

11.2 Have the vendors generate quotes.

-Objective: To list the possible vendors or providers for the different parts needed.
-Deliverable: Detailed drawings and prototypes of desired parts.
-Members: Marcelo Epam Ona
-Timeline: 13 days

11.3 Generate a cost quality analysis.

-Objective: Understand and prepare a budget.
-Deliverable: List 3 or more quotes of parts worth more than $50.
-Members: Fanta Kaba
-Timeline: 13days

11.4 Choose the vendor that best suits Project Budget.

-Objective: Pick the parts to satisfy experiment needs at low cost and highest quality available.
-Deliverable: List of parts for assembly.
-Members: Abdullah El Aker/Christian White
-Timeline: 13 days

12. Fabricating and Testing

12.1 Manufacture parts based on the design.

-Objective: Have tangible parts.
-Deliverable: Detailed plan for manufacturing and assembly.
-Members: Yemboado Yonli/Marcelo Epam Ona
-Timeline: 20 days

12.2 Assembly of the parts.

-Objective: Verify the functionality of the designed product.
-Deliverable: List of parts to meet the project requirements.
-Members: Abdullah El Aker
-Timeline: 10 days

13. Final Report and Presentation

13.1 Presenting the problem in detail.

-Objective: Assure audience understands the task at hand.
-Deliverable: Utilizing Microsoft PowerPoint, provide a slide defining the problem.
-Members: Yemboado Yonli
-Timeline: 7 days

13.2 Detailed explanation on the project planning.

-Objective: Show how the project has been divided into multiple steps that allow for full development.

-Deliverable: A list of steps taken to create our physical system.
-Members: Marcelo Epam Ona
-Timeline: 7 days

13.3 Detailed presentation on the literature review.

-Objective: A brief overview of the information helps the concept generations.
-Deliverable: Show the helpful documents used through individual research and result.
-Members: Fanta Kaba
-Timeline: 7 days

13.4 Detailed Presentation of functional decomposition.

-Objective: Help the audience understand the material, energy and information inputs and outputs for the overall subfunctions.
-Deliverable: Show various components of the system and explain why they have been chosen.
-Members: Diana Morales
-Timeline: 7 days

13.5 Detailed presentation on the concept generation

-Objective: Present to the audience chosen concept for full understanding.
-Deliverable: Explanation on why this concept was the most acceptable for this project.
-Members: Abdullah El Aker
-Timeline: 7 days

13.6 Detailed presentation on the design analysis.

-Objective: Present to the audience how the design was generated.
-Deliverable: Bullets points on the major concepts behind the experiment.
-Members: Christian White
-Timeline: 7 days

13.7 The etiquette and laws of the project.

-Objective: Show rules and laws of the engineering were respected.
-Deliverable: A list of rules that were abided by.
-Members: Diana Morales
-Timeline: 7 days

The section above describes the list of tasks that need to be performed to fulfill the goals and objectives of this project. It was mainly done or created by following the Prairie View A&M Department of Engineering Senior Design Project manual, which helps mechanical engineers build a list of actions that need to be completed in the process of designing or building a product. The dates were set up by identifying and recognizing the importance of each task, which led this to come out with an estimated date that such task might take to be completed. Based on how much or little work each task seemed to have once identified, a certain amount of days and hours were given to complete it. For example, when it comes to the Literature review, it is understood that this is actually one of the tasks that will definitely take some time to complete because it mostly focuses on objectives like Identifying most of the potential sources and relevant information related to Measurement of heat transfer coefficient and thermal conductivity of nanofluids that do not accommodate different boundary conditions. As it can be seen, there will be a lot of research and work to do on this objective alone, which also means a lot of time invested into identifying these potential sources. Furthermore, the hours were set up by putting into this project at least 6 hours a week which translate into for every two weeks a total of 12 hours were invested into accomplishing every single objective.

- Problem Formulation (From 09/02/2020 to 09/08/2020) 6 hours are to be invested.
- Project Planning (From 09/10/2020 to 09/15/2020) 6 hours are to be invested.
- Literature Review (From 09/16/2020 to 09/22/2020) 6 hours are to be invested.
- Functional Decomposition (From 09/23/2020 to 09/29/2020) 6 hours are to be invested.
- Concepts Generation (From 09/30/2020 to 10/03/2020) 6 hours are to be invested.
- Concepts Evaluation (From 10/14/2020 to 10/21/2020) 6 hours are to be invested.
- Preliminary Design (From 10/02/2020 to 11/05/2020) 24 hours are to be invested.
- Detailed Design analysis (From 11/06/2020 to 11/21/2020) 12 hour are to be invested.
- Detailed parts specifications (From 11/22/2020 to 11/29/2020) 6 hours are to be invested.
- Budget & Project Cost (From 11/02/2020 to 12/06/2020) 24 hours are to be invested.
- Purchasing (From 01/25/2021 to 02/06/2021) 12 hours are to be invested.
- Fabrication & Testing. (From 02/07/2120 to 04/16/2120) 6 hours are to be invested.
- Final Presentation for Senior 1(From 04/17/2120 to 05/12/2120) 6 hours are to be invested.

Table 2.1 is an organized representation of each task, subtasks and deliverables the group judged important to be performed for the goals and objectives of the project to be reached. The timeline has also been divided in a way that each deliverable would have a specific time during which it has to be completed which is breaking the whole project into smaller and more achievable goals. The group will work in the most diligent way to make good use of its time.

Table 2.1 Detailed Project Tasks, Objectives, Deliverables, Task Duration & Responsible Personnel

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
1. Problem Formulation	1.1 Identify clients and Recognize need	To identify the consumer that may need the product and understand the reason why the product needs to be built	A list of at least 4 potential customers & why they will need our product .	3	9/2	9/4	Marcelo Epam Ona/Christian White
	1.2 Define goals	To have a clear understanding of the output that is needed	A list of objectives such as how the design of this heat transfer measuring system will expel any confusion about how nanofluids interact with different boundary conditions.	3	9/2	9/4	Christian White
	1.3 Define objectives.	To have clear cut objectives while designing the product					
	1.4 Identify the constraints and operating environment.	To understand the limitation of the design and the product	zoom meeting setup, a list of 4 different constraints, formulation of the problem statement.	2	9/3	9/4	Yemboado YONLI
			A list of all measurable performance characteristics with units. A well-drawn and labelled objective tree showing hierarchical relationships and interconnections of the performance characteristics. A list of permissible range for the design parameters, description of the environment in which the design will operate and specifying why different constraints will hinder successful experiments.	5	9/4	9/8	Marcelo Epam Ona/Abdullah El Aker
Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
2. Project Planning	2.1 Identify the tasks	To have a schematic and a clear idea about what the project and its different tasks will look like.	A list of all the tasks needed to be accomplished for the project.	2	9/10	9/11	Diana Morales
	2.2 Develop objectives for each task	To develop objectives (actions needed) for each task.	Detailed list of specific requirements to assure completion of each individual task.	2	9/10	9/11	Fanta Kaba
	2.3 Set up a timeline	To set up estimate dates in which each task might be completed.	Various dates of meetings that involve discussion and time spent applying what has been discussed into the project.	3	9/12	9/14	Fanta Kaba
	2.4 Create a Gantt chart.	To give a visual representation of the timeline	Physical Gantt Chart to give a detailed description of time spent in a 24 hour day.	2	9/14	9/15	Abdullah El Aker

3. Literature Review	3.1 Identify potential sources and relevant information. 3.2 Study convection of nanofluids. 3.3 Study convection of nanofluid under different boundary conditions 3.4 Study measurement techniques of convection and their advantages 3.5 Identify and collect of comparable results 3.6 Conclude the literature review	To understand the background of the project and I have a clear idea of what it is needed for each task to be completed. To understand the mechanism behind convection heat transfer for nanofluids To understand how a change of boundary condition like magnetic field will affect the properties of the nanofluid to identify different measurement technique for convection and sort them out to to get the one that will work best for that project To obtain a range of results that will help make sure that experiment is generating satisfying results To summarize all the information obtained and organize them in a way that will be beneficial for the project	A list of research previously found about convection of nanofluid A list of papers about heat convection of nanofluids under different boundary conditions. A thorough documentation on measurement techniques for convection and their advantages A choice of the most advantageous measurement technique A good understanding on the instrumentations used for the experiment A list of comparable results Conclusion of literature review	2 2 2 2 2 2 1	09/16 09/16 09/17 09/18 09/18 09/20 09/21 09/22	09/18 09/18 09/19 09/20 09/20 09/21 09/22	Marcelo Epam Ona/Christian White Diana Morales/Fanta Kaba Yemboado YONLI Yemboado Yonli/Christian White Marcelo Epam Ona/Abdullah El Aker Christian White
Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
4. Functional Decomposition	4.1 Use strategies used to develop Level 1 Sub functions. 4.2 Use strategies used to develop Level 2 Sub functions. 4.3 Develop the Morphology Table.	To define the general function and what is to be accomplished by the system To define the main functions of what is to be accomplished To break each second level function into sub function until the point of basic functionality	A definition of the major task based on the project statement A List of all ask the major task can be divided in to have more attainable goals a breakdown of the second level function into subfunctions An assignment to each group member of a task to build up in order to complete the project.	1 2 3 2	09/23 09/24 09/25 09/27	09/24 09/26 09/28 09/29	Christian White/Marcelo Epam Ona/Abdullah El Aker Yemboado YONLI/Fanta Kaba Diana Morales/Cristian White/Abdullah El Aker Yemboado Yonli/ Marcelo Epam Ona/Fanta Kaba

5. Concept Generation	5.1 Generate techniques for generating concepts from functions. 5.2 Develop a conceptual design of the experimental set up that would be based on the properties of nanofluid and the boundary conditions that would be applied	To Generate concepts using concept generation techniques To Consolidate individual concepts and sketches into team concepts for each function.	Techniques to generate a concept would be brainstorming, developing, and communicating abstract ideas. Combining individual concepts and sketches by communicating collectively on the concept each person has come up with. Then choosing the best concepts that are aligned with the scope of the project.	2 3	09/30 10/3	10/2 10/05	Christian/ Fanta/Bryan/Marcelo/Diana/Abdullah Christian/ Fanta/Bryan/Marcelo/Diana/Abdullah
Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person

6. Concept evaluation	6.1 Evaluate based on Go-No-Go 6.2 Evaluate based on decision matrix	To select and acquire relevant information based on how it might relate to the project. Decisions will be made based on a descriptive matrix evaluation method.	Select 4 merits that may meet the needs of the customer. Select the best choice from the matrix with an explanation on why it was selected.	6 1	10/14 10/19	10/19 10/20	Diana Morales/Cristian White/Abdullah El Aker Yemboado Yonli/ Marcelo Epam Ona/Fanta Kaba
7. Preliminary Design	7.1 Make the design Sizing & Components Analysis 7.2 Develop methods for design analysis 7.3 Apply ASME Codes & Standards 7.4 Consider public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors in Design.	Where the project must be designed and analyzed, it is essentially a decision-making process in which analytical tools are derived from basic sciences. Where the different methods used have to be chosen and accommodated to its respective part of the project. Where the different rules and ethics must be applied in order to obtain the best of the product. Where it must be made sure that the product is safe for consumers and that it will be used in its designated environment	Select the proper tools needed for the experiment to give the desired results. A proper method is chosen for each respective part so that the experiments give needed results as expected. Defining 5 rules that are necessary for this experiment to function with the most accurate results. List at least 10 rules that would make this experiment safe for consumers and environment.	5 4 4 4	10/21 10/26 10/29 11/02	10/28 10/30 11/023 11/05	Diana Morales/ Cristian White/Abdullah El Aker Yemboado Yonli/ Marcelo Epam Ona/Fanta Kaba Diana Morales/ Cristian White/Abdullah El Aker Yemboado Yonli/ Marcelo Epam Ona/Fanta Kaba
Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person

8. Detailed design	8.1 Design CAD models of project parts & components 8.2 Develop Engineering Drawings from part models 8.3. Develop sub-system assembly and system assembly	Generating a design of the different parts needed with the precise measurements. Having access to different apps and software that can give a perspective or schematic of how the project will look like. Creating a simpler system that can be used to assemble all the different parts of the experiment. Making sure that each part fits perfectly and functions accordingly.	The designed parts needed are generated with precise measurement. A schematic of the design is obtained through the different mechanical software, which could be NX or AutoCAD. A simpler system is created to assemble all the different parts of the experiment. It is made sure that each part fits and works for the purposes it was made for. Every part of the design fulfills its task.	7 7 5	11/06 11/12 11/16	11/13 11/19 11/21	White/Marcelo Epam Ona/Abdullah El Aker Yemboado YONLI/Fanta Kaba Diana Morales/ Cristian White/Abdullah El Aker
9. Detailed part Specification	9.1 specify of parts 9.2 Identify the use of each part	To be able to identify each part To identify the utility of each part	Identify each part Determine the utility of each part build each part	3 3 2	11/22 11/24 11/27	11/25 1/27 11/29	White/Marcelo Epam Ona/Abdullah El Aker Yemboado YONLI/Fanta Kaba Diana Morales/Cristian White
10. Budget and Project cost	10.1 Identify the material needed for the parts 10.2 Identify parts that can directly be bought 10.3 Identify manufacturing cost 10.4 Summarize into a budget that can cover all costs	to know what should be bought To identify what does not need to be bought but can be directly acquired To know how much it would cost on average for manufacturing the part To create a sound budget and make sure that every dollar is properly spent.	Determine the material needed and where it can be found identify every part that can be directly bought identify the cost of the part that can be directly acquired add the supposed cost together set up a final budget	3 2 2 2 2	11/30/20 12/01/20 12/02/20 12/03/20 12/04/20	12/02/20 12/03/20 12/04/20 12/05/202 12/06/20	Christian White. Fantakaba/Diana Morales. Yemboado Yonli Marcelo Epam Ona Abdullah El Aker
Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person

11. Purchasing	11.1 Research Vendors able to manufacture the needed parts based on the Design 11.2. Have the Vendors Generate quotes. 11.3 Generate a cost quality analysis 11.4 Choose the vendor that best suits Project Budget	To list the companies or manufacturers that can build the parts needed to develop the product. To list the possible vendors or providers of the different parts needed for the project, contact them to get an estimate on the prices and delivery dates. To come out with a budget of what they need and what they might not for the desirable project. To pick the parts to satisfy their needs at lower cost possible and at the highest quality available.	Prepare a list of the parts specifications to be purchased and manufactured. Prepare Detailed drawing and prototypes of desired parts. List 3 or more quotes of parts more than $50 List the parts with prices and quotes for the product. Purchase the parts and start manufacturing. Test and inspect the parts to proceed to assembly of the product.	13 13 13 13	01/25 01/25 01/25 01/25	02/06 02/06 02/06 02/06	Yemboado Yonli Marcelo Epam Ona Fanta Kaba Diana Morales Abdullah El Aker Christian White
12. **Manufacturing and Assembly of the Product**	12.1 **Manufacture part based of the design** 12.1 Assemble **of the part**	To have tangible parts To assemble the parts and verify the functionality of the designed product	Prepare detailed codes and standards used in the project. Establish a detailed plan for manufacturing and assembly of the product. Risk assessment and identifications of critical issues for in depth analysis. Assemble the parts to meet the project requirements. Test the product and collect measurements and data	20 20 14 10 10	02/07/21 02/27/21 03/11/21 03/25/21 04/06/21	02/27/20 03/11/21 0\3/25/21 04/05/21 04/16/21	Yemboado Yonli/Marcelo Epam Ona Fanta Kaba Diana Morales Abdullah El Aker Christian White
Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person

13. **Final senior Design Presentation**	13.1 Detailed Project Presentation of the Problem	To make the audience understand the task at hand.	Utilizing Microsoft PowerPoint, a specific slide will be incorporated defining the problem.	7	04/17/21	04/24/21	Yemboado Yonli
	13.2. Detailed Explanation on the Project Planning	Show how the project has been divided into multiple steps that allow its good development.	Reference the timeline and Gantt chart created earlier in the project. Create a list of steps taken to create our physical system.	7	04/19/21	04/23/21	Marcelo Epam Ona
	13.3. Detailed Presentation on the literature Review	A brief overview of the information that has been found on previous projects of that same kind and how it helped the concept generations.	Show our helpful documents conducted through individual research within the group pertaining to specific functions of the project.	7	04/23/21	04/30/21	Fanta Kaba
	13.4. Detailed Presentation of functional decomposition	Make the audience understand the material, energy and information inputs and outputs for the overall and the subfunctions.	Show various components of the system and explain why they have been chosen.	7	04/24/21	05/01/21	Diana Morales
	13.5. Detailed presentation on the concept generation	To present to the audience the concept chosen and the reason why this concept was the most acceptable for this project	Show personal meeting notes with the project advisor and professors who have insight on this specific project. Show feedback given by professors who grade weekly assignments.	7	04/27/21	05/03/21	Abdullah El Aker
	13.6. Detailed presentation on the design analysis	Present to the audience how the design must be generated based on the concept that was brought up and how the design will be created.	Create bullets points on the concept behind the experiment and its functionality and why it works on PowerPoint slides.	7	05/01/21	05/08/21	Christian White
	13.7. The etiquette and laws of the project	To show to the that the rules and laws of the engineering world were respected	Make a list of rules that were abided by that show rules were followed.	7	05/05/21	05/12/21	Diana Morales

2.3 Gantt Chart

Using the Gantt chart will help the group member to stay on top of the project and its tasks, we can easily access the Gantt chart to look at the day and what we are supposed to do and accomplish, this way is more efficient than looking for each major task and subtask individually. We were able to identify each task and what needs to be done to complete the milestone. Currently we completed the first 3 major tasks of the report as shown in Table 2.1. At the moment we are completing the 4th major task as shown in Table 2.1 and by looking at Table 2.1 we can tell by next week we have to start the work on the major task 5 and finish before October 5th, 2020 to be able to stick with the deliverables and the milestone of that task.

Table 2.2 shows the Gantt chart of the Major task and its corresponding sub-tasks for Fall 2020

ID	Task Name	Duration	Start	Finish
1	1. Problem formulation	5 days	Wed 9/2/20	Tue 9/8/20
2	1.1 Identify the consumer that may need the product and understand the reason why the product needs to be	3 days	Wed 9/2/20	Fri 9/4/20
3	1.2 Have a clear understanding of the output that is needed	3 days	Wed 9/2/20	Fri 9/4/20
4	1.3 Have clear cut objectives while designing the product	2 days	Thu 9/3/20	Fri 9/4/20
5	1.4 Understand the limitation of the design and the	3 days	Fri 9/4/20	Tue 9/8/20

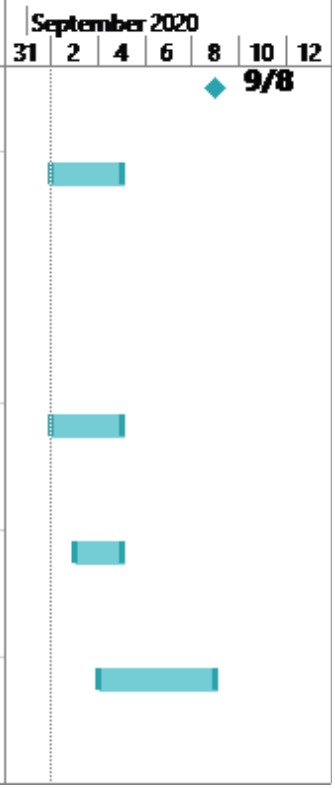


Table 2.2 shows the Gantt chart of the Major task and its corresponding sub-tasks for Fall 2020

ID	Task Name	Duration	Start	Finish
8	2.1 Have a schematic and a clear idea about what the project and its different tasks will	2 days	Thu 9/10/20	Fri 9/11/20
9	2.2 Develop objectives (actions needed) for each	2 days	Fri 9/11/20	Sat 9/12/20
10	2.3 Set up estimate dates in which each task might be completed.	2 days	Sat 9/12/20	Mon 9/14/20
11	2.4 Give a visual representaation of the timelime	2 days	Mon 9/14/20	Tue 9/15/20

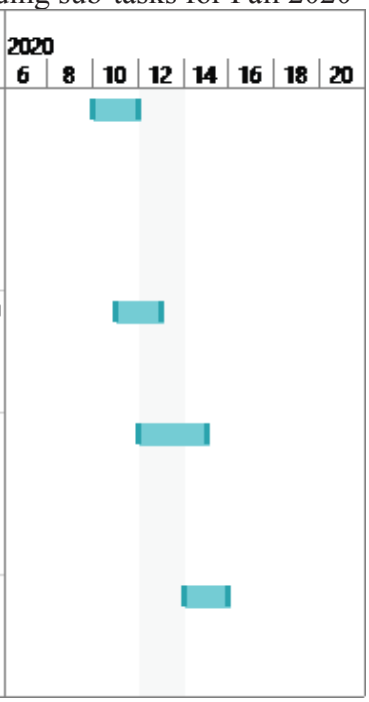


Table 2.2 shows the Gantt chart of the Major task and its corresponding sub-tasks for Fall 2020

ID	Task Name	Duration	Start	Finish
12	3 Literature Review	4 days	Wed 9/16/20	Mon 9/21/20
13	3.1 Understand the background of the project and I have a clear idea of what it is needed for each task to be completed.	3 days	Wed 9/16/20	Fri 9/18/20
14	3.2 Understand the mechanism behind convection heat transfer for	3 days	Wed 9/16/20	Fri 9/18/20
15	3.3 Understand how a change of boundary condition like magnetic field will affect the properties of the	3 days	Thu 9/17/20	Sat 9/19/20
16	3.4 Identify different measurement technique for convection and sort them out to to get the one that will work best for that	2 days	Fri 9/18/20	Sun 9/20/20
17	3.5 Obtain a range of results that will help make sure that experiment is generating satisfying results	2 days	Sun 9/20/20	Mon 9/21/20
18	3.6 Conclusion of the literature review	2 days	Mon 9/21/20	Tue 9/22/20

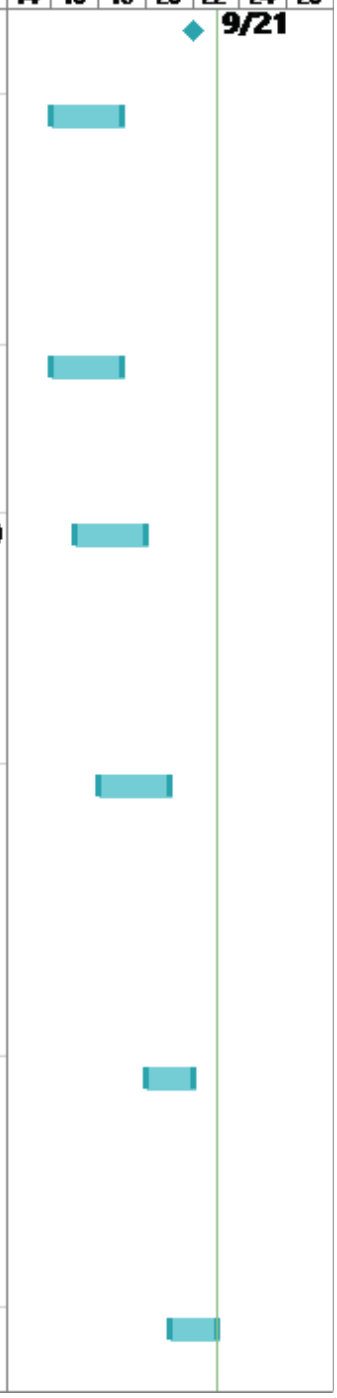


Table 2.2 shows the Gantt chart of the Major task and its corresponding sub-tasks for Fall 2020

ID	Task Name	Duration	Start	Finish
19	4. Functional Decomposition	5 days	Wed 9/23/20	Tue 9/29/20
20	4.1 Define the general function and what is to be accomplished by the	2 days	Wed 9/23/20	Thu 9/24/20
21	4.2 Define the main functions aof what is to be accomplished	3 days	Thu 9/24/20	Mon 9/28/20
22	4.3 Break each second level function into sub function until the point of	3 days	Sun 9/27/20	Tue 9/29/20

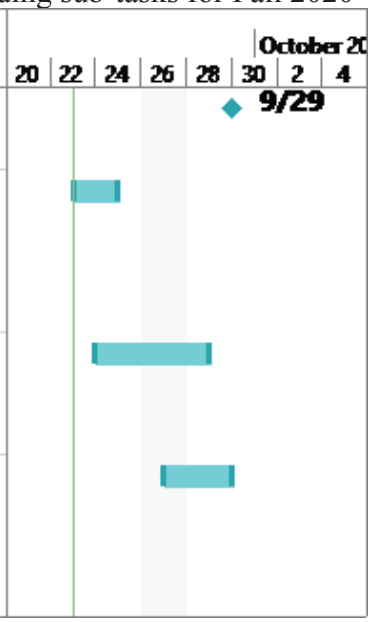


Table 2.2 shows the Gantt chart of the Major task and its corresponding sub-tasks for Fall 2020

ID	Task Name	Duration	Start	Finish
23	5. Concept Generation	4 days	Wed 9/30/20	Mon 10/5/20
24	5.1 Generating concepts using concept generation	3 days	Wed 9/30/20	Fri 10/2/20
25	5.2 Consolidating individual concepts and sketches into team concepts for each function.	2 days	Sat 10/3/20	Mon 10/5/20

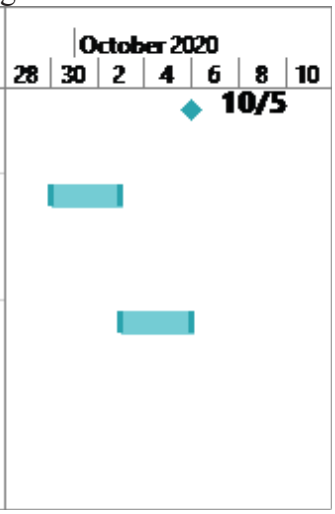


Table 2.2 shows the Gantt chart of the Major task and its corresponding sub-tasks for Fall 2020

ID	Task Name	Duration	Start	Finish
26	6. Concept evaluation stage	5 days	Wed 10/14/20	Tue 10/20/20
27	6.1 Select and acquire relevant information based on how it might relate	4 days	Wed 10/14/20	Mon 10/19/20
28	6.2 Decisions will be made based on a descriptive matrix evaluation method.	2 days	Mon 10/19/20	Tue 10/20/20

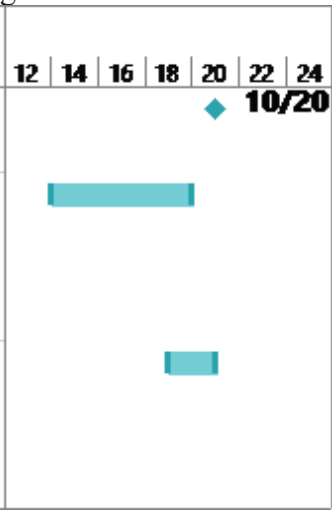


Table 2.2 shows the Gantt chart of the Major task and its corresponding sub-tasks for Fall 2020

ID	Task Name	Duration	Start	Finish
29	7. Preliminary Design	12 days	Wed 10/21/20	Thu 11/5/20
30	7.1 Select the proper tools needed for the experiment in order to give the desired results.	6 days	Wed 10/21/20	Wed 10/28/20
31	7.2 A proper method is chosen for each respective part so that the experiments give needed results as expected.	5 days	Mon 10/26/20	Fri 10/30/20
32	7.3 Defining 5 rules that are necessary for this experiment to function with the most accurate	3 days	Thu 10/29/20	Mon 11/2/20
33	7.4 List at least 10 rules that would make this experiment safe for consumers and environment.	4 days	Mon 11/2/20	Thu 11/5/20

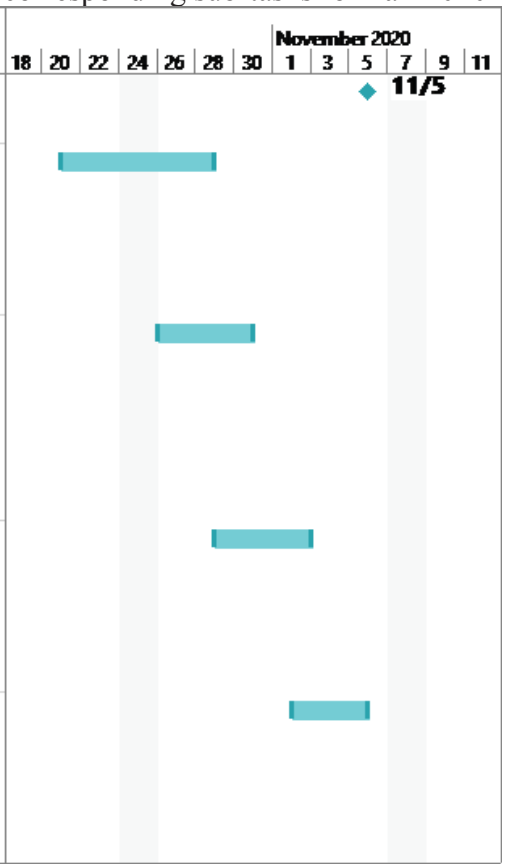


Table 2.2 shows the Gantt chart of the Major task and its corresponding sub-tasks for Fall 2020

ID	Task Name	Duration	Start	Finish
34	8. Detailed Design Analysis	12 days	Fri 11/6/20	Sat 11/21/20
35	8.1 Where the project has to be designed and analysed, it is essentially a decision-making process in which analytical tools are derived from basic	6 days	Fri 11/6/20	Fri 11/13/20
36	8.2 Where the different methods used have to be chosen and accommodated to its respective part of the	6 days	Fri 11/6/20	Fri 11/13/20
37	8.3 Where the different rules and ethics have to be applied in order to obtain the best of the product.	6 days	Thu 11/12/20	Thu 11/19/20
38	8.4 Where it must be made sure that the product is safe for consumers and that it will be used in its designated environment	6 days	Mon 11/16/20	Sat 11/21/20

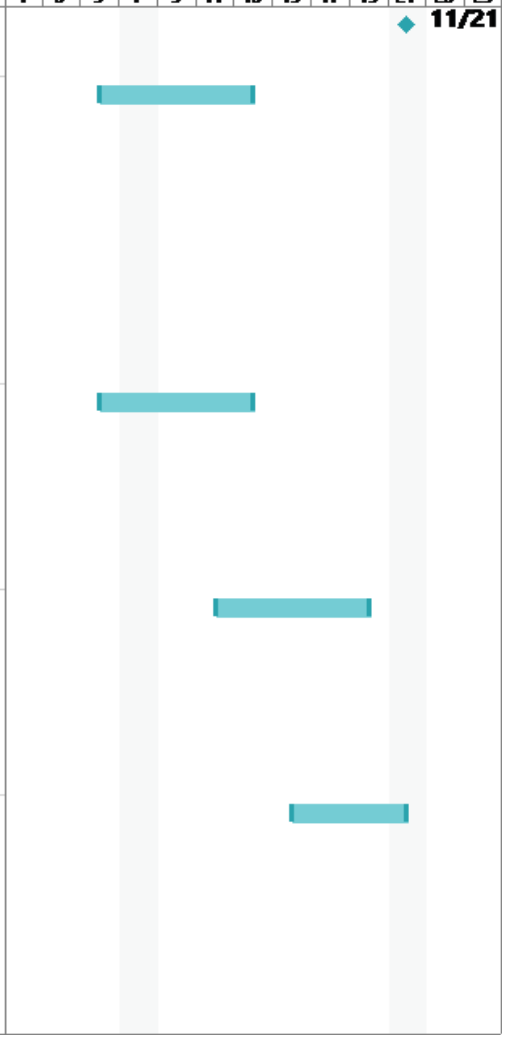


Table 2.2 shows the Gantt chart of the Major task and its corresponding sub-tasks for Fall 2020

ID	Task Name	Duration	Start	Finish
39	9. Detailed part Specification	14 days	Wed 11/11/20	Mon 11/30/20
40	9.1 Identify each part	14 days	Wed 11/11/20	Mon 11/30/20
41	9.2 Determine the utility of each part	7 days	Thu 11/12/20	Fri 11/20/20
42	9.3 Build each part	14 days	Wed 11/11/20	Mon 11/30/20

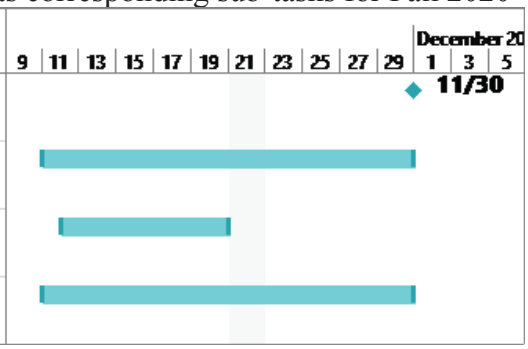


Table 2.2 shows the Gantt chart of the Major task and its corresponding sub-tasks for Fall 2020

ID	Task Name	Duration	Start	Finish
43	10. Budget and Project cost	2 days	Wed 12/2/20	Thu 12/3/20
44	10.1 Determine the material needed and where it can be	2 days	Wed 12/2/20	Thu 12/3/20
45	10.2 Identify every part that can be directly bought	1 day	Wed 12/2/20	Wed 12/2/20
46	10.3 Identify the cost of the part that can be directly	1 day	Wed 12/2/20	Wed 12/2/20
47	10.4 Add the supposed cost	1 day	Wed 12/2/20	Wed 12/2/20
48	10.5 Set up a final budget	1 day	Wed 12/2/20	Wed 12/2/20

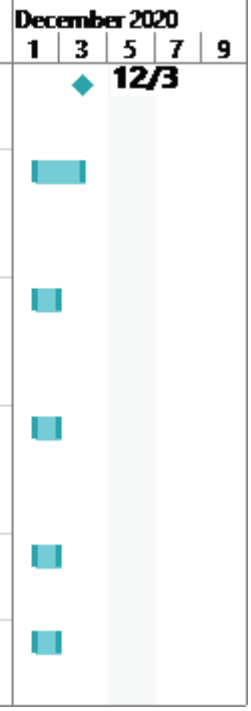


Table 2.3 shows the Gantt chart of the Major task and its corresponding sub-tasks for Spring 2021

ID	Task Name	Duration	Start	Finish
49	11. Purchasing	11 days	Mon 1/25/21	Sat 2/6/21
50	11.1 list the companies or manufacturers that are able to build the parts needed to develop the product.	11 days	Mon 1/25/21	Sat 2/6/21
51	11.2 List the possible vendors or providers of the different parts needed for the project, contact them to get an estimate on the prices and	11 days	Mon 1/25/21	Sat 2/6/21
52	11.3 Come out with a budget of what they need and what they might not for the desirable project.	11 days	Mon 1/25/21	Sat 2/6/21
53	11.4 Pick the parts to satisfy their needs at lower cost possible and at the highest quality available.	11 days	Mon 1/25/21	Sat 2/6/21

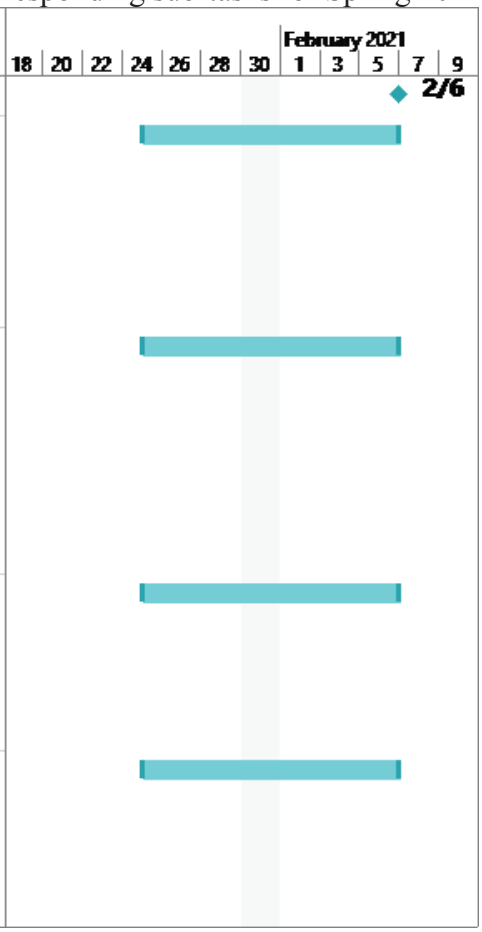


Table 2.3 shows the Gantt chart of the Major task and its corresponding sub-tasks for Spring 2021

ID	Task Name	Duration	Start	Finish
54	12. Manufacturing and Assembly of the Product	51 days	Sun 2/7/21	Fri 4/16/21
55	12.1 Prepare detailed codes and standards used in the project.	17 days	Sun 2/7/21	Sat 2/27/21
56	12.2 Establish a detailed plan for manufacturing and assembly of the product.	25 days	Sun 2/7/21	Thu 3/11/21
57	12.3 Risk assessment and identifications of critical issues for in depth analysis.	11 days	Thu 3/11/21	Thu 3/25/21
58	12.4 Assemble the parts to meet the project requirements.	8 days	Thu 3/25/21	Mon 4/5/21
59	12.5 Test the product and collect measurements and data	9 days	Tue 4/6/21	Fri 4/16/21

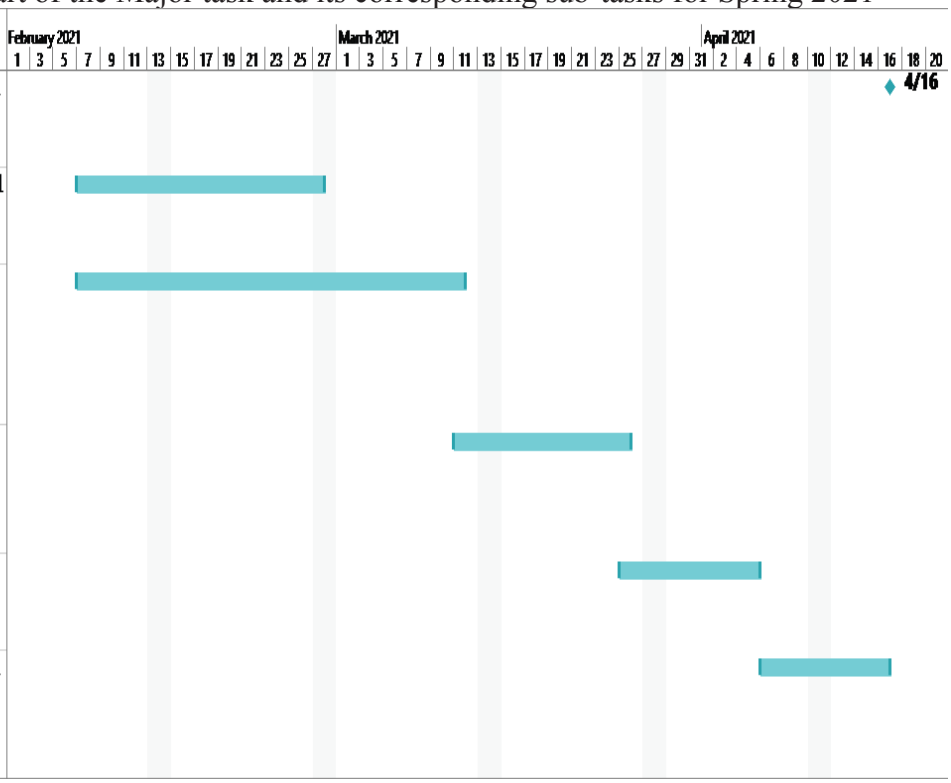
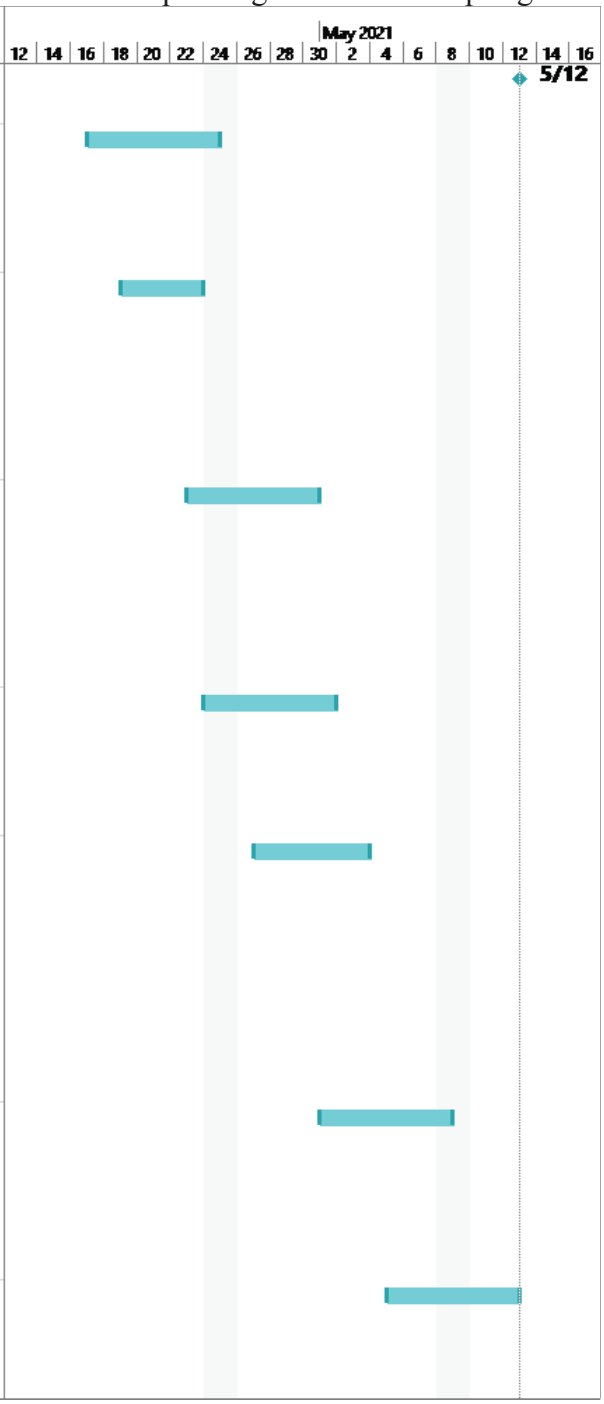


Table 2.3 shows the Gantt chart of the Major task and its corresponding sub-tasks for Spring 2021

ID	Task Name	Duration	Start	Finish
60	13. Final senior Design Presentation	19 days	Sat 4/17/21	Wed 5/12/21
61	13.1 Utilizing Microsoft Powerpoint, a specific slide will be incorporated defining	7 days	Sat 4/17/21	Sat 4/24/21
62	13.2 Reference the timeline and Gantt chart created earlier in the project. Create a list of steps taken to create our physical system.	5 days	Mon 4/19/21	Fri 4/23/21
63	13.3 Show our helpful documents conducted through individual research within the group pertaining to specific functions of the	6 days	Fri 4/23/21	Fri 4/30/21
64	13.4 Show various components of the system and explain why they have been chosen.	7 days	Sat 4/24/21	Sat 5/1/21
65	13.5 Show personal meeting notes with the project advisor and professors who have insight on this specific project. Show feedback given by professors who grade weekly	5 days	Tue 4/27/21	Mon 5/3/21
66	13.6 Create bullets points on the concept behind the experiment and its functionality and why it works on	7 days	Sat 5/1/21	Sat 5/8/21
67	13.7 Make a list of rules that were abided by that show rules were followed.	6 days	Wed 5/5/21	Wed 5/12/21



3. LITERATURE REVIEW

The purpose of this project is to design a proper method to measure the convection transfer coefficient for nanofluids under different boundary conditions. In order to completely understand the scope of this experiment, the identification of relevant information is necessary to ensure the functionality in the measurement technique selected. Relevant sources are reviewed to establish a well-planned literature review, which focuses on examining existing similar designs and its components, relevant design analysis methods, fabrication, and testing, as well as, relevant codes and standards.

3.1 Identification of Information Relevant to the Project

These specific resources were determined through intense study and research to better understand the scope of our specific project. This project is a design of a system that will efficiently measure heat transfer coefficient and effective thermal conductivity in nanofluids under different boundary conditions. Knowing that, it was determined that the best way to approach this project was by first researching other experiments conducted by professionals who have studied the different types of nanofluids, as well as respective measuring techniques. It was also determined that research on the concentration of nanoparticles, controlled parameters, and hybrid nanofluids will help to gain an understanding for the design of this project.

The types of information to be reviewed to understand the systematic approach for measuring the heat transfer coefficient and effective thermal conductivity in nanofluids consists of past experimental projects, research documents that highlight the study of nanofluids under different boundary conditions, studies stating the effects of temperature and nanoparticles concentration, documents that describe multiple measuring techniques regarding a nanofluids heat transfer coefficient, documents that determine efficient measurement techniques for the measuring of thermal conductivity, a review on the control parameters of natural convection, and lastly, the review of past experiments for the determination of viscosity of water-based magnetite nanofluid in heating and cooling systems. Determination of viscosity of water-based magnetite nanofluid in heating and cooling systems.

3.2 Potential Sources of Information for Project

These references were identified by the group to state that the following resources are the best options to efficiently understand the system for this project. The reference list contains articles which were written by professionals who have studied different measuring techniques as well as nanoparticles related to various boundary conditions.

- Masoud, M.E., *"Experimental study on thermal conductivity of water-based Fe3O4 nanofluid: Development of a new correlation and modeled by artificial neural network"* Islamic Azad University, Najafabad, Iran pp 262-269

- Masoud, M.E., *"Effects of temperature and nanoparticles concentration on rheological behavior of Fe3O4–Ag/EG hybrid nanofluid: An experimental study"*Islamic Azad University, Najafabad, Iran pp 38-44

- Colmanetti, P.O., *"Heat transfer coefficient: a review of measurement techniques"*Heat Transfer Research Group, Department of Mechanical Engineering, Sao Carlos School of Engineering, University of São Paulo pp 264

3.3 Existing Similar Designs & Functions

In the process of learning more about measuring the heat transfer coefficient of nanofluid (h), a few devices capable of doing so were discovered. Each Design brings with it a lot of advantages but also some disadvantages. Care has been put into finding devices that were used in experiment with conditions as similar as the one this group is aiming to perform. For that matter two designs were identified.

3.3.1 Design 1

An interesting device was the one used by S. Rostami, E. Raki, A. Abdollahi, A. S. Goldanlou [1], which is represented by Figure 3.1

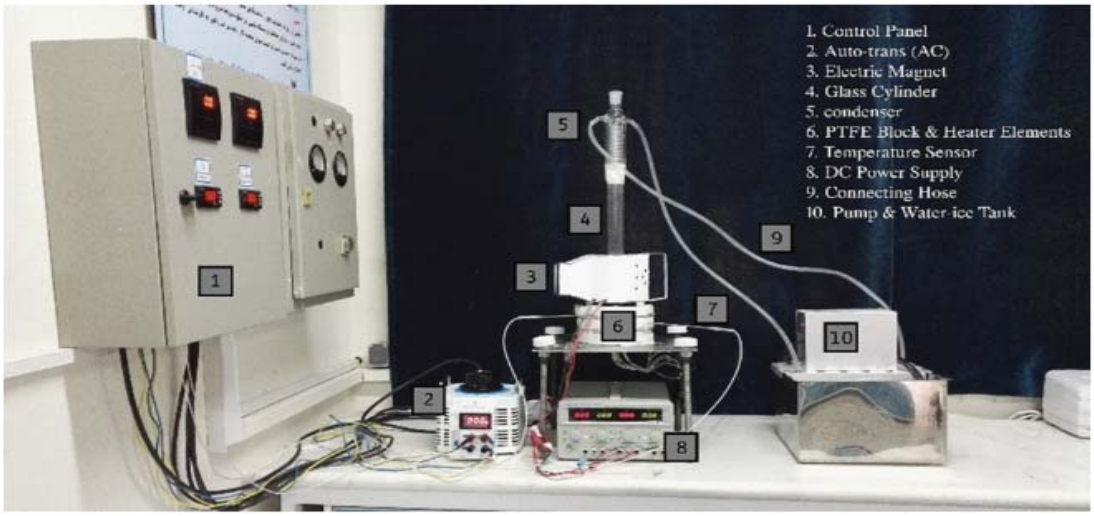


Figure 3.1 An overview of the device used by S. Rostami, E. Raki , A. Abdollahi , A. S. Goldanlou [1]

According to Fig. 3.1, the pool boiling device with the specified components was utilized to calculate the heat transfer in the pool boiling. The components of the device, in accordance with the performed numbering, include the control panel, DC power supply, temperature sensors, electric magnet, boiling glass cylinder condenser, cooling water pipes, pump, cold water tank, Teflon body (insulated), autotrans, and heat elements.

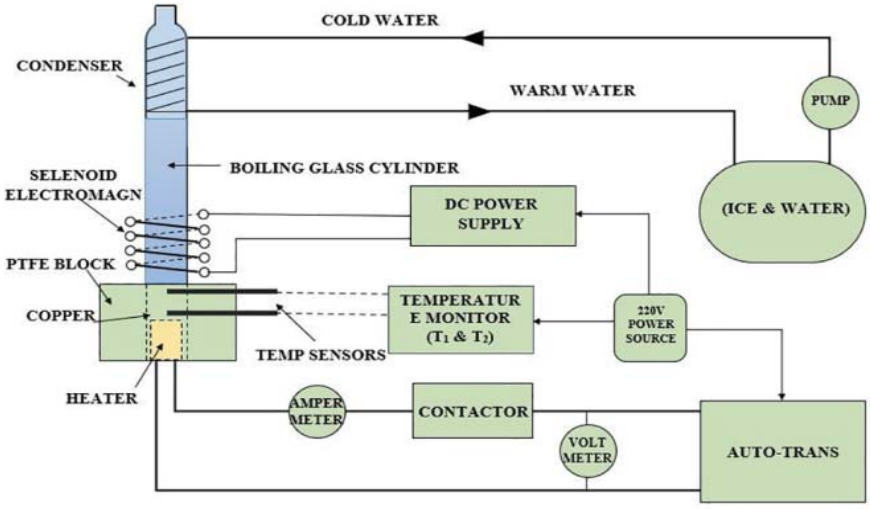


Figure 3.2 The operational diagram of the device

According to Figs. 3.1 and 3.2, the application of the introduced components includes: the control panel has a monitoring system for the ampere, the input voltage (Autonics TC4Y) to the heat elements, and the temperature of the resistance temperature detector (RTD) sensors embedded in the copper block. The copper block is cylindrical with high purity, with a diameter of 40 mm and a length of 90 mm. The thermal conductivity

coefficient of the high purity copper was measured using a KD2 Pro device manufactured by the Decagon Company (401 W/m.K). The whole copper wall is completely threaded. The length of the thread pitches is 2 mm. Four steel elements (electric heaters) with a diameter of 6 mm and a length of 40 mm, with 200 W power each, are embedded inside the copper cylindrical block from below. The copper cylindrical block is heated by these four elements. The Teflon cylinder has a height of 90 mm and a diameter of 150 mm. The Teflon around the copper is polytetrafluoroethylene (PTFE), where its thermal conductivity coefficient is measured using the KD2 Pro device (0.25 W/m.K). Due to the insulation effect of PTFE Teflon around the copper block, the radial heat transfer is ignored. The copper cylinder is Teflon-wrapped and fastened in the hole using the threads on its exterior wall. PTFE tapes, produced by the Sitco Company with ISO9001 standard, were also used on the threads of the copper wall to prevent the fluid leakage. The positions of the sensors, the heat elements, and the copper block are shown in Fig. 3.3. The sensors are passed through a hole with a diameter of 3 mm and placed in the center of the copper block. The upper surface of the copper block is in touch with the fluid, and the glass cylinder into which the fluid is poured is installed on top of it using holding clips. The height of the glass is 350 mm, its external diameter is 40 mm, and the thickness of the wall is 3 mm. An electromagnet, which is generated using a solenoid and a tubular core is installed around the glass cylinder (Fig. 3.4). This magnet has a variable magnetic field intensity that changes by changing the input ampere of the magnet. The intensity of the magnetic field was examined and measured using a magnetometer (Lutron MG-3003SD) in several steps and for various amperes. By generating magnetic fields with a maximum capacity of 1000 gauss in the wall of the metal core and 300 gauss in the central core, this device is designed and produced for a maximum amperage of 10 A DC and is set up using a DC power supply. Its contour and field direction are shown in Fig. 3.5. The condenser, which is connected to the pump and the cold-water tank using two flexible hoses, is installed on top of the glass cylinder. The cold water is pumped to the condenser using the pump, and this circulation leads to the cooling of the condenser and conversion of the vapor produced through boiling to the fluid and returning to the initial volume of the fluid. This causes the fluid volume to be constant. According to Fig. 3.6, the top surface of the condenser is open, which causes the boiling pressure to be equal to the environment pressure. Due to the effect of the roughness of the boiling copper surface on the heat transfer, a 600-grit sandpaper was used to achieve a constant roughness for all of the experiments.

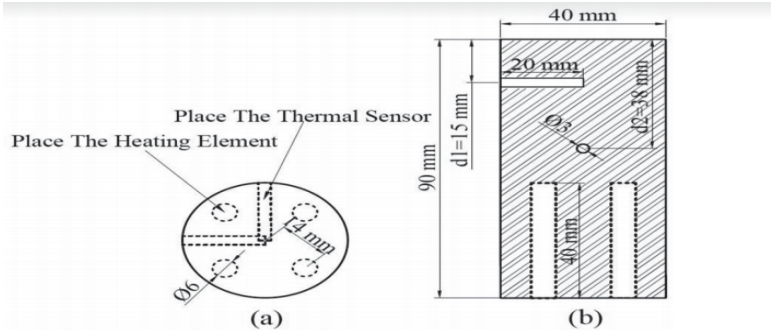


Figure 3.3 Schematic view of the position of the sensors, heat elements inside the copper block (a) from the top and (b) from the side

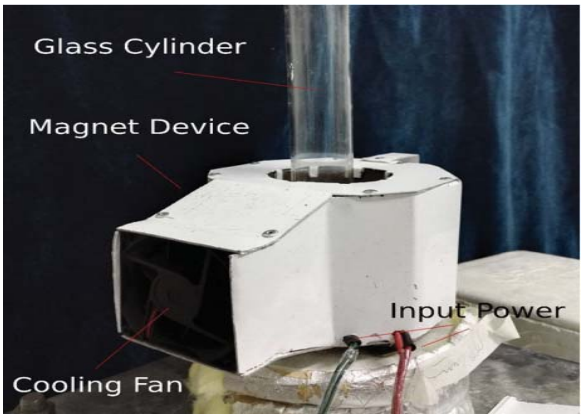
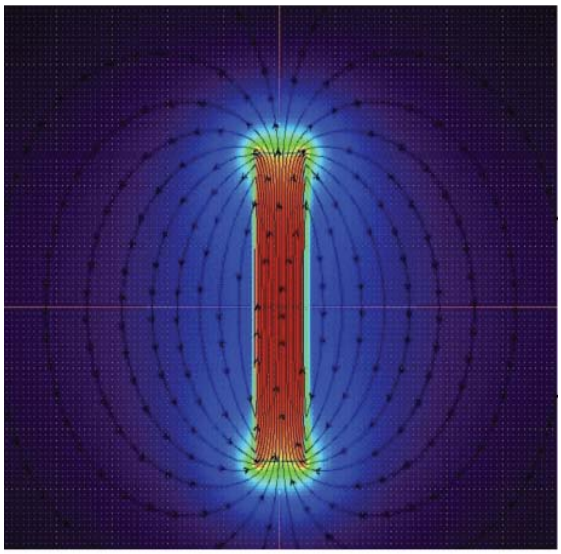


Figure 3.4 An image of the magnetic field Generator


Figure 3.5 Magnetic field contours (electromagnet with tube cores)

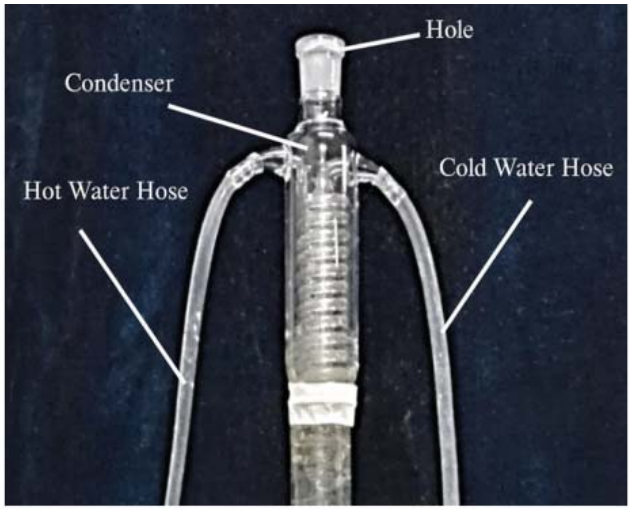


Figure 3.6 A view of the condenser used to cool the vapor down

Advantages of Design 1

The most important advantage of that device is the condition in which it has been used. the magnetic field has been changed many times, affecting then the heat transfer coefficient of the nanofluids used during the experiment. This is a major change in boundary conditions in the experiment which goes along with the kind of apparatus that would be beneficial for the current project. This also suggests that the magnetic field does not affect the material used to fabricate the experimental set up which is a huge advantage for that experiment. the insulation around the copper block also allows the heat transfer coefficient to be measured as a one-dimensional parameter which is also a good advantage

Disadvantage of Design 1

The device was used in that experiment to measure the boiling heat transfer coefficient of the nanofluid. For the experiment that group number 3 wants to practice the heat transfer coefficient does not have to be measured only at boiling point. So, the device might have to be adapted to the situation. Another problem is that the only change in boundary condition applied was the change in magnetic field. The device used by group 3 for the experiment must be able to sustain other changes in boundary conditions. Also, the device does not measure directly the temperature. the temperature must be manually calculated.

3.3.2 Design 2

Another design that looked interesting and could fit the project was the one used by [2] M. Ahmadi & G. Willing represented in Fig. ~~3.1~~. The heat transfer coefficients of prepared base and nanofluids were measured using a lab-built test rig. The entire system is made from 1⁄4 in stock copper tubing and fittings. The fluid flows from the reservoir with 1.5 l capacity through a variable speed gear pump (Grainger 6NY97). Flow rates are measured using an inline flow meter connected into an electronic readout. From here the fluid flows through a copper coil held in a hot water bath which can maintain the test fluid at any temperature from room temperature up to 96C. The fluid then enters the heat exchange section. There are two thermocouples placed in the fluid at both the inlet and outlet of this section. The section itself is formed from high thermal conductivity copper refrigerator tubing that is 1.095 m length and 0.0048 m inner diameter. Six type-T thermocouples are attached equidistant along the exterior of the copper tube in this section. The entire heat exchange section is wrapped in heat tape that provides a constant heat flux to the fluid. Two layers of insulation are wrapped around the heating tape to ensure low heat loses within the heat exchange section. Temperatures are monitored in real time using a Labview program designed for the system. The heat transfer coefficient enhancement ratio at an inlet fluid temperature of 70 C and different CuO concentrations were calculated from experimental measurements.

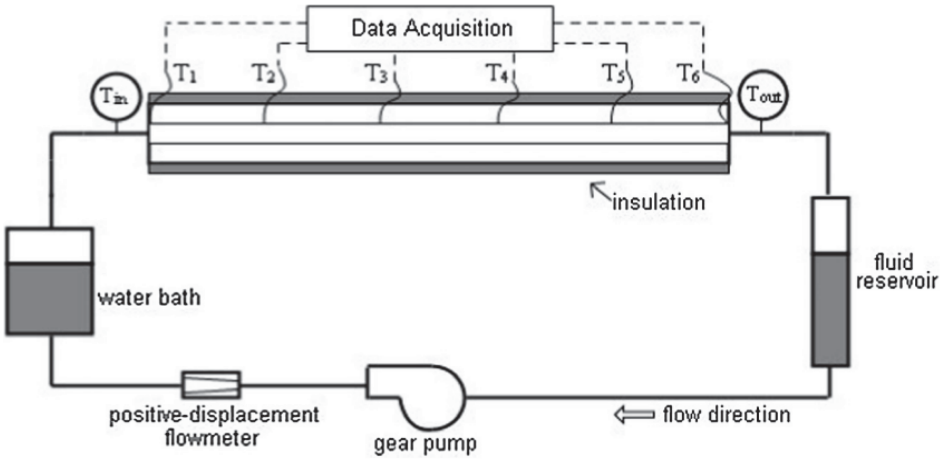


Figure 3.7 Schematic of heat transfer Test rig used by M. Ahmadi, G. Willing [2]

Advantages of Design 2
The design is simple which makes it more understandable and potentially easier to build and easier to improve. This design has a flowmeter that allows to read directly the flow of fluid going through the apparatus. The thermocouples also allow the temperature to be directly measured.

Disadvantages of Design 2
This device has been used in steady state boundary condition. the device might have to be revised in order to be able to apply boundary conditions that will only affect the fluid.

3.3.3 Design 3
The experimental set-up used in the study is B. Sahin, E. Manay,E.F. Akyurek [4] schematically shown in Figure 3.1, which consists of a heating unit, a cooling unit, a flow circulation unit, a control, and the measurement unit. The test section made from aluminum pipe has thermocouples, heater tapes, and pressure transmitters (Huba Control Inc.). The inner diameter of the aluminum test pipe with a length of 770 mm is 11.7 mm and the thickness are 1.5 mm. The test pipe was heated with coiled heaters, which provided a constant heat flux boundary condition. The heater output power was 2000 W at 187 V, and the measurement current was 10.7 A. The electrical power input to the heater was controlled by a Variac transformer to obtain constant heat flux along the test tube. The power supplied to the heater was controlled and measured with a power analyzer (Hioki USA Inc.). The outside of the test pipe was insulated with a layer of glass wool and rock wool. The flow rates were measured with an electromagnetic flowmeter (Euromag International) and the flowmeter was validated before the use. A pump, a flowmeter, a tank, and a collecting tank are used in the flow circulation unit. For the data collection, a computer, a data acquisition card, a multiplexer, and a printer were used. Two thermocouples were inserted into the flow at the inlet and outlet of the test section to measure bulk temperatures of nanofluids. The steady-state inlet and outlet bulk temperatures of the nanofluids and the surface temperature of the pipe at seven stations were measured by copper-constantan thermocouples with 0.25 mm inner diameter. The copper-constantan thermocouples were calibrated in a thermostat (Polyscience) within ±0.1∘C deviation before using them in the experiments. The readings of the thermo-couples were recorded using a computer via a data acquisition card (ADVANTEC, HG818 and 789D multiplexer), and the average of these readings was taken. The temperature of the pipe surface was taken as the average of the readings from the seven thermocouples. It is assumed that the steady state conditions were reached when the variations on each temperature station were lower than 0.5. C. Whenever the thermal equilibrium was reached, the measured data was recorded. The Reynolds number of the CuO-water nanofluid ranging from 4.000 to 20.000 was based on the bulk mean properties and the pipe inner diameter.

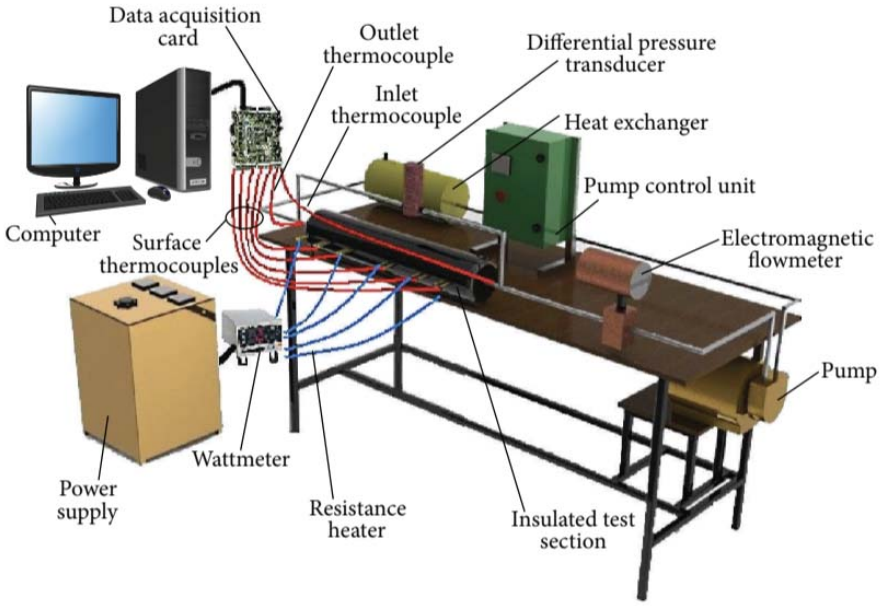


Figure 3.8 Experimental set-up [4]

Advantages
This experimental set-up is advantageous because it also measures the pressure drop of the nanofluid through the piping system. It is also a simpler apparatus that uses the voltage and the current intensity to calculate the convection heat transfer rate that allows to calculate the convection heat transfer rate and the heat transfer coefficient. The Reynolds number and Nusselt is also determined through the piping system. It also uses multiple thermocouples.

Disadvantages
The boundary conditions in the apparatus are kept stable and are not changing. This is something that has to be taken into consideration.

3.4 Codes and Standards Applied to Design

Any engineering design generated must be submitted to certain codes and standards in order to make sure that the safety of the one using it is taken into account. This is not only about safety but also about usability, cost and quality and also the innovation that is brought through the design. In the United States the ASME (American Society of Mechanical Engineers) is the one to set the standards. For this experiment the heat transfer coefficient of nanofluid is to be measured. It is to assume then that the ASME Boilers and Pressure vessel codes will be used. The code the has been taken is the code fully detailed will be listed below:

1. Section I, Power Boilers.

2. Section II, Material Specifications.

3. Section III, Rules for Construction of Nuclear Power Plant Components.

    - Division 1, Nuclear Power Plant Components.
    - Division 2, Concrete Reactor Vessel and Containments.
    - Division 3, Containment Systems and Transport Packaging for Spent Nuclear Fuel and High-Level Radioactive Waste.

4. Section IV, Heating Boilers.

5. Section V, Nondestructive Examination.

6. Section VI, Recommended Rules for Care and Operation of Heating Boilers.

7. Section VIÏ, Recommended Rules for Care of Power Boilers. Section VIII, Pressure Vessels

    - Division 1, Pressure Vessels.
    - Division 2, Pressure Vessels (Alternative Rules).
    - Division 3, Alternative Rules for Construction of High- Pressure Vessels.

8. Section IX, Welding and Brazing Qualifications. Section X, Fiber-Reinforced Plastic Pressure Vessels.

9. Section XI, Rules for In-Service Inspection of Nuclear Power Plant Components.

10. Section XII, Rules for Construction and Continued Service of Transport Tanks.

11. Code Cases: Boilers and Pressure Vessels. Code Cases: Nuclear Components.

For more detail on each section the 2017 edition of the Process Piping **Design** Handbook [3] can be visited.

As the design is supported a lot by pipes, we will try to use the ASTM codes and standards.

A typical American Standard for Testing Materials covers, among many things, the following:

- Scope.
- Referenced documents.
- Ordering information.
- Chemical composition.
- Mechanical requirements—tensile strength, yield strength^ elongation.
- Dimension, mass, and permissible variations
- Length
- Heat treatment.
- Workmanship, finish, and appearance. Additional supplementary requirements.
- End Finish
- Test
- Retest
- Safety
- Certification
- Product making

3.5 Identifying Major Components

The first design shown in Figure 3.1 by S. Rostami , E. Raki , A. Abdollahi , A. S. Goldanlou [6] has major components of control panel, DC power., supply, temperature sensors, electric magnet, boiling glass cylinder condenser, cooling water pipes, pump, cold water tank, Teflonbody (insulated), autotrans, and heat elements. The **control panel** manages the peripheral devices and communicates between the host computer and the peripheral devices. The control panels have the following functions: Consolidation of all connections to peripheral devices. Provision of power, as needed, to peripheral devices. In other words, it connects the module with a computer and maintains the power and input between the two. it also can be used as the command center of the module/design. The **DC power** converts direct current coming from the power source (a battery) from one voltage level to another depending on the point-in-time needs of the device being supplied. ... Just like with AC power supplies, DC-DC power supplies may use regulators to smooth out the signal and eliminate ripple voltage. It can be summed to the control center of the power going in and out of the device to the module. The **temperature sensors** convert thermal energy sent from an object in a wavelength range of 0.7 to 20 um into an electrical signal that converts the signal for display in units of temperature after compensating for any ambient temperature. These sensors are used to measure temperature when: Thermocouples or probes cannot be used. Another program can be used with correlation of the data collected from the sensors to shut down the module if the temperature is going above or below the safe limit. The electromagnet can be used to generate electricity with adding a coil of wire or moving it around one. It pushes the electrons in the wires and creates an electrical current, it will then convert kinetic energy into electrical energy (power). The **Condenser** condenses incoming refrigerant vapor into liquid, a compressor to raise the pressure of the refrigerant and move it along, and a fan for blowing outside air through the heat exchanger section to cool the refrigerant inside. The amount of cooling will depend on the temperature sensors. The condenser must have access to a low temperature reservoir (cold water tank) and will be moved inside pipes. The **Teflonbody** is used to coat the parts to insulate any heat or energy loss. The **Storage** is where the energy is being conserved.

Another design used by M. Ahmadi & G. Willing in Figure 8 has some similarity in the major components. The **pump** moves thermal energy in the opposite direction of spontaneous heat transfer, by absorbing heat from a cold reservoir and releasing it to a warmer one. It works similar to the condenser as they are both used to cool the device using a cold source and release it into the environment or a hot reservoir.

3.6 Relevant Subject Areas & General Equations

Most of the subject areas used in our project falls under the big umbrella of Thermodynamics, Fluids mechanics and Heat transfer. We will always start with the basic energy balance equation Etot=Ein - Eout + EStorage and derive based on the needs.

3.6.1 Sizing the Thermal Fluid Heater

The heater needs to be sized for the maximum BTU/hr requirements of the system during peak load. If the customer plans on expanding in the future, the future BTU/hr requirements also should be considered. In most cases, the customer knows what size heater is required. Otherwise, the heat required must be calculated by using the following equation:

$$Q=M \times Cp \times \Delta T$$

where
Q is the heat required.
M is the quantity of material being heated.
Cp
ΔT is the difference between final temperature and initial temperature.
This calculation must include the product being heated as well as the vessel containing the product and any piping that carries the hot fluid to the product. Remember that the vessel must heat up in order to heat its contents. Heat losses also must be taken into consideration, and proper engineering practices must be followed to determine an appropriate safety factor.

3.6.2 Determining the Required Flow Rate

When flow rates have to be calculated, it is important to revert back to the equation to determine how much flow is required to remove the appropriate amount of heat from the thermal fluid flow stream. However, for this calculation, we must rearrange the equation to solve for flow rate. It looks like this:

$$M=Q / (Cp \times \Delta T)$$

where
Q is the heat being transferred to the user from the thermal fluid.
M is the required flow rate of the thermal fluid
CP is the specific heat of the thermal fluid
ΔT is an allowable temperature drop for the thermal fluid across the inlet and outlet of the user.

3.6.3 Heat Losses to the Environment

Conduction Losses:

These occur when a hot object is in touching contact with a cooler object and heat energy passes from the hot object to the cool one. It can be calculated using the following equation:

Convection Losses:

Heat losses due to convection are more difficult to calculate because there are many ways for heat to be removed from an object through a surrounding medium. The main challenge, among others, is due to the fact that the convection medium can be motionless or flowing, referred to as natural convection or forced convection. Convection rates also are affected by the orientation of the object in the medium due to the effects of convection boundary layers in the medium. It can be calculated using the following equation:

Radiation Losses:

Losses due to radiation usually are insignificant at low temperatures, but they can be a large contributor of heat loss at temperatures above 500oF and should be considered when calculating wattage requirements.

3.6.4 Resistance Temperature Detectors (Sensors)

RTDs are used to measure temperature by correlating the resistance of the RTD with temperature. This correlation between the resistance and temperature of the RTD is described by the **Callendar-Van Dusen** equation:

For Temperature: -200˚C ≤ t ≤ 0˚C,

$$R_T = R_o[1 + A_T + B_{T2} + (T - 100)C_{T3}$$

Where,

RT= Resistance at Temperature, T

Ro= Resistance at 00C

T = Temperature in °C

For Temperature: 0˚C ≤ t ≤ 661˚C

$$R_T = R_o(1 + A_T + B_{T2})$$

A, B and C are known as the Callendar-Van Dusen constants, defined by the following equations:

$$A = \boldsymbol{\alpha} + (\boldsymbol{\alpha}\delta)/100$$

$$B = -(\boldsymbol{\alpha}\delta)/1002$$

$$C = -(\boldsymbol{\alpha}\boldsymbol{\beta})/1004$$

$$\boldsymbol{\alpha} = (R100 - Ro)/(100 + Ro)$$

$\boldsymbol{\beta}$= constant if t < 0 °C, else zero

$$\delta = (Ro[1 + \boldsymbol{\alpha}(260)] - R200)/(4.16\ Ro\boldsymbol{\alpha})$$

3.6.5 Heat Loads and Condensers

Total heat load can be calculated using the following equation:

$$h = c_p\, \rho\, q\, dt$$

where,

h = heat load (Btu/h)

c_p = 1 (Btu/lb_m ^oF) for water

ρ = 8.33 (lb_m/gal) for water

q = water volume flow rate (gal/min)

dt = temperature difference (^oF)

Evaporator water flow rate *can be expressed as:*

$$q_{evap} = 24\ h_{evap}/dt$$

where

qevap = evaporator water flow rate (gallons per minute - gpm)

hevap = air condition load

Condenser water flow rate *can be expressed as:*

$$q_{cond} = 30\ h_{cond}/dt$$

where

qcond = condenser water flow rate (gallons per minute - gpm)

hcond = air condition load

3.7 Identifying Fabrications, Testing Methods and Procedure for Similar Designs

3.7.1 Identifying Testing Methods

Based on an article published by the Journal of the Brazilian Society of Mechanical Sciences and Engineering on May 27 2019, there are five experimental methods used for the measurement of heat transfer coefficient, which were classified into five major groups: (1) direct method, (2) transient method, (3) Wilson method, (4) heat/momentum/mass transfer analogy method and (5) boundary layer thickness method. However, this chapter will mainly be focused on two direct and transient methods since these seem to be so closer to the group project. To analyze these methods, it should be considered the constraints and accuracy reported by the improvement in the temperature and heat flux measurements techniques.

3.7.2 Direct Methods and Fabrications

The direct method is based on the application of the heat transfer definition that is given by Newton's cooling law, where all the variables that are found in this equation are measured. These variables are (1) fluid bulk temperature $T_{\infty,}$(2) wall surface temperature $T,$ (3) heat flux on the wall surface q'':

$$h = \frac{q''}{T_s - T_\infty}$$

This technique has been widely employed in research involving single-phase convection, boiling and condensation. Now, the temperature and heat flux are measured using methods such as mechanical, electrical and optical. Mechanical measurement techniques, in which liquid column expansion thermometer is one of the most widespread temperature measurement techniques, the principle involved in this method is the thermal expansion of liquid due to changes in the surrounding temperature bulb. Mercury, the most widely fluid employed due to its low vapor pressure, wide temperature range (-30 to 300 °C) and high accuracy (<0.1 °C). Electrical measurements techniques, which are defined by the use of sensing elements that produce an electrical output signal when temperature is changed. These electrical output signals are voltage, current and electrical resistance. Optical measurement techniques, which are a set of emerging techniques that maximize new applications hardly solved by mechanical or electrical temperature sensors. Their main advantages are non-contact measurements, which are easy integration for obtaining high-resolution 2D temperature techniques. These techniques are chosen based on their respective application's restrictions.

Table 3.1 shows recent experiments that used this technique, describing the used temperature and heat flux measurement methods, the convection mode, application and reported uncertainties. More than 12 distinct direct-mode techniques are included in this table.

Table 3.1 Application and reported uncertainties

Convection mode	References	Temperature/heat flux technique	Application	Reported HTC uncertainty (%)
Gas free convection	[70,71,72]	Thermocouple/interferometry	Vertical flat plate, air	9
		Thermocouple/heat flux sensor	Building wall, air	
Gas forced convection	[54, 73]	Thermocouples/boundary layer temperature profile	Flame heat transfer	7.5
		Thermocouples/enthalpy		8–45
Liquid free convection	[74,75,76]	Thermocouple/interferometry	Supercooled water, flat plate	–
		Thermocouple/Joule effect	Horizontal gap water	–
		Platinum wire self-temperature and heating by Joule effect	Horizontal platinum wire, water	21
Liquid forced convection	[77, 78]	Thermocouple/Joule effect—direct tube heating	Water-based nanofluid	4.5
Nucleated boiling	[80, 81]	Thermocouple/Joule effect—cartridge resistance	Cylindrical surfaces with R123, R22, R134a	1.3–20 > 1
		Infrared/Joule effect	Flat horizontal surface, water	
Convective boiling	[82, 83]	Thermocouple/Joule effect—tape resistance	Horizontal copper tubes, R22, R134a, R404a	17
		Thermocouple/enthalpy profile (water)	Horizontal flat tubes, R22, R404a	6
Microchannel flow boiling	[84]	Infrared thermocouple/direct tube Joule effect	Ethanol/water flow boiling	15

	[29]	Liquid crystal/Joule effect	Vertical rectangular microchannel, R123 and R11	16.45
	[42, 85, 86]	Thermocouple/direct tube Joule effect	Single microchannel, R134a, R245fa	< 30
	[87]	Infrared RTD/Joule effect	Flow boiling multi-microchannel	15
	[88]	Thermocouple/enthalpy profile	Flow boiling inside a single microchannel, R134a and R32	8
	[41]	Infrared-TSP-thermocouple/direct tube Joule effect	Flow boiling, HF7100	–
In-tube condensation	[89]	PT100/enthalpy	Smooth and microfin tube	23
Microchannel condensation	[90]	Thermocouple/Joule effect similarity	Single channel, R134a	19.9
	[43]	Thermocouple/Peltier heat flux sensor	Parallel microchannels, R134a	5–70
Film condensation	[91]	Thermocouple/enthalpy	Steam condensation of hydrophobic surface	11.1

3.7.3 Transient Methods and Fabrications.

The transient technique is used when unsteady boundary conditions or non-equilibrium initial conditions in convective problems can be applied. First, a mathematical model of the system describing the transient response in terms of the heat transfer coefficient must be produced. With this model, the problem resumes to minimize the error between the mathematical transient model and the experimental transient data. The value of the heat transfer coefficient of the mathematical model that minimizes the error between a chosen parameter of the model and the experiment is assumed as the heat transfer coefficient value for the experiment. The main benefit of the transient method is the simplification of experiment procedure since temperature becomes the only variable needed to be considered for a long time. The transient thermal mathematical model can be of any complexity, from single lumped parameter to multidimensional transient system solved by finite-element techniques. The boundary conditions used in the experiment are bulk fluid temperature step change, plug flow and square-wave or sine wave heat flux boundary condition. Parameters used for the minimization between the mathematical model and the experimental data are maximum slope temperature derivatives, system thermal time constant, system thermal phase lag, system gain, frequency response and temperature derivatives, frequency response and temperature curve fitting usually by least square methods.

Table 3.2 shows some studies of HTC measurements that used the transient technique. The table provides a description of the mathematical models using the boundary condition or initial conditions, type of convection problem, application, time and spatial resolution obtained for the HTC and experimental uncertainty ranges.

Table 3.2 application, time and spatial resolution obtained for the HTC and experimental uncertainty ranges.

Transient mathematical model type/boundary conditions	References	Convection mode/application	HTC temporal/spatial resolution	Reported HTC uncertainty
1D axial conduction solid porous matrix/convection fluid bulk temperature step change	[92]	Liquid forced convection/packed bed	Time and space average	–
1D axial conduction solid porous matrix/convection fluid bulk temperature step change	[93]	Gas forced convection/bed of solids	Time and space average	–
1D conduction solid porous matrix/convection fluid bulk temperature step change	[94]	Heat exchanger surfaces/plate-fin type	Time and space average	7.5–15% (Colburn factor)
1D conduction solid porous matrix/convection	[95]	Gas forced convection/heat exchanger surfaces/plate-fin type	Time and space average	< 4.32%

fluid bulk temperature step change				
1D conduction, Fourier analyses/oscillating fluid temperature	[96]	Liquid forced convection water	Time and space average	< 27% (Colburn factor)
1D Fourier analyses/oscillating fluid temperature	[97]	Plate heat exchangers|	Time and space average	2.9%
1D and lumped model transfer function between fluid and solid, frequency response analysis/plug flow temperature changes	[98]	Plate heat exchangers|	Time and space average	5%
1D conduction sphere/bulk temperature step change in the convection boundary	[99]	Natural convection/food HTC	Instantaneous/space average	–
2D conduction, phase delay/square-wave radiant laser heat input	[100]	Spray cooling	Time-average/2D spatial resolution	< 20.8%
Lumped conduction/non-equilibrium initial condition in solid temperature	[101]	Natural convection/food HTC	Instantaneous/space average	–
2D conduction/square wave radiant laser heat input	[102]	Plate heat exchangers| IR measurement	Time -average/2D spatial resolution	11%
1D radial conduction/convection fluid bulk temperature step change	[103]	Air jet impingement. IR measurement	Time-average/1D radial resolution	–
Lumped conduction/bulk temperature step	[104, 105]	Boiling, single-phase convection/quenching	Instantaneous/space average	–

change in the convection boundary				
1D radial conduction/sinusoidal oscillation wall heat flux (Joule heating)	[106]	Tube internal liquid forced convection. IR measurement	Time and space average	11%
2D cylindrical coordinates heat conduction FEM inverse method/bulk temperature step input in the convection boundary	[107]	Boiling, single-phase convection/quenching	Instantaneous/space average	<8%
Lumped conduction/bulk temperature step change in the convection boundary	[108]	Natural convection/container	Time and space average	10%
1D axial conduction/sinusoidal oscillation wall heat flux (Joule heating)	[109]	Air water multiport internal liquid forced convection. IR measurement	Time and space average	13.2%
1D conduction/convection fluid bulk temperature step change	[110]	Gas forced convection/plate	Time and space average	< 10%
1D conduction/convection fluid bulk temperature step change, maximum slope method	[111]	Gas forced convection/compact heat exchanger air	Time and space average	12%

The simplest mathematical models used in transient experiments are mostly focused on single lumped models for low Biot numbers (Bi ≪ 1). Biot numbers smaller than 0.1 provide 5% maximum temperature different among all the existing points inside the boundary of the system and lumped models can be modeled by the following equation:

$$h \times As(T-T\infty) = m \times c \frac{dTdT}{dt\,dt}$$

With the initial condition given by T (t=0) = Ti. The instantaneous heat transfer coefficient can be obtained by solving for the heat transfer coefficient “h”, which remains constant over time. The only variable that does not

remain constant over time is the temperature "T" considering that T∞ also remains constant, which shows how simple this method is. If the heat transfer coefficient remains constant over time, the time constant of the system can also determine the time-average heat transfer coefficient as:

$$h = \frac{m \times c}{As \times T} = \frac{m \times c}{As \times T}$$

When Biot number becomes close to or higher than the unity multidimensional transient does conduction models are necessary.

3.7.4 Procedure Taken for the Direct Method

Here is some example of the direct methods used to measure the heat transfer coefficient, where it can be also shown the different procedures and approaches taken by his main protagonist: Naylor and Duarte measured the free convection heat transfer coefficient over a vertical flat plate for air using interferometry technique. The surface and fluid bulk temperatures were measured by thermocouples, and the heat flux was measured by interferometry. Electrical strip heaters impose the heat flux on the back surface of the plate. Interferometry enabled the measurement of one-dimensional heat transfer coefficient over the entire vertical plate profile. Yoon applied a similar technique for water as the fluid. Water has higher Prandtl than air making the boundary layer thinner, which makes the optical reading of the isothermal strips obtained from interferometric readings more difficult. Yang used thermocouples to measure wall and fluid bulk temperature in free convection over a building wall. Heat flux sensors measured the wall heat flux, and they were able to measure both convective and radiant heat transfers. The advantage of the technique is that no external heat flux was imposed on the wall for the heat flux determination. Problems, however, are related to the intrusiveness of the heat flux sensor, which can add a thermal resistance layer and disrupt surface heat transfer characteristics near the wall. Han and Goldstein measured the HTC of air flowing over the surface of the turbine end wall. They used a thermocouple probe to measure the temperature profile inside the fluid boundary layer using a five-axis measurement unit (four axial and one rotational degrees of freedom). The thermocouple junction had 76 μm diameter, and the measurement unit had a 5 μm position resolution. The heat flux was determined.

3.7.5 Procedure Taken for the Transient Methods

Here are some example conducted by this method: Schumann was the first to solve the transient one-dimensional problem systematically for HTC measurements. He demonstrated a solid porous matrix with internal flow as a one-dimensional transient conduction problem subject to fluid bulk step alteration initial condition. This technique is also known as single-blow transient technique and characterized by a fluid stream flowing steadily in the test matrix up to an instance where a transient perturbation of the fluid temperature is forced. The variation in the test matrix temperature enables the heat transfer coefficient determination. Furnas, Pucci, Heggs and Burns adapted the method to different conditions, as a bed of solids and heat exchangers. Becker and Fricke utilized a one-dimensional transient conduction model of a sphere to analyze the heat transfer coefficient of food during a cooling process. Krishnakumar reviewed the single-blow method for transient heat transfer coefficient measurements. Freund developed a spray cooling system measuring the two-dimensional HTC distribution on the wall. The spray cooled one side of the wall, and the backside was heated by a 0.25-Hz-pulsed laser source. An infrared camera with 0.4 mm spatial resolution and 30 Hz acquisition rate measured the temperature field in the back wall. A two-dimensional mathematical model of the system was developed and solved by a finite-difference method in order to transform the measured temperature field into the equivalent heat transfer coefficient of the spray side. Freund and Kabelac applied a similar technique to study a plate heat exchanger.

4. PRELIMINARY DESIGN

This status report covers some of the information on the preliminary design chapter of the project report, which was mostly based on the functional decomposition and how the group members were able to come out with different ideas to solve the problem that was presented to them during the senior design project selection. In this status report, group members had the chance to participate and present their ideas on how the problem could be solved through the functional decomposition method. This selection method focuses on three main levels where the best ideas were selected through a process run by four levels. Those are level zero, which is where the problem statement or overall function is presented, level one, where the first and different functions were extracted from group members, level two, which is taken form level one due to similarities among the different ideas and level three, which follows and was taken from level two also due to the same reasons as level two was extracted from level one.

4.1 Functional Decomposition

In this section the team worked together in order to generate an overall function that was further broken down into multiple levels of subfunction. The functions go from level 0 (overall function) to level 3 subfunction. The generation of each function started as an individual assignment where each group members worked on creating their own function based on their understanding of the project. Then based on a consensus the functions are chosen and sub functions are produced from the previously chosen functions and the same process is repeated. The process of creating each level function will be further described below.

In this section, the sticky notes sheets were used to create the overall function of the project using the guidelines provided by the mechanical engineering senior manual. The sticky notes from each group member were collected and pasted on a page to produce a figure similar to Figure 3 in the splash guard found on the senior design manual. Each function is made of a verb, a noun and a modifier that describe the goal and objective of each function. From the suggestions on the sticky notes, group members discussed, combined or eliminated in order to arrive at a suitable level 0 function for the project similar to that shown in Figure 4 for the Splash guard. Then, the inputs and the outputs for the function were identified as detailed on what it is needed for the project to be accomplished. The Figure 4.1 is a representation of the sticky notes that were created by each member.



Figure 4.1 level 0 Sticky notes generated by each member of the group

Below Figure 4.2 shows the overall function chosen and all the necessary inputs and outputs that will go through the apparatus.

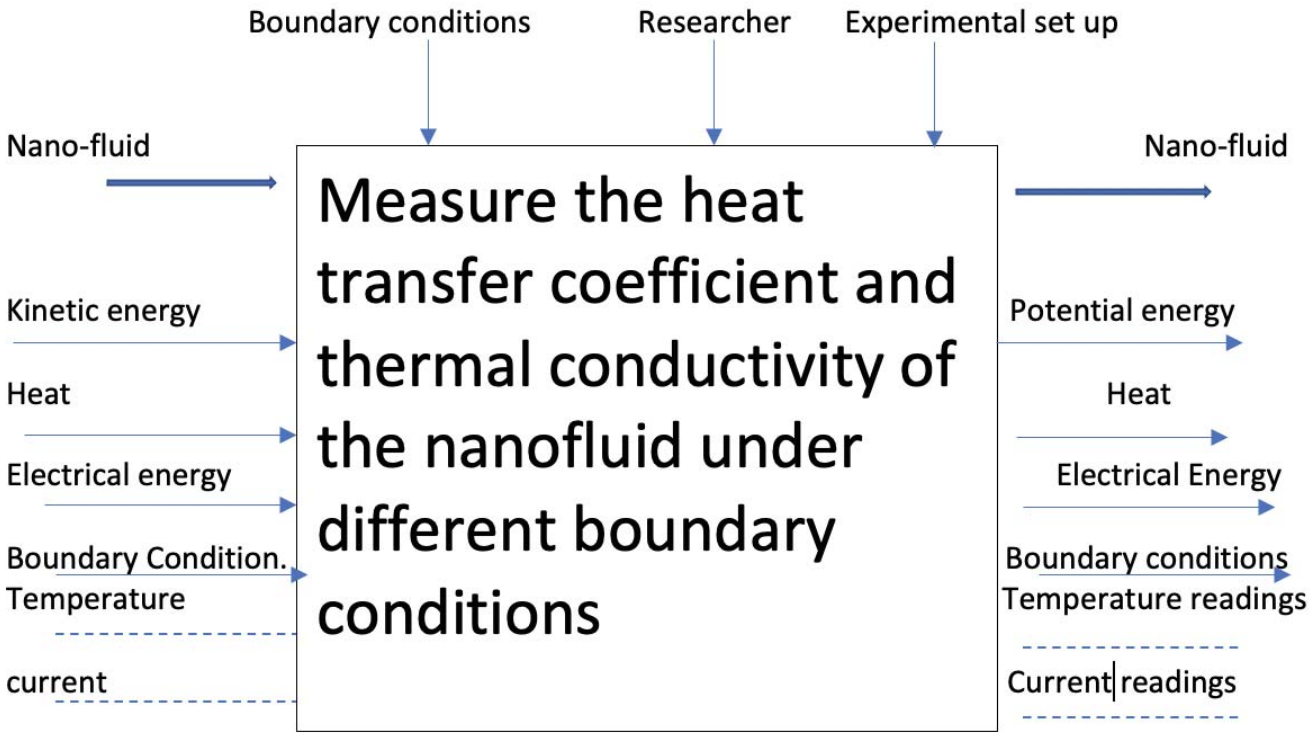


Figure 4.2 Overall function of the Project

In this section, the sticky notes sheets were used to decompose the overall function into simple level 1 sub-function descriptions using the guidelines provided by the mechanical engineering senior manual. Each member created sticky notes based on what the group agreed to be the overall function. The sticky notes from each group member were then collected and pasted on a page to produce a figure similar to Figure 3 in the splash guard found on the senior design manual. To describe the sub functions verbs nouns and modifiers were used to better describe the goal and objective of each sub function. From the suggestions on the sticky notes, group members discussed, combined and eliminated in order to arrive at suitable level 1 sub-functions for the project similar to that shown in Figure 4 for the Splash guard. Then, the inputs and the outputs for each sub-function were identified as detailed on what it is needed for the function to be accomplished. Figure 4.3 shows the sticky notes generated by each group member.



Figure 4.3 sticky notes for level 1 functions generated by each group member based on the overall functions

Down below a visual representation of the break down from level 0 to level 1 is represented in Figure 4.4

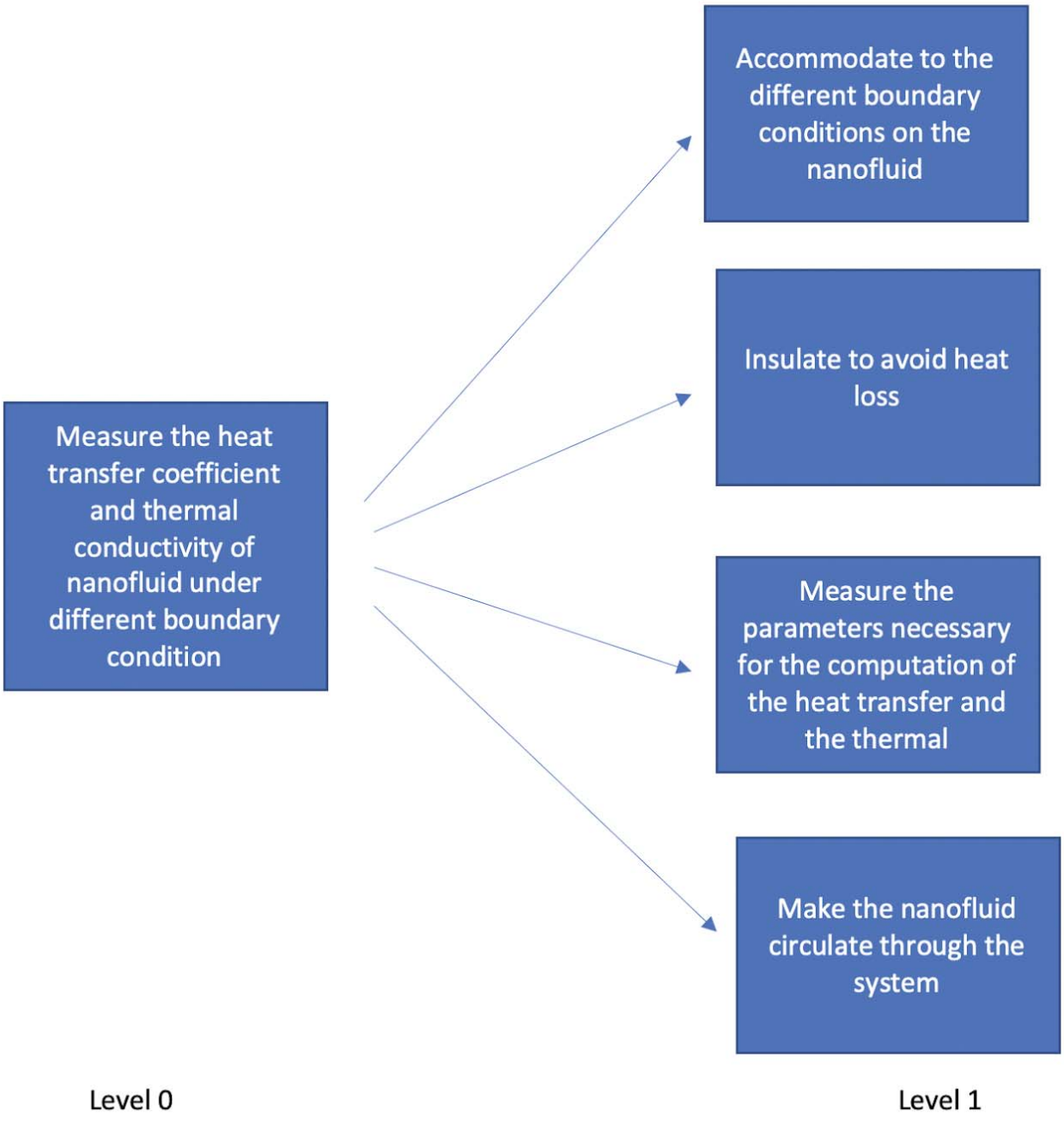


Figure 4.4 level 0 to level 1 functions breakdown

To determine the level 2 sub-functions, each member of the group was tasked with decomposing each of the level 1 sub-functions. As a group, sticky notes were created on an external website (canvas) to stay decent and in order and keep track of which group member suggested the respective level 1 sub-functions. Each sticky note was represented with an overlapping text box containing potential level 2 sub-functions in the form of action items and verbs. After compiling each sticky note on a blank page, the group discussed which sub-functions could be combined, eliminated, or conformed to be appropriate to the project pertaining to our group. This would lead into suitable level 2 sub-functions that the group approves of as a whole and gives the group an opportunity to identify the inputs and outputs for our now level 2 sub-functions.

Figure 4.5, 4.7 and 4.9 and 4.11 show the sticky notes related to each level 1 function in their respective order. In figure 4.6 4.8 and 4.10 and 4,12 the chosen level 2 sub-functions are listed. In figure 4.13 a comprehensive breakdown is provided going from level 0 to level 2



Figure 4.5 Level 2 sticky notes for level 1" accommodate to the different boundary conditions applied to the nanofluids Group Consensus"

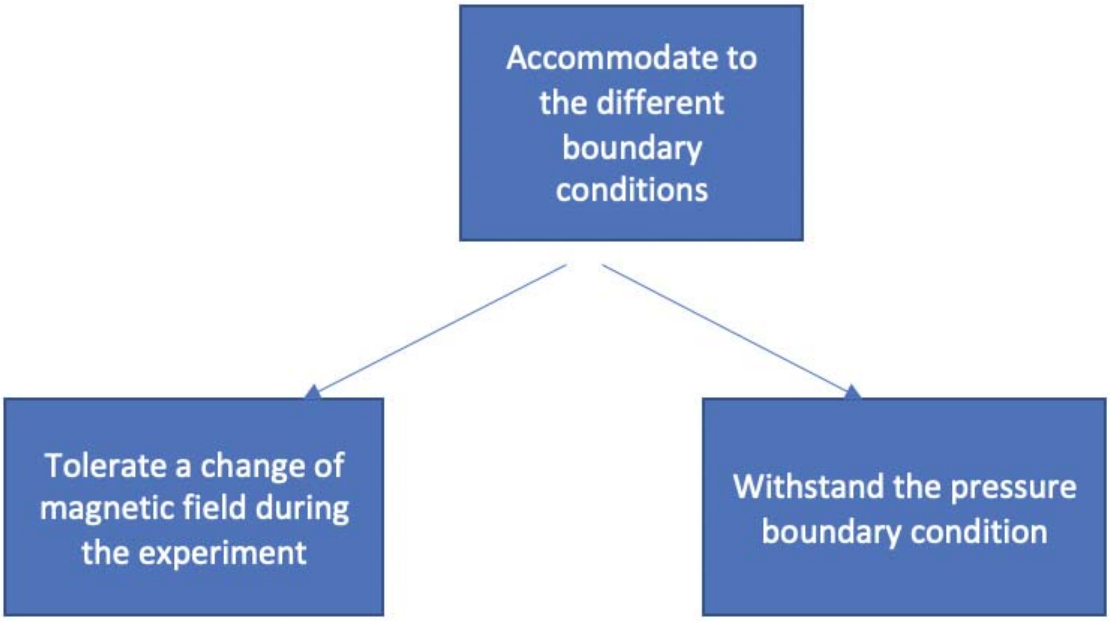


Figure 4.6 Level 2 Consensus for level 1 “accommodate to the different boundary conditions applied to the nanofluids Group Consensus”



Figure 4.7 Level 2 sticky notes for level 1" Insulate to avoid heat loss"

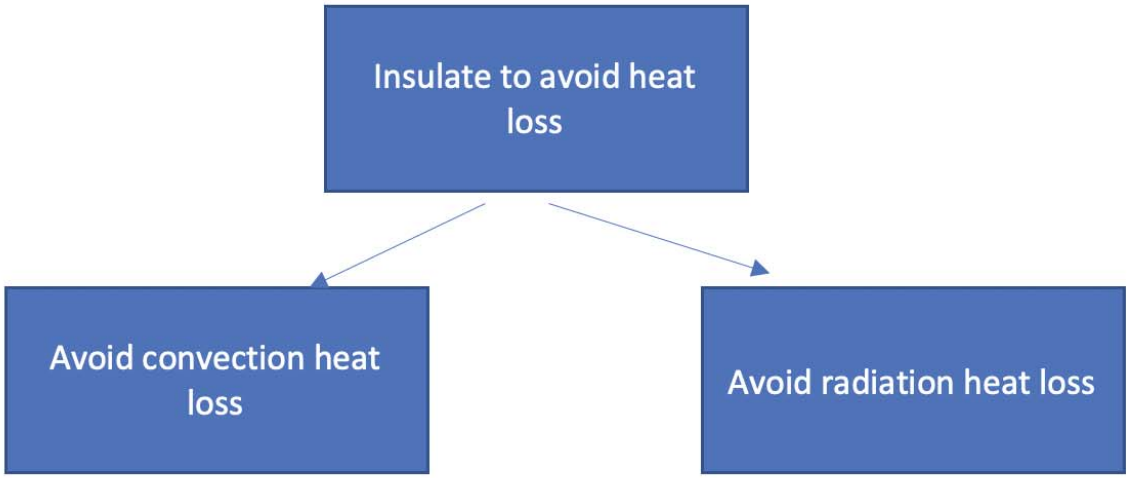


Figure 4.8 Level 2 Consensus for level 1 “Insulate to avoid heat loss”

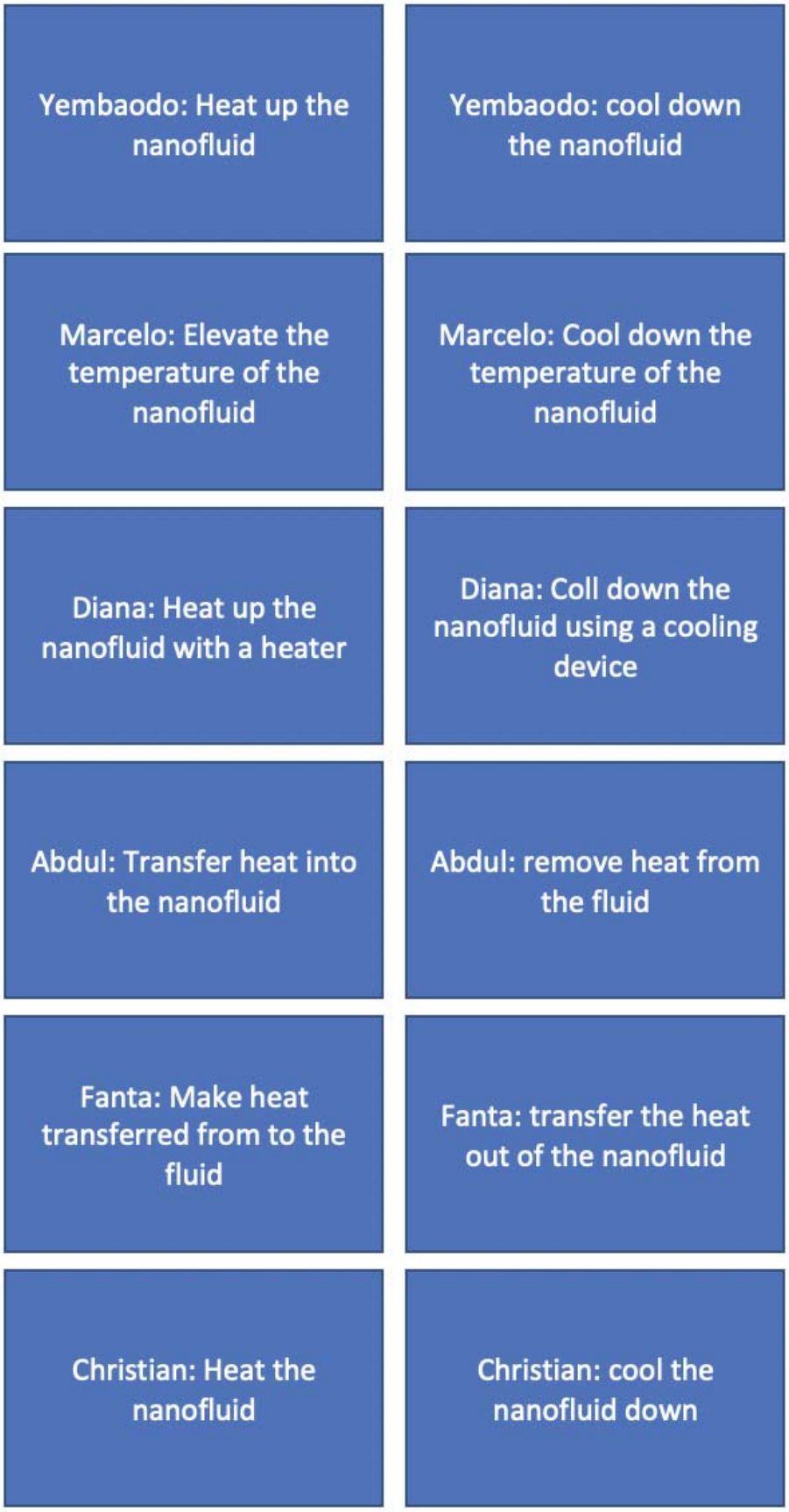


Figure 4.9 Level 2 consensus on level 1 function “make the nanofluid circulate through the piping system”

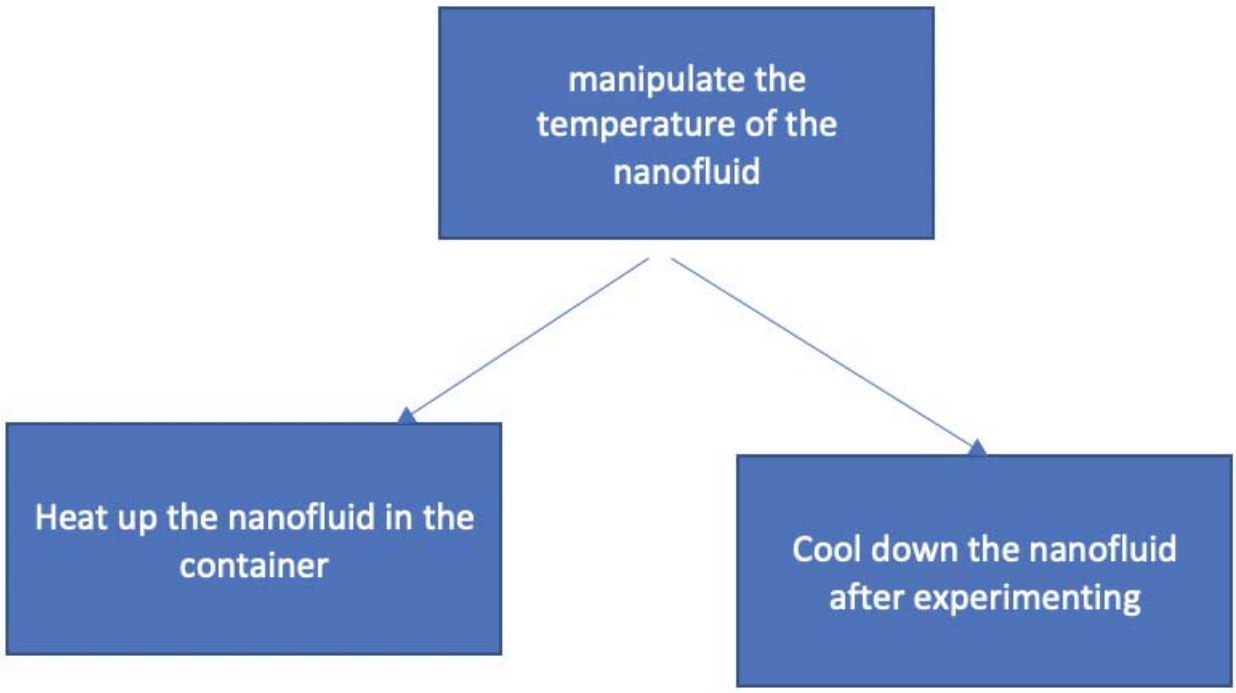


Figure 4.10 level 2 sticky notes on level 1 function “make the nanofluid circulate through the piping system”



Figure 4.11 Level 2 Functions on level 1 “measure the parameters necessary for the computation of the heat transfer coefficient and the thermal conductivity”

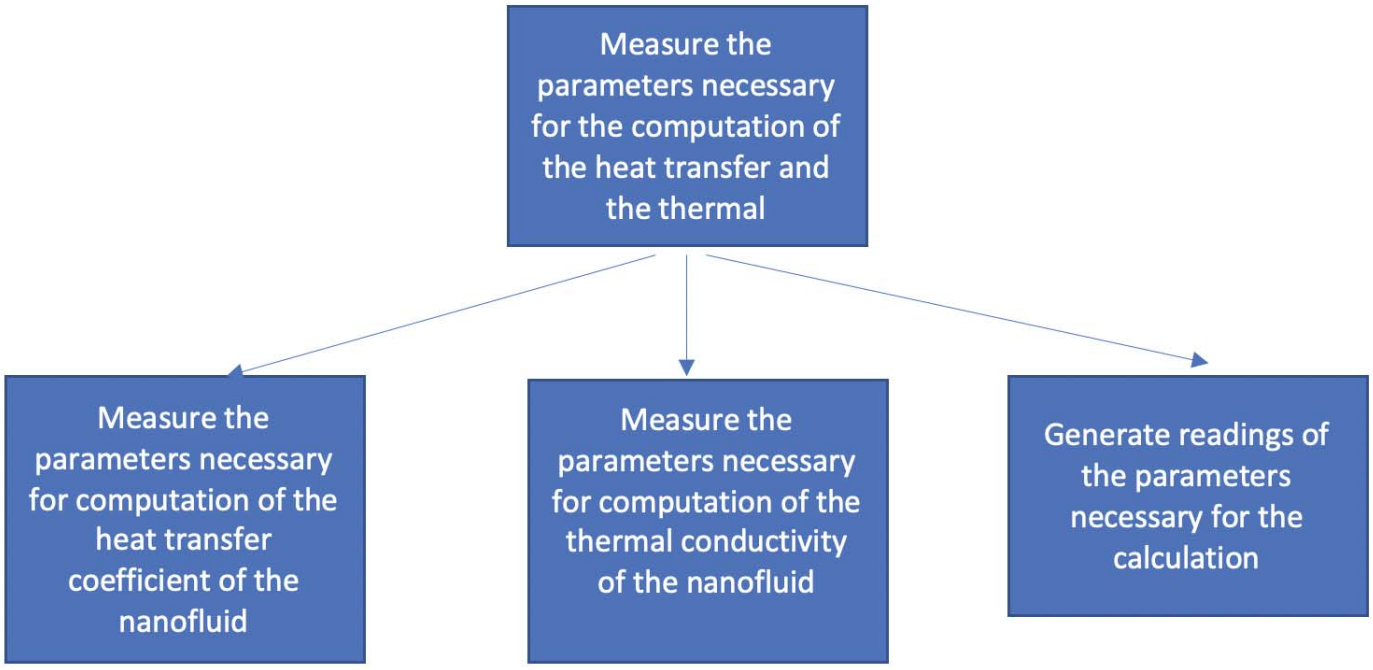


Figure 4.12 Level 2 Functions on "Measure the parameter necessary for the computation of the heat transfer coefficient and the thermal conductivity"

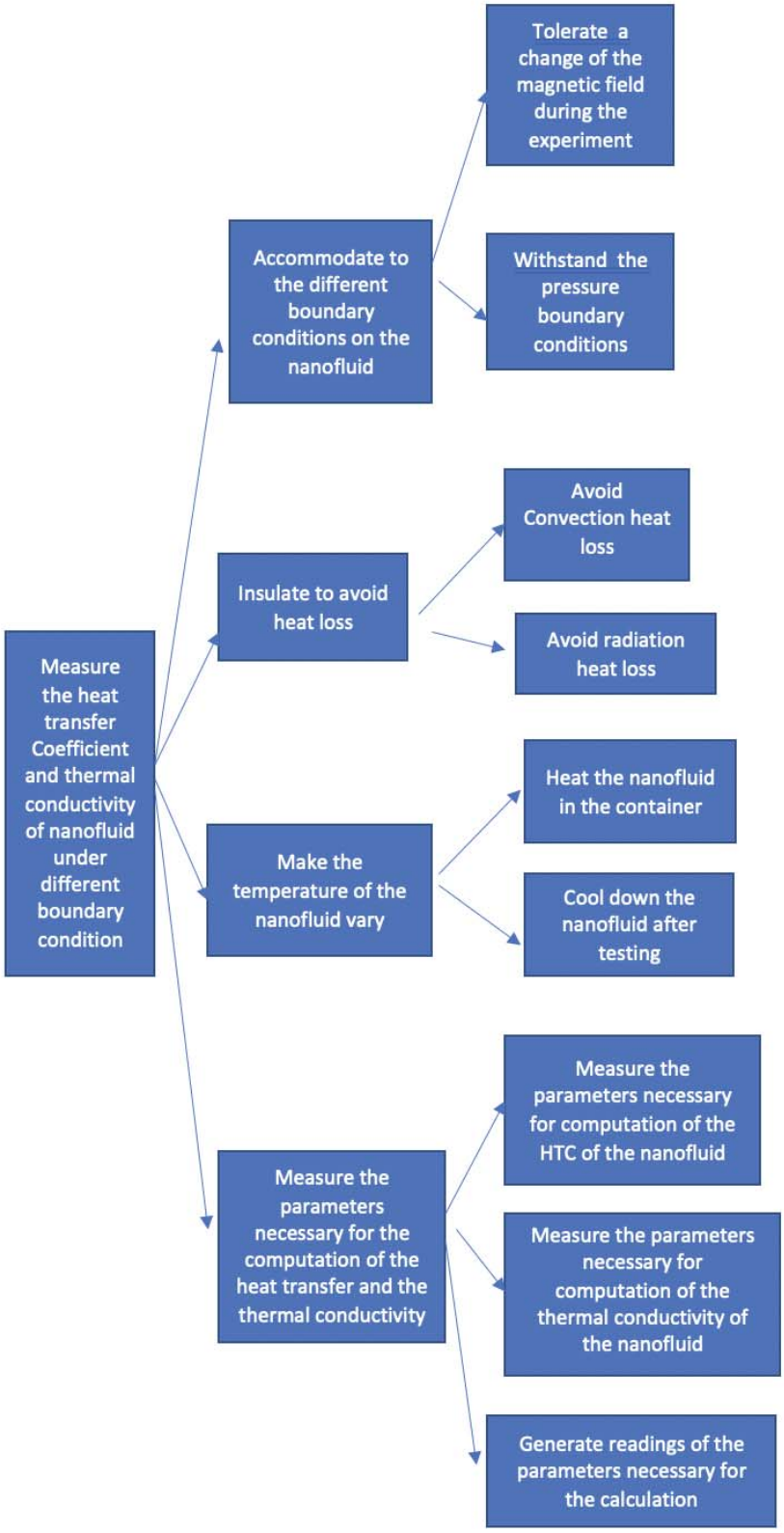


Figure 4.13 Level 0 to level 1 to level 2

After identifying the level 2 sub-functions, we repeated step 3 to create step 4 which would be our level 3 sub-functions. We continued to decompose the remaining sub-functions until we were unable to decompose any further which gave us a clear understanding of our sub-functions for each level as well as any sub-functions that were extended past level 3 sub-functions.
Figure 4.14 shows the sticky notes related to the measure of the heat transfer coefficient. It is immediately followed by Figure 4.15 which is the function chosen by the group member that the design must do to accomplish that task.

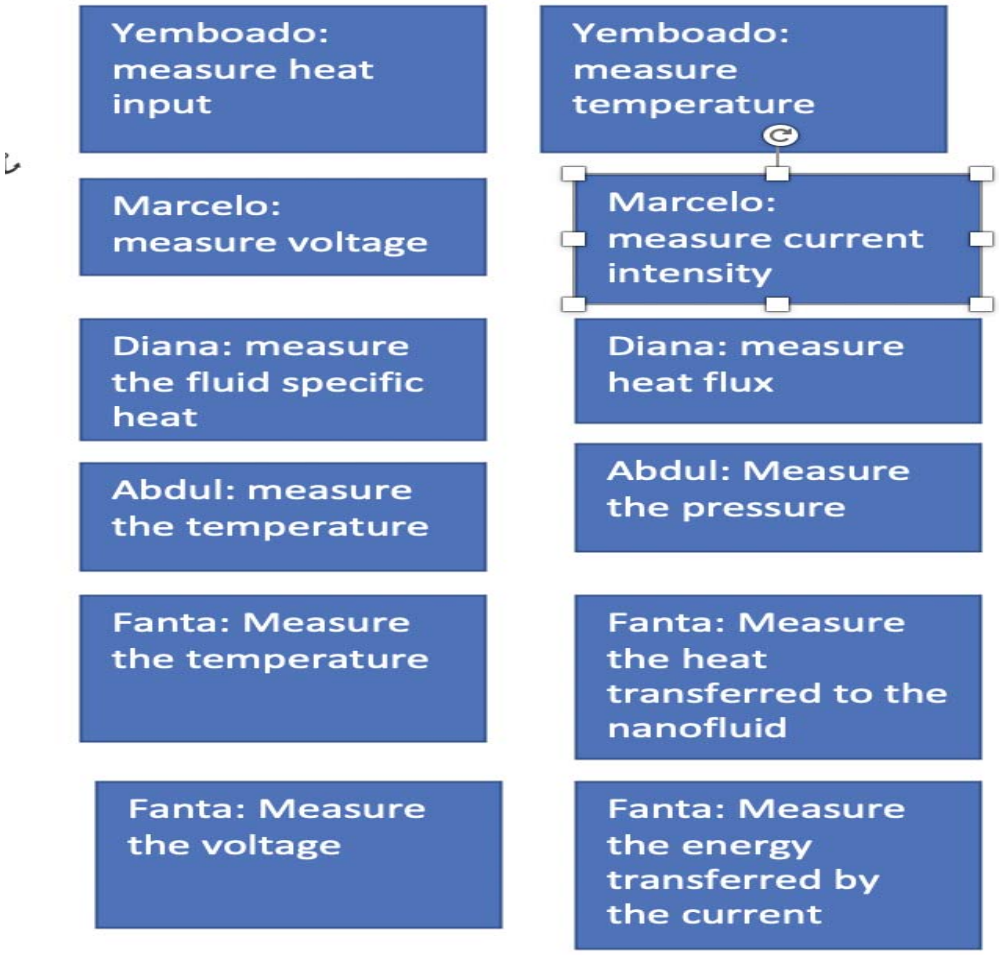


Figure 4.14 Level 3 sticky notes on level 2 “Measure the heat transfer coefficient of nanofluid in the experiment”

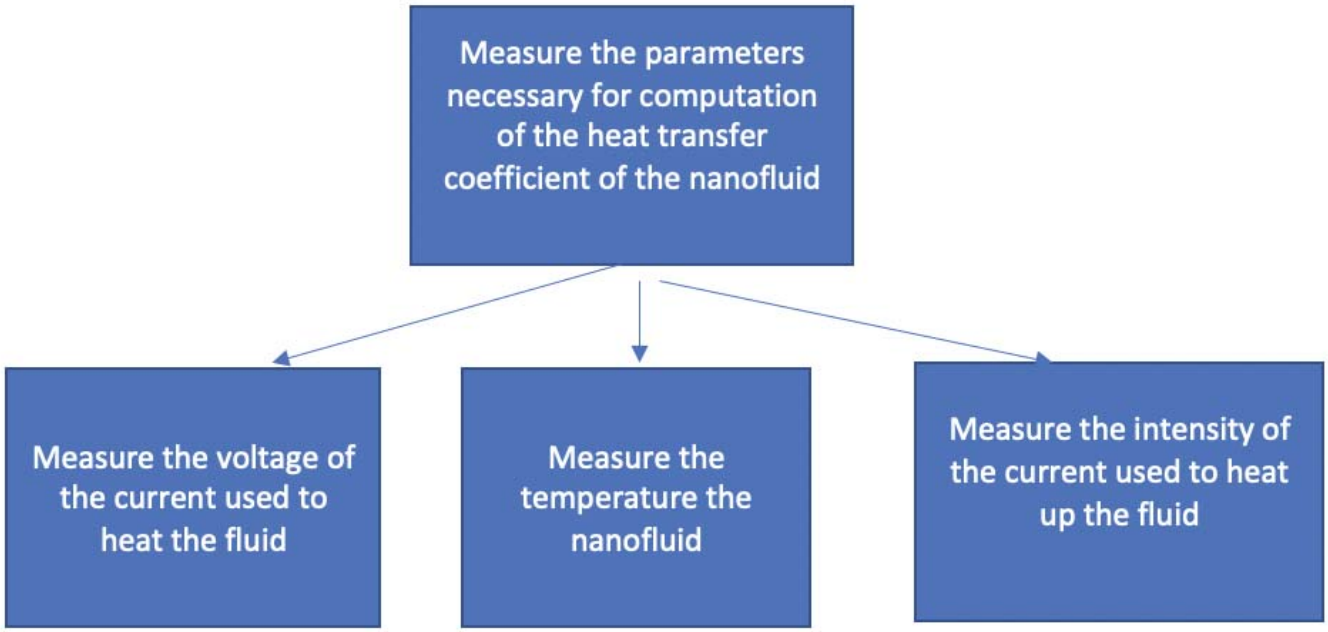


Figure 4.15 Level 3 chosen functions on level 2 “measure the heat transfer coefficient of nanofluid in the experiment”

Figure 4.16 shows the sticky notes related to measure of the heat thermal conductivity. It is immediately followed by Figure 4.17 which is the function chosen by the group member that the design must do to accomplish that task. It is to be noted that level 3 sub function for the level 2 functions ``measure the heat transfer coefficient of the nanofluid” and “measure the thermal conductivity of the nanofluid” are essentially the same.

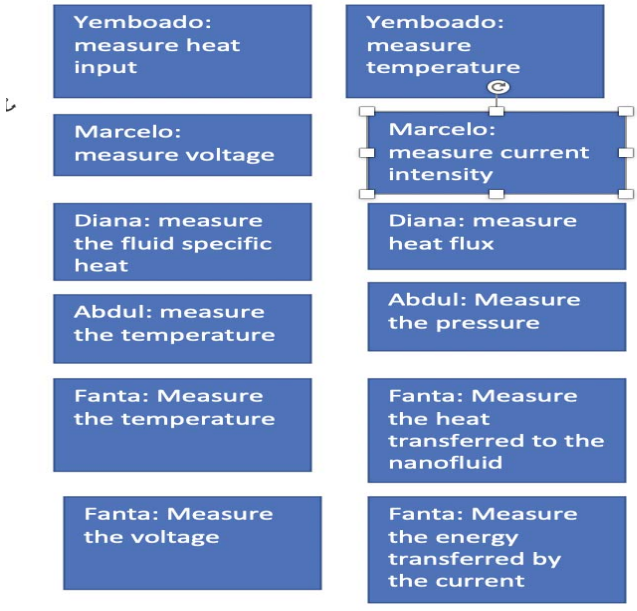


Figure 4.16 Level 3 sticky notes on level 2 “measure the thermal conductivity of nanofluid in the experiment”

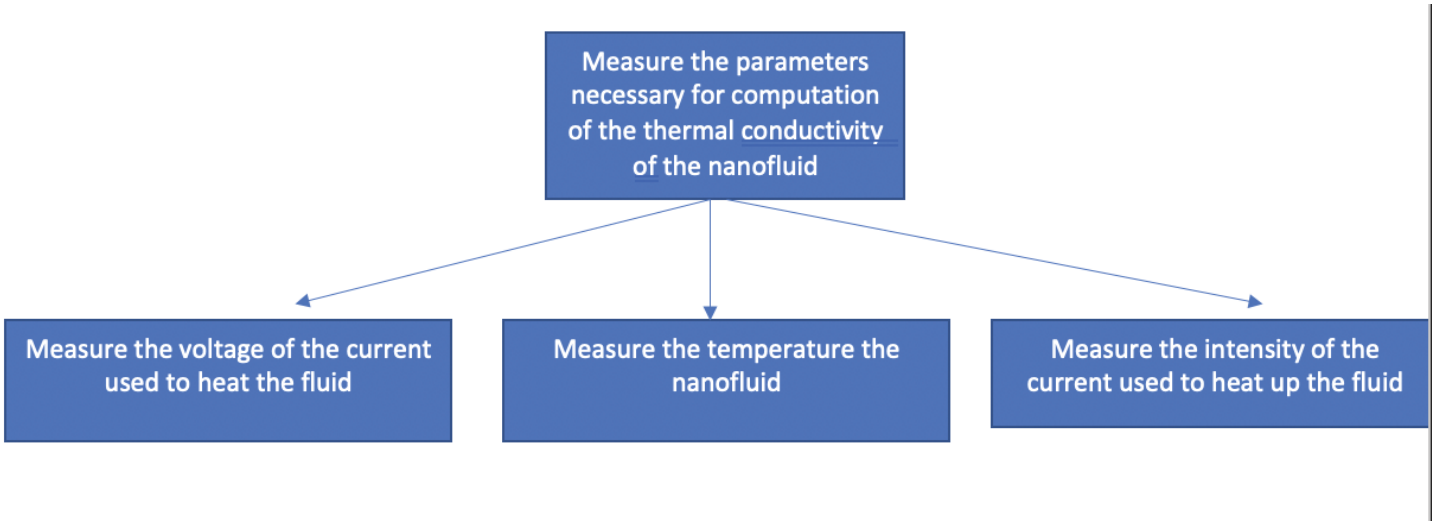


Figure 4.17 Level 3 "chosen functions on level 2 measure the thermal conductivity of nanofluid in the experiment"

Figure 4.18 shows the sticky notes related to measure of the heat thermal conductivity. It is immediately followed by figure 4.19 which is the function chosen by the group member that the design must do to accomplish that task.



Figure 4.18 Level 3 sticky notes on level 2 "Generate readings of parameters necessary for computation"

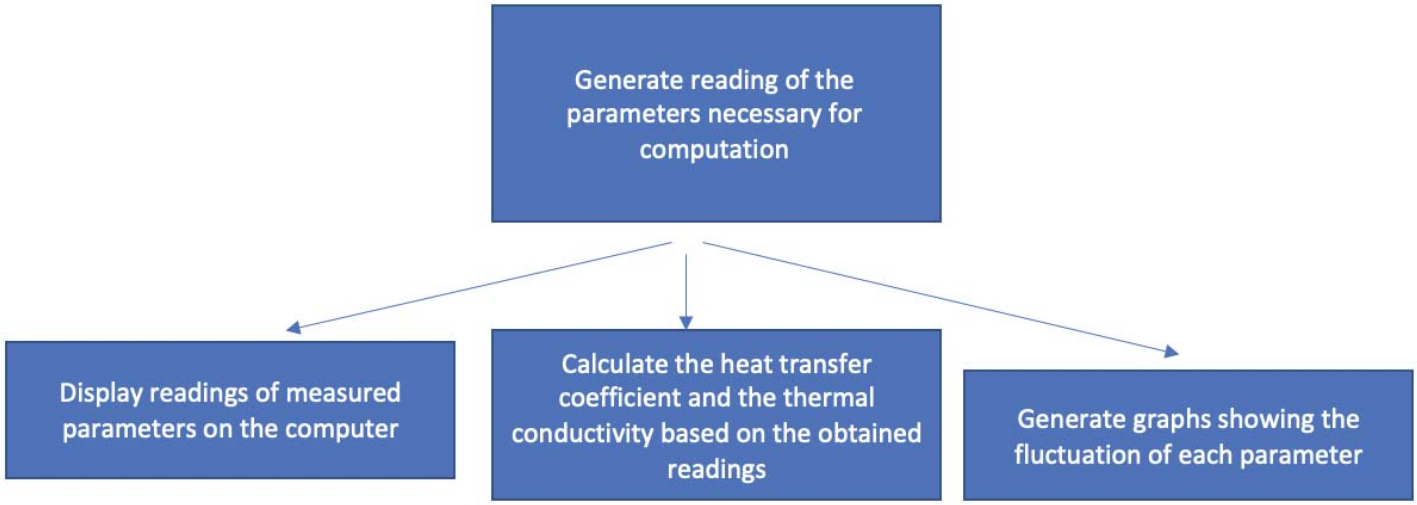


Figure 4.19 Level 3 chosen functions on level 2 “Generate readings of parameters necessary for computation”

Figure 4.20 is a visual breakdown of all the functions going from level 0 to level 3.

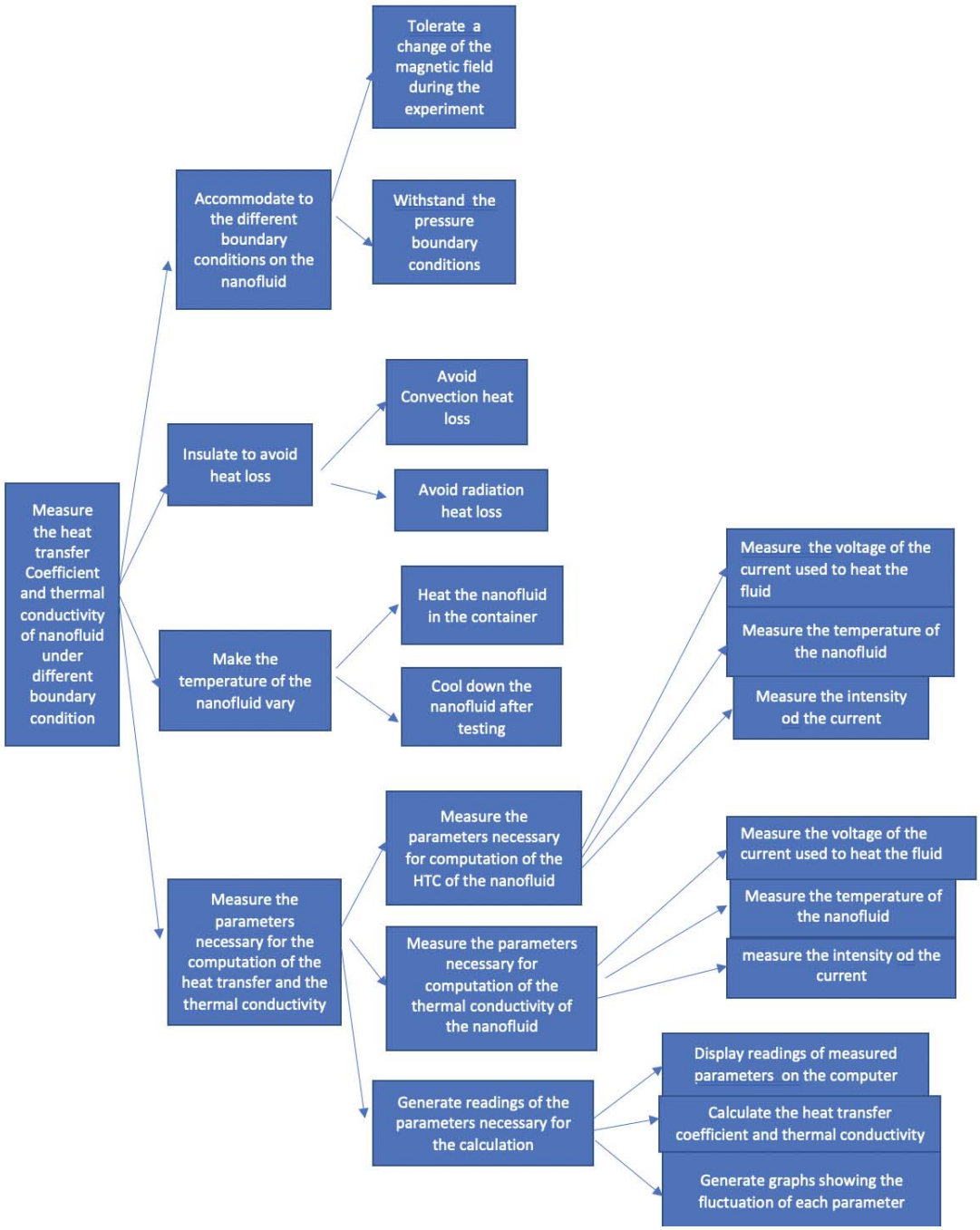


Figure 4.20 Function broken down from level 0 to level 3

For the last section of our functional decomposition, ~~table 4~~.1 was created to show a visual representation of what the design must be able to do in order to reach the project end goal. This table will identify the overall function, level 1 sub-functions, level 2 sub-functions, and level 3 sub-functions. The overall functions, and sub-functions are broken down into verbs, nouns, and modifiers to make clear the description of the sub-functions to the project owner and customers

Table 4.1 Morphology table

Overall Function	Level 2 Sub-functions	Level 3 Sub-functions	Concept 2		Concept 3		Concept 4		
			Sketch	Description	Sketch	Description	Sketch	Description	Sketch
Measure the heat transfer coefficient and the thermal conductivity of nanofluid under different boundary conditions	Make the temperature of the nanofluid vary	Heat up the nanofluid before pumping							
		cool down the nanofluid after the measurements are made							
	Insulate to avoid heat loss	Avoid convection heat loss							
		Avoid radiation heat loss							
	Accommodate to the magnetic field change								
	Accommodate to the pressure boundary condition change								
	Measure the heat transfer coefficient of the nanofluid in the experiment	Measure the voltage(V) drop in the boiler							
		Measure the nanofluid temperature of the nanofluid (Tin and Tout)							

		Measure the intensity of the current used to heat up the nanofluid							
	Measure the thermal conductivity of the nanofluid in the experiment	Measure the voltage(V) drop in the boiler							
		Measure the nanofluid temperature of the nanofluid (Tin and Tout)							
		Measure the intensity of the current used to heat up the nanofluid							
	generate readings of the parameters necessary for calculation	Display readings of measured parameters on a computer software							
		Calculate the heat transfer coefficient and the thermal conductivity based on the obtained readings							

		Generate Graphs showing the fluctuation of each parameter							

VNM= **V**erb action-**N**oun the verb is acting on-**M**odifier E.g. Protect-Rider-From Dirt

4.2 Concept Generation

~~This status report covers some of the information on the preliminary design chapter of the project report. Consequently, it was written in a detailed descriptive form as discussed based on the senior design manual.~~ The purpose of this ~~status report~~ was to come with concepts for each function chosen in the functional decomposition. To do that, it was very necessary for the group leader to assign a function to different members of the group in order to elaborate different concepts for each individual subfunction. These concepts will actually help the group introduce solid ways that the functions and subfunctions might be conducted in order to successfully complete this project.

The group members were assigned to utilize the morphology table created in status report 6a to generate concepts for the final functions which were broken down into level 1, level 2, and level 3 sub-functions. The work was split as in Table 4.2. Four members were assigned per function. Each member was asked to create at least 3 concepts for each function they were assigned. Each group member was assigned 9 different final-level functions, and sub-functions, to which each group member generated 27 total concepts with the corresponding sketches which would then be consolidated by the entire group. The group then met on a zoom meeting to discuss which concepts needed to be consolidated in order to meet the appropriate amount of 4 concepts for each function. Once this was completed, each member was assigned functions to attach the various concepts with their respective functions and add the appropriate sketches to these concepts.

Table 4.2 Individual Assignment for Concept Generation

Overall Function	**Level 1 Sub-functions**	**Level 2 Sub-functions**	**Level 3 Sub-functions**	**Name**	**Name**	**Name**	**Name**
Measure the heat transfer coefficient and the thermal conductivity of nanofluid under different boundary conditions	Make the nanofluid temperature vary during the experiment	Heat up the nanofluid before pumping		Fanta	Abdoul	Christian	Marcelo
		cool down the nanofluid after the measurements are made		Fanta	Christian	Yemboado	Diana
	Accommodate to different type of boundary conditions for the experiment	Accommodate to the magnetic field change		Yemboado	Marcelo	Christian	Abdoul
		Accommodate to the pressure boundary condition change		Diana	Fanta	Christian	Abdoul

	Measure the heat transfer coefficient and the thermal conductivity of the nanofluid	Measure the heat transfer coefficient of the nanofluid in the experiment	Measure the voltage(V) drop in the boiler	Fanta	Abdoul	Christian	Marcelo
			Measure the nanofluid temperature of the nanofluid (Tin and Tout)	Yemboado	Diana	Abdoul	Marcelo
			Measure the intensity of the current used to heat up the nanofluid	Fanta	Christian	Yemboado	Diana
		Measure the thermal conductivity of the nanofluid in the experiment	Measure the voltage(V) drop in the boiler	Yemboado	Marcelo	Christian	Abdoul
			Measure the nanofluid temperature of the nanofluid (Tin and Tout)	Diana	Fanta	Christian	Abdoul
			Measure the intensity of the current used to heat up the nanofluid	Yemboado	Marcelo	Diana	Fanta
		generate readings of the parameters necessary for calculation	Display readings of measured parameters on a computer software	Yemboado	Marcelo	Diana	Christian

			Calculate the heat transfer coefficient and the thermal conductivity based on the obtained readings	Marcelo	Yemboado	Abdul	Fnata
			Generate Graphs showing the fluctuation of each parameter	Yemboado	Marcelo	Fanta	Abdoul
	Be insulated to avoid heat loss	Avoid heat loss from Convection		Marcel	Diana	Christian	Abdoul
		Avoid Heat loss From Convection		Yembaodo	Fanta	Abdoul	Christian

In this part every group went ahead and based on the function that were assigned to them developed concepts that would help achieve the actual function of the apparatus. This assignment was made individually so the concepts could be as broad and different as possible. The number of concepts asked for each member was 3 per assigned function. It was also asked for the group member to have a brief description of their concept for better understanding.

After each Group member had 27 concepts with the sketches needed the group met on zoom to consolidate the concepts. The consolidation was made on the basis of resemblance, ability to be applied and whether or not the concepts made sense. from all this filtering the group retained 4 concepts from each function. After the concepts were chosen, they were all put together functions by functions with their sketches. In the morphology table all chosen concepts were listed in front of corresponding functions with the figure numbers corresponding to the sketches associated with them. Table 4.3 shows the completed morphology table.

Table 4.3 group 3 Morphology Table (Functional Decomposition and Concepts)

Overall Function	**Level 1 Sub-functions**	**Level 2 Sub-functions**	**Level 3 Sub-functions**	**Concept 1**		**Concept 2**		**Concept 3**		**Concept 4**	
				Description	**Sketch**	**Description**	**Sketch**	**Description**	**Sketch**		
Measure the heat transfe	Create a temperature variatio	Heat up the nanofluid before pumping		Ban heater	Figure 4.2 1	Heat exchanger	Figure 4.2 2	Boilers	Figure 4.2 3	Hot plate	Figure 4.2 4

r coefficient and the thermal conductivity of nanofluid under different boundary conditions	n in the nanofluid	Cool down the nanofluid after measurements		A condenser	Figure 4.25	cold plates	Figure 4.26	"Open feedwater cooler"	Figure 4.27	a liquid cooling heat exchanger	Figure 4.28
	Accommodate to different type of boundary conditions for the experiment	Accommodate to the magnetic field change		Stainless steel	Figure 4.29	The permeability	Figure 4.30	Crystals pipes	Figure 4.31	Magnetic field stabilizer	Figure 4.32
		Accommodate to the pressure boundary condition change		A pressure sensor	Figure 4.33	The pressure sensor	Figure 4.34	pressure Sensor	Figure 4.35	a control valves.	Figure 4.36
	Measure the heat transfer coefficient and the thermal conductivity of the nanofluid	Measure the heat transfer coefficient of the nanofluid in the experiment	Measure the voltage (V) drop in the boiler	Analog voltmeters	Figure 4.37	The control	Figure 4.38	An analog multimeter	Figure 4.39	A digital voltmeter	Figure 4.40
			Measure the temperature of the nanofluid (Tin and Tout)	Multipoint temperature sensors"	Figure 4.41	A temperature gauge"	Figure 4.42	"Thermistors"	Figure 4.43	"The KD2 Pro"	Figure 4.44
			Measure the intensity of the current used to heat up the nanofluid	Moving coil ammeters	Figure 4.45	Electrodynamic ammeters	Figure 4.46	Digital Ammeters	Figure 4.47	Digital Multimeters	Figure 4.48
		Measure the therma	Measure the voltage	Voltage	Figure	Digital Voltmeter	Figure	VTVMs and	Figure	Analog Voltmeters	Figure

		l conductivity of the nanofluid in the experiment	(V) drop in the boiler	Control Panels	4.49		4.50	FET-VMs	4.51		4.52
			Measure the temperature of the nanofluid (Tin and Tout)	Temperature sensor	Figure 4.53	Pyrometer	Figure 4.54	Thermo couple probe	Figure 4.55	Thermo couple sensor	Figure 4.56
			Measure the intensity of the current used to heat up the nanofluid	Moving coil Ammeters	Figure 4.57	Electrodynamic Ammeters	Figure 4.58	Tangent galvanometer	Figure 4.59	The KD2 pro measurement	Figure 4.60
		Generate readings of the parameters necessary for calculation	Display readings of measured parameters on a computer software	SCADA software	Figure 4.61	DCS software	Figure 4.62	“IC Measure”	Figure 4.63	“Manually collecting data”	Figure 4.64

			Calculate the heat transfer coefficient and the thermal conductivity based on the obtained readings	LabVIEW	Figure 4.65	EES	Figure 4.66	MATLAB	Figure 4.67	Manual	Figure 4.68
			Generate Graphs showing the fluctuation of each parameter	SCADA software	Figure 4.69	Entered data using EES	Figure 4.70	"Mark-10 software +	Figure 4.71	"MATLAB" i	Figure 4.72
	Be insulated to avoid heat loss	Avoid heat loss from radiation		Aluminum foil	Figure 4.73	Fiber glass	Figure 4.74	Mineral wool	Figure 4.75	Foam glass	Figure 4.76
		Avoid Heat loss From Convection		Vacuum insulation panel	Figure 4.77	Vacuum insulation pump	Figure 4.78	Glass insulation	Figure 4.79	Double pipe vacuum insulation	Figure 4.80

After everyone 's individual assignment where put together this is how the group consolidated them in order to create Table 4.2

Function 1.1: Heat up the nanofluid before pumping

Concept 1: band heater

The Figure 4.21 presented below is a picture of a ban heater, which is used to heat the nanofluid during the experiment. The device is to be installed before the pump so it can adjust the temperature based on the input.



Figure 4.21 shows an image of a Band Heater.

Concept 2: Heat exchanger

A heat exchanger in a furnace separates the combustion process from your breathing air. A combination metal chamber and passageway start at the burner assembly and ends approximately where the chimney vent connects to the furnace. Figure 4.22 shows a schematic of a heat exchanger as well as its different parts.

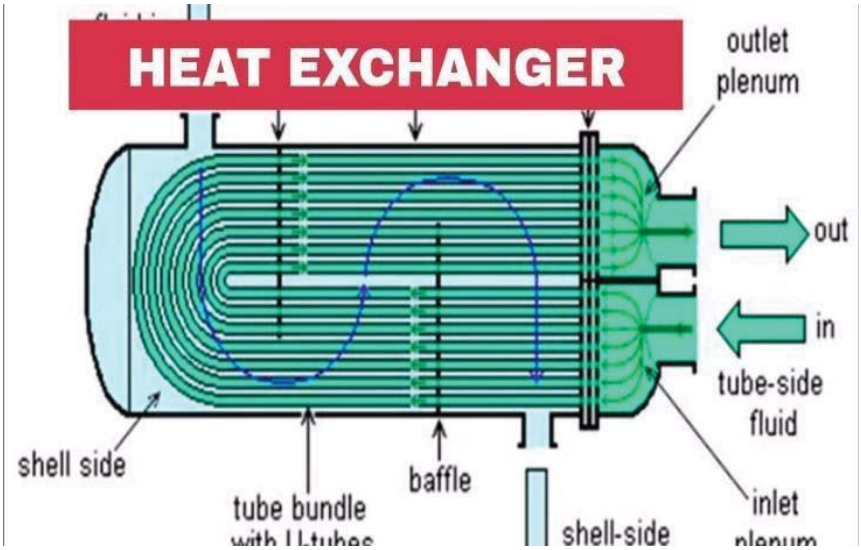


Figure 4.22 shows a picture of a heat exchanger.

Concept 3: Boiler

Allow nanofluid to heat in the boiler before the pumping process begins by feeding nanofluid into the feedwater inlet and passing through to the boiler before pushing forward in the process. Figure 4.23 is a schematic of the boiler and some of its different components.

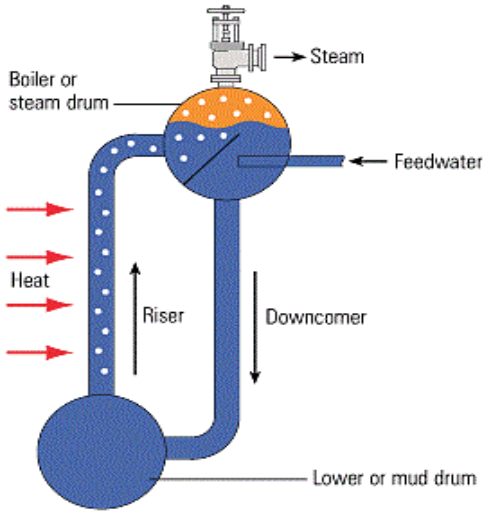


Figure 4.23 schematic of a boiler.

Concept 4: Hot Plate

A **hot plate** is a portable self-contained tabletop small appliance cooktop that features one or more electric heating elements or gas burner. A hot plate can be used as a stand-alone appliance but is often used as a substitute for one of the burners from an oven range or a kitchen stove. Figure 4.24 shows the image of a tabletop burner



Figure 4.24 an image of an electric tabletop burner

Function 1.2: Cool down the nanofluid after the measurements are made

Concept 1: Condenser

A condenser can be found at the end of the experimental set up, which is used to cool nanofluid after passing through the final evaporator. Figure 4.25 shows how condenser work.

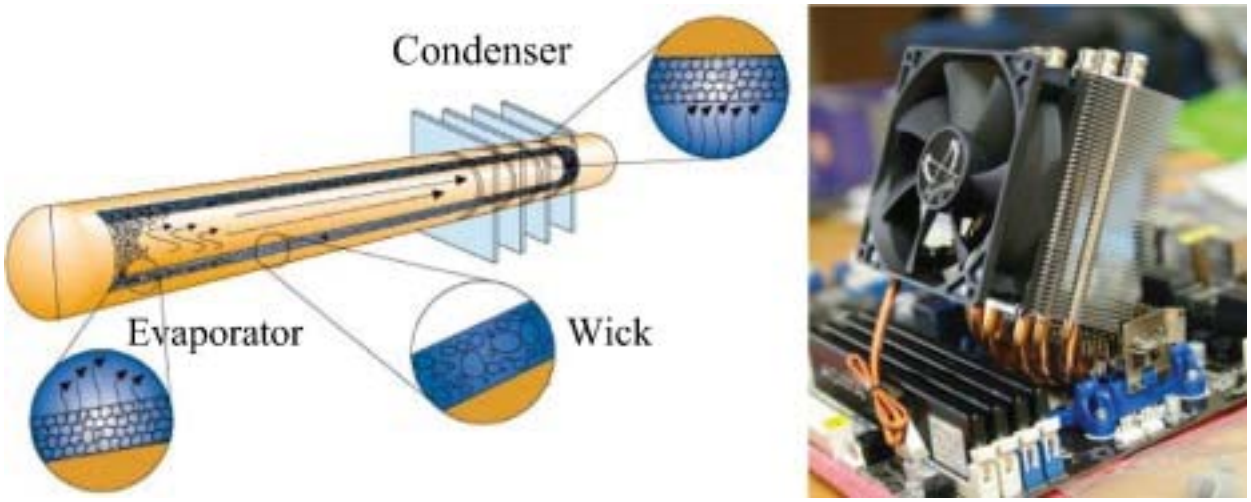


Figure 4.25 sketch of how a condenser works.

Concept 2: Cold Plate

cold plates are plane structure that can be used to cool down the nanofluid after the measurements are taken. The tubed cold plates are constructed of metal and can easily cool the fluid. Figure 4.26 represents the concept of cold plates.



Figure 4.26 sketch of a cold plate.

Concept 3: Heat sink

A **heat sink** (also commonly spelled **heatsink)** is a passive heat exchanger that transfers the heat generated by an electronic or a mechanical device to a fluid medium, often air or a liquid coolant, where it is dissipated away from the device, thereby allowing regulation of the device's temperature. Figure 4.27 shows an aluminum extrude heat sink

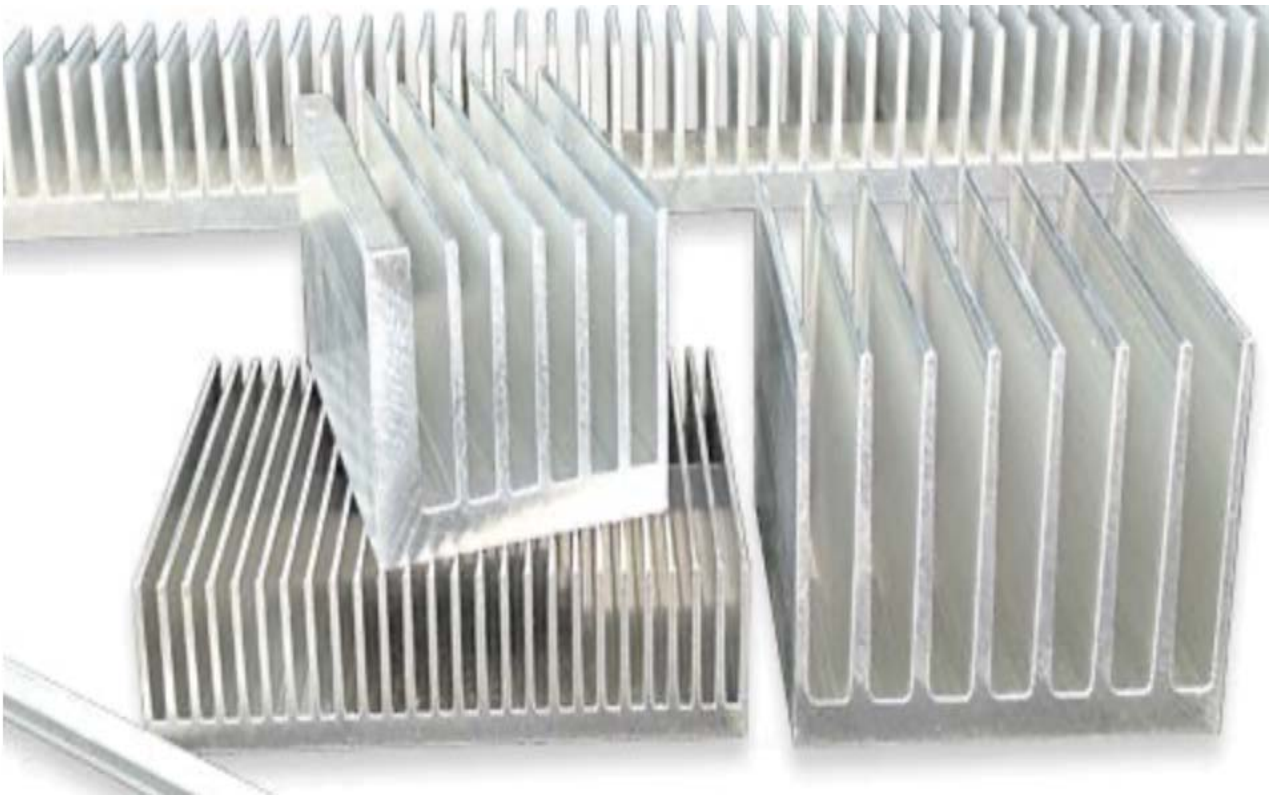


Figure 4.27 shows a figure of an extrude heat sink made of aluminum.

Concept 4: Liquid cooling heat exchanger

A liquid cooling heat exchanger that can be used to cool down the nanofluid after the measurements are made. The figure 4.28 shows a lightweight and small heat exchanger that can dissipate heat from a high efficiency plate-plate fin.



Figure 4.28 Liquid cooling heat exchanger.

Function 2.1: Accommodate to the magnetic field change

Concept 1: Stainless steel

It is a group of iron-based alloys that contain a minimum of approximately 11% chromium, a composition that prevents the iron from rusting, as well as providing heat-resistant properties. It cannot be easily influenced by the magnetic field. Figure 4.29 represents stainless steel bars.

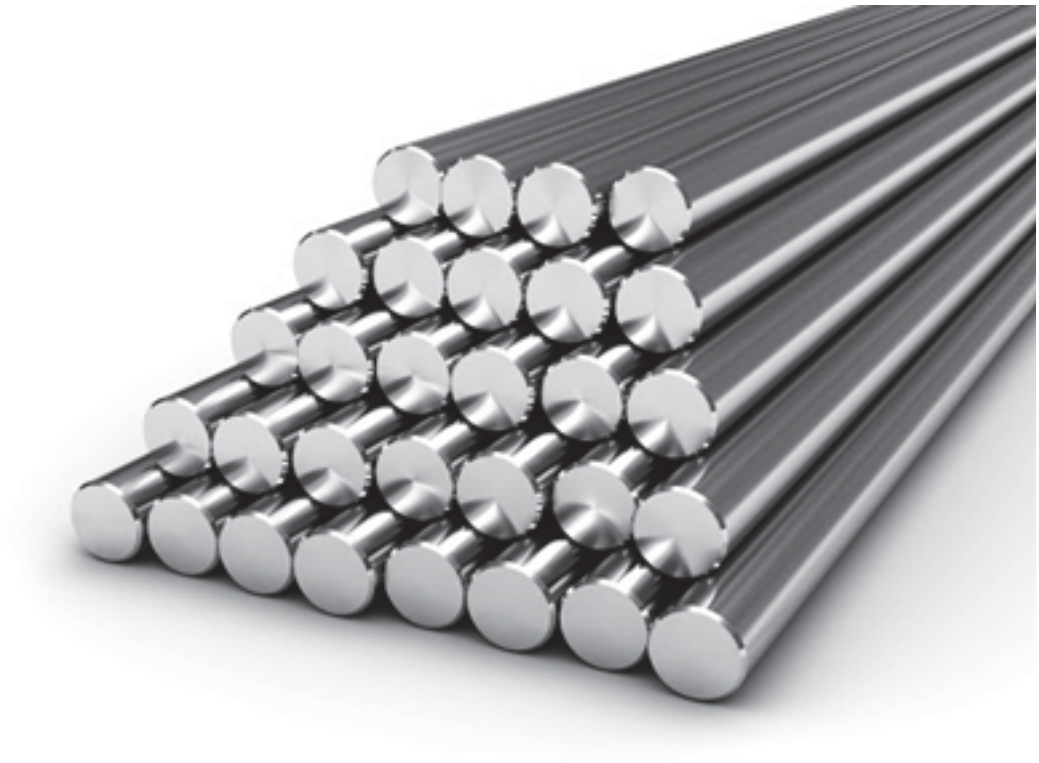


Figure 4.29 shows a sketch of Stainless steel.

Concept 2: Permeability to magnetic field

The permeability measures the ability of the material to allow the magnetic lines of force to pass through it. This would allow to have a magnetic field that goes through the material and have a direct impact on the nanofluid without the material being affected. Permeability is typically represented by the Greek letter μ and is not a constant as it can vary with the position in the medium, the frequency of the applied magnetic field, humidity, temperature, and other parameters. Figure 4.30 represents the current concepts.

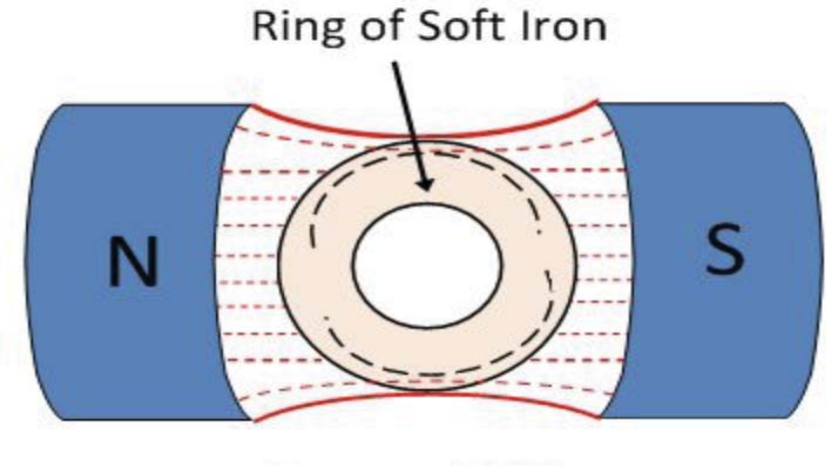


Figure 4.30 Sketch of a magnetically permeable soft iron ring.

Concept 3: Materials made of Crystals

A piece of a homogeneous solid substance having a natural geometrically regular form with symmetrically arranged plane faces. For instance, it can be used as a crystal pipe. Figure 4.31 shows a pipe made of crystal.



Figure 4.31 shows a sketch of a crystal pipe.

Concept 4: Magnetic field stabilizer.

Accommodating the magnetic field change requires a stabilizer, it works as maintaining the current throughout the different boundary conditions. A Coil ring accelerator in Figure 4.16 can also maintain the magnetic field under different boundary conditions. Transformers Figure 4.32 can maintain the current

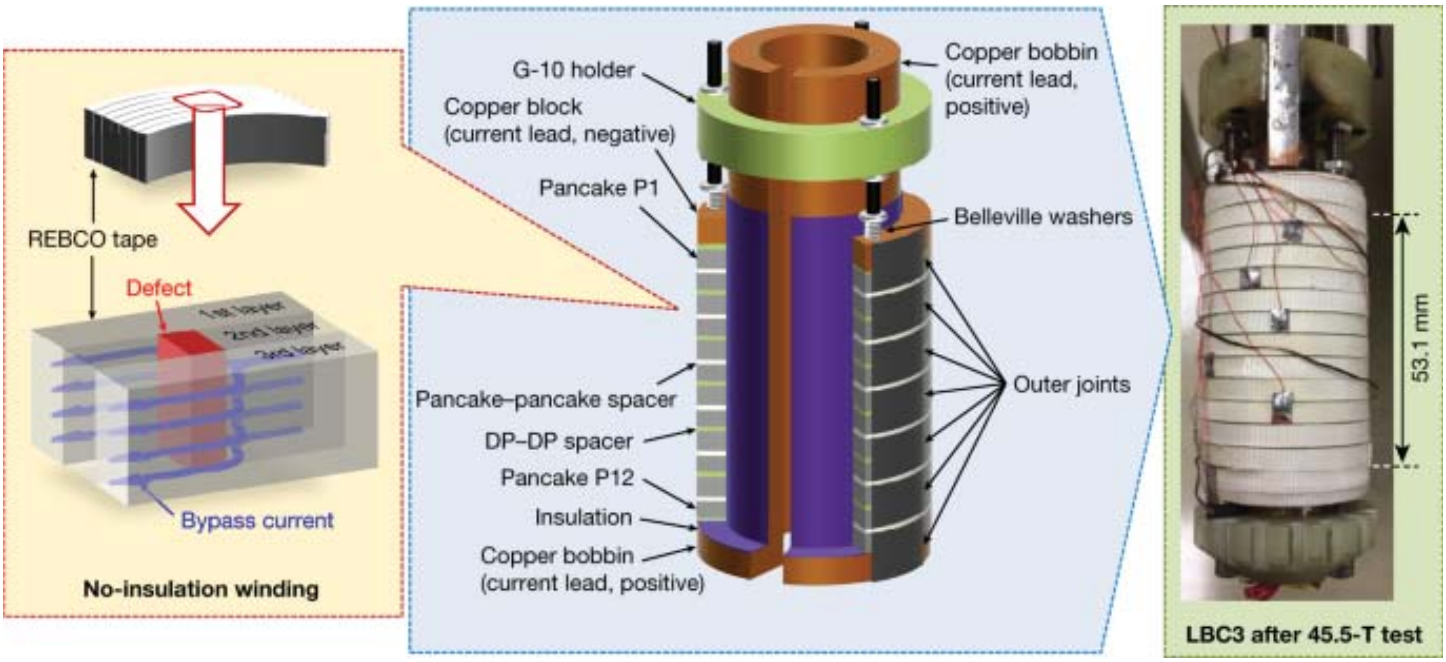


Figure 4.32 shows an image of a Magnetic field Stabilizer

Function 2.2: Accommodate to the pressure boundary condition change

Concept 1: Pressure Sensor

Figure 4.33 shows the concept of a pressure sensor to help keep track of the pressure to assure the pressure is steady. The pressure sensors are digital, ceramic and UL approved.



Figure 4.33 shows a image of a Pressure Sensors

Concept 2: Pressure boundary condition change

This Figure 4.34 is a schematic of a heat transfer experimental set up. Focusing mainly on pressure boundary change, located by the valve, there is a pressure sensor. The pressure sensor exits to a data acquisition which logs into a computer to see the characteristics of the pressure changes under different boundary conditions.

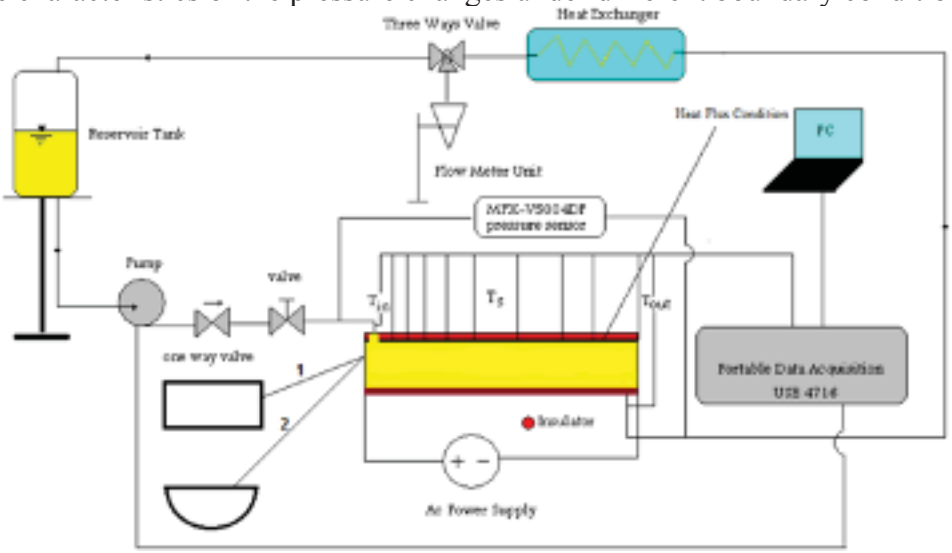


Figure 4.34 Shows an image on how the pressure boundary condition changes.

Concept 3: Set pressure inlet and outlet using pressure sensor

Set pressure inlet and pressure outlet to set pressure for specific experiments whilst using the pump in the systematic design to cause pressure to rise and fall. Figure 4.35 depicts a pressure sensor.

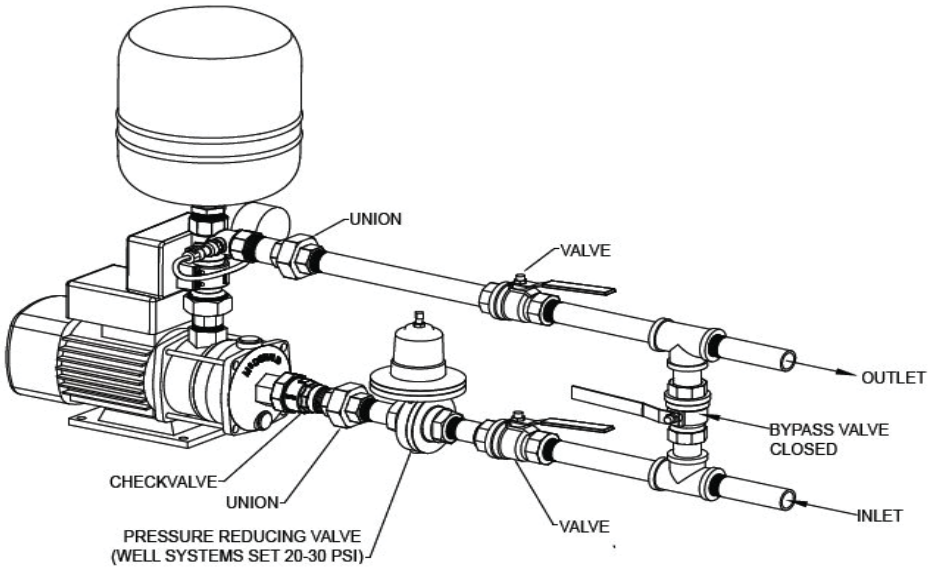


Figure 4.35 shows the image of a pressure sensor.

Concept 4: Valve

To control the fluid pressure in the system a control valve can be used as a device. As there are many different valves that can perform the same function pressure regulators as shown in Figure 4.36



Figure 4.36 shows an image of a Pressure control valve

Function 3.1.1: Measure the voltage(V) drop in the boiler (for convection calculation)

Concept 1: Analog Voltmeters

Analog voltmeters measure voltage or voltage drop in a circuit. They display readings using a needle rather than digital display. Analog voltmeters are widely used to measure voltage with d'Arsonval moving-coil galvanometers being most commonly used. Figure 4.37 is a sketch of an analog voltmeter.



Figure 4.37 shows an image of an analog voltmeter.

Concept 2: “control panel”
Using the control panel, it can monitor and measure the voltage in the system. The device has to be connected to a computer or if the experimental device has a motherboard it can be connected directly to it, a different type of the control panel has the same function. Multimeters can be used to measure the voltage manually as will. Figure 4.38 represents control panels.



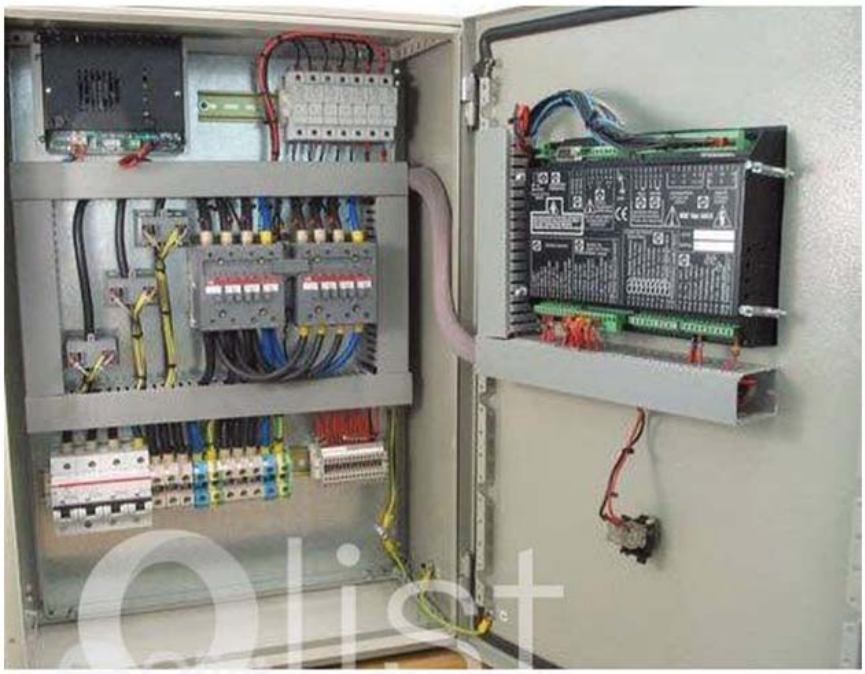


Figure 4.38 shows an image of a control panel, which is used to measure the voltage.

Concept 3: Analog multimeter

An analog multimeter to measure precise and accurate voltage for necessary computation at the end of the experiment.

Figure 4.39 is a sketch of a multimeter.



Figure 4.39 shows an image of a multimeter.

Concept 4: Digital voltmeter

A digital voltmeter measures an unknown input voltage by converting the voltage to a digital value and then displays the voltage in numeric form. Digital voltmeters are usually designed around a special type of analog-to-digital converter called integrating converter. Figure 4.40 represents a digital voltmeter



Figure 4.40 shows an image of a digital voltmeter

Function 3.1.2: Measure the temperature of the nanofluid (Tin and Tout) (for convection calculation)

Concept 1: multipoint temperature sensors

~~multipoint~~ temperature sensors accurately measuring temperatures at various locations along the sensor's length. Figure 4.41 is a sketch of a multipoint thermocouple.



Figure 4.41 shows an image of a multipoint temperature sensors

Concept 2: Temperature gauge

Consists of utilizing a temperature gauge which will accurately depict the temperature measured throughout the nanofluid in the system. The sketch in ~~figure~~ 4.42 shows the appropriate temperature gauge.



Figure 4.42 shows an image of a temperature gauge.

Concept 3: Thermistors

consists of utilizing thermistors which have an increased sensitivity thermally whose prime function is to exhibit a large, predictable, and precise change in electrical resistance when subjected to corresponding change in body temperature. Figure 4.43 represents a thermistor.



Figure 4.43 shows an image of Thermistors.

Concept 4: KD2 Pro

The figure 4.44 is an experimental set up of measuring temperature of a nanofluid. Focusing on the KD2 Pro and the sample label, shown in the setup is a KD2 Pro which measures temperature. The KD2 Pro is wired to a nanofluid sampler. This process allows the measurement of the nanofluid sample temperature to be made.

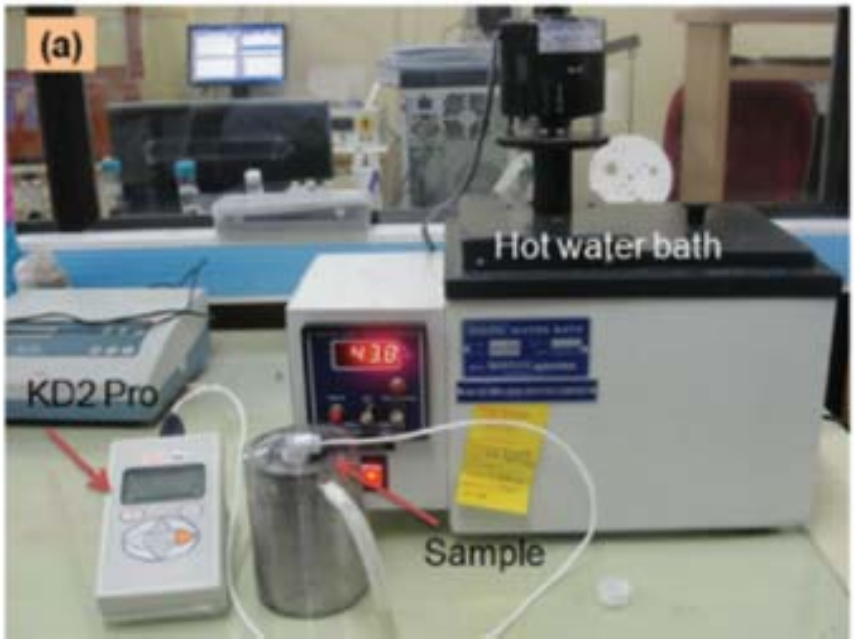


Figure 4.44 is an image that shows how KD2 operates.

Function 3.1.3: Measure the intensity of the current used to heat up the nanofluid (for convection calculation)

Concept 1: Moving coil Ammeter

This type of ammeter uses magnetic deflection where current passing through a coil causes the coil to move in a magnetic field. The uniform air gap between the iron core and the permanent magnet poles make the deflection of the meter linearly proportional to current. These meters have linear scales. Basic meter movements can have full-scale deflection for currents from about 25 microamperes to 10 milliamperes. Moving Coil Instruments are used for measuring DC quantities. They can be used on AC systems when fed through bridge rectifiers, but some products are rectified moving coils and can be used in AC systems directly. Figure 4.45 represents a moving coil ammeter.

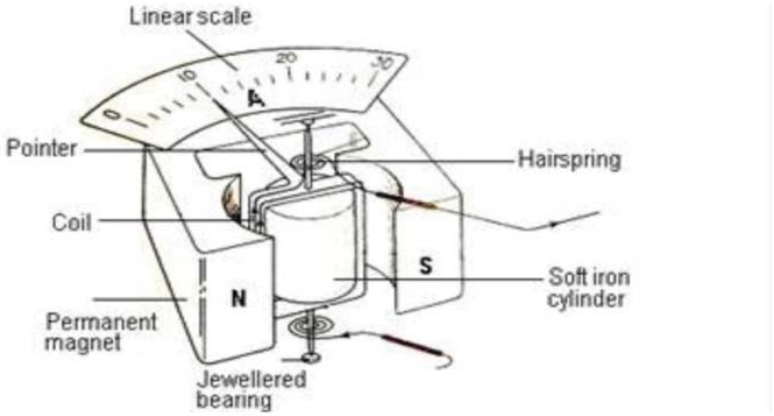


Figure 4.45 is a sketch of a moving coil ammeter.

Concept 2: Electrodynamic Ammeter

An electrodynamic movement uses an electromagnet instead of the permanent magnet of the d'Arsonval movement. This instrument can respond to both alternating and direct current and also indicates true RMS for AC. Figure 4.46 represents an electrodynamic ammeter.

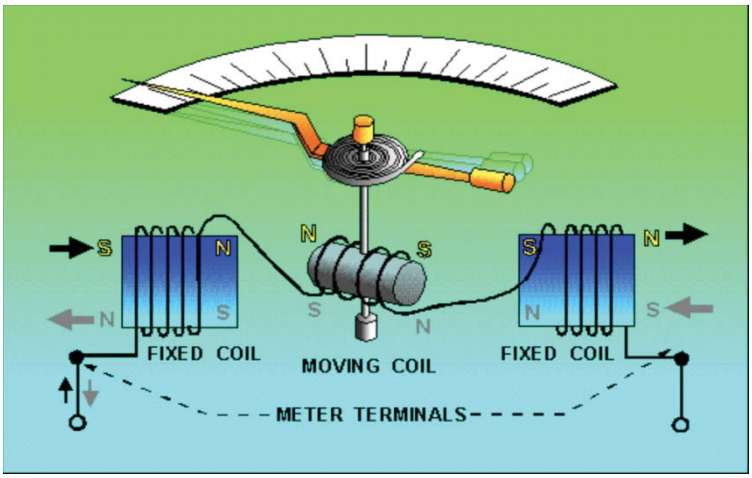


Figure 4.46 is Sketch of an electrodynamic ammeter.

Concept 3: Digital Ammeter

Digital ammeters use a shunt resistor to produce a calibrated voltage proportional to the current flowing. This voltage is then measured by a digital voltmeter, through use of an analog to digital converter (ADC); the digital display is calibrated to display the current through the shunt. Figure 4.47 represents a digital ammeter.



Figure 4.47 Sketch of a digital ammeter.

Concept 4: Digital Multimeter

Figure 4.48 shows the concept of a digital multimeter that can be used to measure the intensity of the current used to heat the nanofluid. This is a handheld digital device with two probes that connect to the multimeter and can connect to the system to measure the current.



Figure 4.48 digital multimeter.

<u>Function 3.2.1: Measure the voltage(V) drop in the boiler (for conduction calculation)</u>

Concept 1: Voltage Control Panel

Using the control panel shown in Figure 4.49, it can monitor and measure the voltage in the system. The device has to be connected to a computer or if the experimental device has a motherboard it can be connected directly to it.



Figure 4.49 Voltage control panel.

Concept 2: Digital Voltmeter

DVMs display the measured voltage using LCDs or LEDs to display the result in a floating-point format. Obviously, if voltage measurements are taken and the results are displayed digitally with LED or LCD display, the instrument has to contain an A/D converter. Using a programmed microcontroller, ADC and LCD display, the following circuit is ready to provide accurate digital display of analog values from 0 to 15 volts DC. Figure 4.50 is a sketch of a digital voltmeter.



Figure 4.50 Sketch of a digital voltmeter.

Concept 3: VTVMs and FET-VMs

These types of instruments handle DC voltage, AC voltage, and resistance measurements. In this type of voltage measuring device an electronic amplifier is used in between the input and the meter. Figure 4.51 represents a VTMS.



Figure 4.51 Sketch of a VTVMS.

Concept 4: Analog Voltmeters

Analog voltmeter includes deflecting type of indicating voltmeters. These are like moving iron, moving coil, electrostatic types of voltmeters. Moving coil instruments are of two types namely permanent magnet and dynamometer types. Figure 4.52 is a sketch of an analog voltmeter.

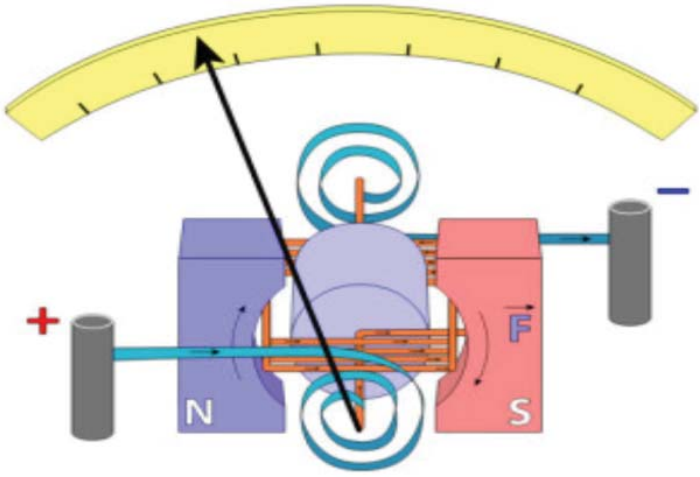


Figure 4.52 Sketch of an analog voltmeter.

<u>Function 3.2.2: Measure the temperature of the nanofluid (Tin and Tout)</u>

Concept 1: Temperature sensor

Figure 4.53 shows the concept of a temperature sensor that can be used to measure the temperature of the nanofluid. Two of these can be used to measure the temperature in and out of the system

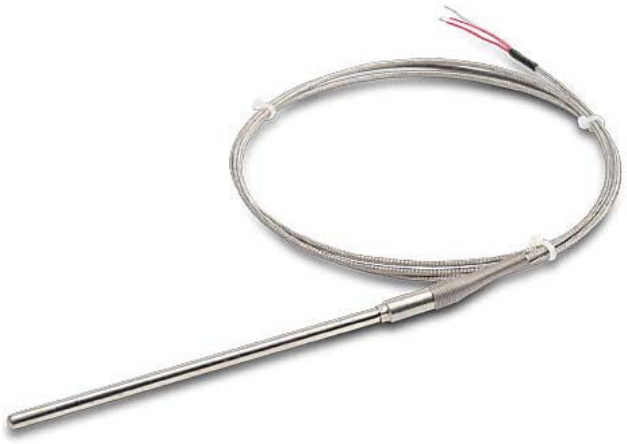


Figure 4.53 Temperature sensor

Concept 2: Pyrometer

A pyrometer is an instrument that measures temperature remotely, i.e. by measuring radiation from the object, without having to be in contact. Most pyrometers work by measuring radiation from the body whose temperature is to be measured. In an elementary radiation pyrometer, the radiation from the hot object is focused onto a thermopile, a collection of thermocouples, which generates an electrical voltage that depends on the intercepted radiation. Figure 4.54 shows an image of a Pyrometer.



Figure 4.54 Pyrometer

Concept 3: Thermocouple probe

Figure 4.55 shows the concept of a thermocouple probe that can be used to measure the temperature of the nanofluid. Two of these could be used in order to get the temperature in and out.



Figure 4.55 Thermocouple Probe

Concept 4:

A thermocouple is an electrical device consisting of two dissimilar electrical conductors forming an electrical junction. A thermocouple produces a temperature-dependent voltage as a result of the thermoelectric effect, and this voltage can be interpreted to measure temperature. Figure 4.56 shows a Sketch of Thermocouples.

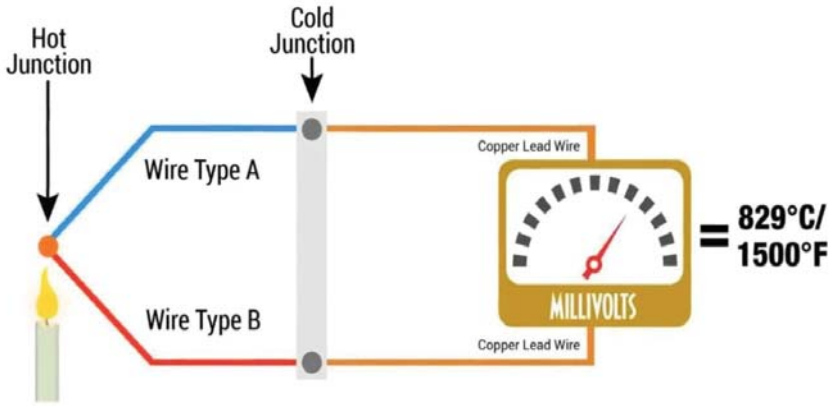


Figure 4.56 shows a Sketch of Thermocouples.

<u>Function 3.2.3: Measure the intensity of the current used to heat up the nanofluid (for conduction calculation)</u>

Concept 1: Moving coil Ammeter

This type of ammeter uses magnetic deflection, where current passing through a coil causes the coil to move in a magnetic field. The uniform air gap between the iron core and the permanent magnet poles make the deflection of the meter linearly proportional to current. These meters have linear scales. Basic meter movements can have full-scale deflection for currents from about 25 microamperes to 10 milliamperes. Moving Coil Instruments are used for measuring DC quantities. They can be used on AC systems when fed through bridge rectifiers, but some products are rectified moving coil and can be used in AC systems directly. Figure 4.57 represents a moving coil ammeter.

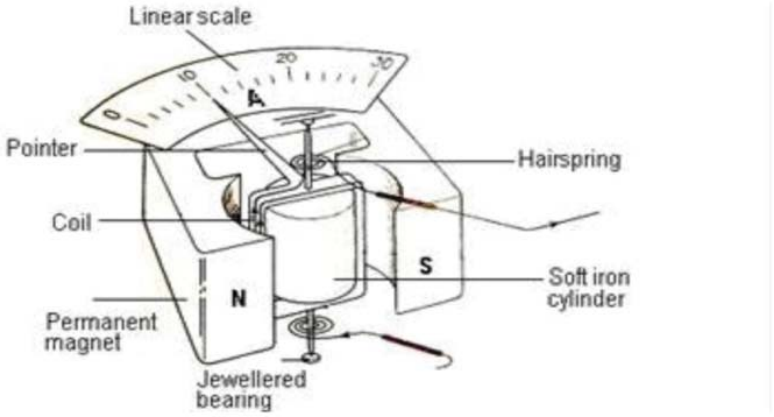


Figure 4.57 shows an image of Moving coil Ammeter

Concept 2: Electrodynamic Ammeter

An electrodynamic movement uses an electromagnet instead of the permanent magnet of the d'Arsonval movement. This instrument can respond to both alternating and direct current and also indicates true RMS for AC. Figure 4.58 is a sketch of an electrodynamic ammeter.

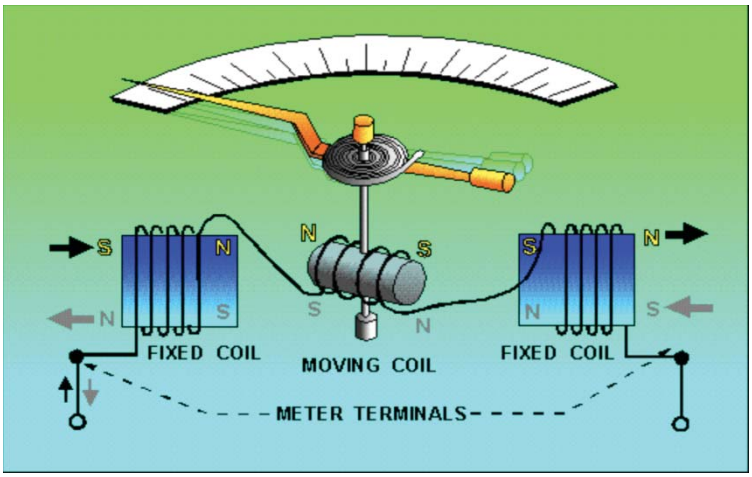


Figure 4.58 shows an image of an electrodynamic movement.

Concept 3: Tangent galvanometer

Figure 4.59 shows the concept of a tangent galvanometer that can measure the intensity of the electric current used to heat the nanofluid. Features a nonmagnetic rotating tripod base and a removable compass.


Figure 4.59 shows a tangent galvanometer.

Concept 4: KD2 pro measurement

The figure 4.60 is an experimental set up of measuring the intensity of current used to heat up nanofluid. Shown in the setup is a KD2 Pro which measures current. There is a hot water bath machine that is wired to a nanofluid sample. The sample equipment is attached to the KD2 Pro where measurement data are located.



Figure 4.60 show an image of a KD2 pro

Function 3.3.1: Display readings of measured parameters on a computer software

Concept 1: SCADA

Supervisory control and data acquisition systems are a control system architecture comprising computers, networked data communications and graphical user interfaces for high-level process supervisory management. It uses a computer acquisition card that gathers data and transfers it to a computer software. Figure 4.61 represents the schematic of a SCADA system.

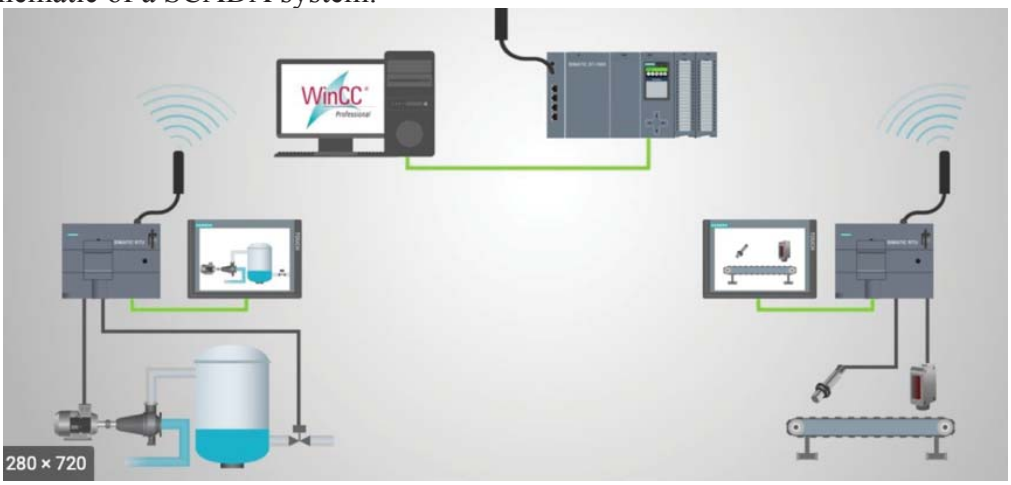


Figure 4.61 sketch of a SCADA system.

Concept 2: DCS

DCS stands for decentralized control systems. A decentralized system in system theory is a system in which lower level components operate on local information to accomplish global goals. Figure 4.62 is a sketch of a DCS system.

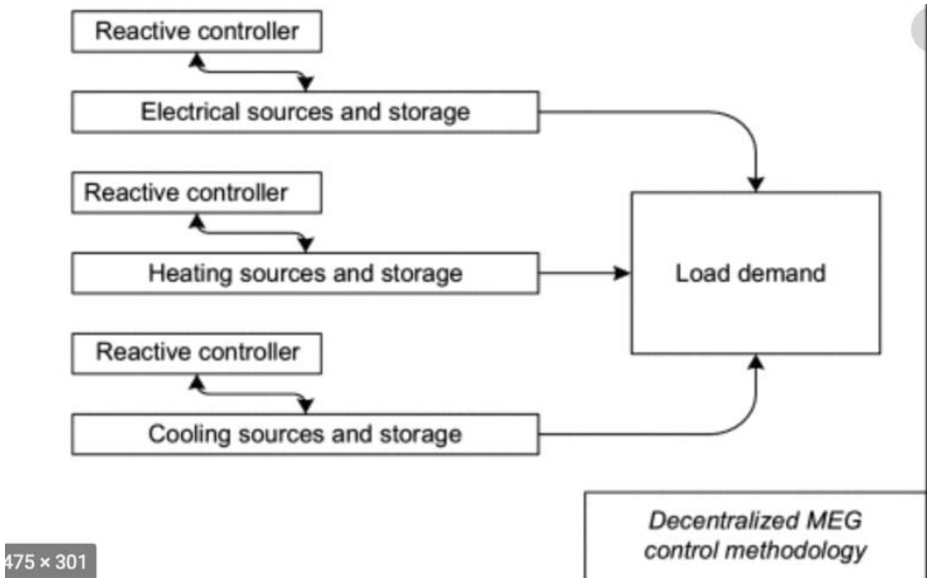


Figure 4.62 sketch of a DCS system

Concept 3: IC Measure

IC Measure from computer software technology can be used to measure calculations and parameters accurately. Figure 4.63 is a sketch of IC measure.

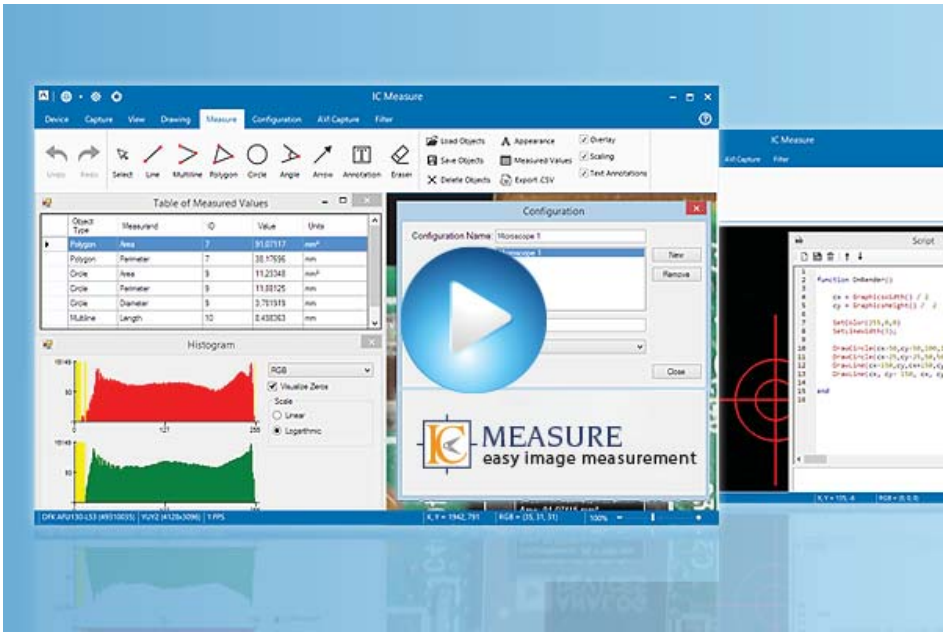


Figure 4.63 a sketch of IC Measure

Concept 4: Manually collecting data

The data of the experiment can be recorded manually at regular intervals of times instead of using a data acquisition system, and then entered manually in an engineering software to be analyzed. Figure 4.64 is a sketch of how data can be manually collected.



Figure 4.64 sketch of data manually collected

Function 3.3.2: Calculate the heat transfer coefficient and the thermal conductivity based on the obtained readings

Concept 1: Lab View

LabVIEW, short for *Laboratory Virtual Instrument Engineering Workbench*, is a programming environment in which you create programs using a graphical notation (connecting functional nodes via wires through which data flows). It is an interactive program development and execution system designed for people, like scientists and engineers, who need to program as part of their jobs. AN overview of LabView is represented in Figure 4.65

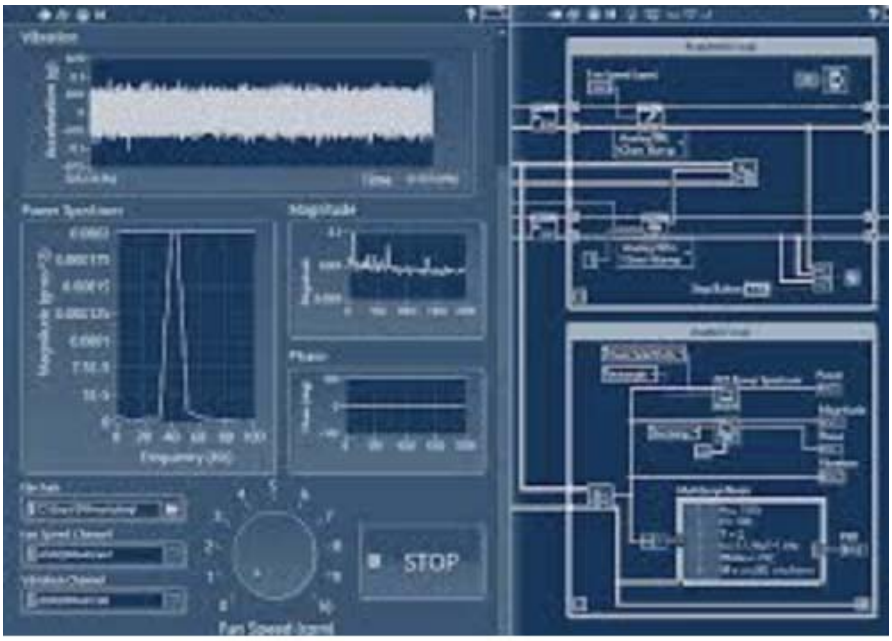


Figure 4.65 LabView overview

Concept 2: EES

EES is a general equation-solving program that can numerically solve thousands of coupled non-linear algebraic and differential equations. The program can also be used to solve differential and integral equations, do

optimization, provide uncertainty analyses, perform linear and non-linear regression, convert units, check unit consistency, and generate publication-quality plots. An over view of EES is represented in figure 4.66

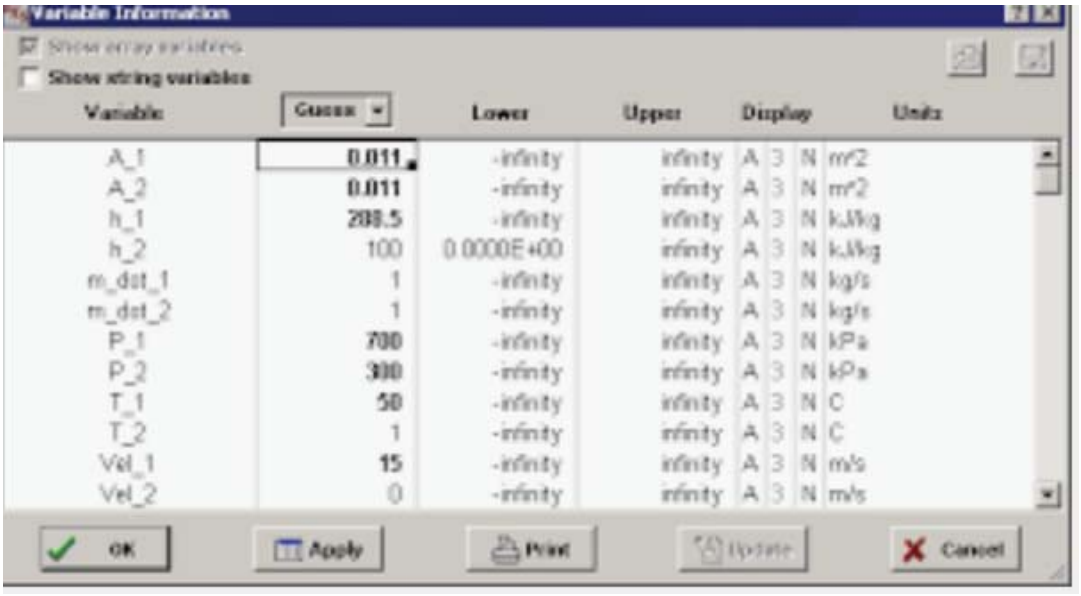


Figure 4.66 Sketch of a use of EEs

Concept 3: MATLAB
It is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include: Data analysis, exploration, and visualization. Figure 4.56 shows a representation of what MATLAB can do. Figure 4.67 shows how MATLAB works

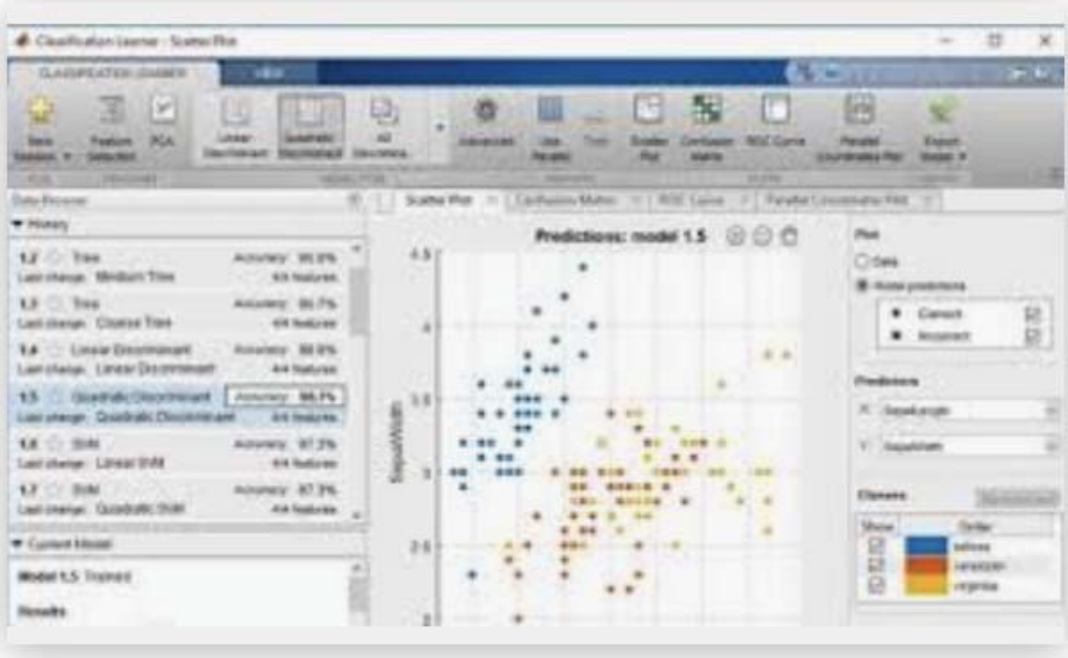


Figure 4.67 MATLAB interface

Concept 4: Manual calculation
Calculation can be manually done base on the formula necessary to calculate the hat transfer coefficient and the thermal conductivity and also the parameters necessary for this calculation like in Figure 4.68



Figure 4.68 heat transfer coefficient hand calculation process

Function 3.3.3: Generate Graphs showing the fluctuation of each parameter

Concept 1: SCADA

Supervisory control and data acquisition are a control system architecture comprising computers, networked data communications and graphical user interfaces for high-level process supervisory management. It uses a computer acquisition card that gathers data and transfers it to a computer software. Figure 4.69 represents the schematic of a SCADA system.



Figure 4.69 shows an image of SCADA software, which is a database operational software.

Concept 2: Graphs of manually entered data using EES

Using a software like engineering equation solver graphs of the entered parameters can be generated over time (time scale has to be included). Figure 4.70 represents a sketch of how manually collected data can be used for graphing by the Engineering Equation solver.

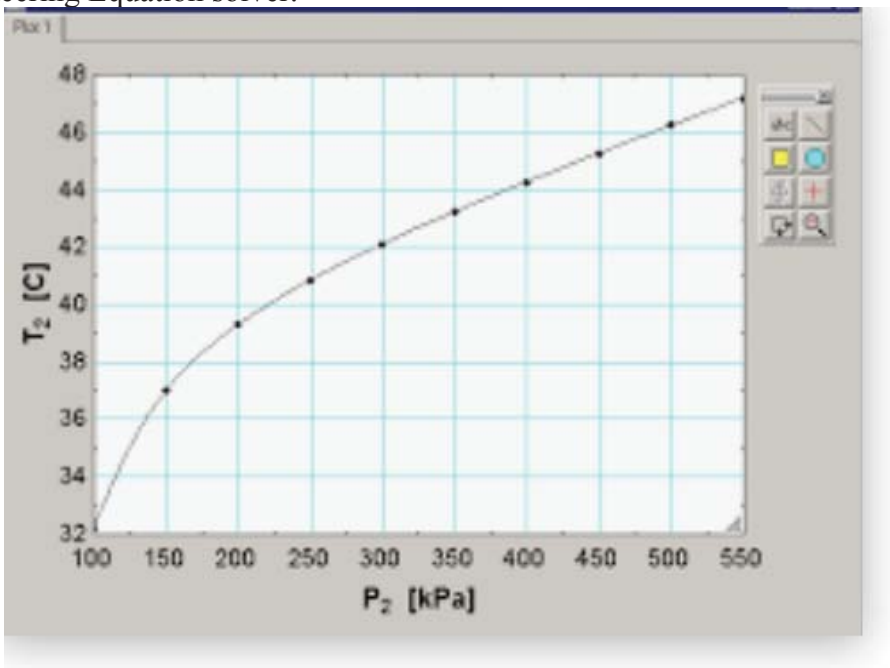


Figure 4.70 Sketch of a graph generated by EES for manually collected data

Concept 3: Mark- 10

It is a software that collects data. The programs include a set of tools to analyze test results, including statistical calculations, quick data export to Microsoft Excel, customizable reports, pass/fail indicators, and many others as shown in Figure 4.71

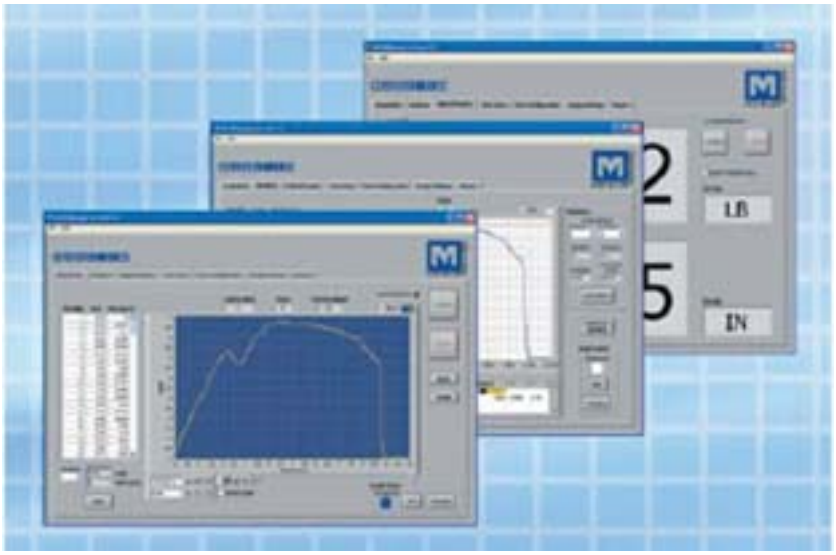


Figure 4.71 shows an image of Mark-10, which is a software database analysis.

Concept 4: MATLAB

It is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include: Data analysis, exploration, and visualization. Figure 4.72 shows a representation of what MATLAB can do.

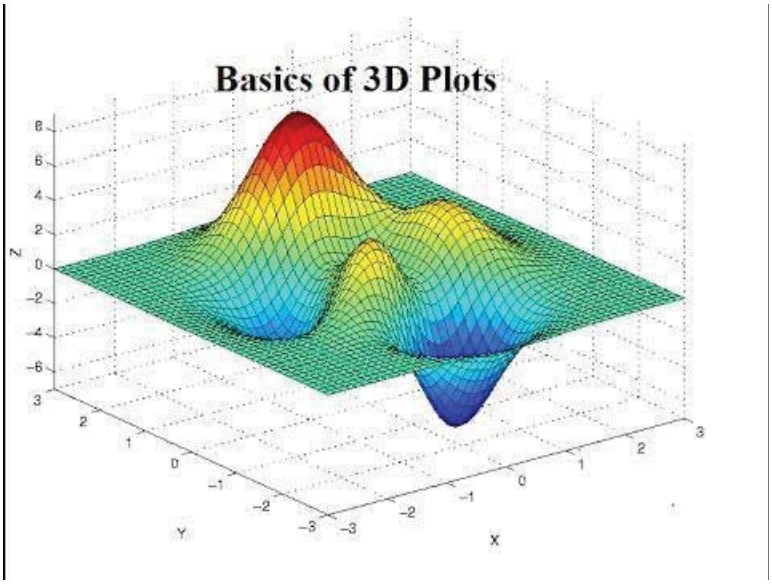


Figure 4.72 shows an image of a graphical representation made by MATLAB.

Function 4.1 Avoid radiation heat loss

Concept 1: aluminum foil

Aluminum foil can be used to create an insulation. The aluminum reflects the heat back which stops radiation heat loss out of the system., The insulation eliminates heat from passing through it. Figure 4.73 is an example of aluminum insulating material.



Figure 4.73 aluminum foil for insulation

Concept 2: fiber Glass

Fiberglass is an immensely versatile material due to its lightweight, inherent strength, weather-resistant finish and variety of surface textures. The development of fiber-reinforced plastic for commercial use was extensively researched in the 1930s. Figure 4.74 is an example of fiber glass material.



Figure 4.74 Fiber glass material

Concept 3: Mineral wool

Mineral wool is any fibrous material formed by spinning or drawing molten mineral or rock materials such as slag and ceramics. Figure 4.75 represents mineral wool.



Figure 4.75 Mineral wool

Concept 3: Foam glass

Foam glass is a porous glass foam material. Its advantages as a building material include its light weight, high strength, and thermal and acoustic insulating properties. It is made by heating a mixture of crushed or granulated glass and a blowing agent (chemical foaming agent) such as carbon or limestone. Figure 4.76 represents foam glass.



Figure 4.76 Foam glass

Function 4.2 Avoid convection heat loss

Concept 1: Vacuum insulation panel

A vacuum insulated panel (VIP) is a form of thermal insulation consisting of a gas-tight enclosure surrounding a rigid core, from which the air has been evacuated. It is used in building construction, refrigeration units, and insulated shipping container to provide better insulation performance than conventional insulation materials. Figure 4.77 represent vacuum insulation panels.



Figure 4.77 Vacuum insulation panel

Concept 2: Vacuum insulation Pump

A vacuum pump is a device that removes gas molecules from a sealed volume in order to leave behind a partial Vacuum. Figure 4.78 represents vacuum pump



Figure 4.78 Vacuum pump

Concept 3: Glass insulation

VIG (vacuum insulation glass) achieves high levels of thermal insulation using the same principles as the Dewar flask – the vacuum eliminates heat transfer between the two glass sheets due to gaseous conduction and convection, and radiative heat transfer is reduced to a low level by one or two internal transparent low emittance coatings. Figure 4.79 represents glass vacuum insulation



Figure 4.79 bell jar

Concept 4: Doubling the pipe and creatin a vacuum space between them
They are a double pipe system in which a space id left in order to create an insulation; the space is emptied of any hear creating a vacuum there's is then no heat transfer. Figure 4.80 represents a double pipe vacuum.

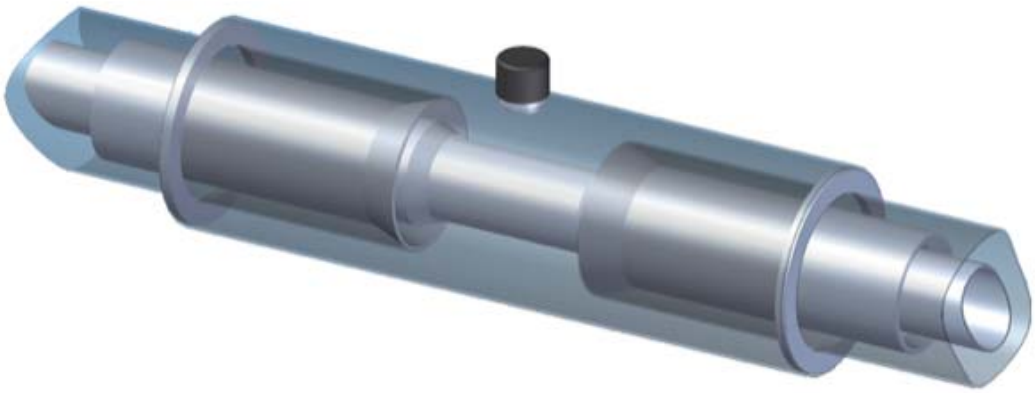


Figure 4.80 Double pipe vacuum insulation

4.3 Concept Evaluation and Selection

~~This status report is section 4.3 of the final report~~ and it focuses on the selection of concepts the group came up with on the previous status report titled concept generation. In this status report, group members were extremely concentrated on selecting concepts that could actually help develop the different functions stated on functional decomposition. To do that. A list of GO-NO-GO and matrices tables were created using a list of criteria that can help the group achieve the goals and objectives of the overall project.

List of Criteria
In this section the group generated an exhaustive list of criteria that were going to serve as a check mark for the selection of different concepts found on the concept generation. These concepts were later used to design a set up of what the groups final apparatus will look like. The list of criteria below was obtained by answering some of the questions stated in the bullet points below.

- What customer requirements are related to the project? Make a list of all customer requirements

1) safety
2) cost effectiveness
3) Ease to operate
4) Durability
5) Ease of assembly

- What operating environments are related to the project? Look at all of your operating environments.

6) applicable to lab settings
7) Eliminate radiation
8) Eliminate convection

- What constraints can affect the project? List all of your project constraints.

9) Size.; products should be small around 11 inches on high and base and 5 inches width.
10) Weight; concepts have to be light weight around 10 to 15 lbf.
11) Heat resistance
12) Physical resistance; devices shouldn't be easy to break.
13) concepts easily influenced by the magnetic field.

- Is current technology available for the functions of the project?

14) Availability of technology and materials
15) Accessibility of technology and materials

- Can the technology/concept be manufactured with known processes?

16) Yes, it can be manufactured in terms ofFeasibility
17) Yes, it can be manufactured when it comes to see how Ease it is to operate
18) Yes it can be manufactured in terms of reliability.

- What are the project objectives? Look at your list of objectives

19) Speed in measuring the heat transfer coefficient and thermal conductivity under different BCs.
20) Accuracy in measuring the heat transfer coefficient and thermal conductivity under different BCs.
21) Measuring HTC and thermal conductivity under different boundary conditions

- Is there a need for experimentation to ascertain how well certain project functions can be achieved?

22) Magnetic field accommodation

23) Boundary layers accommodation.
24) Pressure boundary layer accommodation.
25) Radiation shields.

Table 4.4 is a representation of some requirements and criteria from the list above that were implemented to the functions and subfunctions of the apparatus. If a criterion was thought to be applicable to a function it was assigned to it by using the corresponding number of the criteria from the above list. These criteria would be the ones to be used to evaluate the different concepts tied to the functions.

Table 4.4 Requirements/Criteria Table

Overall Function	Level 1 Sub-functions	Level 2 Sub-functions	Level 3 Sub-functions	Requirements/Criteria Affecting Sub-Function								
				1	2	3	4	5	6	7	8	

Measure the heat transfer coefficient and the thermal conductivity of nanofluid under different boundary conditions	Make the nanofluid temperature vary during the experiment	Heat up the nanofluid before pumping		1	2	11	9	17				
		cool down the nanofluid after the measurements are made		1	2	10	5	19	3			
	Accommodate to different type of boundary conditions for the experiment	Accommodate to the magnetic field change		4	2	15	22	20	18	16		
		Accommodate to the pressure boundary condition change		15	2	9	20	3	18	16		
	Measure the heat transfer coefficient and the thermal conductivity of the nanofluid	Measure the heat transfer coefficient of the nanofluid in the experiment	Measure the voltage(V) from the source	1	2	9	10	13				
			Measure the nanofluid temperature of the nanofluid and set up (Tin and Tout)	10	2	1	4	9	3			
			Measure the current coming from the source	1	2	9	4	19	3			
		Measure the thermal conductivity of the nanofluid in the experiment	Measure the voltage from the source	1	2	9	10	3				
			Measure the nanofluid temperature of the nanofluid and set up (Tin and Tout)	10	2	1	4	9	3			

			Measure the current(I) from the source	1	2	9	4	19	3			
		generate readings of the parameters necessary for calculation	Display readings of measured parameters on a computer software	5	2	3	10	9	1			
			Calculate the heat transfer coefficient and thermal conductivity based on the obtained data	22	8	15	7					
			Generate graphs showing the fluctuation of each parameter	1	2	20	4	9	5			
	Insulate to avoid heat loss	Avoid heat loss from radiation		2	1	3	4	7	11			
		Avoid heat loss from convection		1	2	4	8	16	11			

GO-NO-GO TABLES

In this section the group proceeded to evaluate the different concepts based on GO-NO-GO screening. In order to do so, an odd number of criteria were chosen out of the list above and applied to the concepts stated on Table 4.4. If the concept received more GO's than NO-GO's, then the concept was selected and later on moved to the next evaluation system. Otherwise, the concept was rejected or not used. Table 4.5 up to 4.19 represents the GO-NO-GO's screening of the concepts of every function that the overall system is supposed to perform.

Table 4.5 GO-NO-GO Table for Function 1.1 "Heat up the nanofluid before pumping."

Concepts	Concept 1	Concept 2	Concept 3	Concept 4
Concepts title	Band heater	Heat exchanger	Boiler	Hot plate
Criteria/Requirement	GO-NO-GO	GO-NO-GO	GO-NO-GO	GO-NO-GO
Safety	GO	GO	GO	GO
Cost effectiveness	GO	NO-GO	GO	GO
Heat resistance	GO	GO	GO	GO
Overall Decision	GO	NO-GO	GO	GO

Table 4.6 GO-NO-GO for function 1.2: Cool down the Nanofluid after the measurement are made

Concepts	Concept 1	Concept 2	Concept 3	Concept 4
Concepts title	Condenser	Cold plate	Heat sink	Liquid cooling heat exchanger
Criteria/Requirement	GO-NO-GO	GO-NO-GO	GO-NO-GO	GO-NO-GO
Safety	GO	NO	GO	GO
Feasibility	GO	NO	GO	GO
ease assembly	GO	NO	GO	GO
Overall Decision	GO	NO-GO	GO	GO

Table 4.7 GO-NO-GO for function 2.1: Accommodate to the magnetic field change.

Concepts	Concept 1	Concept 2	Concept 3	Concept 4
Concepts title	Stainless steel	Permeability to magnetic field	Material made of crystal	Magnetic field stabilizer
Criteria/Requirement	GO-NO-GO	GO-NO-GO	GO-NO-GO	GO-NO-GO
Cost effectiveness	GO	GO	GO	NO
Magnetic field accommodation	GO	GO	GO	NO
Size	GO	GO	GO	NO
Overall Decision	GO	GO	GO	NO-GO

Table 4.8 GO-NO-GO for function 2.2 Accommodate to pressure boundary condition

Concepts	Concept 1	Concept 2	Concept 3	Concept 4
Concepts title	Pressure Sensor	Pressure boundary condition	set Pressure sensor inlet and outlet using Pressure sensor	Pressure Control Valve
Criteria/Requirement	GO-NO-GO	GO-NO-GO	GO-NO-GO	GO-NO-GO
Accuracy	GO	NO GO	NO GO	GO
Cost effectiveness	GO	NO GO	GO	GO
Size	GO	NO GO	GO	GO
Overall Decision	GO	NO GO	GO	GO

Table 4.9 GO-NO GO table for evaluating the concepts for the function 3.1.1 Measure the voltage(V) from the source (for convection calculation)

Concepts	Concept 1	Concept 2	Concept 3	Concept 4
Concepts title	Analog Voltmeters	Control Panel	Analog multimeter	Digital Voltmeter
Criteria/Requirement	GO-NO-GO	GO-NO-GO	GO-NO-GO	GO-NO-GO
Size	GO	NO-GO	GO	GO
Easy to operate	GO	NO-GO	GO	GO
Cost effectiveness	GO	NO-GO	GO	GO
Overall Decision	GO	NO-GO	GO	GO

Table 4.10 GO-NO-GO table for Function 3.1.2 “Measure the temperature of the nanofluid and set up (Tin and Tout) ”

Concepts	Concept 1	Concept 2	Concept 3	Concept 4
Concepts title	Multipoint temperature sensors	Temperature gauge	Thermistors	KD2 Pro
Criteria/Requirement	GO-NO-GO	GO-NO-GO	GO-NO-GO	GO-NO-GO
Weight	GO	GO	GO	GO
Cost effectiveness	NO-GO	GO	GO	NO-GO
Safety	GO	GO	GO	GO
Durability	NO-GO	GO	NO-GO	GO
Size	GO	GO	GO	GO
Easy to operate	GO	GO	GO	GO
Overall Decision	NO-GO	GO	GO	GO

Table 4.11 GO-NO-GO table for Function 3.1.3 “Measure the intensity of the current source ”

Concepts	Concept 1	Concept 2	Concept 3	Concept 4
Concepts title	Moving coil ammeter	Electrodynamic ammeter	Digital ammeter	Digital multimeter
Criteria/Requirement				
Accuracy	GO	GO	GO	GO
Reliability	GO	GO	NO-GO	GO
Cost Effectiveness	GO	GO	GO	GO
Overall Decision	GO	GO	GO	NO-GO

Table 4.12 GO-NO-GO table for evaluating the concepts for the function 3.2.1 Measure the voltage(V) from the source (for convection calculation)

Concepts	Concept 1	Concept 2	Concept 3	Concept 4
Concepts title	Voltage Control Panel	Digital Voltmeter	VTVMs and FET-VMs	Analog Voltmeters
Criteria/Requirement	GO-NO-GO	GO-NO-GO	GO-NO-GO	GO-NO-GO
Size	NO-GO	GO	GO	GO
Ease to operate	NO-GO	GO	NO-GO	GO
Cost Effectiveness	NO-GO	GO	GO	GO
Overall Decision	NO-GO	GO	GO	GO

Table 4.13 GO-NO-GO table for Function 3.2.2 “Measure the temperature of the nanofluid and set up (Tin and Tout) ”

Concepts	Concept 1	Concept 2	Concept 3	Concept 4
Concepts title	Temperature sensor	Pyrometer	Thermocouple probe	Thermocouple
Criteria/Requirement	GO-NO-GO	GO-NO-GO	GO-NO-GO	GO-NO-GO
Weight	GO	NO-GO	GO	GO
Cost effectiveness	GO	NO-GO	GO	GO
Safety	GO	GO	GO	GO
Durability	GO	GO	GO	GO
Size	GO	NO-GO	GO	GO
Easy to operate	GO	GO	GO	GO
Overall Decision	GO	NO-GO	GO	GO

Table 4.14 GO-NO-GO table for Function 3.2.3 “Measure the intensity of the current source”

Concepts	Concept 1	Concept 2	Concept 3	Concept 4
Concepts title	Moving coil ammeter	Electrodynamic ammeter	Tangent galvanometer	KD2 pro measurement
Criteria/Requirement				
Accuracy	GO	GO	GO	GO
Reliability	GO	GO	GO	GO
Cost Effectiveness	GO	GO	GO	GO
Overall Decision	GO	GO	GO	NO-GO

Table 4.15 GO-NO GO table for evaluating the concepts for the function "Display readings of measured parameters on a computer software."

Concepts	Concept 1	Concept 2	Concept 3	Concept 4
Concepts title	SCADA	DCS	IC Measure	Manually collecting data
Criteria/Requirement	GO-NO-GO	GO-NO-GO	GO-NO-GO	GO-NO-GO
Ease of accessibility	GO	GO	NO-GO	GO
Cost effective	NO-GO	NO-GO	NO-GO	GO
Easy to operate	GO	GO	NO-GO	GO
Overall Decision	GO	GO	NO-GO	GO

Table 4.16 GO-NO GO table for evaluating the concepts for the function "Calculate the heat transfer coefficient and the thermal conductivity after data collection"

Concepts	Concept 1	Concept 2	Concept 3	Concept 4
Concepts title	Lab view	EES	IC Measure	Manual calculation
Criteria/Requirement	GO-NO-GO	GO-NO-GO	GO-NO-GO	GO-NO-GO
Ease of accessibility	GO	GO	GO	NO-GO
Cost effective	GO	GO	GO	NO-GO
Easy to operate	GO	GO	GO	NO-GO
Overall Decision	GO	GO	GO	NO-GO

Table 4.17 GO-NO GO table for evaluating the concepts for the function "Generate graphs showing the fluctuation of each parameter."

Concepts	Concept 1	Concept 2	Concept 3	Concept 4
Concepts title	SCADA	Mark-10	MATLAB	EES
Criteria/Requirement	GO-NO-GO	GO-NO-GO	GO-NO-GO	GO-NO-GO
Ease to operate	GO	NO-GO	GO	GO
Accessibility of technology	NO-GO	NO-GO	GO	GO
Availability of technology	GO	GO	GO	GO
Overall Decision	GO	NO-GO	GO	GO

Table 4.18 GO-NO GO table for evaluating the concepts for the function "Avoid the heat loss from radiation"

Concepts	Concept 1	Concept 2	Concept 3	Concept 4
Concepts title	Aluminum foil	Fiberglass	Mineral wool	FOam glass
Criteria/Requirement	GO-NO-GO	GO-NO-GO	GO-NO-GO	GO-NO-GO
Eliminate convection	GO	GO	GO	NO
Elimination of radiation	GO	GO	GO	NO
Safety	GO	GO	GO	NO
Overall Decision	GO	GO	GO	NO-GO

Table 4.19 GO-NO-GO screening for the function 4.2 avoid heat loss from convection

Concepts	Concept 1	Concept 2	Concept 3	Concept 4
Concepts title	Vacuum insulation panel	Vacuum insulation pump	Glass insulation	Double pipe vacuum insulation
Criteria/Requirement	GO-NO-GO	GO-NO-GO	GO-NO-GO	GO-NO-GO
Safety	GO	GO	GO	GO
Feasibility	GO	GO	GO	NO GO
Eliminate convection	GO	GO	GO	GO
Overall Decision	GO	GO	GO	NO- GO

MATRIX TABLES

In this Section the group evaluated all the concepts that passed the GO-NO-GO screening. All the criteria that were applicable to the functions were used in this section. All criteria have been weighed on the basis of their importance going from 1 to 10, 1 being for lesser criteria and 10 for very important criteria. Then a score was given to the concept based on how the criteria influenced it. The score was then multiplied by weight to obtain the weighted average of the concept for the corresponding criteria. all the weighted scores were then added together, and a definitive score was attributed to each concept. The concepts with the two highest scores were then respectively selected for design 1 and 2. Table 4.20 up to 4.34 represents the matrix evaluation.

Table 4.20 Decision matrix table for evaluating concepts for function 1.1 "~~Display readings of measured parameters on a computer software~~."

Concepts		Concept 1		Concept 2		Concept 3	
Concepts title		Boiler		Hot plate		Band heater	
Criteria/Requirement	Weights	Scores	Weighted Score	Scores	Weighted Score	Scores	Weighted Score
Safety	10	8	80	8	80	8	80
Cost effectiveness	10	7	70	8	80	8	80
Heat resistance	10	10	100	10	100	10	100
Size	9	8	72	8	72	7	63
Easy to operate	9	8	72	8	72	8	72
Weight	9	9	81	8	72	8	72
Overall Decision			474		476		467

Table 4.21 Decision matrix table for evaluating concepts for the function 1.2 "Cool down the Nanofluid after the measurement is made."

Concepts		Concept 1		Concept 2		Concept 3	
Concepts title		Heat sink		Liquid cooling heat exchanger		condenser	
Criteria/Requirement	Weights	Scores	Weighted Score	Scores	Weighted Score	Scores	Weighted Score
Safety	9	10	90	7	63	6	54
Cost effectiveness	7	7	49	6	42	5	35
weight	5	8	40	7	35	6	30
Ease to assembly	6	6	36	5	30	7	42
Speed	7	8	56	5	35	7	49
Ease to operate	8	5	40	7	56	6	48
Overall Decision			311		261		258

Table 4.22 Decision matrix table for evaluating concepts for the function 2.1"Accommodate the magnetic field change."

Concepts		Concept 1		Concept 2		Concept 3	
Concepts title		Stainless Steel		Permeability to magnetic field		Material made of crystal	
Criteria/Requirement	Weights	Scores	Weighted Score	Scores	Weighted Score	Scores	Weighted Score
Durability	7	7	49	6	42	7	49
Cost effectiveness	7	8	56	7	49	7	49
Accessibility	7	7	49	6	42	8	56
Magnetic field accommodation	9	9	81	8	72	9	81
Accuracy	8	8	64	7	56	7	56
Reliability	7	5	35	4	28	4	28
Feasibility	9	9	81	8	72	9	81
Overall Decision			415		361		400

Table 4.23 Decision matrix table for evaluating concepts for the function 2.2 to accommodate the pressure boundary conditions.

Concepts		Concept 1		Concept 2		Concept 3	
Concepts title		Pressure sensor		Set Pressure inlet and outlet using Pressure sensor		Pressure control valve	
Criteria/Requirement	Weights	Scores	Weighted Score	Scores	Weighted Score	Scores	Weighted Score
Accessibility	3	8	24	8	24	7	21
Cost effectiveness	6	9	54	8	54	6	36
Size	8	9	72	9	72	8	64
Accuracy	3	9	27	9	27	5	15
Ease To Operate	8	8	64	8	64	9	72
reliability	6	9	54	9	54	6	36
feasibility	7	8	56	8	56	8	56
Overall Decision			351		351		300

Table 4.24 Decision matrix table below is showing the matrix for evaluating concepts for function 3.1.1 Measure the voltage from the source

Concepts		Concept 1		Concept 2		Concept 3	
Concepts title		Analog Voltmeters		Analog Multimeter		Digital Voltmeter	
Criteria/Requirement	Weights	Scores	Weighted Score	Scores	Weighted Score	Scores	Weighted Score
Safety	10	10	100	10	100	10	100
Cost Effectiveness	6	5	35	8	48	6	36
Size	5	7	35	7	35	7	35
Weight	3	5	15	6	18	8	24
Ease To Operate	9	9	81	9	81	9	81
Overall Decision			266		282		273

Table 4.25 Decision matrix table for evaluating concepts for the Function 3.1.2 “Measure the temperature of the nanofluid and the set up(Tin and Tout).”

Concepts		Concept 1		Concept 2		Concept 3	
Concepts title		Multipoint temperature sensors		Temperature gauge		Thermistors	
Criteria/Requirement	Weights	Scores	Weighted Score	Scores	Weighted Score	Scores	Weighted Score
Weight	8	8	64	8	64	8	64
Cost effectiveness	9	7	63	9	81	9	81
Safety	9	8	72	9	81	8	72
Durability	9	8	72	9	81	7	63
Size	7	7	49	7	49	7	49
Easy to operate	7	7	49	7	49	7	49
Overall Decision			369		405		378

Table 4.26 Decision matrix table for Function 3.1.3 “Measure the intensity of the current source ”

Concepts		Concept 1		Concept 2		Concept 3	
Concepts title		Moving coil ammeter		Electrodynamic ammeter		Digital ammeter	
Criteria/Requirement	Weights	Scores	Weighted Score	Scores	Weighted Score	Scores	Weighted Score
Safety	10	10	100	10	100	8	80
Cost effectiveness	10	7	70	9	90	7	70
Size	8	8	64	9	81	5	40
Durability	10	10	100	10	100	10	100
Speed	10	10	100	10	100	10	100
Ease to operate	7	7	49	7	49	10	70
Overall Decision			488		520		460

Table 4.27 Decision matrix table for evaluating concepts for function 3.2.1 Measure the voltage from the source

Concepts		Concept 1		Concept 2		Concept 3	
Concepts title		Digital Voltmeter		VTMs and FET-VMs		Analog Voltmeters	
Criteria/Requirement	Weights	Scores	Weighted Score	Scores	Weighted Score	Scores	Weighted Score
Safety	10	10	100	10	100	10	100
Cost Effectiveness	6	8	48	6	36	6	36
Size	5	5	25	5	25	4	20
Weight	1	1	1	1	1	1	1
Ease to Operate	9	8	72	7	63	6	54
Overall Decision			246		225		211

Table 4.28 Decision matrix table for evaluating concepts for the Function 3.2.2 “Measure the temperature of the nanofluid and the set up(Tin and Tout).”

Concepts		Concept 1		Concept 2		Concept 3	
Concepts title		Temperature sensor		Thermocouple probe		Thermocouple	
Criteria/Requirement	Weights	Scores	Weighted Score	Scores	Weighted Score	Scores	Weighted Score
Weight	8	8	64	8	64	7	56
Cost effectiveness	9	8	72	8	72	8	72
Safety	8	7	56	7	56	8	64
Durability	8	6	48	7	56	7	56
Size	9	8	72	8	72	8	72
Easy to operate	7	7	49	7	49	7	49
Overall Decision			361		369		369

Table 4.29 Decision matrix table for Function 3.2.3 “Measure the intensity of the current source ”

Concepts		Concept 1		Concept 2		Concept 3	
Concepts title		Moving coil ammeter		Electrodynamic ammeter		Tangent galvanometer	
Criteria/Requirement	Weights	Scores	Weighted Score	Scores	Weighted Score	Scores	Weighted Score
Safety	10	10	100	10	100	10	100
Cost effectiveness	10	7	70	9	90	9	90
Size	8	8	64	9	81	10	80
Durability	10	10	100	10	100	10	100
Accuracy	10	10	100	10	100	10	100
Ease to Operate	7	7	49	7	49	6	42
Overall Decision			488		520		512

Table 4.30 Decision matrix table for evaluating concepts for the function3.3.1 “Display readings of measured parameters on a computer software.”

Concepts		Concept 1		Concept 2		Concept 3	
Concepts title		SCADA		DCS		Manually collecting data	
Criteria/Requirement	Weights	Scores	Weighted Score	Scores	Weighted Score	Scores	Weighted Score
Ease of accessibility	5	9	45	5	25	10	50
Cost effective	9	9	81	7	63	10	90
Ease to operate	4	5	20	4	16	10	40
Weight	1	1	1	1	1	1	1
Size	3	3	9	2	6	1	3
Reliability	8	8	64	6	48	10	80
Overall Decision			220		159		264

Table 4.31 Decision matrix table for evaluating concepts for the function3.3.2 “Calculate the heat transfer coefficient and thermal conductivity after data collection”

Concepts		Concept 1		Concept 2		Concept 3	
Concepts title		lab view		EES		IC measure	
Criteria/Requirement	Weights	Scores	Weighted Score	Scores	Weighted Score	Scores	Weighted Score
Ease of accessibility	5	9	45	5	25	2	10
Availability of technology	9	9	81	7	63	6	54
Ease to operate	4	5	20	5	20	10	40
Feasibility	1	1	1	1	1	1	1
Overall Decision			147		109		105

Table 4.32 Decision matrix table for evaluating concepts for the function 3.3.3 “Generate graphs showing the fluctuation of each parameter.”

Concepts		Concept 1		Concept 2		Concept 3	
Concepts title		SCADA		MATLAB		EES	
Criteria/Requirement	Weights	Scores	Weighted Score	Scores	Weighted Score	Scores	Weighted Score
Ease of accessibility	5	9	45	10	50	9	45
Cost effective	9	9	81	10	90	9	81
Ease to operate	4	5	20	4	16	9	36
Weight	1	1	1	1	1	1	1
Size	3	1	3	2	6	1	3
Reliability	8	9	72	9	71	9	72
Total weighted			222		234		238

Table 4.33 Decision matrix table for evaluating concepts for the function 4.1"Avoid heat loss from radiation."

Concepts		Concept 1		Concept 2		Concept 3	
Concepts title		Aluminum foil		Fiberglass		Mineral wool	
Criteria/Requirement	Weights	Scores	Weighted Score	Scores	Weighted Score	Scores	Weighted Score
Cost effectiveness	9	10	90	8	72	7	63
Safety	10	9	90	9	90	9	90
Ease to operate	9	9	81	7	63	7	63
Durability	8	6	48	6	48	5	40
Eliminate radiation	8	9	72	8	64	8	64
Heat resistance	4	5	20	3	12	2	8
Overall Decision			401		349		328

Table 4.34 Decision matrix for function 4.2 avoid heat loss from convection

Concepts		Concept 1		Concept 2		Concept 3	
Concepts title		Vacuum insulation Panel		Vacuum insulation pump		Glass vacuum insulation	
Criteria/Requirement	Weights	Scores	Weighted Score	Scores	Weighted Score	Scores	Weighted Score
Safety	9	7	63	8	72	8	72
Cost effectiveness	6	7	42	7	49	7	49
Durability	8	8	64	7	56	8	64
Eliminate convection	6	7	42	8	48	8	48
Feasibility	8	6	48	8	64	8	64
Heat resistance	8	9	72	9	72	9	72
Overall Decision			331		361		369

After the decision matrix, each member of the group used the final two sets of the best concepts, primary and backup, to come up with two different systems. This is summarized in Table 4.36. The next meeting, the group discussed the different ideas, compared them and designed two final systems. Those two systems contain the most important part of our final design and were carefully selected. Figure 4.1 and 4.2 are the representation of the two concepts.

Table 4.35 Concepts for apparatus 1 and 2

	APPARATUS 1	Score	APPARATUS 2	Score
Concept 1	**Hot plate**	474	**Boiler**	467
Concept 2	**Heat sink**	311	**Liquid cooling heat exchanger**	261
Concept 3	**Stainless steel container**	415	**Material made of crystal**	400
Concept 4	**Pressure Sensor**	351	**Inlet and outlet Pressure Sensor**	351
Concept 5	**Analog Multimeter**	282	**Digital Voltmeter**	273
Concept 6	**Temperature gauge**	405	**Thermistors**	378
Concept 7	**Electrodynamic ammeter**	520	**Moving coil ammeter**	488
Concept 8	**Digital Voltmeter**	246	**VTMs and FET-VMs**	225

Concept 9	**Thermocouple probe**	369	**Thermocouple**	369
Concept 10	**Electrodynamic ammeter**	520	**Tangent galvanometer**	512
Concept 11	**Manually collecting data**	264	**SCADA**	220
Concept 12	**Lab View**		**EES**	
Concept 13	**EES**	238	**MATLAB**	234
Concept 14	**Aluminum foil**	401	**Fiberglass**	349
Concept 15	**Glass Vacuum insulation**	369	**Vacuum insulation Pump**	361

Figure 4.81 is a representation of the primary apparatus based on the grades obtained by the concepts in the matrix evaluation. The system is made of a stainless-steel container that is going to be heated using a controlled volume hot plate. A heat sink seats on top of the container in order to dissipate heat. heat is kept inside the set up using a bell jar to keep a vacuum

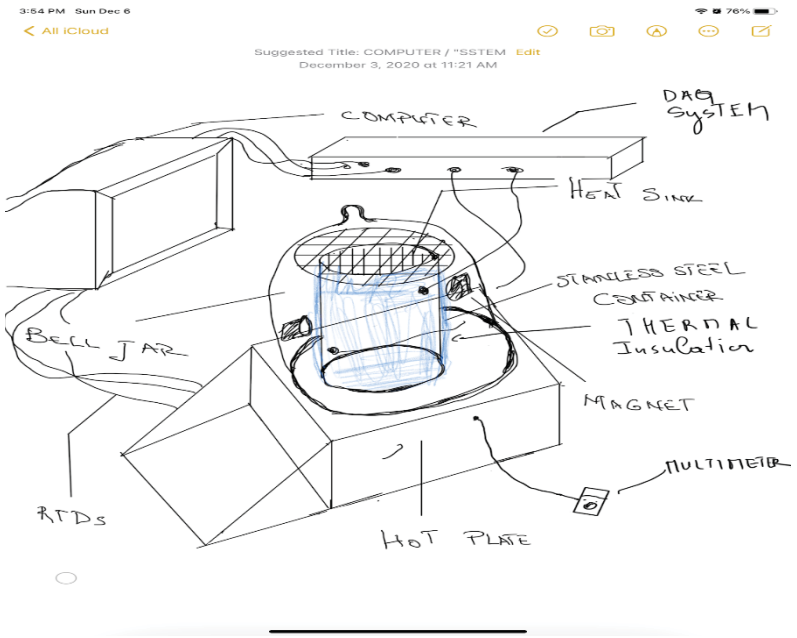


Figure 4.81 Primary apparatus

Figure 4.82 represents the figure of the secondary apparatus that the group came up with based on the points obtained after the matrix evaluation.

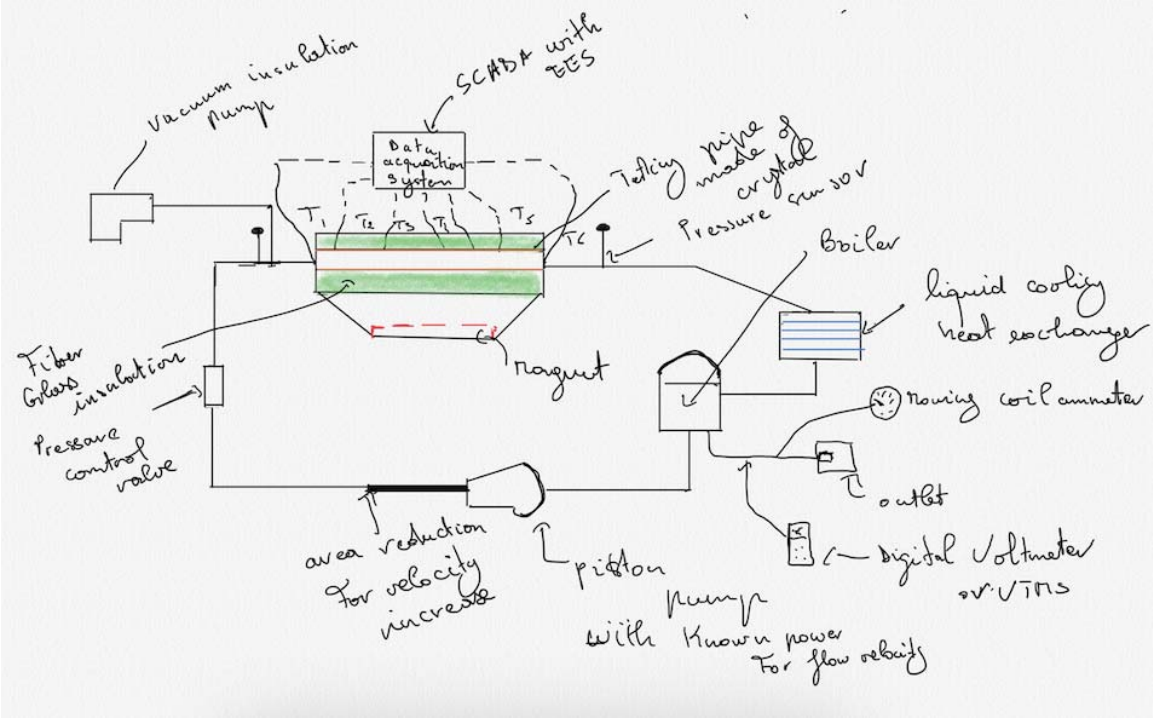


Figure 4.82 secondary apparatus

From the two systems, the group decided that the primary design in Figure ~~8.1~~ was more complete than the second one in Figure ~~8.2.~~ The group members defined the first system as providing more insulation than the second one. Even though the vacuum insulation pump was seen as a good add to the first system, the insulation in the first system still seemed better. The first system also possesses a flow meter which was deemed to be very important to control fluid flow and maintain a laminar flow while the area reduction was deemed not really accurate. The whole system is smaller and made of a uniform material that is stainless steel instead of two in the second apparatus. Besides, stainless steel costs about $6.95 to $10 per pound while a good strong heat resistant crystal costs about $10 to $15 per pound. on a cost analysis basis stainless is more attractive. The first system is smaller than the second and allows more mobility than the first one.

Changes To be made next semester

- The hot plate volume has to be controlled. For that a thin sheet heater will be used.
- A thick base made of aluminum with fins pointing downward and a small hole will be drilled into heat to allow electrical threads to go through while still keeping a vacuum
- on the heat sink aluminum fins will be linked to the base in order for the heat to be transferred to heat
- A fan can be put below the base in order to allow air from following in the base fins
- RTD's will be placed on the base and top of the e container to know the biggest Delta T obtained
- A vacuum pump will be used in order to keep a constant vacuum

5. Detailed System Design

5.1 Identification and Plans for Types of Analysis Needed for the Design

Table 5.1 List of Components

Item #	System Component or part description	Description of analysis needed for the design, sizing, specifying or selecting component	Subject Area	Reference Source for Analysis
1	hot plate	A performance analysis on how should be produce and conducted, which will include an electrical analysis with the maximum voltage and maximum amperage, resistance tolerance	Heat transfer Thermodynamics Electrical engineering Machine Design	https://www.thermaldevices.com/wp-content/uploads/2016/12/Mica-Band-Updated.pdf Fundamentals of electrical engineering, Giorgio Rizzoni
2	Heat sink	A performance on the heat transfer capabilities of heat sink and conduction	Thermodynamics. intro to E.E Heat transfer	Shigley's mechanical engineering Design, tenth edition
3	Stainless steel tube	A performance analysis on the corrosion and whether the small container can lead to a laminar flow or not.	Machine design, Material science. Fluid mechanics.	Fluid mechanics, Fundamentals and application, Yunus A. Cengel, third edition
4	Pressure control valve	flow rate through valve, total pressure drops across valve	Fluid Mechanics	Yunus Cengel, Cimbala John Cimbala (n.d.) *Fluid Mechanics: Fundamentals and Applications*, 4th edn., USA: McGraw-Hill Education.
5	Pressure sensor	density of fluid, standard gravity, height of fluid, column above pressure sensor.	Fluid Mechanics	Yunus Cengel Cengel, Cimbala John Cimbala (n.d.) *Fluid Mechanics: Fundamentals and Applications*, 4th edn., USA: McGraw-Hill Education.

6	Electrodynamic ammeter	Measurement of current	Electrical Circuits	Nave, Rod. "Ammeter." *Moving Coil Meters*, 2000, hyperphysics.phy-astr.gsu.edu/hbase/magnetic/movcoil.html.
7	Temperature gauge (RTD's)	Measurement of the nanofluid temperature	Fluid Mechanics, Heat Transfer	Yunus Cengel Cengel, Cimbala John Cimbala (n.d.) *Fluid Mechanics: Fundamentals and Applications*, 4th edn., USA: McGraw-Hill Education
8	Digital voltmeter	Measurement of the voltage drop within the nanofluid	Electrical Engineering, Fluid Mechanics	Yunus Cengel Cengel, Cimbala John Cimbala (n.d.) *Fluid Mechanics: Fundamentals and Applications*, 4th edn., USA: McGraw-Hill Education
9	Aluminum foil	foil thickness, foil length, manufactured purpose. (made for insulating?)	Shape and Size	Katie Tonarey (2018) *Why Is Aluminum Foil a Better Insulator Than Cotton or Paper?* Available at: *https://www.hunker.com/13416236/why-is-aluminum-foil-a-better-insulator-than-cotton-or-paper* (Accessed: 4th November 2020).
10	Glass insulation (belle jar)	A performance analysis on the amount and type thermal conductivity, which involves the thickness of the material.	Heat transfer	Incropera, F. P., DeWitt, D. P., Incropera, F. P., & Incropera, F. P. (1990). *Solutions Manual to accompany Fundamentals of heat and mass transfer, 3rd ed. and Introduction to heat transfer, 2nd ed.* New York: Wiley.
11	Magnet	Magnetic power analysis of the magnet size and geometry	Electrical engineering	http://www.calctool.org/CALC/phys/electromagnetism/solenoid https://www.mscdirect.com/product/details/06586507

Approval by Project owner: Name_____ Signature _____

5.2 Detailed Engineering Analysis and Simulation for Designing, Sizing, Specifying and Selecting Parts for the Design.

In this section a detailed engineering analysis was performed on each item that the group selected as a major factor or component needed to conduct this project.. The engineering analysis was performed on the shape, size, resistance, heat resistance, pressure and any other aspect that would need to be thoroughly analyzed. After each analysis the group member came up with the design that would be able to meet the parameters of their analysis with their respective values.

5.2.1 Analysis on the on the stainless-steel tube (corrosion resistance and operating environment)

a) Process Diagram of the hot plate

The process diagram of the hot plate is shown below in Figure 5.1. In this mechanism the electrical energy received by the hot plate is converted into heat that is then transferred to the surface that is supposed to be heated.

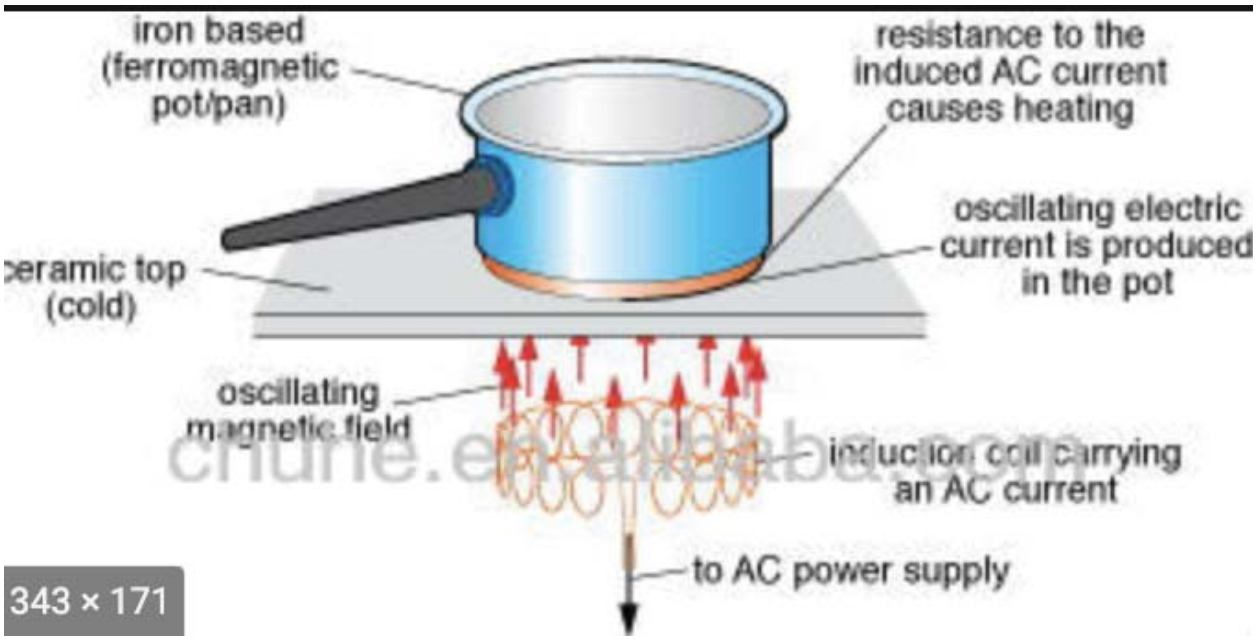


Figure 5.1 hot plate process diagram

b) Analysis equations

The area heated will be calculated using the width and inner diameter of the and heater.
The area of a circular cylindrical surface is calculated using

$$A = Pi * \frac{D}{2} \text{ *W} \quad (1)$$

With D being the diameter.
W being the width of the cylinder shell

Using the power analysis, calculating the wattage will be used

$$Wattage = (WT * Cp * \Delta T) * 3412 * h \quad (2)$$

$$weight = mass * g$$

With g=gravitational velocity

$$mass = volume * density$$

$$volume = Pi * H * \frac{D^2}{4}$$

WT=weight of the heated surface
Cp= specific of the surface area (specific heat of grade 304 stainless steel)
H=hours
change in temperature $\Delta T = Tmax - Troom$
Tmax= Temperature wanted
Troom=room Temperature

From the wattage it is possible to determine the voltage and current required by adjusting either one or the other

$$Wattage = VI \qquad (3)$$

V= Voltage needed
I= current needed

c) Values of known variable

The diameter of the cylinder container is 1 in or 25.4 mm
W= 0.1 in or 2.54
Let's assume that the a Tmax that is wanted is 340℃ and Troom 25℃
Stainless steel grade 304 density = 7930 kg/m^3
Cp stainless steel grade 304= 0.0005J/Kg℃
Hours to heat= 0.25 h
The g=9.8$\frac{m}{s^2}$
We consider I= 0.5A

d) calculated variables

From equation 1, 2, 3 and 4 we obtained the following results.

The calculated area heated
A=0.000001 m^2
Heated area mass= 0.00001 kg
Weight of the of the container part= 0.000098 N
Wattage= 2.42 W
V= 4.84 V

e) Type of hot plate chosen

In regards to the conducted analysis the following hot plate was chosen as the one to use in the current project.



Click image to open expanded view

Scilogex 81112102 MS-H-S Analog Magnetic Hotplate Stirrer, Porcelain Plate, 110V/60Hz, 5-2/7" Diameter

Visit the Scilogex Store

19 ratings | 5 answered questions

List Price: $315.00

Price: $295.00 & FREE Shipping. Details

You Save: $20.00 (6%)

Size: **Porcelain Plate**

- Magnetic hotplate stirrer for mixing and heating samples simultaneously
- Stir speeds from 0 to 1,500rpm and volumes up to 20L
- Automatically stops heating sample when temperature reaches 340 degrees C for sample protection
- Electronic speed control for constant speed even during changes in load
- Enclosed housing conforms to IP42, cTUVus, and CE marking standards

Product Specifications

Ean	0094393613596
Height	3 inches
Item Volume	0.02 milliliters
Item Weight	6.00 pounds
Maximum Stirring Speed	1500 rpm
Model Number	DRG-81112102
Number of Items	1
Part Number	81112102

Figure 5.2 scilogex hot plate with porcelain plate

5.2.2 Analysis on the stainless-steel tube (corrosion resistance and operating environment)

In this section, the analysis on the stainless-steel tube is performed by understanding the corrosion resistance and whether it can conduct a laminar flow. To do that, the melting point of the stainless steel has to be known such as the container inner and outer diameter.
First, the passive layer on stainless steel can be attacked by certain chemical species. Chloride ion is the most common of these and is found in everyday materials such as salt and bleach. Harsh pitting corrosion is a localized damage that eats pits into stainless steel. In addition to chloride ion, can be caused by elevated temperatures for extended amounts of time or lack of oxygen to the surface. This means that the Nano-Fluid should not incorporate none of the chemicals mentioned above because the pipes' layer would not be attacked.

a) Free Body diagram on the container.

Figure 5.3 represents an analysis on the container

- **laminar** - when Re < 2300
- **transient** - when 2300 < Re < 4000
- **turbulent** - when Re > 4000

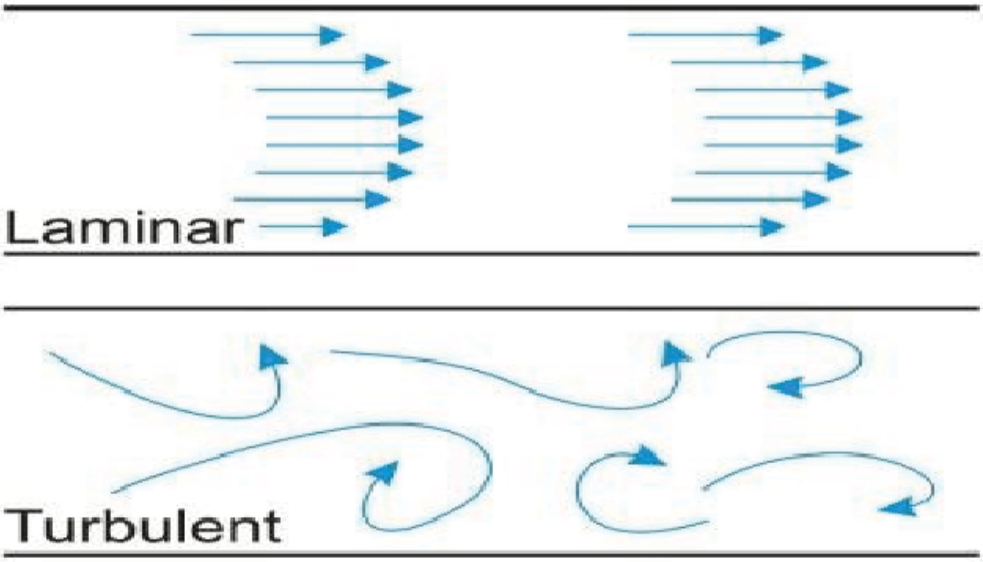


Figure 5.3 laminar and turbulent flow pipes

b) **Analysis Equations**

As stated, the Reynolds number determines whether or not a flow is laminar, transient or turbulent, which is why it should be determined based on the given inner diameter D_{in}=22.4 mm. The Reynolds number can be obtained by using the equation:

Re=$\frac{\rho \times u \times L}{\mu}$ (4)

Where:

Re = Reynolds Number (non-dimensional)

ρ = density (kg/m², lbm/ft³)

u = velocity based on the actual cross section area of the duct or pipe (m/s, ft/s)

μ = dynamic viscosity of the Nano-fluid (Ns/m², lbm/s ft)

L = characteristic length (m, ft)

ν = μ / ρ = kinematic viscosity (m²/s, ft²/s)

For specific pipe, L could be calculated by stating that L=D_h where dh = hydraulic diameter (m, ft)

Then, the equation becomes:

Re $= \frac{\rho\, u\, Dh}{\mu}$ Where V $= \frac{\mu}{\rho}$ and $D_h = \frac{4(\frac{\pi D}{4})}{\pi \times D}$ for a circular tube.

c) **Known parameters**

The known parameters are D=22.4mm, d=0.833ft t=1500s V=2cSt, ν = kinematic viscosity (cSt) (1 cSt = 10-6 m2/s)

Having as final equation:

Re $= \frac{u\,Dh}{V}$ where: $u = d/t$=6 ft/1500s=0.0005533ft/s

d) **Values of computed variables**

Re = 0.000553 which is less than 2300, which means the flow will be laminar.

u = velocity (ft/s)

D_h = hydraulic diameter (in)

e) Based on the calculation

The group came across with the stainless-steel tube.

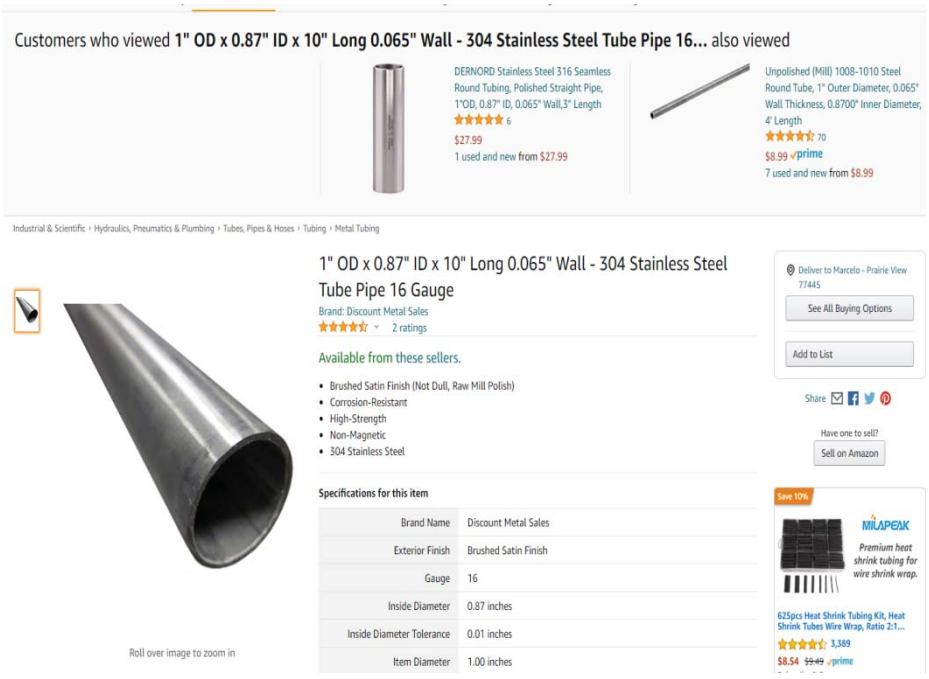


Figure 5.4 shows a figure of the stainless-steel tube needed

5.2.3 Analysis of the heat sink

One of the major constraints in choosing the heat sink will be the material selected and dimensions, the material will have to be able to resist the electromagnetic field generated in the experiment. Its size has to be able to fit relatively with the other components. The heat sink will be used to transfer heat to the nanofluid during the experiment.

The calculations for the heat transfer are provided below. The free body diagram below represents the process of which the nanofluid will be going through. Figure ~~5.X~~ displays the free body diagram of the heat sink. Figure 5.X shows the ideal design for the heat sink components.

(a) Free Body Diagram (FBD)

The free body diagram shows the heat transfer process used in the heat sink shown in Figure ~~5.X~~

In this mechanism the cold nanofluid will be entering the heat sink, with the base of the heat sink having a high temperature source it will radiate heat to the nanofluid. Trying to isolate the nanofluid from the average air temperature to reduce the heat loss, an aluminum duct tape will be used as an isolation component. After the nanofluid is heated it will exit the heat sink.

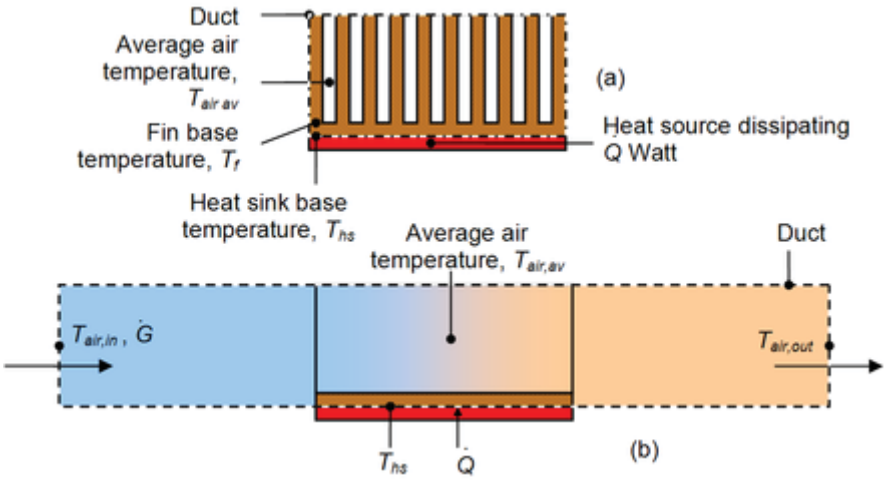


Figure 5.5 Heat Sink

(b) Analysis equations

Using the heat transfer equations, we will be able to find the coefficient of heat transfer rate, this will help us identify the maximum mass transferred as well as under what environmental conditions can this experiment results be accurate.

5.2.4 Analysis for determining the pressure drop and maximum flow rate through a pressure control valve.

In order to select the proper pressure control valve, it was important to analyze the maximum allowable pressure drop for the valve and then the maximum flow rate through the valve. The equation below shows the relationship.

a. Free Body Diagram (FBD)

Because liquids are incompressible fluids, their flow rate depends only on the difference between the inlet and outlet pressures (ΔP, pressure drop). The flow is the same whether the system pressure is low or high, so long as the difference between the inlet and outlet pressure is the same. This is represented in Figure ~~5.11~~

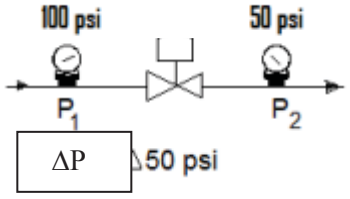


Figure 5.6 Free Body Diagram of the Process in a Pressure Control Valve

b. Analysis Equations

For sizing a control valve, it is important to know how much flow can get through the value for any given opening of a valve for any given opening and any given pressure differential. The relationship between pressure drop and flow rate through a valve is expressed by a flow coefficient (Cv).

$$C_V = Q\sqrt{S/\Delta P} \qquad (12)$$

where,
C_v = valve flow coefficient
Q = fluid flow
S = specific gravity of fluid relative to water
ΔP = Pressure drop (P1 – P2) across the control valve at maximum flow, psi

c. Values of known variables

A reasonable design flow rate would be about 150 gpm.
Since temperature used would be below 200℃, specific gravity would be 1.0
A typical diameter size for the valve would be about 1 inch.
An assumption that the pressure drops of 15 psi.

d. Values of computed variables

With these values, the valve flow coefficient was calculated using equation (12).

$C_V = 150\sqrt{1/15} = 38.7 = 39$

The C_V value is then used as a guide in the valve selection. The valve is much easier to control in the 10 to 80% stroke range. According to the manufacturers guide, a one inch would be appropriate to use. When sizing control valves, a general rule of thumb noted in many engineering publications is to size the valve such that it operates between 20 to 80% open at maximum required flow rate. It is also recommended to have the minimum opening no less than 20% to provide a safety margin at the minimum flow rate required. This approach ensures that as much of the valve control range as possible is used while maintaining a reasonable (but not excessive) safety margin.

e. Specification of Part selected.

Figure 5.7 shows the pressure valve selected. It has a 1-inch valve with bronze EB-45 and threaded.



Figure 5.7 Pressure Control Valve 1 in. Bronze EB-45 Threaded NPT Inlet Pressure Regulating Valve

Figure 5.8 shows the product specification in detail with a general product overview.

Product Overview

The EB-45 Pressure Regulator features a half cartridge design that offers both the performance of a high end, cartridge based valve and the price of a traditional regulator. The EB-45 comes factory set at 45 psi. The pressure may be adjusted to 10 to 70 psi. The EB-45's half cartridge based system allows for easy servicing and installation.

- California residents see Prop 65 WARNINGS
- Compact pressure reducing and regulating valve designed for tight installation considerations
- Solid lead free bronze construction
- Factory set to regulate flow to a safe 45 psi, adjustable from 10 to 70 psi
- Integrated internal by-pass mechanism
- Cartridge based design allows for quick and easy service
- Certified to ASSE 1003 and CSA B356 and listed by ASSE and IAPMO (cUPC)
- Designed for use where inlet pressure does not exceed 400 psi
- Suited for hot (up to 180°) or cold water service

Figure 5.8 Pressure Control Valve Product Overview

5.2.5 Analysis for determining the pressure in a pressure sensor.

In order to determine the pressure from a pressure sensor, the pressure of the fluid flow must be calculated. The pressure sensor is a mechanism that uses the force from the fluid flow to determine the total pressure.

a. Free Body Diagram (FBD)

Figure 5.9 shows the free body diagram of the basic movements on a mechanical pressure sensor. The pressure from the fluid flow will be the force that moves the pointer to display the total pressure at any given moment.

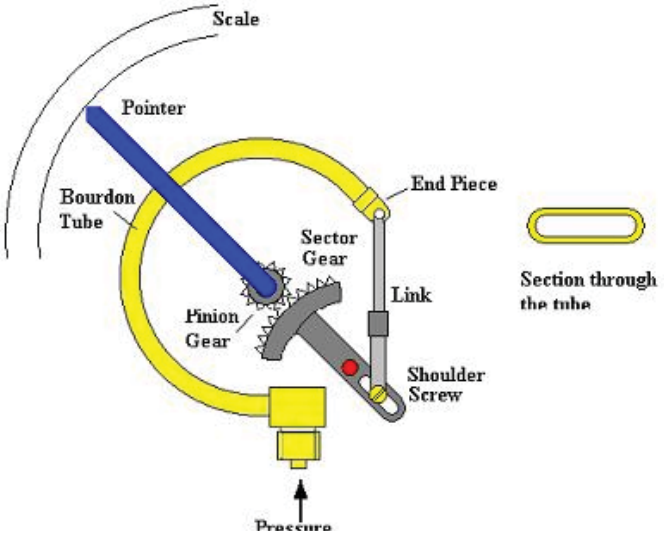


Figure 5.9 Free Body Diagram of a Mechanical Pressure Sensor

b. Analysis Equations

Pressure can be found by calculating the force exerted on a specific area of an object. Pressure is calculated using the equation 2.

$$P = F/A \qquad (13)$$

Here,
F = force
A = cross sectional area of the fluid flow

c. Values of known variables

The value of the cross-sectional area can be estimated to be about .50 in^2

d. Values of computed variables

Depending on the force applied to the mechanism, the device will automatically move the pointer to the appropriate measurement to display the total pressure of the fluid flow.

e. Specification of Part selected.

Figure 5.10 displays the specifications and image of the selected pressure sensor that will be used. It is made out of steel and its max pressure is 200 psi which would be an acceptable measuring mechanism.



Materials	PVC, PTFE/FKM Diaph
Inlet Connection	1/4" MNPT
Installed Gauge	0-200 PSI, Brass, Blk Pntd Steel

Figure 5.10 Mechanical Pressure Sensor Selected with specifications

5.2.6 Analysis on the ammeter

(a) Free Body Diagram

The free body diagram in Figure 5.11 shows the Ammeter Design. The Ammeter (A) is connected in series with a resistor to measure the current through the resistor and is in parallel with the voltage (V). In the design, is the

makeup of an ammeter, the Galvanometer (G) resistance, shunt resistance (Rp), and current (I). The Galvanometer is a sensitive current detector that is designed with the Ammeter. In the design task, the galvanometer resistance and the current value produces full scale readings on the (G). The value of shunt resistance (Rp) must be found, which allows the flow of the design current.

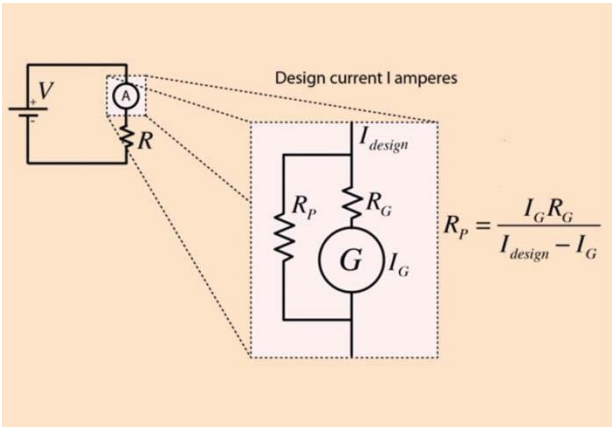


Figure 5.11 Ammeter Design

(b) Analysis Equation

Current flow is calculated using Ohm's Law:

$$I = \frac{V}{R} \tag{16}$$

where,

I is current
V is voltage
R is resistance

The shunt resistance (Rp) equation:

$$Rp = \frac{I_G R_G}{I_{design} - I_G} \tag{17}$$

where,

Rp is shunt resistance [Ω]
R_G is galvanometer shunt resistance [Ω]
I_G is galvanometer current [mA]
I_{design} is current design [amperes]

Voltage (V) equation:

$$V = I_G R_G \tag{18}$$

where,

V is voltage [V]
I_G is galvanometer current [mA]
R_G is galvanometer shunt resistance [Ω]

(c) Values of known variables

A reasonable estimate for shunt resistance (R_G) = 100 Ω
Galvanometer current (I_G) is set at I_G = 3 mA
Current design (I_{design}) was chosen to be I_{design} = 5 amperes

(d) Values of computed variables

With the values chosen, the shunt resistance was computed using equation (17) to be Rp = 0.06 Ω
The voltage was computed using equation (5) to be V = 300 V
The current was computed using Ohm's Law using equation (3) to be I = 5000 amperes

Figure 5.12 is a digital multimeter that measures voltage, current, and resistance. Shown in Table 5.3 the digital multimeter speciation's shows its accuracy level that range with the values drawn from the computed equations.



Figure 5.12 Fluke 179 True-RMS Digital Multimeter

Table 5.2 Detailed specifications

Specifications		
Voltage DC	Accuracy[1]	±(0.09% + 2)
	Max. resolution	0.1 mV
	Maximum	1000 V
Voltage AC	Accuracy[1]	±(1.0% + 3)
	Max. resolution	0.1 mV
	Maximum	1000 V
Current DC	Accuracy[1]	±(1.0% + 3)
	Max. resolution	0.01 mA
	Maximum	10 A
Current AC	Accuracy[1]	±(1.5% + 3)
	Max. resolution	0.01 mA
	Maximum	10 A
Resistance	Accuracy[1]	±(0.9% + 1)
	Max. resolution	0.1 Ω
	Maximum	50 MΩ

5.2.7 Analysis for determining the temperature using the temperature gauge.

(a) Free Body Diagram

The free body diagram shows the insertion of the temperature gauge which will be used to measure the temperature of the nanofluid as it passes through the system. Figure 5.13 shows the appropriate placement of the temperature gauge accompanied with a compression fitting and thermowell which is applied to the system.

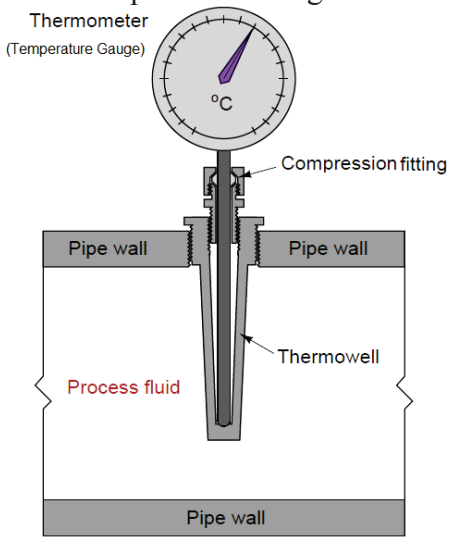


Figure 5.13Free body Diagram of Temperature Gauge

(b) Analysis Equation

The heat transfer equation below must be derived

$$Q = h * A * dT \quad (19)$$

Through derivation to manipulate the temperature and isolate the variables we have

$$\Delta T = T_{in} - T_{out} \quad (20)$$

Where the change in temperature is represented by ΔT and will be calculated by subtracting the temperature of the nanofluid as it enters the pipe, represented by T_{in}, from the temperature of the nanofluid as it exits the system which is represented by T_{out}.

(c) Values of known variables

A reasonable estimate for the temperature of the nanofluid $T_{in} = 298\ K$ will be chosen for the entrance of the nanofluid through the system while $T_{out} = 278\ K$ will be chosen for the exit temperature for the nanofluid.

(d) Vales of computed variables

Using these values and using equation (20) to compute the change in temperature, $\Delta T = 20\ K$ is determined to be the final measurement of the nanofluids temperature.
Figure 5.14 shows the appropriate temperature gauge that will be selected to conduct the measurement process for the nanofluid temperature.



Figure 5.14

5.2.8 Analysis for determining the voltage utilizing a digital voltmeter
(a) Free Body Diagram
The free body diagram shows the working principle of the process of a digital voltmeter calculating the voltage of the nanofluid within the system. This is shown in Figure 5.15

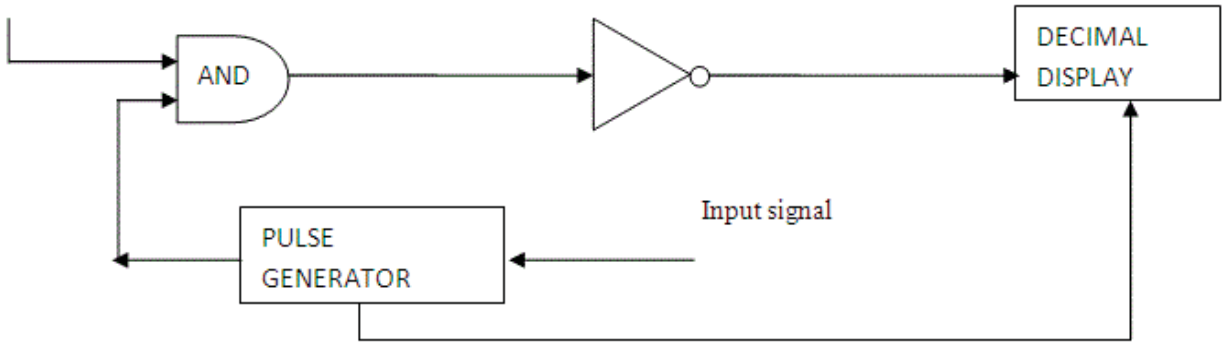


Figure 5.15 Free body diagram of the working digital voltmeter input

(b) Analysis Equation

To calculate voltage, the equation

$$V = I * R \quad (1)$$

Where V represents the voltage, I represents the current which is measured in amps, and R is the resistance measured in ohms.

(c) Values of known variables

A reasonable estimate for the measurement of the current is $I = 2A$ while the resistance estimate is found to be $R = 1\ ohm.$

(d) Values of computed variables

Using equation (1) the voltage comes to be calculated by multiplying the current by the number of ohms.

$$V = 2A * 1ohm$$

Therefore, the voltage is measured to be 2V.

Figure 5.15 is a depiction of the selected digital voltmeter to insure accuracy and precision for measuring the voltage of the nanofluid throughout the experiment.



Figure ~~5.15~~

5.2.9 Analysis for aluminum foil

For insulation, aluminum foil will be used. The surface area to be covered will need to be analyzed which would include the diameter of the tube and length.

a. Free Body Diagram (FBD)

The free body diagram showing the length and width of the foil must be considered for insulation. Figure 5.16 shows the FBD where length and width are measured.

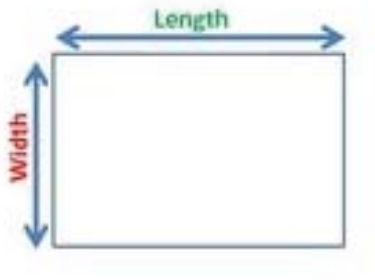


Figure 5.16 Free Body Diagram of an Aluminum Foil Measurement

b. Analysis Equations

$$L\ X\ W = A \qquad (21)$$

Where,
A=Area of the tube
L=Length of foil to cover tube
W= width of the foil wrap around tube

c. Values of known variables

It can be assumed that the surface area to be covered would be about 5 inches.
The length of the foil could be 6 inches to cover the tube.
The width could be about 1 inch.

d. Values of computed variables

To calculate the surface area needed, the known and estimated variables can be substituted to get an idea of how much foil is needed. This is done by using equation 3.

$$6\ in.\ X\ 1\ in. = 6\ in^2$$

e. Specification of Part selected.

Figure 5.17 shows the selected aluminum foil tape chosen. Although it is a half inch in length, it is five yards and it would be sufficient.



↑ Tape Width	Tape Length	Tape Thickness	Tape Shape	Max. Tape Performance Temp.	Min. Tape Performance Temp.	Item #	Price
Series 433L Silicone Adhesive Foil Tape with Aluminum Tape Backing Material							
1/2 in	5 yd	3.5 mil	Continuous Roll	600 Degrees F	-65 Degrees F	45K241	$28.00 / each

Figure 5.17 Aluminum Foil Tape.

5.2.10 Analysis for thermal insulation required to maintain energy and boundary conditions

Since to calculate the coefficient of heat transfer and effective thermal conductivity in nanofluids under different boundary conditions must have a steady insulated flow to have a precision measurements it's crucial that the data remains as close throughout the experiment, using the principles of Dewar Flask the vacuum insulation glass (VIG) will isolate the environment properties of the system.
The calculation for thermal insulation will be mainly induction, convection and radiation, the smaller the values the accurate and better performance the experiment will have. Figure 5.18 displays the diagram of the vacuum insulation glass and its function

(a) Free Body Diagram (FBD)

The free body diagram showing the main components and overall functions of the component.
In this mechanism, the VIG will be covering most of the system components to prevent heat transfer between the system and the environment as shown in Figure ~~5.26~~

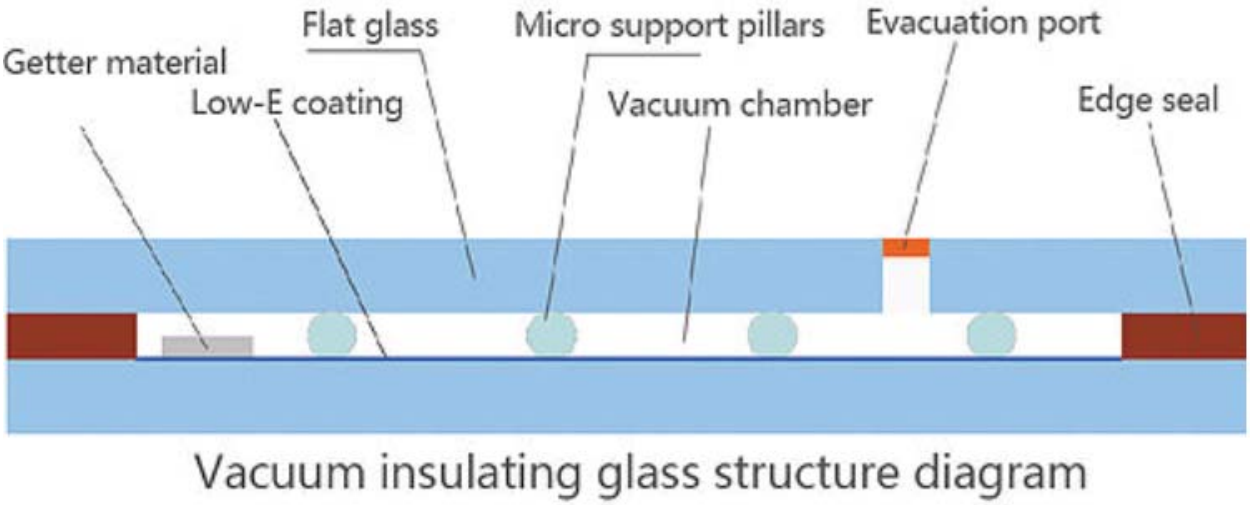


Figure 5.18 FBD of VIG

(b) Analysis Equations

Using the heat transfer equation, a general expression comes up with an equation for the three types of heat transfer. From knowing the environment temperature, the system temperature and the properties of the materials used

$$h = \frac{q}{\Delta T} \text{.....(22)}$$

$where$, h= heat transfer coefficient
q= heat flux
ΔT= difference in temperature between a solid surface and surrounding fluid

Conduction Losses:
These occur when a hot object is in touching contact with a cooler object and heat energy passes from the hot object to the cool one. It can be calculated using the following equation:

= Thermal Conductivity of Material Accepting Heat x Area of Contact x ΔT x 1….(23)
Hour Per Thickness of Material Accepting Heat

Convection Losses:
Heat losses due to convection are more difficult to calculate because there are many ways for heat to be removed from an object through a surrounding medium. The main challenge, among others, is since the convection medium can be motionless or flowing, referred to as natural convection or forced convection.

Convection rates also are affected by the orientation of the object in the medium due to the effects of convection boundary layers in the medium. It can be calculated using the following equation:

= Surface Loss (W/in2) x Area x 1 hr…..(24)

Radiation Losses:
Losses due to radiation usually are insignificant at low temperatures, but they can be a large contributor of heat loss at temperatures above 500oF and should be considered when calculating wattage requirements.

= Radiation Loss (W/in2) x Area x Emissivity x 1 hr……(25)

(c) Values of known variables

A reasonable estimate for the environment temperature $T_e = 22°C$
A standard diameter for the VIG thickness was chosen to be D< 50 mm
Distance between first and second glass panes = 38 to 42 mm

(d) Values of computer variables

With these values, radiation loss was computed using equation (4) to be 0. The convection loss was computed using equation (3) = 20000 W/m^2K. The conduction loss was computed using equation (23) = 98 kW. The coefficient of heat transfer was computed using equation (1) h= 2479 W/m^2K

(e) Specification of part

The VIG must be fully tempered to adapt to low temperature effectiveness and to resist decay caused by glass annealing during high temperature. Energy efficient to eliminate any heat transfer between the system and the environment. Thin structure will have less weight and higher transmittance and optical transparency. Long life proper sealing will have much higher resistance to thermal expansion or contraction caused by the difference between inner and outer surface temperature. Noise reduction to effectively block sound transmission effect against mid and low frequency noises. High adaptability to be suitable for installation at any position. An example of the component shown in Figure 5.19 and 5.20

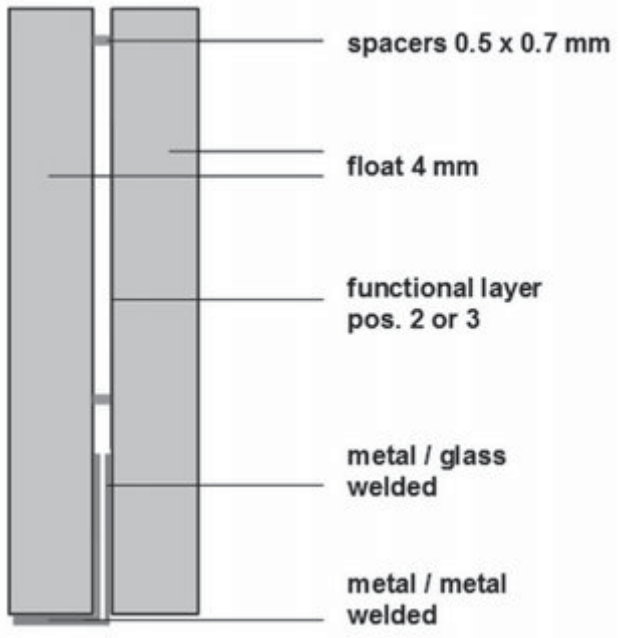


Figure 5.19Vacuum insulation glass

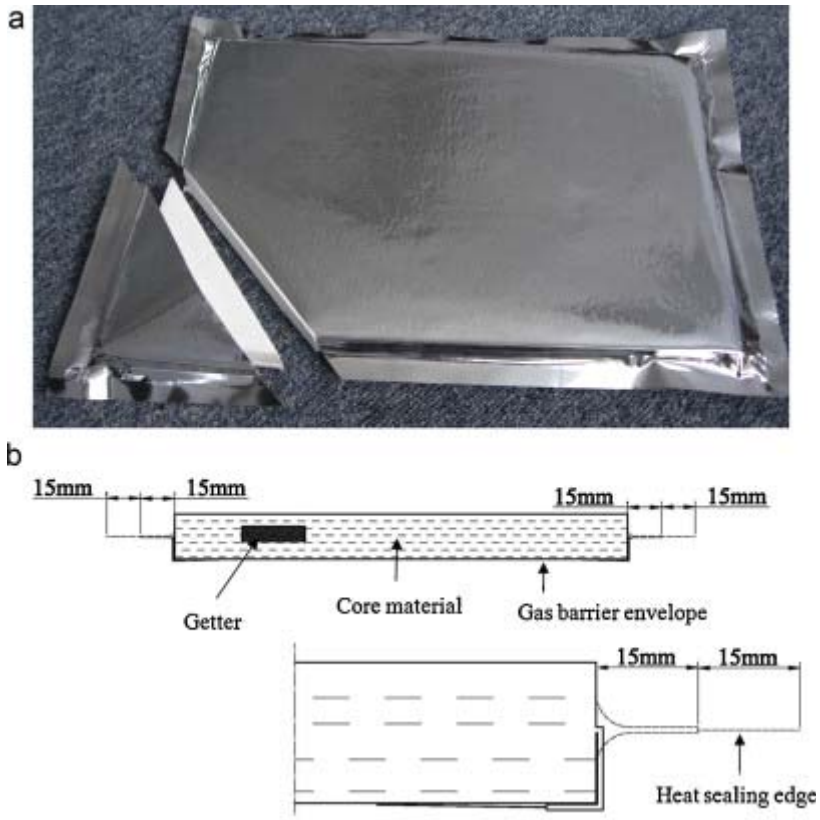


Figure 5.20 Vacuum insulation panel with glass fiber

5.2.11 Force analysis for the magnet(electromagnet)

Since magnets have to be used an analysis has to be conducted on the magnetic force that these magnets can achieve the choice 2 bar magnets emerged has it allows to obtain a uniform magnetic force.

a) Process diagram of an electromagnet

Figure 5.21 represents the process diagram of 2 electromagnets generating a uniform magnetic field

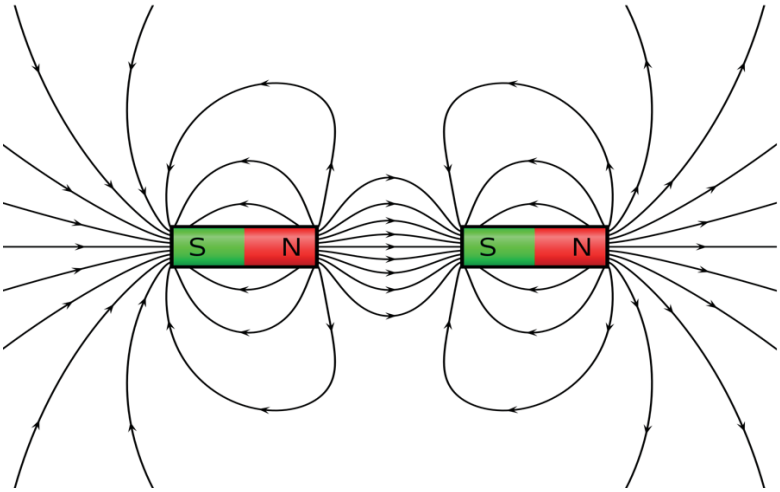


Figure 5.21 electromagnet Process diagram

b) Analysis equation

The force of an electromagnet can be used by the next formula

$$F = [B^2 * A^2 * \frac{L^2 + R^2}{\pi\mu L^2}][\frac{1}{x^2} + \frac{1}{(x+l)^2} - \frac{2}{(x+L)^2}]$$

$$= 4 * pi * 10^{-7}$$

$$B = \frac{\mu * M}{2}$$

where
B is the flux density very close to each pole, in T,
A is the area of each pole, in m^2,
L is the length of each magnet, in m,
R is the radius of each magnet, in m, and
x is the separation between the two magnets, in m
μ=magnetic constant
M=Magnetization

c) Known variables values

L=1in 0r 25.4 mm
R= 0.1in 2.54 mm
x=10in = 254 mm
$M=4.4 * 10^6$

d) Values of calculated variables

μ= 0.00000126
B=2.8
F=12750 GAUSS

f) Chosen electromagnet

After conducting the analysis, the following magnet was chosen for pull for its pull force being in the same range as the analysis conducted represented in ~~figure~~ 5.22

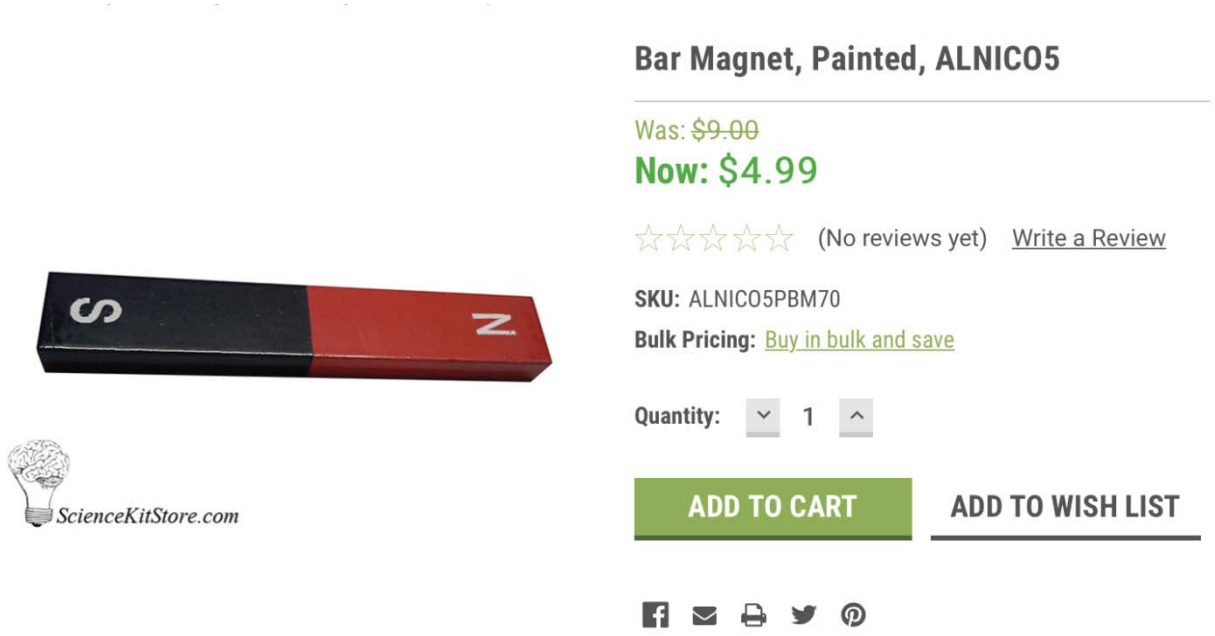


Figure 5.22 Bar Magnet, Painted, ALNIC05

5.3 CAD Models, Detailed Drawings, Sub-assemblies, System Assembly and Equipment specifications and selection

The Figure 5.31 below is the designated heat sink which will be used in the systematic to increase the heat flow within the nanofluid as it travels throughout the system. It will increase the working surface area of the system to which the nanofluids cooling particles will pass and allow the nanofluid to stay within a state of harmony. The heat sink dimensions were calculated based on the surface area of the experiment to keep the factor of manipulation a top priority. In figure 5.32 the dimensions of the heat sink are shown.

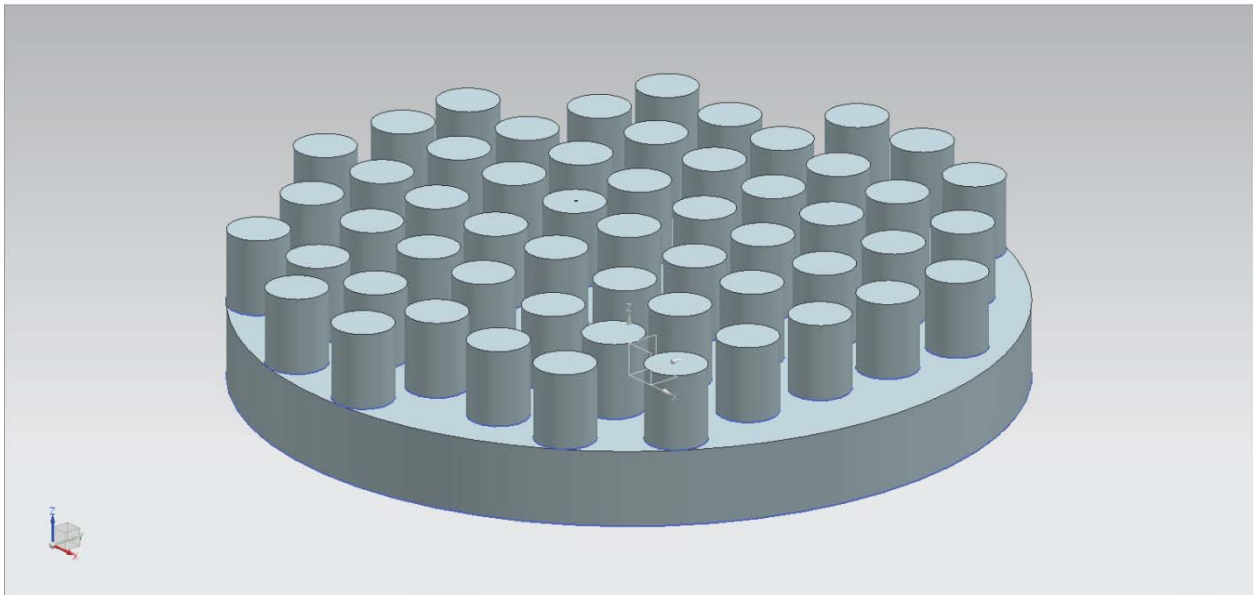


Figure 5.23 Heat Sink

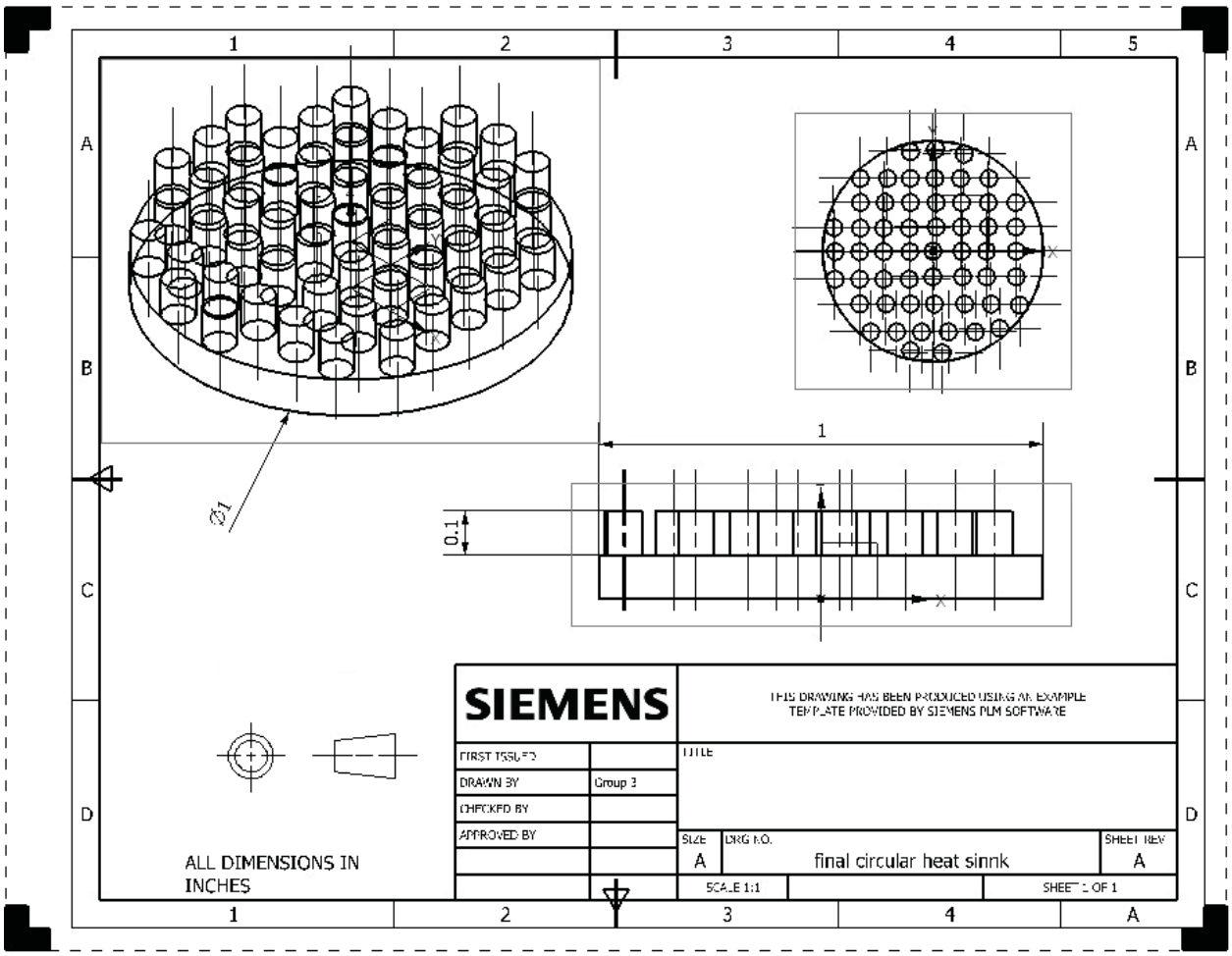


Figure 5.24 Heat Sink dimensions

Figure ~~5.33~~ represents the tube container tube that each sample will be placed in. There will be a hole on the top (red) for the nanofluid to go in and out of the tube. Multiple tubes will be added for different tests under different boundary conditions. ~~Figure 5.34~~ represents the dimensions of the container tube from top, side, and front views to provide a better view of the component. all the dimensions used are in inches.

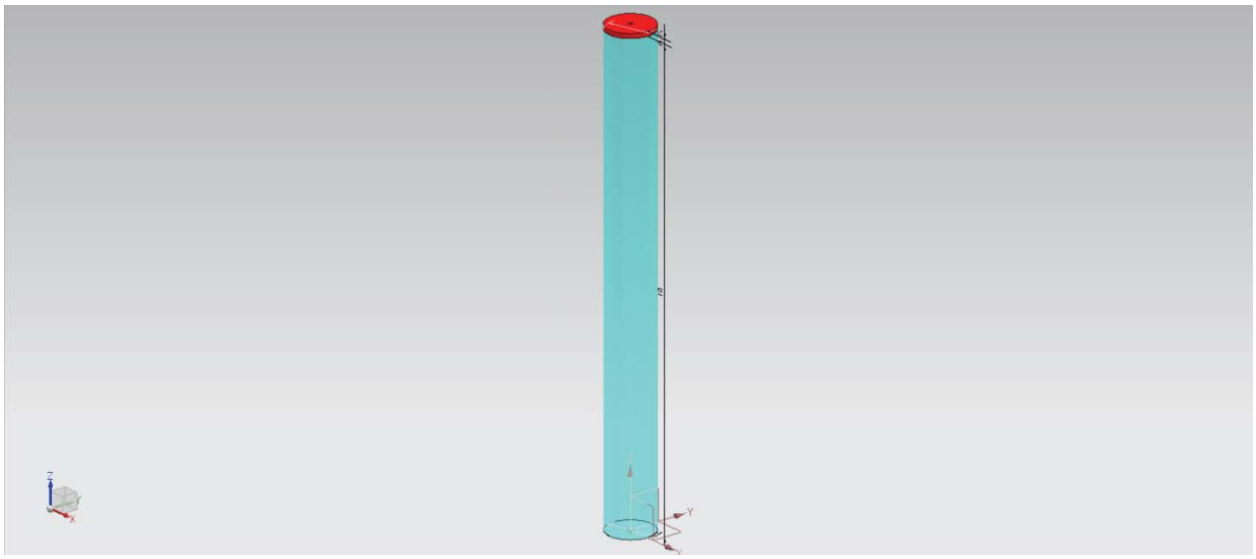


Figure 5.25 Tube Container

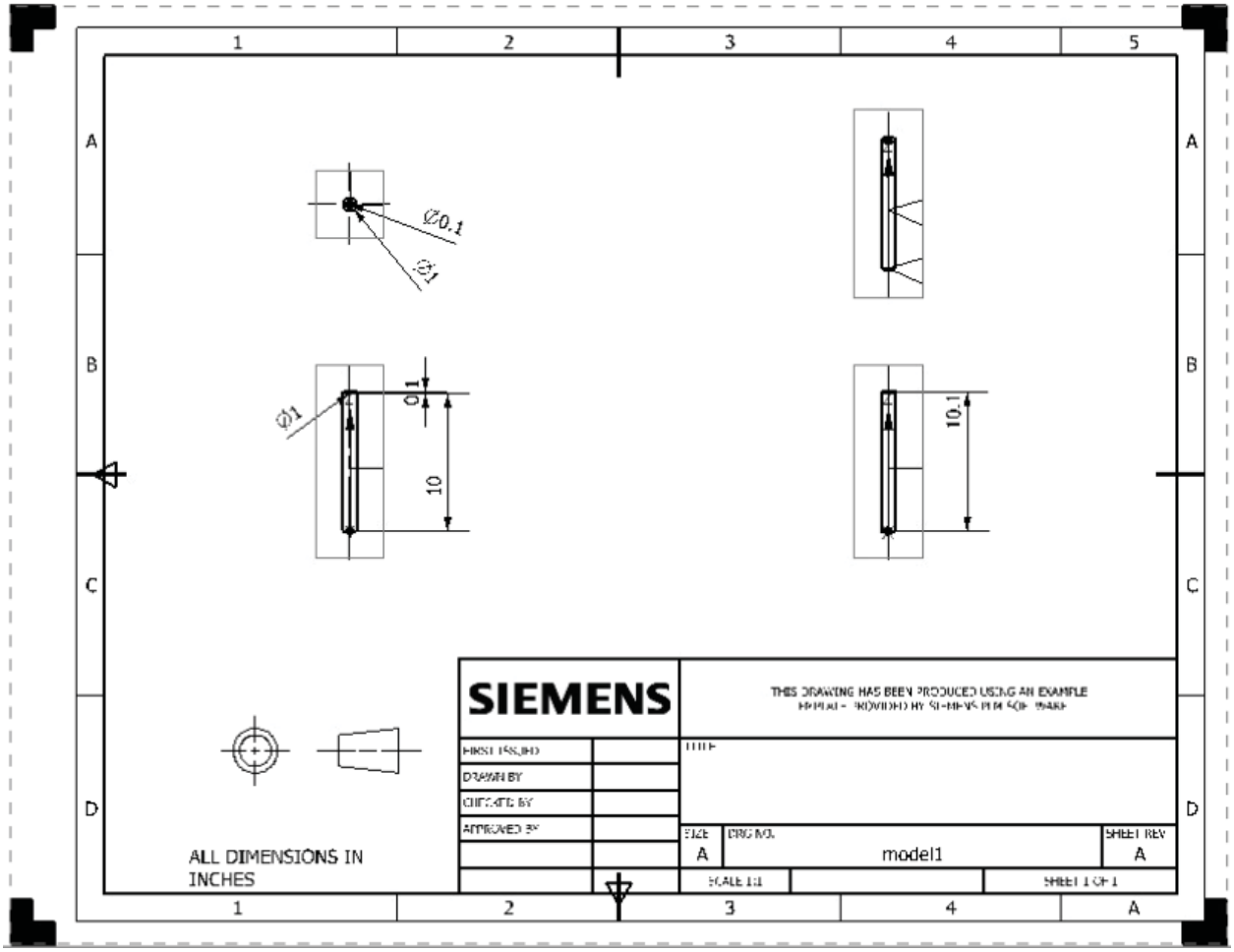


Figure 5.26 Tube Container Drafting

Figure ~~5.35~~ and 5.36 represent the ring magnets used in the experiencement. Placing both ring magnets on the tube without touching will allow a magnetic field. The inner space of the ring still belongs to the outer magnetic field distribution, and part of the magnetic induction line connects the magnetic poles of both ends through the inner hole of the ring. Figure 5.37 represents the dimensions of ring magnets. All units are in inches. The dimensions of the magnets were calculated to compliment the diameter of the container.

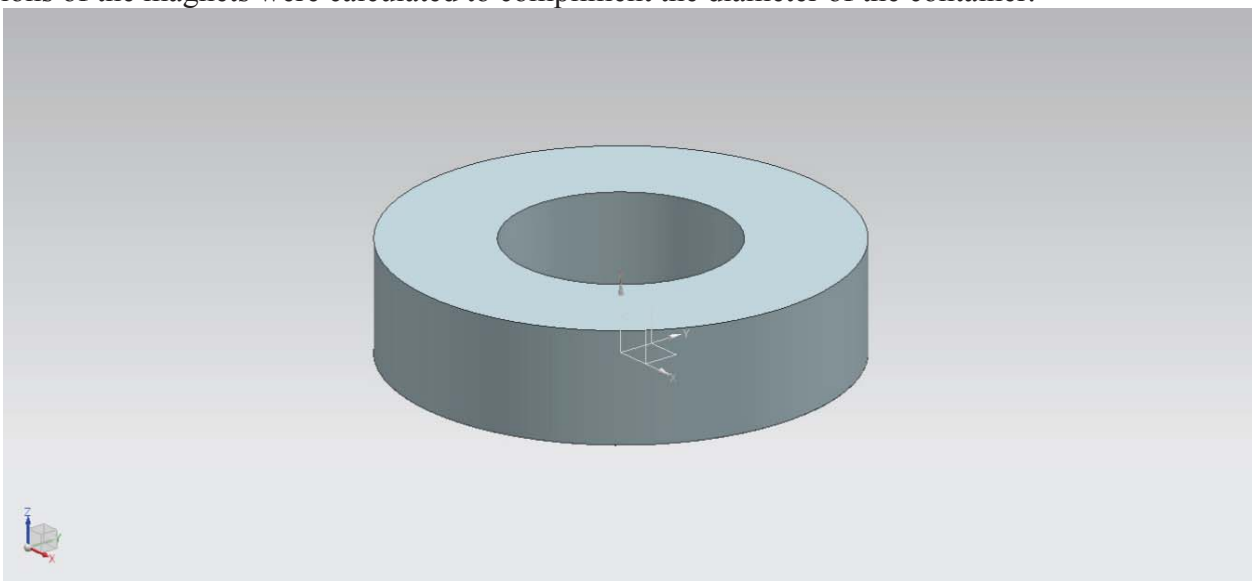


Figure 5.27 Ring Magnet 1

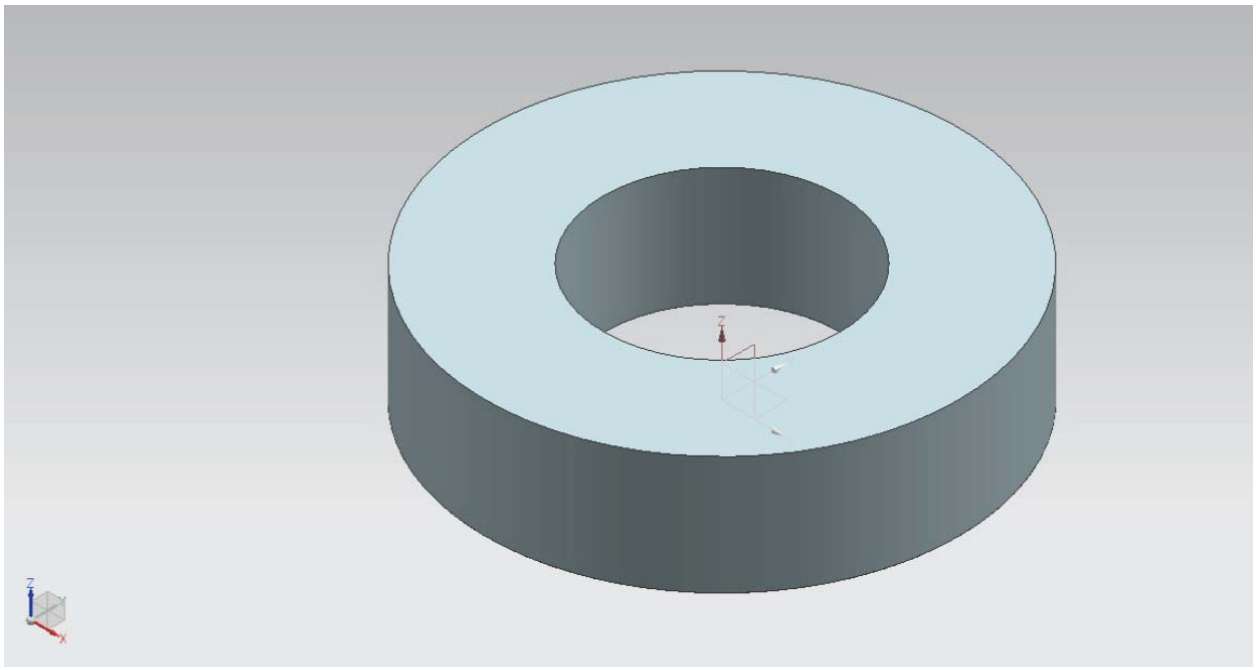


Figure 5.28 Ring Magnet 2

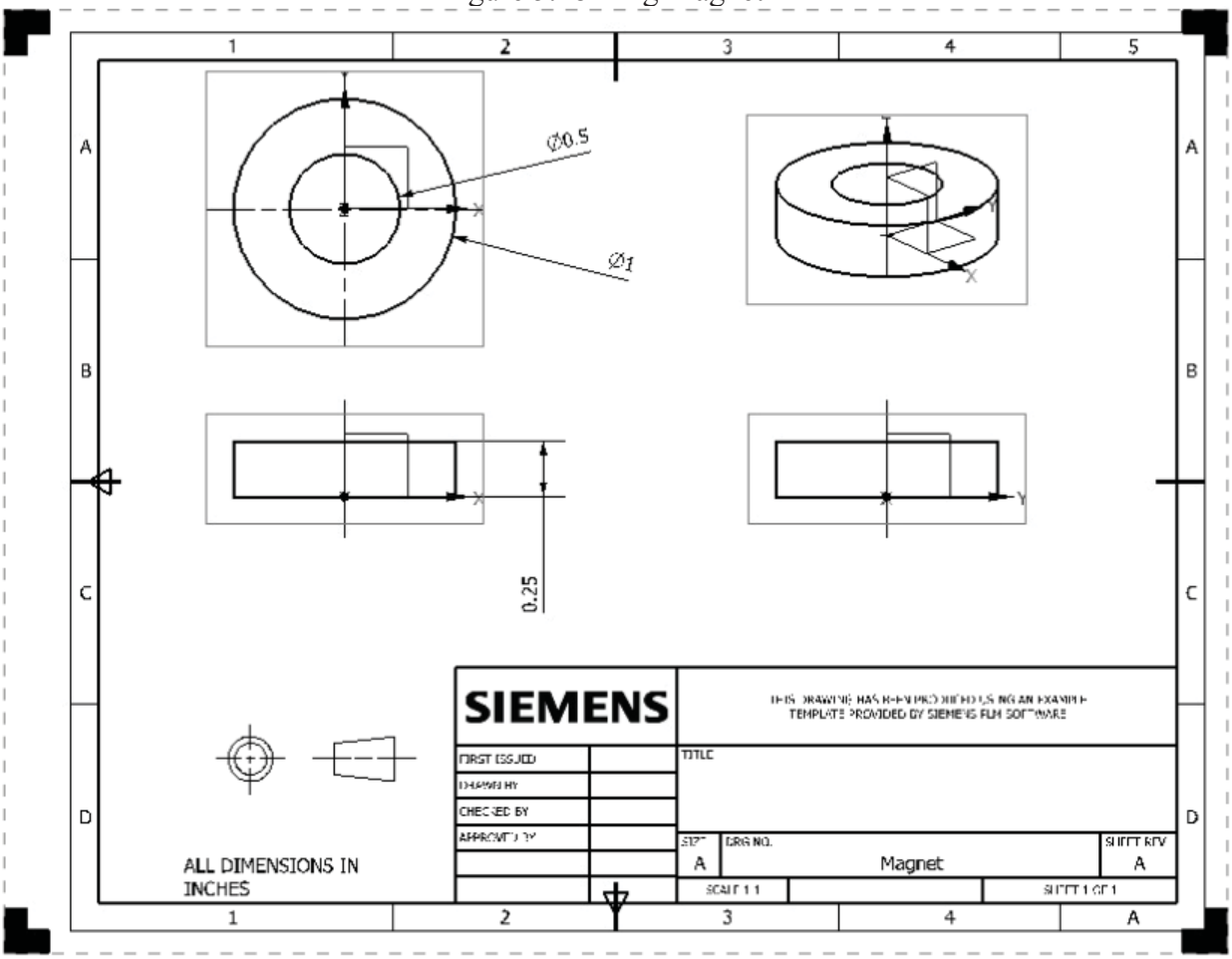
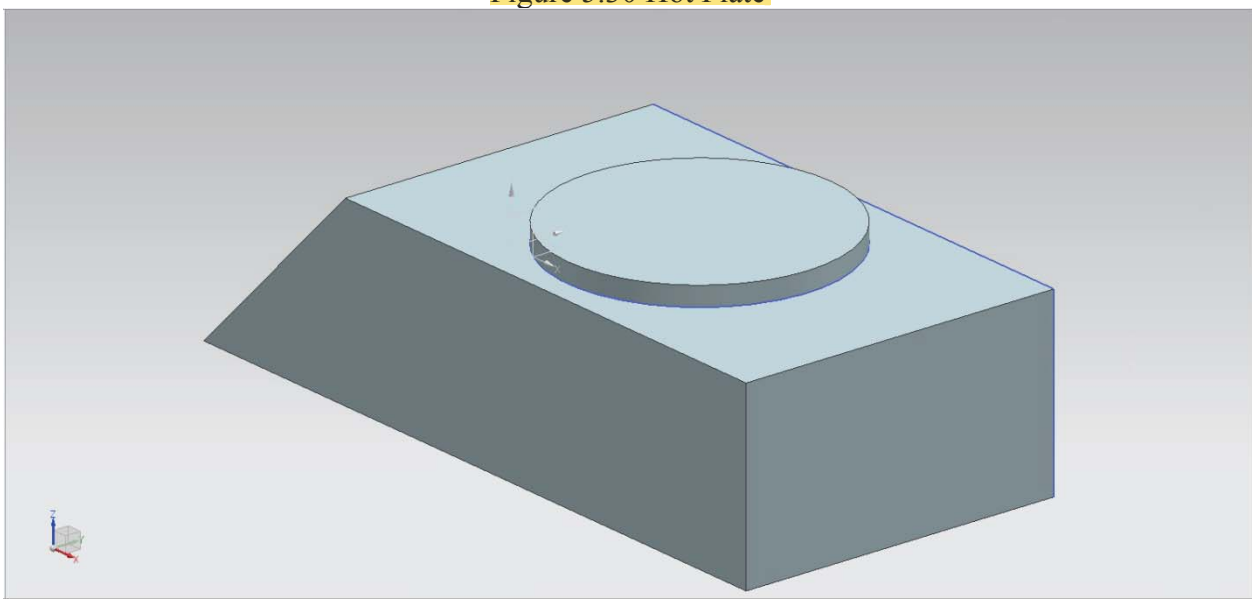


Figure 5.29 Ring Magnet Drafting

Figure ~~5.38~~ below is the design of the hot plate which will be used to heat up the container to which the nanofluid will be captive in and placed in the center of the hot plate. It will coincide with the heat sink regarding transmitting heat as necessary for proper calculation of the heat transfer coefficient and thermal conductivity of the nanofluid. The dimensions of the hot plate were calculated to compliment the size of the container as shown in figure ~~5.39~~.

Figure 5.30 Hot Plate



~~Figure 5.31~~

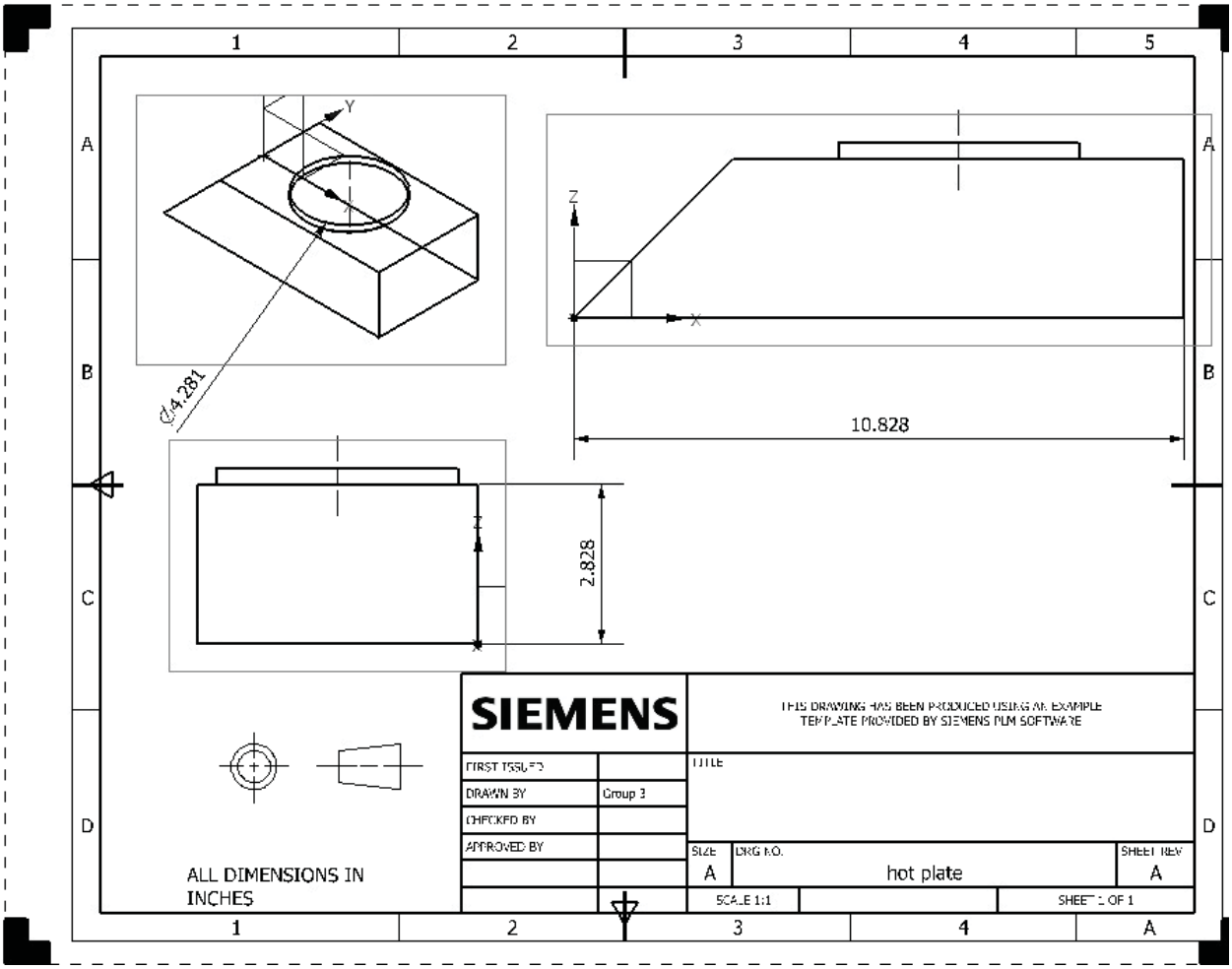
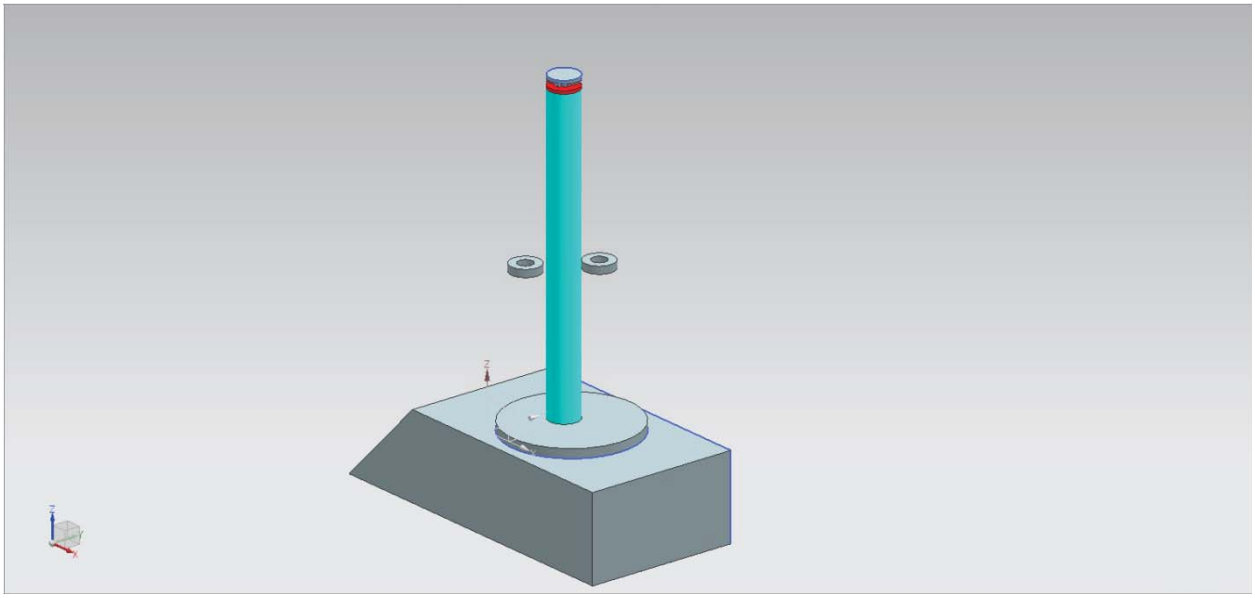


Figure 5.32

2. Generate CAD design(s) of assemblies and sub-assemblies, exploded views that show the components/parts you need to order. The components should be identified with part numbers 1 2 3 etc. subassembly numbers A e If subassemblies are used, exploded views of each subassembly should be provided.

The ~~figure 5.40~~ below consists of all individual components assembled via NX 10 to which displays a computer automated design that reflects which components will be purchased and how they will be assembled in real time.



~~Figure 5.33~~

~~3. Indicate the **standards** used to generate the models, drawings and the assemblies in items 1 and 2.~~

In order to properly generate the designated 3D designs, credible standards were to be chosen to make the correct determinations and style of designing for each component. The standards and codes which were used consisted of the ASME and SAE standards which were basic undergraduate standards to which is commonly used amongst mechanical engineering students across the world.

~~4. For each part, provide a summary of the engineering analysis/calculations that show how each part was sized (geometric, energy, power, structural, etc.) and specification for~~ purchasing each part.

Heat Sink

The heat sink was designed with the intent to mirror common heat sinks used for the calculation of thermal conductivity and the heat transfer coefficient of commonly used nanofluids amongst experiments used with the ASME and SAE standards and codes. The diameter and nodes were calculated using the diameter of the container to which the nanofluid would be placed in order to efficiently allow heat to flow through the surface area without any wasted material.

Tube Container

The container was designated to be 10 inches with a cap to give the nanofluid ample space to conform as the nanofluid particles flow through out the container based on natural convection through the heating and cooling utilizing the heat sink and the hot plate to which the container will be placed upon

Magnets 1 & 2

The magnets used in this system will react with the nanofluid and container to manipulate the nanofluids movement. Each magnet is the same size and is that size with the intent to capture a certain number of particles within the nanofluid to ensure natural convection takes place.

Hot Plate

The hot plate designed in NX 10 is designed based on standard issued hot plates that are used to achieve maximum power and efficiency through the heating of the metal cylinder which will easily transport to the object being placed on top of the metal plate. The dimensions are based on the code of the ASME standards and regulations.

5.4 Economic Analysis

For each of the parts needed, a research was made in the market in order to find the desired components. Furthermore, the parts were selected based on the dimensions found on the CAD drawings. Table …. contains all the parts that have been drawn such as the quantities, market where they were found and phone numbers of the contracted vendors that the group talked in order to make sure the best components were gotten to complete and finalize this project.

Table 5.3 Parts Specifications, Vendor Information and Cost Summary Table

Part #	Part Name	Part Specification/Description	Quantity Needed	Unit Price	Extended Price	Vendor Name	Vendor Phone #	Web-address
1	hot plate	Scilogex 81112102 MS-H-S Analog Magnetic Hotplate Stirrer, Porcelain Plate, 110V/60Hz, 5-2/7" Diameter	1	$295	$295	Amazon	(888) 280-4331	https://www.amazon.com/Scilogex-MS-H-S-Analog-Magnetic-Stirrers/dp/B0079NOMX2/?tag=geometryofmolecules-20

2	heat sink	3.5x1.2inch Round Spiral Aluminum Alloy Heat Sink for 1W-10W LED Silver White	1	$8.90	10	Amazon	(888) 280-4331	https://www.amazon.com/3-5x1-2inch-Spiral-Aluminum-1W-10W-Silver/dp/B00N2HGWMS
3	stainless steel container	Clay - Adams 0901 Stainless Steel Test Tubes Centrifuge Tubes	1	$40	$45	Dotmed		https://www.dotmed.com/listing/other/other/clay-adams-0901-15ml-stainless-steel-test-tubes-centrifuge-tubes/1198543
4	pressure control valve	3/4 in. Push-to-Connect Bronze EB-45 Direct Pressure Regulator Valve	1	$49.97	$49.97	Home Depot	(281)-858-8040	SharkBite 3/4 in. Push-to-Connect Bronze EB-45 Direct Pressure Regulator Valve-23858-0045 - The Home Depot
5	pressure sensor	3/4 in. Bronze Double Union PEX Water Pressure Regulator with Gauge	2	$69.97	$69.97	Home Depot	(281)-858-8040	Apollo 3/4 in. Bronze Double Union PEX Water Pressure Regulator with

								Gauge-APXPRV34WG - The Home Depot
6	Multimeter	CAT III 600 V Class 2 rated multimeter has double insulation	1	$39.94	$39.94	Home Depot	(281)-858-8040	Klein Tools Electrical Test Kit-69149 - The Home Depot
7	RTD	Small Diameter RTD Probes tem# PR-16-2-100-1/16-24-E	6	$154.67	$160	Omega, a spectrum company	888-764-7703	https://www.omega.com/en-us/temperature-measurement/temperature-probes/probes-with-lead-wires/p/fine-diameter-RTD-probes?gclsrc=aw.ds&&_vsrefdom=mca&mchxkw=c:232865952,k:,m:b,p:,d:c,ai:242219079 12,ad:43144865854 7,s:g&gclid=Cj0KCQiAk53-BRD0ARIsAJuNhpsbZUsFH1YIWG5OCPv77GUfRb3k4a1qwVS

								PkUKQ_RW1OPuAS_WiHBcaAlCQEALw_wcB&gclsrc=aw.ds
8	aluminum foil	4 in. x 25 ft. Flexible Aluminum Foil Duct	1	$18.91	$18.91	Home Depot	(281)-858-8040	Everbilt 4 in. x 25 ft. Flexible Aluminum Foil Duct-EVER019 - The Home Depot
9	bell jar	Glass Dome Cloche Bell Jar Terrarium, H-12	1	$31.20	$35	vase market	888-980-9698	https://vasemarket.com/12x12-inch-glass-dome-cloche-centerpiece
10	Magnet	Ring Magnet, Material Ceramic 5, Max. Pull 4.4 lb, Thickness 0.331 in, Diameter 2 23/64 in, Hole Dia. 1 9/64 in, Stability Temp. 400 Degrees F	2	$1.87	$3.74	zoro	(855)-289-9676	Zoro Select 10E795 $1.87 Ring Magnet, 4.4 lb. Pull | Zoro.com
11	Thermal tape	Thermal Adhesive Tape, 25Mx20mmx0.25mm High Performance Thermally Double Side Tapes Cooling Pad Apply To LED Strips, 3D Printer,BCP,CPU,GPU,Laptop Heatsink,And have heat conduction, insulation	2	$10.99	$16.99	Amazon	(888) 280-4331	https://www.amazon.com/Aikenuo-Adhesive-performance-Heatsink-Computer/dp/B075FRPXQ5/ref=sr_1_1_sspa?dchild=1&keywords=thermal+tape&qid=1606970108&sr=8-1-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUFFV

								kI2QVVEOExOUDQmZW5jcnlwdGVkSWQ9QTA3OTU4MjQySzVSN0k2SVhHRjdTJmV uY3J5cHRlZEFkSWQ9QTA0MTIxMzMzVUdSRVhTNjRMNzNFJndpZGdldE5hbWU9c3BfYXRmJmFjdGlvbj1jbGlja1JlZGlyZWN0JmRvTm90TG9nQ2xpY2s9dHJ1ZQ==
	Data acquisition Card	Data logger with oscilloscope, spectrum analyser and signal generator. USB connected and powered. Built-in sensors for light, sound and temperature and an RGB LED. 4 digital input/outputs. Measure pH using standard electrodes. Control up to 20 DrDAQs from one PC. External sensor sockets also allow you extend the functionality of DrDAQ.	1	$129	$129	Newark	800-463-9275	USB DRDAQ - Pico Technology - Data Logger, USB Universal, 14 Channels (newark.com)
	Computer	Dell Optiplex 3010 Certified Refurbished Desktop Bundle Core i3	1	$299	$299	Atmark	855-483-3674	Dell Optiplex 3010 Certified Refurbished Desktop

		3.3GHz with 22" Monitor Windows 10						Bundle Core i3 3.3GHz – Atmark Trading (atmarktrade.com)
	Mixing Chamber	*Gradient : 600ml, Gradient shape can be straight. Size: 205mm 125mm 80mm.*	1	$282	$282	ebay	866-456-0677	Liquid phase gradient mixer for Lab TH300 | eBay
				Total	$1454.52			

6. RESULTS & DISCUSSION

6.1 Summary of Goals and Objectives

The goal for that project is to be able to create an experimental setup that can help in the measurement of the heat transfer coefficient and thermal conductivity of nanofluids. The experimental setup must be able to generate fast results without compromising the accuracy of the results. In order to build the apparatus and conduct the experiment it is important to collect data on and understand different measurement techniques for convection and choose the ones that would be appropriate for nanofluids under different boundary conditions. The accuracy of the results will be judged on the fact that whether or not it is in the range of results from previous experiments of the same kind. However, the goal is to have results more accurate than any previously conducted experiment and this will be made by knowing the flaws of the apparatus in those experiments and make sure that the newly created apparatus is as much as possible free of these flaws.

6.2 Discussion of Completed work (chapter by chapter)

Important subjects such as project planning, literature review, and functional decomposition were discussed throughout the different chapters. For instance, throughout the project planning it can be observed how this group had a chance to identify and divide the different tasks and gave an estimated time on how long it was going to take to complete each and every single one of them. However, on the other hand, chapters like the literature were able to introduce the group to a deeper analysis as far as the project is concerned. For example, the measurements, techniques, apparatus, fabrications equations, advantages and disadvantages that other engineers or scientists came across while dealing with similar projects or designs. This was able to provide important content that was going to help the group have a better understanding of what needed to be done to successfully conduct this project. And finally, finally the functional decomposition, which gave the group the chance to come up with suggestions that were later on turn out into functions made up of verbs, nouns and modifiers that will help the group solve the overall function or original problem scope where the need is well presented.

6.3 Summary of Constraints and Codes used and met by Design

The constraints that were determined were based on past experiments and studies done that previous engineering students, professors, and scientists have conducted to deduce the proper techniques for this project. The codes used were derived from the ASME Boilers and Pressure vessel codes. These were the standards that the group adhered to in order to develop proper language for the project. The constraints consisted of equality constraints which deal with dealing with high level temperatures, inequality constraints which deal with a flexible or inflexible boundary conditions, and lastly “yes or no” constraints which have to deal with success or failure in measuring the heat transfer coefficient and thermal conductivity in the nanofluids. These codes and constraints are essential to the success of this systematic project due to the fact that without these guidelines in place the problem that must be solved within the heat transfer mechanics will go unanswered.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusion

In conclusion the problem of obtaining fast and accurate results on the measurement of heat transfer coefficient and the thermal conductivity is a problem that needs to be solved. Many previous experiments have been conducted on that subject. However, this project is intended to create a better and safer apparatus while respecting the different constraints linked to the execution of the project and while making it also easy to use. The creation of this experimental set up will be a game changer for the industries that work directly with nanofluid as it would be a great time saver and therefore a money saver.

7.2 Recommendations

As it was stated before, there are many advantages and disadvantages scientists came across with when trying to measure the heat transfer coefficient and thermal conductivity of nanofluids under different boundary conditions. From the apparatus to the measurement used and recommendations were made based on how important or useful those were.

For instance, when it comes to looking at design 1, it can be found that one of the devices used on the experiment was the laboratory test rig, which allows the users to change the magnetic fields many times. This affects the heat transfer coefficient of the nanofluids, which is a major change in boundary conditions and could be totally recommended for the current project since one the aspect we will be dealing with as boundary condition is the magnetic field.

Another recommendation would be to use thermocouple to measure wall and fluid bulk temperature in the free convection in the free convection over the building wall since that way, the Heat flux sensors would be able to measure both convective and radiant heat transfer coefficient w just as Yang, one of the scientist who measure the heat transfer coefficient did through the direct method.

LIST OF REFERENCES

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APPENDIX A

A.1 Project Selection and Team Formation

	Name of Group Member	Assigned Role	Phone Number	e-mail Address
1	Fanta Kaba	Writer & Recorder	832-762-1173	fantakaba50@gmail.com
2	Yemboado Brayan Yonli	Design Analysis Leader & Budgeter/Burchaser	713-894-4648	yyonli@student.pvamu.edu
3	Diana Morales	Proof Reader and Ideas Facilitator	281-236-0581	dmorales4@student.pvamu.edu
4	Abdullah EL Aker	Manufacturing & Testing Leader	832-421-0808	aelaker@student.pvamu.edu
5	Marcelo Epam Ona	Group Leader & Organizer	832-614-2426	mepam@student.pvamu.edu
6	Christian White	Graphics & Presentation	713-517-1509	cwhite52@student.pvamu.edu

A.2 Team Management and Assessment

Day of the Week	Meeting Times Start time & End time	Total meeting hours for day	Meeting Location (Location, Building, Room) Or How group plans to meet Provide link, etc. if Zoom or other electronic meeting forms being used
Tuesday	12pm - 3pm	3	https://us04web.zoom.us/j/8188851036?pwd=M083VG9mdGgzNklvUGNNS1lCRndhQT09
Friday	11am - 2pm	3	https://us04web.zoom.us/j/8188851036?pwd=M083VG9mdGgzNklvUGNNS1lCRndhQT09
Saturday	10am - 12am	2	https://us04web.zoom.us/j/8188851036?pwd=M083VG9mdGgzNklvUGNNS1lCRndhQT09
Total Meeting Hours for the week (outside class period)		8 hrs	

Meeting times with Project Faculty Owner [3]

Day of the Week	Meeting Times Start time & End time	Meeting Location (Location, Building, Room) Or How group plans to meet Provide link, etc. if Zoom or other electronic meeting forms being used
Tuesday	11am - 12pm	https://pvpanther.zoom.us/j/8487601860?pwd=TVdIVFpKZ0JHa1NoRWNpWENuNWRqQT09

A.3 Team Organization and Agreement

Dear Group, 3 Members,

This letter (the "Agreement") summarizes my understanding of the agreement that we reached on September 8, 2020 after our zoom conference. If this Agreement is acceptable to you, please sign below in the space in the space designated for your signature.

As I understand it, we have agreed as follows:

1. Agreement

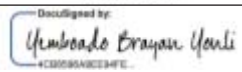
It is my understanding we have agreed to the following in regard to: Group 3.

- *I have read and understood the requirements of the course and the grading policies as stated in the final course syllabus*
- *I agree to abide by the university's policy on scholastic dishonesty*
- *I hereby assign all of my intellectual property rights on the project to the sponsor of the project*
- *I agree to attend every single meeting established by the group and the project adviser unless we had a valid reason such as being in class, sick or work.*
- *Each group member agrees to be penalized by the group leader if they do not complete the part of the project that has been assigned to them.*
- *Each group member agrees to be respectful to other group members when it comes to communicating their ideas and suggestions to the group.*

2. Term

The term of this Agreement ("Term") will commence as of September 8, 2020 and will continue in effect until the end of the senior design project. No part of this Letter of the Agreement may be changed, modified, amended or supplemented. I have read and understood the requirements of the agreement.

Printed names, signatures and dates on agreement.

	Printed Name	Signature	Date
1	Fanta Kaba		9/5/2020
2	Yemboado Brayan Yonli		9/5/2020
3	Diana Morales		9/5/2020
4	Christian White		9/5/2020
5	Abdullah EL Aker		9/5/2020
6	Marcelo Epam Ona		9/5/2020

The agreement signed is binding on each student until the end of the semester and violating the agreement may require you to drop the course.

Note: All signatures must be obtained through DocuSign
Note: Attach a copy of this status report sheet to your work (placed after the cover sheet) [2]
Note: Assignment for Outcome 5 in the syllabus

NOTES ON TEAM ROLES

Technical Team Roles may include but not limited to

1. **Organizer**

Leads in developing, maintaining task scheduling, and reviews progress on project schedule and refocuses efforts to meet deadlines in project schedule.

2. **Ideas Facilitator**

Leads in generating, collecting and organizing ideas.

3. **Graphics/Models Leader**

Oversees development of models, drawings, and simulations.

4. **Design analysis leader**

Oversees the various analysis needed for the design and ensures designated members present accurate design analysis and integrate analysis into the design report.

5. **Manufacturing and Testing Leader**

Oversees the fabrication, assembly, manufacture and testing of the system designed.

Non-Technical Roles may include but not limited to

1. **Budgeter /Purchaser**

Prepares detailed budget and coordinates purchasing of parts for the design

2. **Presentation Manager**

Leads in the organization, preparation and oversees presentation roles of team members.

3. **Technical Writer**

Leads in organizing, structuring and writing of the report using contributions from designated members.

4. **Proofreader**

Responsible for ensuring the report has no grammatical or spelling errors and that the report is written using acceptable clear English language.

5. **Recorder**

Takes minutes and documents all meeting and design activities for the group. Short video clips can be used to catalog the group's activities.

Note: Group can add more roles if needed.

BELOW AVERAGE

MECHANICAL ENGINEERING DEPARTMENT
PRAIRIE VIEW A&M UNIVERSITY

MCEG 4472 Y01/Y02/Y03

SENIOR DESIGN Final REPORT

Design and Analysis of Steering and Suspension System

Fall 2020

Group 8

Robert Barbee, Jonathon Horta, Aramis King, Todd Maxwell, Michael Samuel, Daniel Ward & Titus Woodard

No	Group Member Name Group Member signature	Brief Description of Work Assigned to Member	% Completed by Member*	Your Score
1	Robert Barbee *Robert Barbee*	Corrected chapters 1 and 2 and calculations for chapter 5. Format table of contents and list of figures. Completed chapter 6 and 7.	100	
2	Jonathan Horta *Jonathon Horta*	Completed Appendix A and corrected chapter 4 in the final report.	100	
3	Todd Maxwell *Todd Maxwell*	Corrected chapters 4 and 5	100	
4	Michael Samuel *Michael Samuel*	Correction on reports and Formatting on figure and tables	100	
5	Aramis King *Aramis King*	Corrected tables names and deleted cells in chapter 8	100	
6	Daniel Ward *Daniel C. Ward*	Report formatting; Chapters 3-5	100	
7	Titus Woodard *Titus Woodard*	Assisted formatting report tables and figures 7-8	100	

Letter of Transmittal

December 7, 2020

Dr. Peng, Dr. Biney & Dr. Duan

Mechanical Engineering Department

Prairie View A&M University

Dear Professors:

The attached report contains relevant information as a result from collaborating and researching on Steering and Suspension Systems for Off-Road Vehicles between September 4, 2020 and December 7, 2020. This report contains a detailed description of the project formulation, project planning, literature review, and concept generation portions of the design project.

Sincerely,

Group 8

Acknowledgment

In great contribution to the design and analysis of steering and suspension systems, Dr. Duan and Dr. Peng assisted the team in the overall production requirements of this midterm report. Baja Club Team leaders, Carrie Conton and Vicaessee Paul helped influence ideas to organize research and begin the design process. Special thanks to Dr. Park and other department faculty and staff for their contributions and feedback as well.

ABSTRACT

1. The purpose of the project

The purpose of this project is to construct unique steering and suspension systems capable of withstanding challenging off-road terrains while also avoiding easy steering disengagements and suspension component dislocations.

2. The brief description of the method used

Up to this point of the project, credible resources have been utilized to create tables and figures critical to completing a successful design. The tables used up to this point elaborate on objectives, sub objectives, tasks, deliverables, and methodologies in an organized manner. The figures used up to this point include an objective tree, gantt charts, system components, necessary math equations, result examples, black boxes, and sticky notes. All these tables and figures assist the audience in better understanding the background of the project before any fabricating or testing begins.

3. Results

In the end, the sizing of the components were based on the vehicle. The group designed a steering and suspension system that was compatible with a chassis that was provided. The range of motion for all components allow the vehicle to absorb external forces as well as letting the driver have full control of the vehicle at all times.

4. Conclusion

In conclusion, the group still needs to pick a material for the vehicle that is lighter than 4130 stainless steel but just as strong. The pricing needs to be determined by reaching out to vendors to determine the price for the group's components. The final design for the two systems are completed and are shown in this report.

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1. Project Scope

This chapter will cover a series of information that will help the audience comprehend the purpose and background of the project from a bird's eye point of view. A project scope, problem statement, client identification and recognition of need, goals, objectives, and constraints will all be included in this chapter. However, tables and figures are included in this to assist with project organization due to the need of referencing from this chapter in the near future.

1.1 Problem Statement

There's a need for a unique steering and suspension system for an off-road vehicle that's reliable enough to withstand all forces and loads applied onto it by challenging terrains. This project is important because different industries rely on off-road transportation to get missions completed and the steering and suspension system is the part of the off-road vehicle that is put under the most stress. Some benefits from this project are the unique system being able to be utilized in diverse areas such as space exploration and also the military, and it possibly being adopted by automotive companies into future off-road vehicle designs. Some applications of this project consist of creating literature reviews on how the system operates, designing a steering and suspension system that is compatible with a chassis provided, formulating a test that will analyze the design with multiple forces acting on itself, fabricating and assembling the steering and suspension after multiple iterations until the system passes all tests and can withstand all forces for the chassis. The steering and suspension mechanisms should withstand all internal and external stresses on the off-road vehicle for a provided off-road course.

1.2 Client Identification and Recognition of Need

This section will discuss the clients that this project can be proposed to for better steering and suspension systems. This section will also show the recognition of the need for this project with problems with current steering and suspension systems.

Toyota, the U.S. Army, and NASA are the clients for this project. This system will be designed and fabricated for an off-road vehicle. Once the system is fabricated and can withstand all forces and stresses, the system could be sold to companies needing off-road vehicles with similar specs, such as weight and chassis design to accomplish similar goals. Off-roads vehicles are getting more attention drawn towards them and over $200 million dollars is being spent on these vehicles each year. When designing the steering and suspension system, our goal is to improve stability and increase range of motion for the vehicle which will improve desirability from other potential clients.

Domestic Use

The PV Baja team's off-road vehicle will be showcased in the SAE Baja competition as a contestant [1]. SAE calls for bright minded students to produce various vehicles to compete and prove their skills in a tedious competition style format based on engineering, science and overall knowledge of automobiles. Under these circumstances, SAE is the team's main audience but there are still plenty of other consumers who could possibly take interest in the vehicle design.

Prairie View A&M is only one of many schools who participate in the annual Baja competition. It is definitely plausible for other institutions to take interest in the team's project if it proves to

be a great design satisfactory for competition [1]. Other students will be able to be influenced by the PV Baja team for future builds and design specs.

Aside from student based programs, the vehicle may appeal to those who may want to utilize it for personal use [2]. Whether it be hunting, recreational off-roading or sports, this design may also be used for these purposes as an all-weather, all-terrain resource.

Commercial Use

Other than competition and the possibility of domestic use, there may be a plausible case for the vehicle to be utilized in industry on a much larger scale. The team has partnered with Toyota who is known for their very own off-road vehicle and baja programs [3]. It wouldn't be a surprise if the Japanese powerhouse were to reach out to the team for design implementations to use for their own competitive means. To piggyback, it may also be appealing for other manufacturers and car companies to bear interest in the vehicle to compete amongst their industry.

The possibility of this vehicle to be used in the fields of aerospace and defense are remarkably high as well. NASA is well known for its space exploration projects and taking on outer space missions to the moon and even Mars [4]. Most have heard about NASA's space exploration vehicle; the Rover program is used to track various terrains and withstand a differentiation of unknown elements. Based on this, it is very likely that the government would be interested in seeking an outside contractor, as they do already through companies such as Raytheon Technologies and Lockheed Martin, to provide a concept vehicle for extra-terrestrial purposes and planetary exploration. Northrop Grumman may also be a contender for a project such as this, as this company is looking to be 'number one in space' in the next few years [5]. Such a vehicle would allow them to assist or even compete with NASA for certain contracts and expand their opportunities in the industry.

Outside of space systems, the military may also have some use for this type of vehicle for mission systems [6]. The military is known to use a great deal of vehicles by means of combat and transportation. Most of these vehicles are plated with armor, specialized equipment and tailored for off-road capabilities for combat and even non-combat situations. Figure 1.1 and Figure 1.2 show examples of commercial use that this project can improve.



Figure 1.1: NASA Rover on Mars mission [5]



Figure 1.2: Heavily armored and fully equipped military grade buggy [6]

Recognition of Need
As far as steering alone, there has been dissatisfaction in maneuverability for off-road vehicles. Since the steering faces challenging environments, many issues can occur in the off-road vehicle's steering system. The steering system has become disengaged in previous off-road vehicle designs and has caused the driver to lose control. This is a major safety issue for the driver. As far as the suspension, there has been dissatisfaction in joints for off-road vehicles. The stresses of different terrains apply larger stresses than usual on the suspension, which calls for different areas on the suspension to absorb these stresses. Joints can be the weakest points on a suspension and can result in dislocation from high stresses. This could also be a safety issue.

1.3 Project Goals and Objectives
This section will be covering project goals and objectives in detail. This will consist of listing the project's objectives and sub objectives, creating an objective tree from this information, and stating the measurement basis, criteria, and units for each objective. The information in this section was put together by the entire group brainstorming on ideas and braking these ideas down to their smallest factor.

Project Goal
The project goal is to present a high quality and affordable suspension and steering design for PV Racing Team's off-road vehicle. Also, to meet design deadlines given by SAE Baja as well as abide design constraints given by the organization. Consistently keep track of all progress made within meetings and share this information with the organization. Test the off-road vehicle suspension and steering system to make adjustments to the design if necessary. Successfully complete the off-road vehicle design before the competition date and present the final design to the organization.

Project Objectives
The project objectives were found as a collaborative effort as a group. From a meeting the students discussed all the objectives that were wanted to be accomplished for the suspension and steering system. As the group discussed the project, some research was done to fulfill all needs for a better suspension and steering system than that is already designed. The list below contains all of the objectives collected for this project that will aid in improvement of current suspension and steering systems.

Project Objectives:
A. Safety
B. Durability
C. Economical
D. Safe for environment
E. Driver safety
F. Low Maintenance
G. Safety of bystanders
H. Affordable
I. Easy Repair
J. Range of motion
K. Withstand high speeds

L. Stability of vehicle
M. Sustainable
N. Handle all weather conditions
O. Interchangeable with other vehicles
P. Able to adjust to different terrains
Q. Fixed alignment
R. Able to support weight of vehicle but lightweight

This section consists of presenting an organized table of all the design objectives and sub objectives created by the group. This section required the group matching design sub objectives into similar categories and identifying the major objectives. This section would help further sections interpret information in a more organized manner.

Table 1.1 includes all the design objectives and sub objectives the entire group came up with. The main objectives are identified at the top of the table, and the sub objectives trail directly under the objectives they correspond to. Table 1.1 reflects the list of objectives created for section 1.3.2.

Table 1.1 Design Objectives

Safety	Durability	Economical
Safety of driver	Able to withstand several terrains	Affordable
Safety of bystanders	Able to support weight of vehicle	Low maintenance
Safe for environment	Range of motion	Sustainable
Handling all weather conditions	Withstand high speeds	Easy repair
	Stability	Interchangeable with other vehicles
	Fixed alignment	

This section consists of using a different tool to create an objective tree. Microsoft powerpoint was the tool utilized to create an objective tree for this section. The purpose of this section was to present an organized set of objectives and sub objectives to the audience in an amplified visual manner.

Figure 1.3 presents an objective tree, which reflects Table 1.1. This tree helps the audience understand the order of objectives and sub objectives visually. This figure was put together through a series of connecting the dots between all the objectives and sub objectives the group came up with.

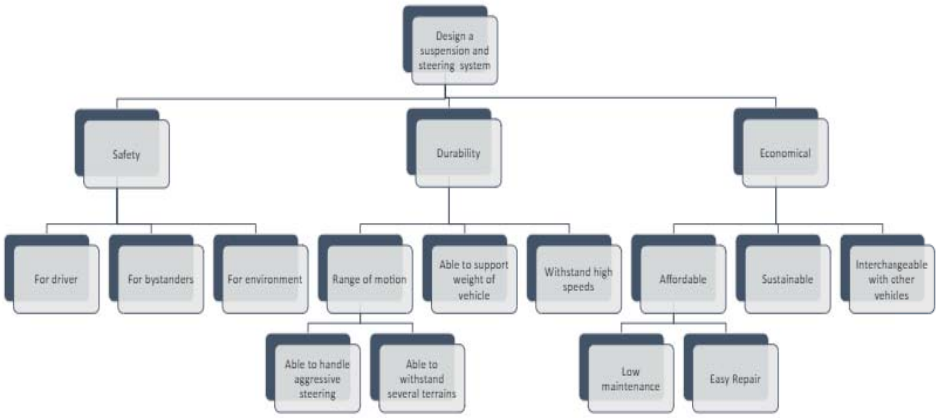


Figure 1.3 Objective Tree

Table 1.2 presents all the project objectives and their measurement basis, criteria, and units. These objectives give us a broader view on what everything falls under and exactly how they can be measured. It also presents a list of the project objects categorized into detailed subsections reflecting the major objectives**.** This shows a broader scope of what areas and viewpoints we are taking as a group through a measurement basis , criteria and units.

Table 1.2 Objectives and Units of Measurement

Objective	**Measurement Basis**	**Criteria**	**Units**
Economical	Steel material machined and assembled as designed	cost	USD
Durability	Internal & external load acting on the suspension	Force	N/m^2 (si) or lb/in^2
Safety	Life expectancy of suspension	Factor of safety	Unitless
Range of motion	Motion	Movement	Degrees

Safety of driver	Life expectancy of suspension	Factor of safety	Unitless
Safety of bystanders	Life expectancy of suspension	Factor of safety	Unitless
Safe for environment	Life expectancy of suspension	Factor of safety	Unitless
Handling all weather conditions	Life expectancy of suspension	Factor of safety	Unitless
Able to withstand several terrains	Internal & external load acting on the suspension	Force	N/m^2 (si) or lb/in^2
Able to support weight of vehicle	Internal & external load acting on the suspension	Force	N/m^2 (si) or lb/in^2
Range of motion	Internal & external load acting on the suspension	Force	N/m^2 (si) or lb/in^2
Withstand high speeds	Internal & external load acting on the suspension	Force	N/m^2 (si) or lb/in^2
Stability	Internal & external load acting on the suspension	Force	N/m^2 (si) or lb/in^2
Fixed alignment	Internal & external load acting on the suspension	Force	N/m^2 (si) or lb/in^2
Affordable	Steel material machined and assembled as designed	cost	**USD**
Low maintenance	Steel material machined and assembled as designed	cost	**USD**

Sustainable	Steel material machined and assembled as designed	cost	**USD**
Easy repair	Steel material machined and assembled as designed	cost	**USD**
Interchangeable with other vehicles	Steel material machined and assembled as designed	cost	**USD**

1.4 Potential Impact of Project on Society (Global, national, local)

This section will discuss the impact of the suspension and steering system on society. The suspension system is responsible to keep the tires on the ground and sustain the weight of the vehicle. The suspension system absorbs forces from the environment to allow a stable drive for the driver and keep the vehicle/driver safe during the whole drive. The steering system is responsible for pointing the vehicle in the direction the driver wants the vehicle to drive. The steering system allows the driver to have full control of the vehicle at all times and have precision through all adjustments to get to the designated location. The suspension and steering systems that the group was working on increases the performance of the vehicle as well as the safety for the driver, vehicle, bystanders, and the environment through all levels of society.

Global

The Baja competition is an event that is recognized across the world. Many designs and concepts are shared between different countries through competition and presentations. A suspension system and steering system on any given car could be fabricated from different countries. A Wisconsin based manufacturer like Briggs and Stratton could collaborate on a given car with Suzuki, which headquarters are located in Japan. Road conditions are different around the world. According to a few reports Singapore has the world's best road quality, followed by Switzerland and the Netherlands. On the other hand, the Dominican Republic has the most dangerous roads in the world.

National

Current National Issues

As a society as a whole, it can be assumed that the world has come a long way in establishing a decent form of transportation. People put their vehicles through a lot, especially for those who are required to cross state borders and travel long distances. Roads across the nation are meant to bridge the gap between the major cities and economies; bringing people, culture, and resources

to be exchanged for further necessities. However, these roads may not be the safest or fully developed for travel, consequently, putting a lot of wear and tear on people's vehicles. Adjustments need to be made to adapt to this quick-paced lifestyle without having to sacrifice safety or performance.

How these issues could be resolved

These issues could be resolved through the continuous remodeling and redesigning of suspension and steering systems within newer vehicles. These vehicles should be able to withstand various conditions without having to worry about frequent breakdowns or dissembling of the systems.

How our designs could solve these national issues

Advancements in suspension and steering systems benefit nationally when it comes to inner state commerce. Vehicles involved in traveling long distances across states are recommended to have suspension and steering systems that are very durable. Advancement in these systems also leads to the comfortability of drivers traveling long distances.

How soon could the nation be impacted

The nation could start advancing as soon as today. Baja competitions are done every year and there are modifications done to every design to give the driver leverage between comfortability and maneuverability. Improving the compatibility within interchangeable parts is also a focus for the design. This is important because the designs currently being created for the suspension and steering systems require manufacturing, which is something that doesn't happen in a matter of seconds. Some suspension and steering parts are only manufactured in specific states. This brings a sense of urgency to wanting parts that would benefit from being easily interchangeable.

Local

Local road conditions differ, depending on the location but a car suspension and steering system is responsible for smoothing out the ride and keeping the car in control in any type of road conditions. The suspension system maximizes the friction between the tires and the road to provide steering stability and good handling. The suspension system also provides comfort for passengers to limit the impact of particular road conditions to not only the car but the passengers riding inside. Road conditions can change at any time. This means the suspension system has to be able to adjust to the environment as quickly as possible.

1.5 Initial Project Constraints and Operating Environment

This section will dive deeper into what are the project constraints for both the suspension and steering systems. It will also discuss the operating environmental conditions these systems will experience.

Initial Project Constraints

Within manufacturing and production, my team was delivered with certain constraints and regulations that we must follow in order to meet the necessary specifications given by the company as well as follow the rules given by the SAE Baja Organization. This list below are the constraints for this project:

- The suspension included with the off-road vehicle and tires cannot be wider than 64” as stated in the baja rule book
- The suspension must be conceived, designed, manufactured and fabricated by the team members without direct involvement from professional engineers, faculty or professionals
- The suspension must be able to operate while holding the weight of the vehicle
- Kit Vehicles Prohibited
- The steering system must be compatible with the suspension system

Operating Environment

In manufacturing and design of a suspension and steering in an Off-road motor vehicle you have to understand the conditions and measure the vehicle will face while operating on different forms of terrain.

List of operating environmental conditions:

- The vehicle must be capable of safe operation over rough land terrain including obstructions such as rocks, sand, logs, steep inclines, mud, and shallow water in any or all combinations and in any type of weather including rain, snow and ice.
- The vehicle must have adequate ground clearance and traction for the terrain type at the competition.

2. Project Planning and Task Definition

This chapter is about how the group is to handle tasks in greater detail. This chapter will also contain how the tasks and subtasks were developed as well as the order of those tasks.

2.1 Task identification

During the semester there are tasks that need to be completed during set time windows to ensure the team meets deadlines set by project owner's and advisors. With each of these tasks there are a set of activities which need to be performed to ensure completion. These specified tasks were identified by collaborating on the weekly team zoom call along with the Baja Project president and board members and were distributed accordingly. Each individual within the group was assigned a specific task based on the previously constructed Gantt Chart. The first task is to complete the project scope. The activities that are involved with this task is to define the objective and create the project formulation which goes in detail regarding the formulation of the project scope, problem statement and other various deliverables, including the identification of the client, needs, constraints, goals and objectives. The second task is project planning in which the Gantt Chart and objective tree will be constructed with emphasis on the identification of the team's tasks and overall project timeline. The third task is to complete the literature review and this will be conducted finding the details needed and identify the sources to ensure the literature review is accurate and organized with coherent facts and information needed. The next tasks will be the functional decomposition as well as the generation and evaluation of concepts. The final tasks that will need to be completed is the preliminary and detailed design. These tasks will be the most time consuming and have the highest number of activities that need to be completed. These activities consist of reviewing codes and standards that must be met, analysis of equations and specified parameters; taking in consideration other underlying factors regarding safety and welfare, CAD design for prototype model, and complete an analysis on the prototype. The project tasks, subtasks and activities associated with each task are listed below.

- Problem Formulation
    - Define Project scope - primary focus and expected results
    - Identify Problem statement - determination of problem and applied tasks
    - Identify the client - who does this project serve
    - Identify the needs - determine measurable performance characteristics of design
    - Define project goals and objectives - arrange characteristics into higher/lower level objectives; utilizing tree structures to determine hierarchy and interconnections
    - Identify the constraints and operating environments - permissible range and parameters
- Project Planning
    - Identify Tasks - identification of major tasks and needs
    - Create Timeline - length of tasks
    - Generate Gantt chart - organization of timeline based on specified tasks
    - Create Detailed Table -create a table that contains project tasks, objectives, deliverables, task duration & responsible personnel
- Literature Review
    - Identify information needed - important project information and details
    - Identify sources - necessary source location
    - Compose the literature review - full review of relevant information found
        - General information of Baja vehicles
        - look up different designs for suspension systems
        - look up different designs for steering systems
        - Find potential clients for this project
        - Parts of the suspension system
        - Parts of the steering system
        - Math involved with each system

        - Safety considerations
- Functional Decomposition
    - Identify functions and subfunctions - list of all functions
    - Generate functional decomposition diagram - graph of related functions
- Concept Generation
    - Develop individual concept generation - each team member develops their own concept of design functions
    - Gather group concept generation - combined ideas of group developed by individual functions
- Concept Evaluation
    - Use multiple evaluation techniques - concepts developed by stated methods
    - Utilize techniques to arrive at overall design - mentioned techniques and methods to produce the design
- Preliminary Design
    - Review codes and standards - relevant codes and specifications that must be followed
    - Identify analysis equations - list of critical equations needed for design specifications
    - Perform engineering detailed analysis needed to size and specify parameters for selecting parts and components - Sketches based on calculations
    - Interpret details regarding public health, safety, welfare and other factors in the design - design must meet needs and provide a safe environment for personnel
- Detailed Design
    - Use NX or CAD to model parts and components
    - Assemble all parts and components
    - Use analysis software to test individual/whole assembly
    - Making changes to design
- Detailed Parts Specifications
    - Use NX or CAD software to create detailed drawings
    - Apply drawing standards to drawings
- Budget & Project Cost (Economic Analysis)
    - Project cost analysis
    - Part specifications needed
    - Receiving vendor quotes
- Purchasing
    - Prepare detailed drawings to meet prototype requirements
    - Discussion of timelines for equipment on order
    - Selection of vendors for components
- Fabrication & Testing
    - Detailed plans on manufacturing and assembly of system
    - Conduct testing in the lab
    - Test system on Chassis
- Final Report & Presentation
    - Complete each part of the report along the way
    - Create a project poster for visual representation
    - Prepare for presentation

2.2 Project Timeline

Tasks that are assigned are collaborated and agreed upon by each group member. Reading over the syllabus during the first meeting really helped us organize assigned tasks and deliverables throughout both semesters. Also the group decided to individually find resources such as articles, videos and previous reports so there would be a variation of perspectives on how to attack each objective. This will help us gradually complete every topic on time. During meetings with Dr. Jiang and Dr. Peng, necessary questions were asked to keep the reports as detailed and efficient as possible. Their experience and feedback really helped make sure the divided roles, assignments and objectives were not disorganized. Lastly, meeting with The Baja Club regularly really helps complete all goals including putting in extra hours, understanding the total design and most importantly having every group member participate and be hands on. The gantt chart and table 1 are the exact goals and deadlines needed to be successful in this design.

Below is a brief description and synopsis of timeline, that includes the duration period for the different objectives given along with the duration it takes to complete this task and which team member participated. The team has prepared for the duration of the Steering and Suspension of an Off-road motor vehicle, breaking the sections down throughout the different group members, some objectives have been assigned due to the strong area of expertise that individuals have. As well as some areas are assigned through collaboration of team members to better understand given tasks.

1.1 Project Scope

- **To identify the client with what is set out to be completed**
- **A description of what major points should be focussed on throughout the project and what are the expected results**
- **Duration: 7 days 9/3/20-9/10/20 Robert Barbee**

1.2 Problem statement

- **To determine the problem and the task that will be taken to solve the problem**
- **Complete description of the problem behind this project and how it will be solved**
- **Duration: 7 days 9/3/20-9/10/20 Jonathon Horta**

` 1.3 Identify the client

- **To identify the client what is the purpose behind the project**
- **A structured statement that defines the overall project goal**
- **Duration: 7 days 9/3/20-9/10/20 Michael Samuel**

1.4 Identify the needs

- **To define measurable performance characteristics of design**
- **A list of all measurable performance characteristics with units**
- **Duration: 7 days 9/3/20-9/10/20 Aramis King**

1.5 Project goals and objectives

- **To arrange performance characteristics into higher-level & lower-level objectives in diagrammatic tree structure showing hierarchical relationships and interconnections**
- **Well drawn and labelled objective tree showing hierarchical relationships and interconnections of the performance characteristics**
- **Duration: 7 days 9/3/20-9/10/20 Titus Woodard/ Daniel Ward**

1.6 Identify constraints and operating environments

- **To identify the permissible range of the design and performance parameters and the operating environment**
- **A list of permissible range for the design parameters, description of the environment in which the design will operate**
- **Duration: 7 days 9/3/20-9/10/20 Todd Maxwell**

2.1 Task identification

- **To identify the major tasks that need be completed for the project**
- **Complete a list including the project's major tasks**
- **Duration: 14 days 9/10/20-9/24/20 Aramis King/ Daniel Ward**

2.2 Timeline

- **Develop a timeline for the length of how long each task should take**
- **List of tasks with the estimated time to complete to be transferred to a Gnatt chart**
- **Duration: 14 days 9/10/20-9/24/20 Todd Maxwell /Titus Woodard**

2.3 Gantt Chart

- **Create a Gantt Chart based off the timeline developed**
- **Gantt Chart With actual time to complete tasks as well as estimated time to complete the tasks**
- **Duration: 14 days 9/10/20-9/24/20 Michael Samuel**

2.4 Detailed Project Tasks, Objectives, Deliverables, Task Duration & Responsible Personnel

- **Create a detailed table based off the Gantt chart and actions taken for the project**
- **Complete a table including specific information for all portions of the project**
- **Duration: 14 days 9/10/20-9/24/20 Jonathon Horta/ Robert Barbee**

3.1 Identify information needed

- **To identify important information needed for the project**
- **Complete a description of important information needed for project**
- **Duration: 12 days 9/17/20-9/29/20 Robert Barbee/ Jonathon Horta/Michael Samuel**

3.2 Identify sources

- **To identify where the important project information will be coming from**
- **Create a list of sources used**
- **Duration: 12 days 9/17/20-9/29/20 Jonathon Horta/Robert Barbee/ Daniel Ward**

3.3 Composing the literature review

- **Create a full literature review with all relevant information found**
- **A Finalized literature review**
- **Duration: 12 days 9/17/20-9/29/20 Todd Maxwell/ Titus Woodard/ Aramis King**

4.1 Identify functions and subfunctions

- **To create a list that contains all functions**
- **A detailed listed of all functions**
- **Duration: 7 day 9/23/20-9/30/20 Jonathon Horta/ Robert Barbee/ Daniel Ward**

4.2 Functional decomposition diagram

- **Compose a graph showing how all functions are related to each other**
- **Create a diagram that shows functions and their sub-functions and how they relate to each other**
- **Duration: 7 day 9/23/20-9/30/20 Michael Samuel/Todd Maxwell**

5.1 Individual Concept Generation

- **Each member creates their own concept of functions for a design**
- **A concept list of functions for a design**
- **Duration: 7 days 9/30/20-10/07/20 Everyone**

5.2 Group Concept Generation

- **The group combining their ideas to come up with all functions**
- **Collaborating all concepts with each member to form a full function list for consideration of a design**
- **Duration: 14 days 9/30/20-10/14/20 Everyone**

6.1 Using multiple Evaluation techniques

- **Evaluate concepts using multiple methods including feasibility study, go-no-go, and decision matrix**
- **Positive evaluation results which push our project to its design stage**
- **Duration: 7 days 10/14/20-10/20/20 Robert Barbee/ Michael Samuel**

6.2 Using techniques to arrive at the overall design

- **Apply concept evaluation techniques for each function to get to an overall design**
- **A list of functions tested to make sure all functions were considered and the design stage may now begin**
- **Duration: 3 days 10/20/20-10/23/20 Jonathon Horta/ Todd Maxwell**

7.1 Review codes and standards

- **Pull up relevant codes and standards that should be followed throughout the project**
- **Provide a list of standards that were followed to approve our design**
- **Duration: 1 days 10/21/20-10/22/20 Jonathon Horta**

7.2 Identify analysis equation

- **Find list of equations critical to project that is needed to come up with the design**
- **Provide a list of equations that we used to come up with our design**
- **Duration: 3 days 10/22/20-10/25/20 Robert Barbee/ Daniel Ward**

7.3 Perform engineering detailed analysis needed to size and specify parameters for selecting parts and components

- **Sketch the idea of the design based of calculations**
- **A beginning sketch of our design based on the calculation and standards for the system**
- **Duration: 8days 10/24/20-11/1/20 Robert Barbee/ Daniel Ward**

7.4 Consider public health, safety, welfare, and other factors in the design

- **Make sure design is not harmful to the environment or the public**
- **Considerations that were made to the design for the safety of everyone**
- **Duration: 5 days 10/30/20-11/4/20 Titus Woodard/ Aramis King**

8.1 Use NX or CAD to model parts and components

- **Create a NX model for all the parts of the system**
- **A NX or CAD model of all the individual parts**
- **Duration: 8 days 11/4/20-11/12/20 Michael Samuel**

8.2 Assemble all parts and components

- **Assemble all parts of the system to show the design**
- **An assembly of all of the parts**
- **Duration: 3 days 11/10/20-11/13/20 Robert Barbee**

8.3 Use analysis software to test individual/whole assembly

- **Use Ansys to run stress tests to see how the system relates to the calculations**
- **Stress analysis test results which determine if we need to make changes to our design**
- **Duration: 5 days 11/12/20-11/17/20**

8.4 Making changes to design

- **Make changes in design based on the analysis tests to make a suitable and passing system**
- **Updated design with passing stress tests**
- **Duration: 2 days 11/17/20-11/19/20**

9.1 Use NX or CAD software to create detailed drawings

- **Use Nx software to come up with detailed drawings of all parts and assemblies**
- **Detailed drawings of all parts and assemblies**
- **Duration: 10 days 11/4/20-11/14/20 Jonathon Horta**

9.2 Apply drawing standards to drawings

- **Make sure drawings are up to standards**
- **Drawings that will be used to send to vendors for quotes**
- **Duration: 6 days 11/14/20-11/20/20**

10.1 Project cost analysis

- **Determine the price of all parts in the system**
- **A table showing total cost of the project and the cost of all individual parts**
- **Duration: 7 days 10/21/20-11/4/20 Jonathon Horta**

10.2 Part specifications needed

- **Determine the parts needed to be ordered**
- **A list of all the parts needed to be ordered and their detailed drawings**
- **Duration: 7 days 10/21/20-11/4/20 Aramis King/ Daniel Ward**

10.3 Receiving vendor quotes

- **Research companies that can make the parts needed for the system**
- **A List of at Least 3 companies we will send our drawings to**
- **Duration: 7 days 10/21/20-11/4/20 Robert Barbee/ Michael Samuel**

11.1 Prepare detailed drawings to meet prototype requirements

- **Gather all information that will be sent to companies to produce our parts/materials**
- **A list that was sent to the company for the fabrication of our parts**
- **Duration: 7 days 2/19/21-2/26/21 Titus Woodard**

11.2 Discussion of timelines for equipment on order

- **Discuss when each part needs to be ordered to fit timeline to begin fabricating the system**
- **A table of when all of the parts that will be needed to order from third party companies**
- **Duration: 7 days 2/19/21-2/26/21 Robert Barbee**

11.3 Selection of vendors for components

- **Choose which companies the team will be outsourcing from**
- **A list of companies that we ordered from**
- **Duration: 7 days 2/19/21-2/26/21**

12.1 Detailed plans on manufacturing and assembly of system

- **Create a detailed plan stating the order of how parts will be assembled**
- **A Timeline of how we are going to assemble the system**
- **Duration: 34 days 2/26/26-4/1/21 Robert Barbee**

12.2 Conduct testing in the lab

- **Find real world testing techniques to run on the system**
- **Results from our system with found techniques that are used in automobile industries**
- **Duration: 34 days 2/26/21-4/1/21**

12.3 Test system on Chassis

- **Weld system to chassis to see performance of the design**
- **The success of our system ran on homemade obstacle course**
- **Duration: 34 days 2/26/21-4/1/21 Daniel Ward/ Aramis King**

13.1 Complete each part of the report along the way

- **To complete each section of the report as each assignment is fulfilled**
- **A final report of all the work done to successfully finish our system**
- **Duration: 28 days 04/1/21-04/29/21 Everyone**

13.2 Create a project poster for visual representation

- **Create a project poster and powerpoint for presentation**
- **A poster and powerpoint to visualize our system and how we achieved it**
- **Duration: 28 days 04/1/21-04/29/21 Michael Samuel**

13.3 Prepare for presentation

- **Prepare how information will be presented from the overall experience of this project**
- **Presented our project with the desirables of the panel**
- **Duration: 28 days 04/1/21-04/29/21 Everyone**

This is a detailed table of each major task with its subtasks. It also includes the objectives, deliverables, the duration of the task, start/ end date, and the person it was assigned to. Table 2.1 is a detailed table for both semesters and contains all major tasks, sub-tasks, objectives and deliverables for each sub-task, estimated duration for each sub-task and the student assigned to that sub-task.

Table 2.1 Detailed table for Tasks, Objectives, and Deliverables

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
1. Problem Formulation	1.1 Project Scope	To identify the client with what is set out to be completed	A description of what major points should be focussed on throughout the project and what are the expected results	7	9/3/20	9/10/20	Robert Barbee
	1.2 Problem statement	To determine the problem and the task that will be taken to solve the problem	Complete description of the problem behind this project and how it will be solved	7	9/3/20	9/10/20	Jonathon Horta
	1.3 Identify the client	To identify the client what is the purpose behind the project	A structured statement that defines the overall project goal	7	9/3/20	9/10/20	Michael Samuel
	1.4 Identify the needs	To define measurable performance characteristics of design	A list of all measurable performance characteristics with units	7	9/3/20	9/10/20	Aramis King
	1.5 Project goals and objectives	To arrange performance characteristics into higher-level & lower-level objectives in diagrammatic tree structure showing hierarchical relationships and interconnections	Well drawn and labelled objective tree showing hierarchical relationships and interconnections of the performance characteristics	7	9/3/20	9/10/20	Titus Woodard/ Daniel Ward
	1.6 Identify constraints and operating environments	To identify the permissible range of the design and performance parameters and the operating environment	A list of permissible range for the design parameters, description of the environment in which the design will operate	7	9/3/20	9/10/20	Todd Maxwell
Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration	Start date	End Date	Primary Respons
2. Project Planning	2.1 Task identification	To identify the major tasks that need be completed for the project	Complete a list including the project's major tasks	14	9/10/20	9/24/20	Aramis King/ Daniel Ward
	2.2 Timeline	Develop a timeline for the length of how long each task should take	List of tasks with the estimated time to complete to be transferred to a Gnatt chart	14	9/10/20	9/24/20	Titus Woodard /Todd Maxwell
	2.3 Gantt Chart	Create a Gantt Chart based off the timeline developed	Gantt Chart With actual time to complete tasks as well as estimated time to complete the tasks	14	9/10/20	9/24/20	Michael Samuel
	2.4 Detailed Project Tasks, Objectives, Deliverables, Task Duration & Responsible Personnel	Create a detailed table based off the Gantt chart and actions taken for the project	Complete a table including specific information for all portions of the project	14	9/10/20	9/24/20	Jonathon Horta/ Robert Barbee
3. Literature Review	3.1 Identify information needed	To identify important information needed for the project	Complete a description of important information needed for project	13	9/17/20	9/29/20	Robert Barbee/ Jonathon Horta/ Michael Samuel
	3.2 Identify sources	To identify where the important project information will be coming from	Create a list of sources used	13	9/17/20	9/29/20	Jonathon Horta/Robert Barbee/ Daniel Ward
	3.3 Composing the literature review	Create a full literature review with all relevant information found	A Finalized literature review	3	9/27/20	9/30/20	Todd Maxwell/ Titus
4. Functional Decomposition	4.1 Identify functions and subfunctions	To create a list that contains all functions	A detailed listed of all functions	4	9/23/20	9/27/20	Jonathon Horta/ Robert Barbee/ Daniel Ward
	4.2 Functional decomposition diagram	Compose a graph showing how all functions are related to each other	Create a diagram that shows functions and their sub-functions and how they relate to each other	4	9/27/20	10/10/20	Michael Samuel/Todd Maxwell

				(Days)			ible Person
5. Concepts Generation	5.1 Individual Concept Generation 5.2 Group Concept Generation	Each member creates their own concept of functions for a design The group combining their ideas to come up with all functions	A concept list of functions for a design Collaborating all concepts with each member to form a full function list for consideration of a design	15 15	9/30/20 9/14/20	10/14/20 10/22/20	Everyone Everyone
6. Concept Evaluation	6.1 Using multiple Evaluation techniques 6.2 Using techniques to arrive at the overall design	Evaluate concepts using multiple methods including feasibility study, go-no-go, and decision matrix Apply concept evaluation techniques for each function to get to an overall design	Positive evaluation results which push our project to its design stage A list of functions tested to make sure all functions were considered and the design stage may now begin	6 3	10/14/20 10/29/20	10/29/20 11/5/20	Robert Barbee/ Michael Samuel Jonathon Horta/ Todd Maxwell
Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person

7. Preliminary Design	7.1 Review codes and standards	Pull up relevant codes and standards that should be followed throughout the project	Provide a list of standards that were followed to approve our design	3	11/5/20	11/8/20	Jonathon Horta
	7.2 Identify analysis equations	Find list of equations critical to project that is needed to come up with the design	Provide a list of equations that we used to come up with our design	6	11/8/20	11/12/20	Robert Barbee/ Daniel Ward
	7.3 Perform engineering detailed analysis needed to size and specify parameters for selecting parts and components	Sketch the idea of the design based of calculations	A beginning sketch of our design based on the calculation and standards for the system	8	10/24/20	11/1/20	Robert Barbee/ Daniel Ward
	7.4 Consider public health, safety, welfare, and other factors in the design	Make sure design is not harmful to the environment or the public	Considerations that were made to the design for the safety of everyone	5	10/30/20	11/4/20	Titus Woodard / Aramis King
Major Tasks Description	**Sub-Task Description**	**Objective(s) for Task**	**Deliverables to be Submitted**	**Duration (Days)**	**Start date**	**End Date**	**Primary Responsible Person**

8. Detailed Design	8.1 Use NX or CAD to model parts and components 8.2 Assemble all parts and components 8.3 Use analysis software to test individual/whole assembly 8.4 Making changes to design	Create a NX model for all the parts of the system Assemble all parts of the system to show our design Use Ansys to run stress tests to see how the system relates to our calculations Make changes in design based on the analysis tests to make a suitable and passing system	A NX or CAD model of all the individual parts An assembly of all of the parts Stress analysis test results which determine if we need to make changes to our design Updated design with passing stress tests	8 3 5 5	11/4/20 11/10/20 11/12/20 11/12/20	11/12/20 11/13/20 11/17/20 11/28/20	Micheal Samuel Robert Barbee Aramis King Todd Maxwell
9. Detailed Parts Specifications	9.1 Use NX or CAD software to create detailed drawings 9.2 Apply drawing standards to drawings	Use Nx software to come up with detailed drawings of all parts and assemblies Make sure drawings are up to standards	Detailed drawings of all parts and assemblies Drawings that will be used to send to vendors for quotes	4 2	11/26/20 11/30/20	11/30/20 12/2/20	Daniel Ward Jonathon Horta
10. Budget & Project Cost (Economic Analysis)	10.1 Project cost analysis 10.2 Part specifications needed 10.3 Receiving vendor quotes	Determine the price of all parts in the system Determine the parts needed to be ordered Research companies that can make the parts needed for the system	A table showing total cost of the project and the cost of all individual parts A list of all the parts needed to be ordered and their detailed drawings A List of at Least 3 companies we will send our drawings to	3 3 4	2/05/21 2/5/21 2/8/21	2/8/21 2/8/21 2/12/21	Jonathon Horta Aramis King/ Daniel Ward Robert Barbee/ Michael Samuel
Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration	Start date	End Date	Primary Respons

				(Days)			ible Person
11. Purchasing	11.1 Prepare detailed drawings to meet prototype requirements	Gather all information that will be sent to companies to produce our parts/materials	A list that was sent to the company for the fabrication of our parts	7	2/19/21	2/26/21	Titus Woodard
	11.2 Discussion of timelines for equipment on order	Discuss when we need to order each part to fit our timeline to begin fabricating our system	A table of when all of the parts that will be needed to order from third party companies	7	2/19/21	2/26/21	Robert Barbee
	11.3 Selection of vendors for components	Choose which companies we will be outsourcing from	A list of companies that we ordered from	7	2/19/21	2/26/21	Michael Samuel
12. Fabrication & Testing	12.1 Detailed plans on manufacturing and assembly of system	Create a detailed plan stating the order of how we are going to assemble the parts	A Timeline of how we are going to assemble the system	34	2/26/21	4/1/21	Robert Barbee
	12.2 Conduct testing in the lab	Find real world testing techniques to run on the system	Results from our system with found techniques that are used in automobile industries	34	2/26/21	4/1/21	Todd Maxwell
	12.3 Test system on Chassis	Weld system to chassis to see performance of our design	The success of our system ran on homemade obstacle course	34	2/26/21	4/1/21	Daniel Ward/ Aramis King
13. Final Report & Presentation	13.1 Complete each part of the report along the way	To complete each section of the report as we are finishing each assignment	A final report of all the work done to successfully finish our system	28	4/1/21	4/29/21	Everyone
	13.2 Create a project poster for visual representation	Create a project poster and powerpoint for presentation	A poster and powerpoint to visualize our system and how we achieved it	28	4/1/21	4/29/21	Michael Samuel
	13.3 Prepare for presentation	Prepare how we are going to present the information from the overall experience of this project	Presented our project with the desirables of the panel	28	4/1/21	4/29/2021	Everyone

2.3 Gantt Chart

This section will show a visual of the gantt chart and the estimated timeline for each task as well as show important milestones. Figure 2.1 is the gantt chart for this project created on microsoft project for the Fall 2020 semester. Figure 2.2 is the gantt chart for this project created on microsoft project for the Spring 2021 semester.

Commented [1]: Up to date

ID	Task Mode	Task Name	Duration	Start	Finish
1		**Senior Design And Professionalism**	**0 days**	**Thu 9/3/20**	**Thu 9/3/20**
2	✓	1. Problem Formulation	2 days	Thu 9/3/20	Fri 9/4/20
3	✓	1.1 Project Scope	3 days	Thu 9/3/20	Sat 9/5/20
4	✓	1.2 Problem Statement	5 days	Thu 9/3/20	Wed 9/9/20
5	✓	1.3 Identify the Client	6 days	Thu 9/3/20	Thu 9/10/20
6	✓	1.4 Identify the needs	8 days	Thu 9/3/20	Sat 9/12/20
7	✓	1.5 Project goals and objectives	8 days	Thu 9/3/20	Sun 9/13/20
8	✓	1.6 Identify constraints and operating environments	8 days	Thu 9/3/20	Mon 9/14/20
9		Completed Problem Formulation	0 days	Mon 9/14/20	Mon 9/14/20
10	✓	2. Project Planning	3 days	Thu 9/10/20	Mon 9/14/20
11	✓	2.1 Task identification	3 days	Thu 9/10/20	Mon 9/14/20
12	✓	2.2 Timeline	7 days	Thu 9/10/20	Fri 9/18/20
13	✓	2.3 Gantt Chart	10 days	Thu 9/10/20	Wed 9/23/20
14	✓	2.4 Detailed Project Tasks, Objectives, Deliverables, Task Duration & Responsible Personnel	10 days	Thu 9/10/20	Wed 9/23/20
15		Completed Project Planning	0 days	Wed 9/23/20	Wed 9/23/20
16	✓	3. Literature Review	4 days	Thu 9/17/20	Tue 9/22/20
17	✓	3.1 Indentify information needed	6 days	Thu 9/17/20	Thu 9/24/20
18	✓	3.2 Identify Sources	11 days	Thu 9/17/20	Thu 10/1/20
19	✓	3.3 Composing the literature review	11 days	Thu 9/17/20	Thu 10/1/20
20		Completed Literature Review	0 days	Thu 10/1/20	Thu 10/1/20
21	✓	4. Functional Decomposition	7 days	Wed 9/23/20	Thu 10/1/20
22	✓	4.1 Identify functions and subfunctions	9 days	Wed 9/23/20	Sat 10/3/20
23	✓	4.2 Functional decomposition diagram	14 days	Wed 9/23/20	Sat 10/10/20
24		Mid Term Presentation/ Report 6 Due	0 days	Thu 10/8/20	Thu 10/8/20
25		Mid Term Report is Due	0 days	Sat 10/10/20	Sat 10/10/20

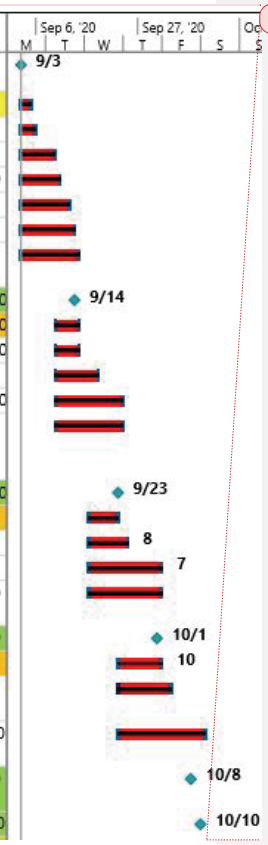


Figure 2.1: Gantt Chart for Fall 2020

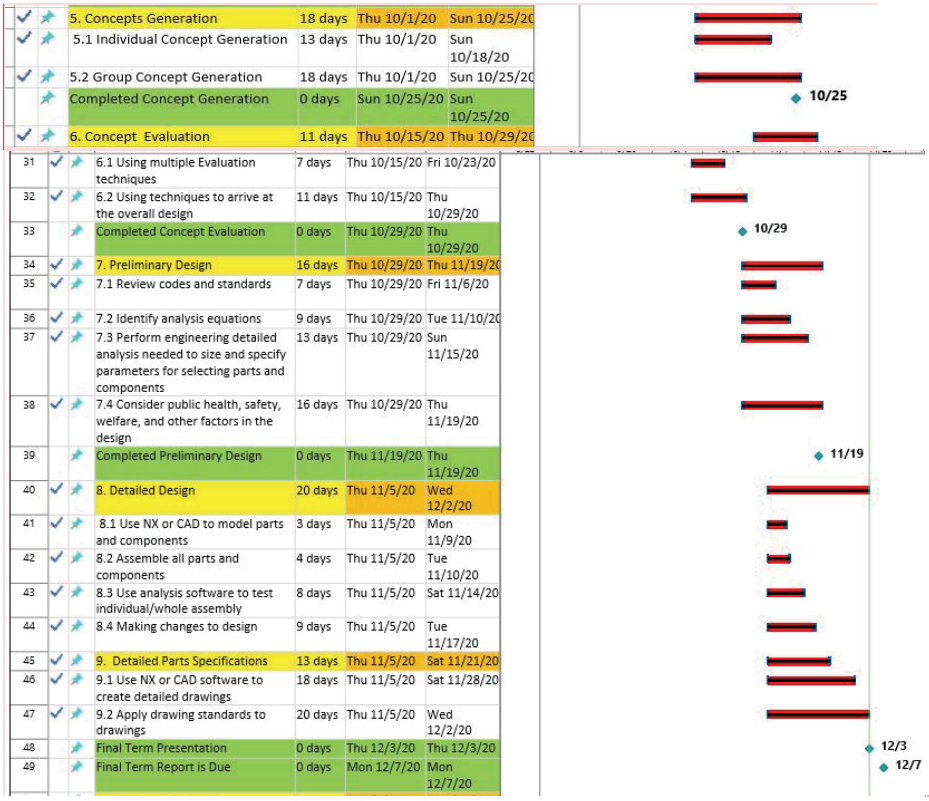


Figure 2.2: Gantt Chart for Spring 2021

Commented [2]: Gantt Chart UPDATED

The team will use the gantt chart to make sure tasks are completed on time and in an orderly fashion. Also, to document all of the start and end date of each task. With roles assigned to each member, it is easy for each member to know when they need to start the task and the deadline for that task. The member assigned the role will be able to wrap up each task or know when to ask for help if the deadline is approaching. This gantt chart will allow us to stay focused on the project and show everyone what is in progress and what is next to start.

3. LITERATURE REVIEW

This chapter discusses all of the information needed to understand this project. Topics such as the baja car for which this steering and suspension system will be a part of will be discussed in literature review. The descriptive functions of these systems as well as different designs that are available for each system with their pros and cons. After that, this report will present relevant equations for each system that will need to be solved to come up with a design later on. The report will end with elaborating on clients that this project is relevant to along with the safety factors we are considering throughout this project.

3.1 Identification of Information Relevant to the Project

For the information relevant to this project, the group had a meeting to talk about what would need to be researched to give a complete overview of this project. During this time, we began to break down the project as a whole to see what was included. We came up with a list to start out with and if any more topics came up as we began research it, bring it to the group to discuss if we should create a new section for that topic. We assigned at least one person to each topic to cover every section to give a complete overview of this project. The list of topics that we concluded are:

- General information over baja car
- Suspension system
- Steering system
- Math equations involved
- Safety Considerations
- Audience/ Clients
- Identify Fabrication and Testing Methods
- Identify Codes and Standards applicable to design

3.2 Potential Sources of Information for Project

As mentioned in the section above, every member was assigned to a different section to pull sources that would help provide more information for the overall of this project. The sources were pulled from several different articles, reports, textbooks, and detailed videos on each individual topic. The reference page will include all of the sources that were used for this literature review.

3.3 Miscellaneous Information on Baja Vehicle

This section will be covering miscellaneous information about the baja vehicle based on design requirements and suggestions from groups with previous experiences. This section also helps the audience understand the environment around the steering and suspension systems, and how exactly it collaborates with the design.

3.3.1 Overall Miscellaneous Information

The vehicle will be travelling in the conditions of an off-road terrain, which include bumpy surfaces, muddy surfaces, loose dirt, and shallow waters. The vehicle will be graded by judges observing the vehicle go through a total of 12 tests [7]. The performance side focuses on the vehicle's instant reactions based on the different terrains [7]. A report on the vehicle's design and marketing cost is required by the judges [7]. The most expensive areas on the kart would be the suspensions and the differential/axles [8]. Reverse direction tread on the vehicle's tires are one of

the things that helps for medium to dry surfaces and soft or muddy surfaces [8]. The courses for this competition will be challenging, so there's a higher chance for failures to occur.

Table 3.1 presents the specifics on how the performance on the vehicle will be graded. Each event is associated with points and has a description of what results the judges are looking for in a vehicle.

Table 3.1 Description of Formula SAE Competition Trials [7]

Events	Points	Description
Preliminary tests	**0**	**Pre-competition safety tests.**
Technical inspection	-	General check of car by judges.
Tilt	-	Car inclination up to 60º checking its stability and that no type of liquid is leaking.
Brakes	-	Simultaneous blocking of all four wheels after a brief acceleration.
Noise	-	Check to ensure vehicle emits less than 110 dB under certain acceleration conditions.
Static	**325 in total**	**Presentations and oral defence in front of the judges of technical solutions adopted.**
Design	150	Technical defence of vehicle design and solutions proposed.
Presentation	75	Marketing presentation, convincing the judges to choose their car compared to the others.
Costs	100	Written report detailing cost of each part and component of the unit built.
Dynamic	**675 in total**	**Different on-track trials with the single-seater.**
Acceleration	75	Cover 75 m on a straight run in the shortest possible time
Manoeuvrability (Skidpad)	50	Manoeuvrability to run a 9 metre circle in both directions.
Sprint	150	Quick lap of the circuit.
Endurance	350	Overall vehicle performance and reliability in 22 laps of a circuit.
Fuel	50	Minimum consumption in endurance trial
Total	**1000**	

3.3.2 Steering and Suspension Miscellaneous Information

Steering and suspension systems are two different portions of the vehicle, but they are connected through linkages and work together. A minimum of 11in. clearance of the suspension has been used and recommended by groups with previous designs [8]. Weight, cost, and functionality are the main factors of a rear suspension.. The upper arm should be slightly shorter than the lower arm. As the vehicle's suspension system compresses, the roll center typically moves upward and

eventually causes deflection. Having an axis of motion in vertical direction helps the suspension react in horizontal and vertical direction as a result of impacts [8]. The steering system makes up about 4% of the weight distribution of the vehicle, while the suspension system makes up about 26% of the weight distribution. The vehicle will have higher net weight towards the back of the vehicle. The rear suspension should be lightweight, but remain strong. The rear suspension could be adjustable to assist in traveling through different terrains [9].

3.4 Suspension system

In this section the various types of suspension systems and components involved with the designs are discussed and compared. There are various types of systems and component combinations can be used and some are more suitable for off-road vehicles than others.

3.4.1 Types of Suspension

There are two types of suspension systems. They are classified as dependent and independent. The dependent system is a beam connecting two wheels which transmits a load or movement to both wheels. It is a rigid system and there is a lack of adjustability. Independent systems allow more flexibility needed for off-road driving[10]. The types of various independent systems and their pros and cons are described below.

The Double Wishbone (Double A-Arm) is a suspension system setup that uses two control arms and a shock assembly[10]. The two control arms are connected to the chassis and the wheels of the vehicle. The system can be used in the front or rear of the vehicle. There are two different types of wishbone systems. The first is equal length. With an equal length setup, both the top and bottom control arms are the same length. The second double wishbone setup in an unequal length setup. With this set up the upper control arm is shorter than the bottom control arm. Below are the pros and cons related to choosing the Double Wishbone system. Figure 3.1 below shows the Double Wishbone system[10].

Pros: Resistive to high loads, load handling abilities, easy to adjust

Cons: Weight, high cost, complex components, takes up a lot of space

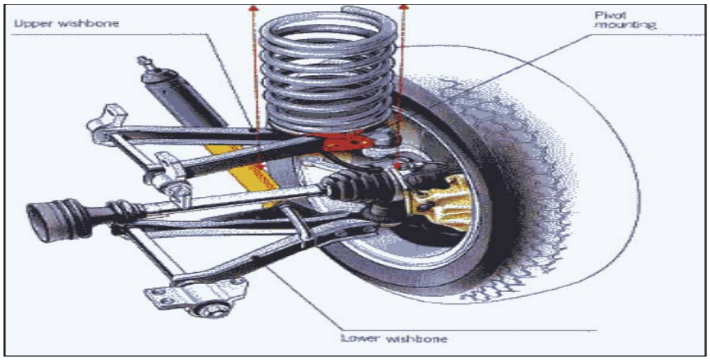


Figure 3.1: Double Wishbone System [10]

The Macpherson system (A-Arm) is also known as the single control arm system[10]. The design consists of one control arm, a wheel hub, and shock or strut assembly. The strut and control arm connects directly to the chassis of the vehicle. The other side of the control arm connects to the bottom of the wheel hub to get connection to the wheels. The strut or shock assembly connects at the top of the hub assembly. The pros and cons of the Macpherson system are as follows. Figure 3.2 below is the image of a Macpherson system[10].

Pros: Simple setup, low cost, light weight, does not take up a lot of space

Cons: Increased ride height, more difficult to turn

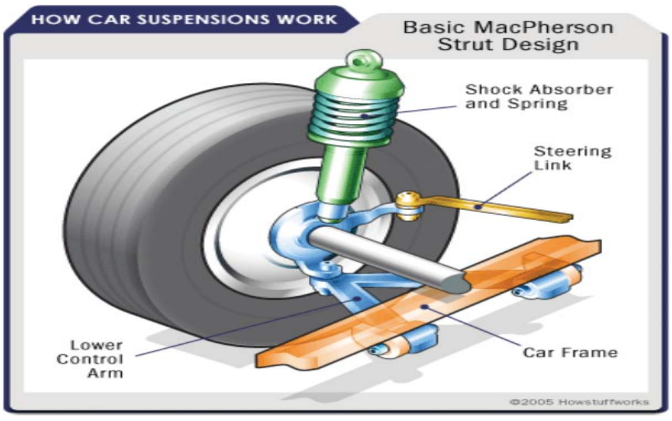


Figure 3.2: Macpherson System [10]

The semi-trailing and trailing arm systems use pivoting arms that are attached to the vehicle. These two systems are only used for the rear of the vehicle. The arms are also located in the front of the wheel which creates a trailing effect. The difference between the semi-trailing and trailing arm lies in the position of the pivot points. Semi-trailing arms are positioned at an angle to the

centerline and trailing arms are positioned perpendicular to the centerline. Figure 3.3 below shows the difference between a trailing and semi-trailing arm[10].

Pros: Rigid design, simple, not many mechanical components

Cons: Can only be used in rear of vehicle, weight, high cost

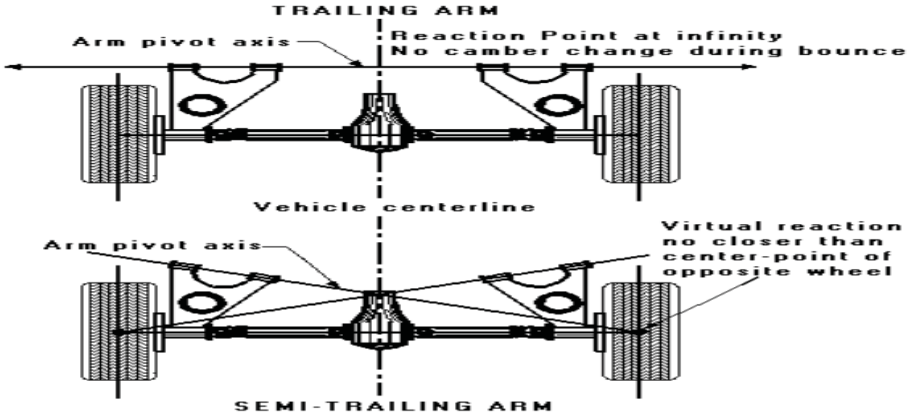


Figure 3.3: Trailing/Sem-Trailing System [10]

The Swingaxle suspension is a very old system that provides independent shock absorption. It isn't used much today due to weakness of the system and does not have good handling. Figure 3.4 below is an image of how swing axle suspension operates[11].

Pros: Independent shock absorption

Cons: Difficult handling, weak system, old system

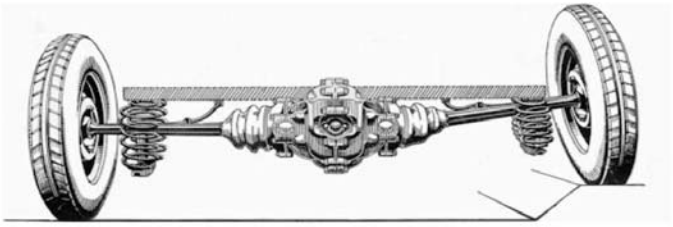


Figure 3.4: Swing axle suspension [11]

The Leaf Spring suspension system is made up of a stack of arc shaped pieces of steel that are bolted together. All the pieces of steel are different sizes with the longest on top and decreases in size with each bottom piece. It is then attached to the rear axle of the vehicle. There are also more advanced leaf spring systems such as the transverse leaf spring suspension but uses very high cost composite materials. Figure 3.5 below shows the leaf spring system[12].

Pros: light weight, added support
Cons: Not flexible, high cost

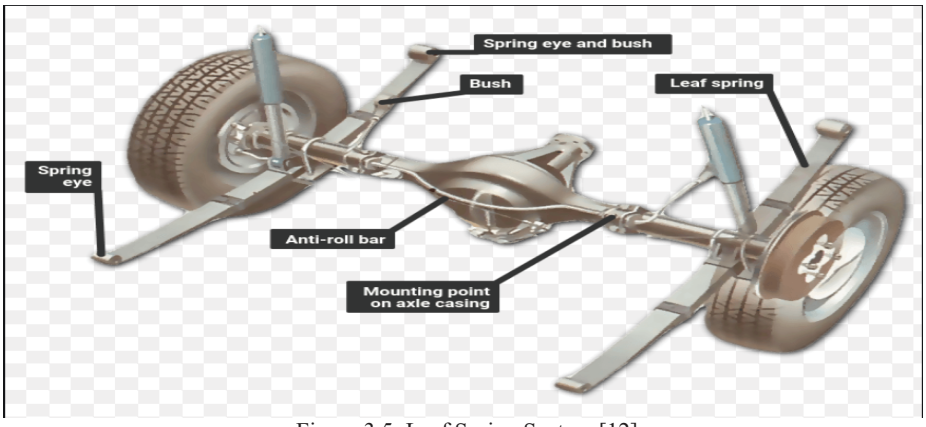


Figure 3.5: Leaf Spring System [12]

3.4.2 Components that make up a suspension
This section will dive deeper into each individual component of a suspension system. The list below will include the parts name, its function, and the pros and cons of that part.
Shocks- Keeps the vehicle from bouncing. Figure 3.6 shows what shocks look like.

Pros: Good for off road vehicle
Cons: High Cost, can be difficult to tune


Figure 3.6: Shocks System

Coil springs- The function of coil springs is to support the vehicle at its desired height, to maintain proper alignment angles and to absorb road shock transmitted through the tires and shock absorbers. Figure 3.7 shows what coil springs look like.

Pros:Performance and Off-Road Capability, Customizable, flexible and comfortable
Cons:Not For Heavy Vehicles, can be expensive



Figure 3.7: Coil Springs

Control Arms- (lower & Upper)- control arms connect the suspension to the actual vehicle frame. They are connected to the frame through a component called bushings, while they attach to the suspension through the ball joint. That allows the vehicle to turn its wheel and pivot, connecting the tire to the car's suspension[13]. Figure 3.8 shows what control arms look like.

Pros: allow you to set the camber to your desired setting.

Cons:you will spend hours messing with it and trying to decide the right angles



Figure 3.8: Control Arms System

Ball joints- Ball joints consist of a ball and socket similar to the hip joint of the human body. Ball joints of your front suspension provide pivoting movement between the steering knuckles and control arms to provide a safe, smooth ride and allow you to precisely control your vehicle[14]. Figure 3.9 shows what ball joints look like.

Pros: Allows free movement in two directions at the same time, including rotating

Cons: Dry ball joints increases frictions and can cause steering stiffness



Figure 3.9: Ball Joint

Sway bar (if needed)- a bar that torsionally couples the right and left front-wheel suspensions of an automobile to reduce roll and sway[15]. Figure 3.10 shows what the sway bar looks like.

Pros: Allows less body roll

Cons:High cost



Figure 3.10: Sway bar

Steering box / system - The steering gearbox contains the gears that transmit the driver's steering inputs to the steering linkage that turns the wheels, and it multiplies the driver's steering changes so that the front wheels move more than the steering wheel[16]. Figure 3.11 shows what the steering box looks like.

Pros: simple construction

Cons: Sensitive to impact



Figure 3.11: Steering box

Tire- A tire is a ring-shaped component that surrounds a wheel's rim to transfer a vehicle's load from the axle through the wheel to the ground and to provide traction on the surface over which the wheel travels.

Pros:Improves traction

Cons:High cost

3.5 Steering System

The steering system is a complex system which integrates between several other systems in a vehicle. The steering is composed of linkages that move side to side based on the way the steering wheel is turned to turn the vehicle. The way that those linkages are placed will determine the turning radius of the vehicle. The geometry will also determine the movement of the tires when approaching and during the turns. The placement of the system is crucial due to the drivetrain and suspension being inches away from each other. The geometry and design will have to be considered based on the pros and cons of each geometry and design as well as the

room available in the chassis. There are three steering geometries that a vehicle can have. The three geometries are Ackerman, parallel, or reverse Ackerman steering. These geometries are used for different types of scenarios such as desired turn radiuses and speeds at turns. Along with these geometries there are different designs that can be considered. A steering box can be used to steer the car or a rack and pinion can be used to achieve steering to our desirability. This section will discuss the pros and cons of each geometry and designs for the steering system.

3.5.1 Steering Geometries

The three steering geometries used today are the ackerman, parallel and reverse ackerman. These geometries are used for different applications that one is looking for. Figure 3.12 will show the different geometries and with the corresponding turning radius possible.

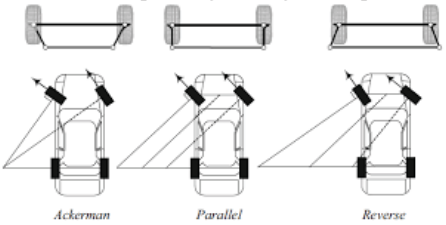


Figure 3.12: This image above shows the difference between the three geometries [17].

Ackerman steering

The first type of steering geometry and most commonly used for off-road vehicles is the Ackerman geometry. The theory of ackerman is having the inside tire of the vehicle to turn more than the outside tire allowing for a greater turn radius. By having a greater turn radius, the vehicle will have to approach the turn at lesser speeds. A higher tire angle is achieved on the inside tire. Slip angle is the angle between the direction the tire is pointing and the direction the car is actually moving. A low slip angle is desired when it comes to turning a common vehicle to reduce drag and to prevent an increase in temperature in the front tires. A higher slip angle causes more drag for the inside tire and higher temperature of that tire. This is important in a competitive setting. When using the Ackerman geometry the joint connected to the wheel needs to be aligned with one end of the steering rod all the way to the center of the rear axle. Figure 3.13 shows the imaginary lines that connect the tire connection, steering rod joint and the center of the rear axle.

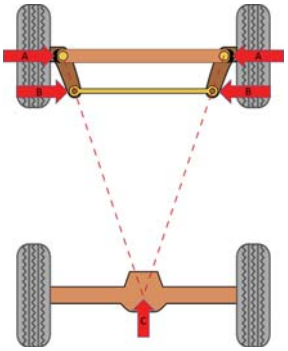


Figure 3.13: The picture above shows the Ackerman geometry [18].

The list below will show the pros and cons on using the Ackerman geometry.
Pros

- Sharper turns
- Easy to fabricate
- Avoids front tire slippage
- Simple geometry
- Lower slip angle at lower speeds

Cons

- Lower speeds at turns
- Not ideal on flat surfaces
- Increased drag on inside tire causing increase in temperature on that tire

Parallel steering

When the front tires are turned at the same angle when the steering wheel is turned is called parallel steering. This steering geometry is commonly used for racing cars. This geometry puts lower slip angles for the front tires. With the front tires moving at the same angle, there is less drag on the inside tire which means there is no increase in temperature for the tire not slowing the vehicle down. Figure 3.14 will show what the geometry of parallel ackerman will look like.

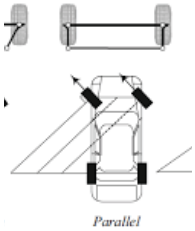


Figure 3.14: The picture above is to show the front tires turning at the same angle.
The list below will show the pros and cons for the parallel steering geometry.

Pros

- Less drag on the tires
- Can approach turns at higher speeds
- Less increase in tire temperature
- Good static turning radius

Cons

- Not ideal for off-road surfaces
- Limited turn radius
- Understeering may occur

Reverse Ackerman

The steering geometry where the outside front tire turns more than the inside tire is called reverse Ackerman. This geometry is ideal for indie and formula cars. This geometry is for very high speeds and wider turns. The tires achieve the best grip when it is taking a wider turn. Since this car is traveling very fast and approaching turns at higher speeds it is noticeable that the cars using this geometry are low to the ground to prevent the car from tumbling on a turn. Figure 3.15 shows what the geometry of reverse ackerman looks like and the unsymmetrical rotation of the tires.

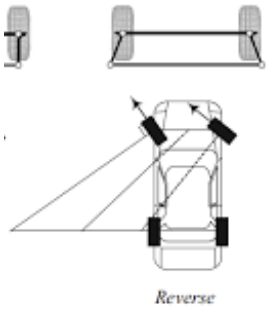


Figure 3.15: The picture above is to show how the outside front tire turns more than the front inside tire during a turn.

The list below will show the pros and cons of the reverse ackerman steering geometry.

Pros

- Better grip on tires on wider turns
- Approach turns at higher speeds
- Ideal for flat surfaces

Cons

- Wider turns
- Need lower center of gravity
- Drag on outside tire slowing down vehicle

- Not practical for off-road setting

3.5.2 Steering Designs

There are several designs when it comes to steering systems. Since our design will be intended for off-road vehicles and need to have four wheel drive we are choosing a basic steering design. These designs are easier to fabricate because these designs are less complex. The main steering designs are rack and pinion, worm and sector, and recirculating ball [19]. This section will dive deeper into the pros and cons of these steering designs.

Rack and Pinion

The rack and pinion steering design consists of the fewest moving parts compared to the others [20]. The main object for rack and pinion is designing the gearset to our best interest. With the gears continually grinding against each other, there is no repair available. The only option is to replace the gears and steering rod. The driver would turn the steering wheel therefore turning the pinion which would move the rack side to side turning the tires to their desired location. The gearbox needs to consider making the pinion bigger or smaller with certain parameters of each. If the pinion is smaller than the steering wheel would be easier to turn but more revolutions of the wheel would be necessary to make a tighter turn. If the pinion is bigger then it would be harder to turn but the driver would barely need to move the steering wheel. This type of steering design is very precise compared to the others. Figure 3.16 will show all components of the rack and pinion steering system.

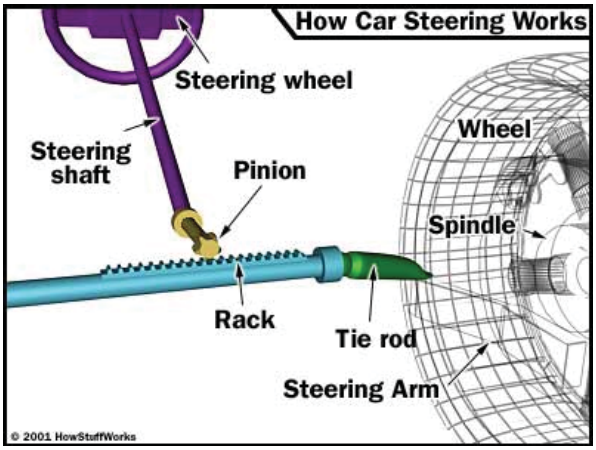


Figure 3.16:The illustration above shows all parts of a rack and pinion design [21].

Worm and sector

The worm and sector design is more complex than the rack and pinion design. This steering design does have more moving parts and is more difficult to assemble correctly. With more moving parts in this design, there is more room for loss of motion. When there is a lot of loss of motion, the car will not move appropriately. This design is easier for new drivers but with more moving parts, this design has a lot of areas where parts can lock up and will not allow any

steering for the vehicle. Also, with many bumps and rocks in the road there is an increased chance that joints can lock up during unexpected forces from the environment. This design is not ideal for off-road environments. Figure 3.17 will show the overall design for the worm and sector steering design.

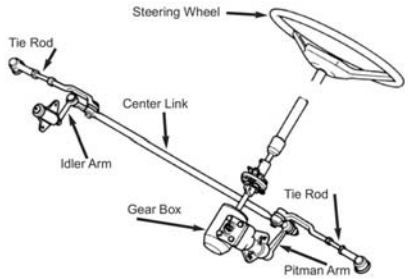


Figure 3.17: The diagram above shows the parts of a worm and sector steering design [22].

Recirculating Ball

The most complex of these three designs is the recirculating ball steering design. This design is similar to a rack and pinion with several tiny spheres in the middle of the gears contact points. These tiny spheres help slow down the wear in the gears providing a longer life to the steering system as a whole. The spheres also help reduce slop in the gear. Slop is the feeling when you change direction in the gears and it wheels loose when turning the steering wheel [23]. With more components in the steering system, there is more room for loss of motion and the cost of this system will be significantly higher than the others. This system works more like levers pushing and pulling the tires side by side. Figure 3.18 shows the complexity of the recirculating ball steering design. Figure 3.19 shows the overall setup for the recirculating ball steering system.

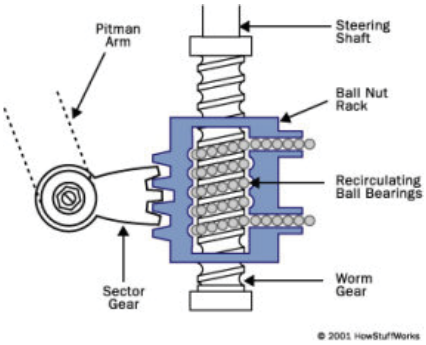


Figure 3.18: The picture above shows the tiny spheres within the grooves [24].

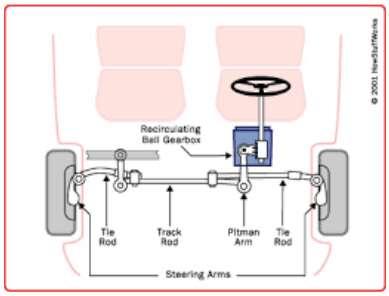


Figure 3.19: This diagram shows the whole recirculating ball steering design [25].

3.6 Math Equations involved

This section of the literature review will include the equations that will be used throughout this entire project. This section is split between three categories which are finite element, kinematic, and machine design equations.

3.6.1 Finite Element

Finite elements is a commonly used tool in engineering systems, as you can calculate solutions for vibrating systems. This was measured by the FEA to better understand the behavior of a structure that is placed in boundary conditions and loads. This strategy is used by breaking the systems into different sections in order to understand the displacement the system is facing. The calculations are represented by nodes and the collaboration of the Finite Elements to determine the mesh of programs which determine the effect of the loads. The system most commonly used is the quarter of the suspension system. Figure 3.20 shows the simulation of one quarter of the suspension system. Figure 3.21 shows the displacement of nodes in a system.

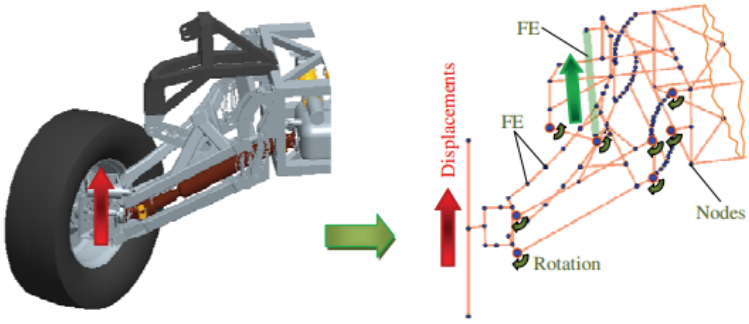


Figure 3.20: This diagram shows quarter of the suspension system

$$[k]\cdot\{u\}=\{f\},$$

- K: denotes the global stiffness matrix of a structure

- U: defines the global nodal vectors displacement , $u_i,\ v_i,\ w_i$
- F: introduces the global nodal vectors of applied forces

1. Defines the rotational vectors, $\theta_x,\ \theta_y,\ \theta_y$

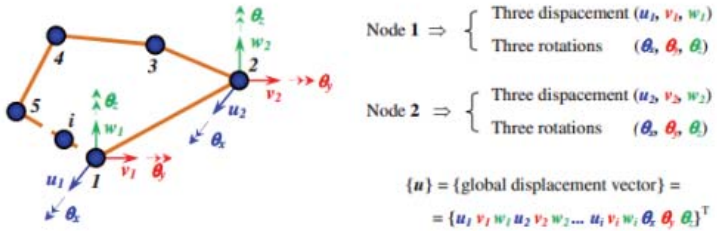


Figure 3.21 Shows the displacement of nodes

Analysis:
In this understanding we were able to use the Global Equation to measure the nonlinear formation of two joining nodes which allows to measure the displacements and rotational movement in the vehicle. With the Global Equation you are able to break down the measurement system into multiple categories, with relations to the stiffness matrices, vector displacements and the applied forces nodes can be determined. As shown in Figure 3.20 we are able to show the vibrations of stresses through a simulation to categorize the displacement the vehicle withstands through various obstacles.

3.6.2 Kinematics

Kinematic Design Analysis is used to calculate motion of a machine during movement while being able to calculate the geometry of motion in the system.Kinematics is being used to measure the dynamic movement of the suspension and steering system. Figure 3.22 and Figure 3.23 shows the overall linkage system for each suspension design.

The MacPherson system removes the top a-arm from the previous system and instead connects the damper directly to the knuckle through a struct.	Double wishbone system (DWS), requires two a-arms connected to a knuckle that connects to the tires through a steering link, while the damper system is placed on the bottom a-arm and connects to the car while both a-arms connect to the chassis.

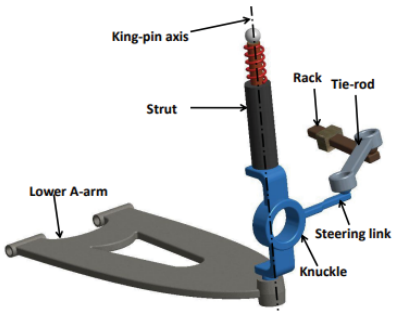


Figure 3.22: Solid model of the MacPherson system

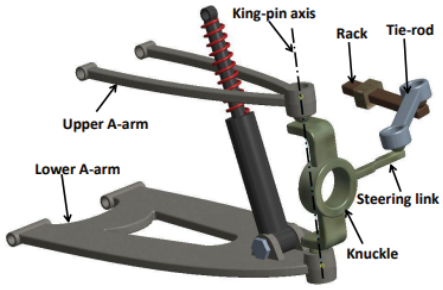


Figure 3.23: Solid model of the DWS

Figure 3.24 and Figure 3.25 shows the variables involved in solving kinematic problems and will help us design a system with the desired movement from all the components. Using kinematics will also allow the group to prevent an unwanted motion that would cause failure to the system.

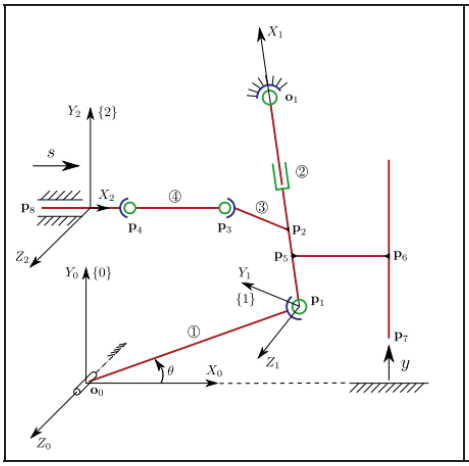


Figure 3.24 Kinematic diagrams before movement

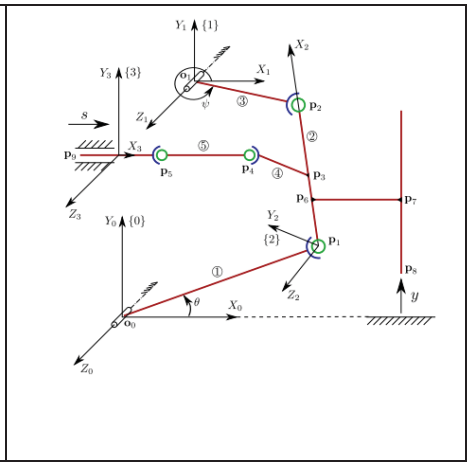


Figure 3.25 Kinematic diagram after movement

Analysis:
Through Kinematic Analysis we are able to understand that in both The Macpherson and The Double Wishbone Systems are compiled of a four bar spatial and five linkages. With that information we are able to measure both systems in the same manner using the linkages of the suspension to calculate the machine's motion, displacement and overall geometry. As shown in Figure 3.24 and Figure 3.25 both have different formation of movement that can be measured through a genetic algorithm to calculate various angles and dimensions displaying the dynamic movement of suspension and steering system of motion through various.

3.6.3 Machine design

For the machine design math equations involved are centered toward creating a gearbox for certain steering designs. These equations range from generating the gearbox ratio to stress equations on each tooth. These equations are being pulled from the textbook "SHIGLEY'S MECHANICAL ENGINEERING DESIGN, TENTH EDITION". This textbook contains all equations for creating gearboxes from start to finish. The list of equations below show equations to arrive at important parameters of each gear [26].

$$P = N/d$$
$$m = d/N$$
$$p = \pi d/N = \pi m$$
$$pP = \pi$$

where P = diametral pitch, teeth per in
N = Number of teeth
d = pitch diameter, in or mm
m = module, mm
p = circular pitch, in or mm

$$V = \pi dn/12$$

where V = pitch-line velocity, ft/min
d = gear diameter, in
n = gear speed, rev/min

$$W_t = 33000\frac{H}{V}$$

where Wt = transmitted load, lbf
H = power, hp
V = pitch-line velocity, ft/min

The next three equations are used to find the transmitted load on the gear that is needed to move the rack that will then move the tires in the direction that is desirable. If necessary, equations for all transmitted forces are provided below.

$$W_r = W \sin\phi_n$$
$$W_t = W\cos\phi_n\cos\psi$$
$$W_a = W\cos\phi_n\sin\psi$$

where W = total force
Wr = radial component
Wt = tangential component (transmitted load)
Wa = axial component (thrust load)

When designing this gearbox, the material will be an important fact as far as life for the system. Also, a goal is to make a gearbox with the highest efficiency possible to prevent any failures while the vehicle is in motion.

3.7 Safety considerations

Safety is the most integral part of any designing process of machinery. Without hours of testing and errors, vehicles would not be able to legally operate under any circumstances. Off road vehicle safety has some the same standard rules as regular vehicles, but adding safety designs to your off road vehicle according to [27].

3.7.1 Driver Safety

Driver Safety is very important when operating any moving mechanism. In order to understand the danger of operating a vehicle, especially an off road vehicle, one must follow all safety guidelines to limit incidents. Figure 3.26 shows all of the safety equipment necessary for the driver demonstrated by another group. Based on research through , here is a list of recommended off-road Driver Safety [28].

- Operator must be 18yrs or older.
- Operator must NOT be more than 250lbs.
- Protective headgear/eye and gloves are recommended.
- Operator must wear a Harness/seatbelt
- Neck collar is recommended
  (Optional for the driver, but reduces uncontrolled neck movements.)
- Operator must wear long sleeve bottoms/tops and No synthetic materials.



Figure 3.26 All necessary safety gear [27]

3.7.2 Design Safety

Design safety limits any danger to potential consumers. The group's design process includes the safest practices to prevent harm to the driver. The safety approach to building the group's vehicle will allow for the design to withstand rigid terrains, harsh conditions and competition success. With devoted research from where the group found these safe ways to create a proper design [29].

- Deep treaded tires
  - Allows safe traction for off road driving.
- Ground clearance
  - With proper clearance it allows the underbelly to not scrape ground when operating on rocky terrains or bumps.
- Roll cage
  - Protects the driver during off road challenges, also prevents structural integrity
- Harness
  - The strap restraint to hold the driver in place.
- Kill switch
  - Stops electrical flow from the ignition system if any accident/danger occurs.
- Fire wall
  - Machined metal separating the driver from the engine compartment.
- Fire Extinguisher
  - In case of fire

- Daily/weekly inspections are also recommended to maintain upkeep of every component of the vehicle.

Figure 3.27 and Figure 3.28 are detailed visuals for the roll cage and the harness.

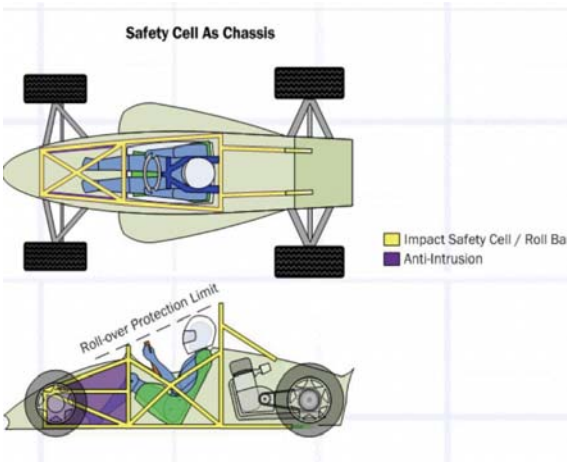


Figure 3.27: Roll Bar/Roll Cage [30]

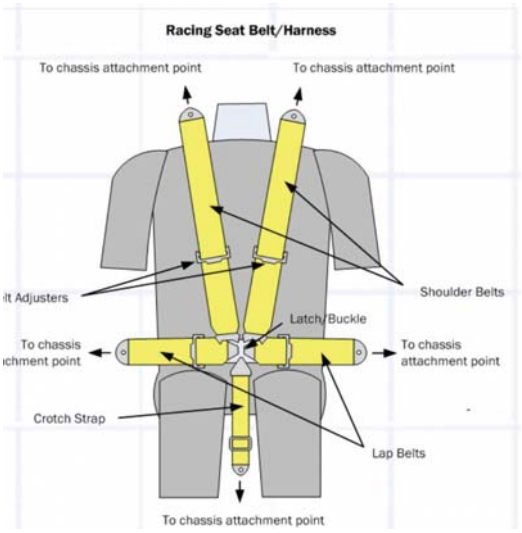


Figure 3.28: Proper harness/seatbelt [31]

4. PRELIMINARY DESIGN

This chapter will show the breaking down of this project from an overall most important function. The group decided to break this project into two different sections. One for the suspension system and one for the steering system. By separating the two systems, the group will be able to optimize the performance of each system.Each student will bring forward their idea for a function and sub function. The group will collaborate and determine the next level subfunction. By breaking down the overall function, the group will be able to develop sketches and designs.

4.1 Functional Decomposition

This section will dive deeper in the process that the group took to come up with the overall function of each system and break them down all the way to level 3 sub-functions. For this project, there are two different systems that the group will design, analize, and fabricate. To optimize each system the group decided to use the functional decomposition method on each system.

The overall most important function of each system was generated from using the sticky note system. This system involves each student to come up with at least three black boxes for each function and sub-function. When every student generated three black boxes, the group gathered them all together and collaborated to create the most important overall function. Figure 4.1 will demonstrate the first process of using the sticky note system for the suspension system. Figure 4.2 will show the overall most important function and all of the variables going in and out of the suspension system. Figure 4.3 demonstrates the sticky note system that was used to come up with the overall function of the steering system. Figure 4.4 shows the overall function of the steering system that was decided by the group.

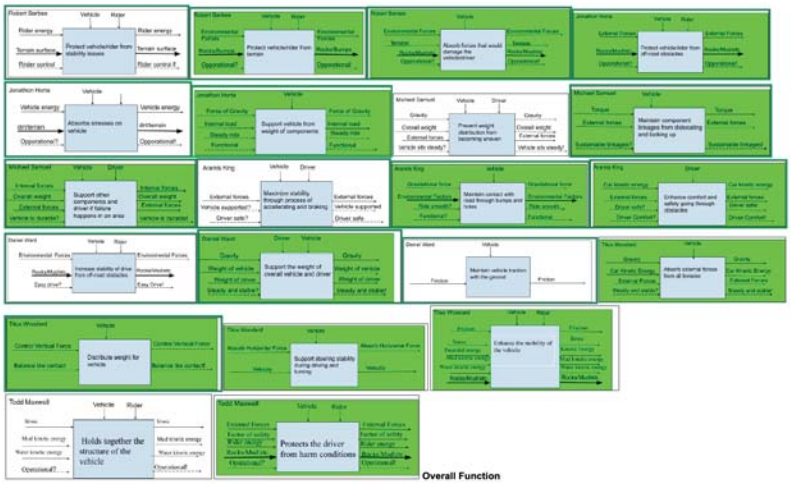


Figure 4.1 The sticky note system for the overall function of the suspension system

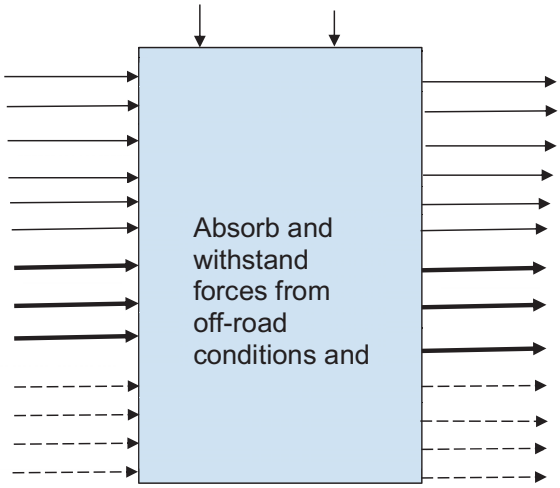


Figure 4.2 The overall most important function for the suspension system

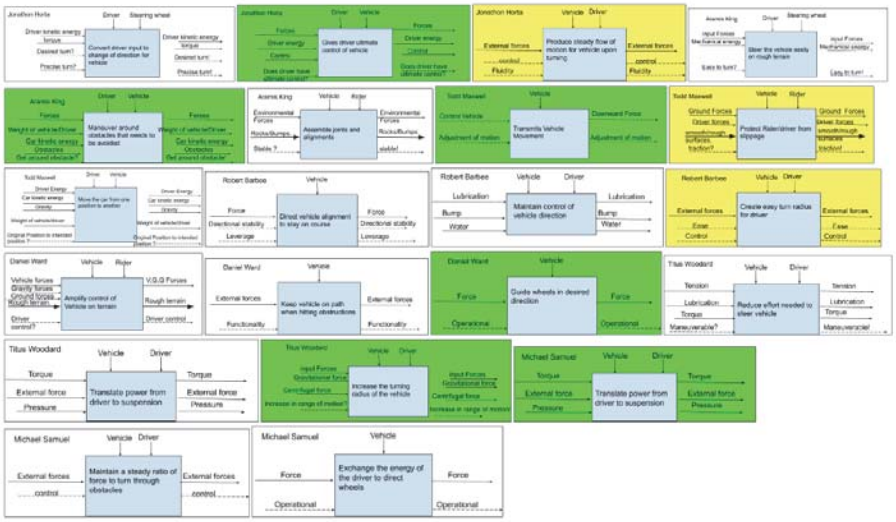


Figure 4.3 Sticky note system for the overall function for the steering system

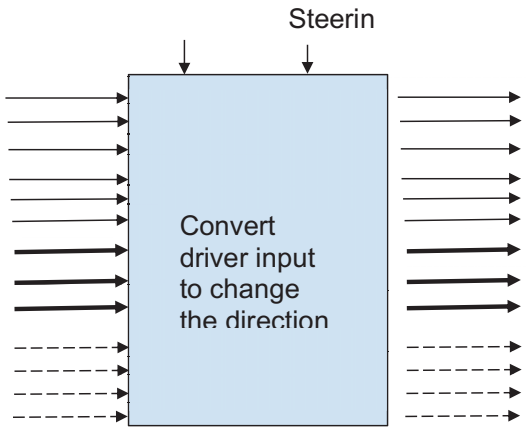


Figure 4.4 The overall most important function for the steering system

Once the overall function for each system was decided, the group had to generate more black boxes to break the overall function into level one sub functions. Each student had to come up with at least three level one sub-functions and bring them to the group. When all the students brought their black boxes together, the group began to work together to gather similar black boxes and created a level one sub-function. The perk of the sticky note system was the group was able to see other students' ideas together as the group discussed what should be a level one sub-function. The group tried to generate as many level one sub functions as possible to make sure the overall function was covered in every aspect. When all of the level one sub-functions were generated, the overall function black box was updated with all the level one sub-functions included. Figure 4.5 shows the sticky note system used to create the level one sub-functions for the suspension system. Figure 4.6 shows the updated overall function black box for the suspension system. Figure 4.7 shows the sticky note system used to create the level one sub-functions for the steering system. Figure 4.8 shows the updated overall function black box for the steering system.

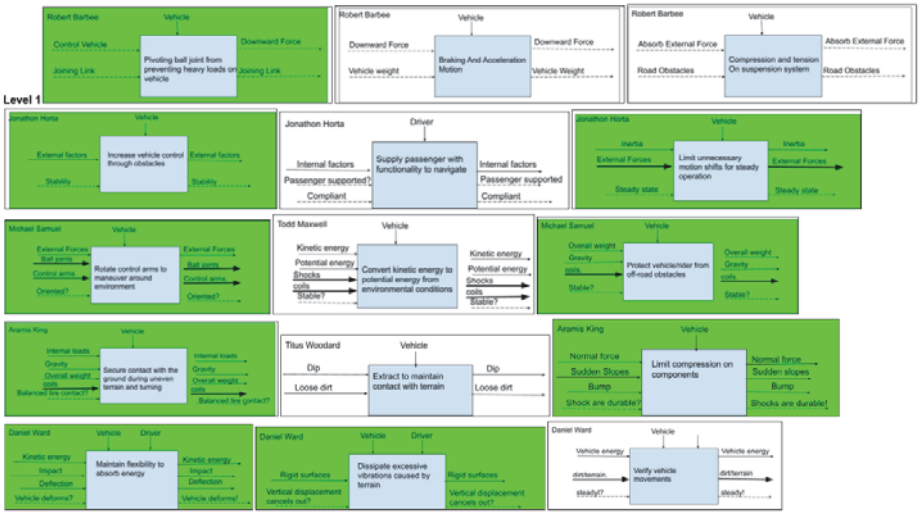


Figure 4.5 The sticky note system of the level one sub-function for the suspension system

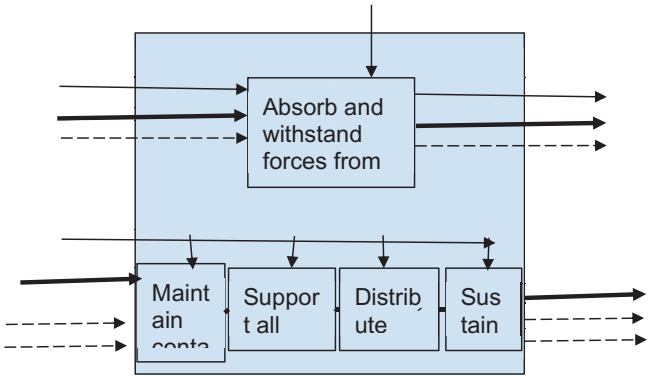


Figure 4.6 The overall function and the level one sub-function for the suspension system

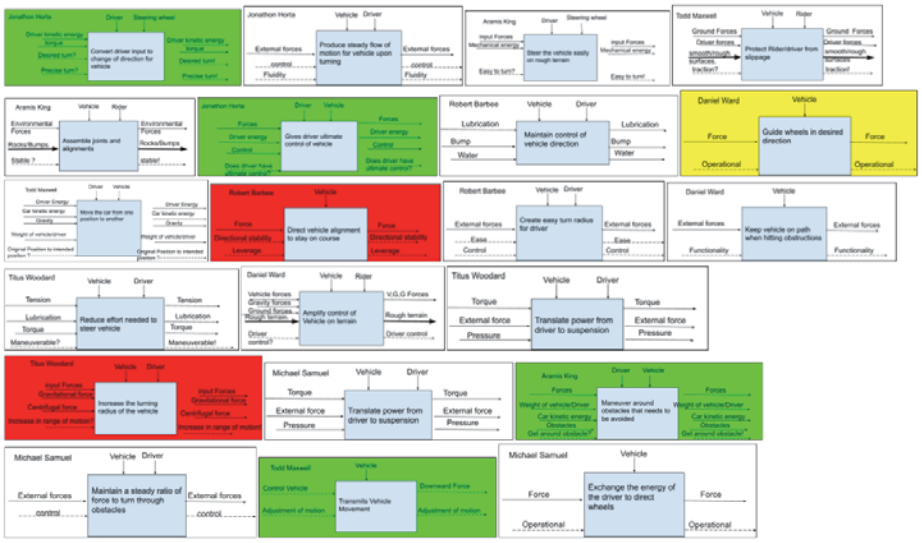


Figure 4.7 The sticky note system that was used for the level one sub-function of the steering system

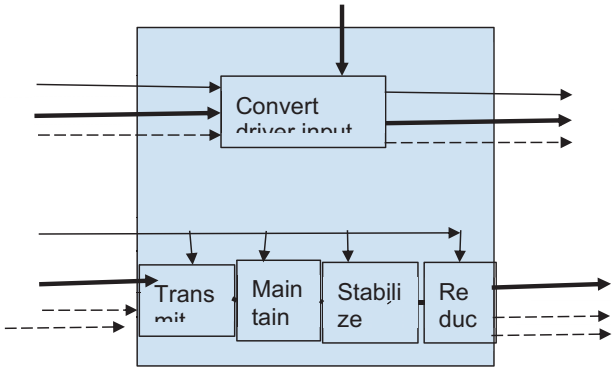


Figure 4.8 The overall function and level one sub-functions of the steering system

After the level one sub-functions were created, the group repeated the process of the sticky note system. This time the group had to come up with their own ideas for the level two sub-functions for each level one sub-function. Once the group all had their own ideas, all of the ideas were combined and the group decided on what the level two sub functions are for each system. After the level two sub-functions were agreed upon, a new diagram was created for each level one sub-function. Figure 4.9 shows the sticky note

system for the level two sub-functions for maintaining contact with the ground for the suspension system. Figure 4.10 shows the new diagram for maintaining contact with the ground. Figure 4.11 shows the sticky note system for the level two sub-function for sustaining the mobility of moving parts of the suspension system. Figure 4.12 shows the new diagram for sustaining mobility of moving parts. Figure 4.13 shows the level two sub-functions for distributing forces throughout the suspension system. Figure 4.14 shows the new diagram for distributing forces throughout the suspension system. Figure 4.15 shows the sticky note system used to come up with the level two sub-functions for supporting internal and external forces from vehicle conditions. Figure 4.16 shows the new diagram for supporting all forces from vehicle conditions. Figure 4.17 shows the sticky note system for the level two sub-functions for maintaining control of the vehicle for the steering system. Figure 4.18 shows the new diagram for maintaining control of the vehicle. Figure 4.19 shows the sticky note system for the level two sub-function for transmitting motion of the vehicle of the steering system. Figure 4.20 shows the new diagram for transmitting motion of the vehicle. Figure 4.21 shows the level two sub-functions for stabilizing the vehicle alignment to stay on course for the steering system. Figure 4.22 shows the new diagram for stabilizing the vehicle alignment to stay on course. Figure 4.23 shows the sticky note system used to come up with the level two sub-functions for reducing effort of the driver of the steering system. Figure 4.24 shows the new diagram for reducing effort of the driver.

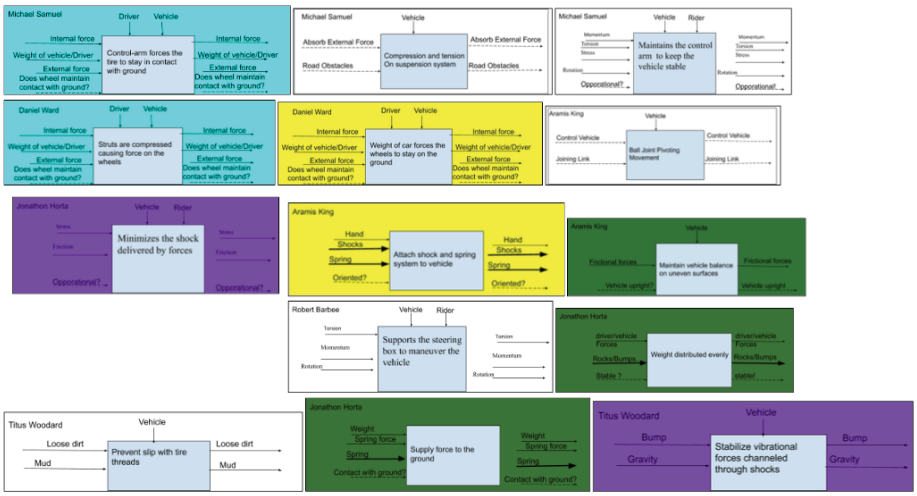


Figure 4.9 Sticky note system for level 2 sub function maintaining contact with ground

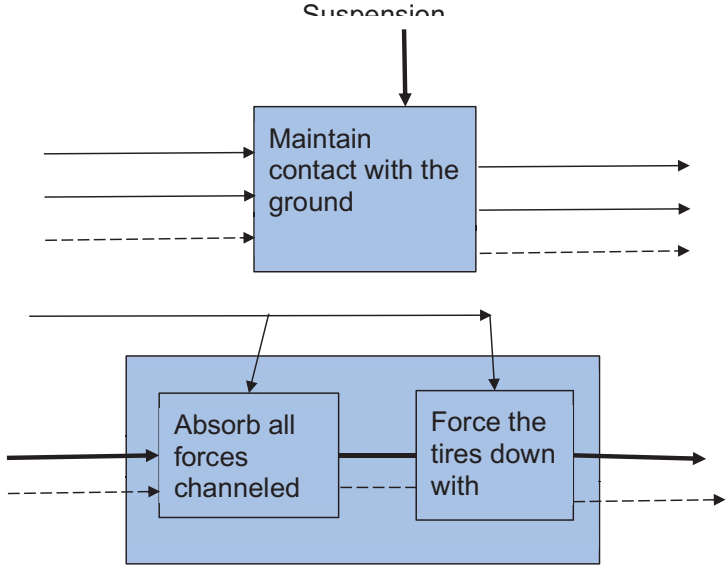


Figure 4.10 Diagrams breaking down of level one sub-function maintaining contact with the ground

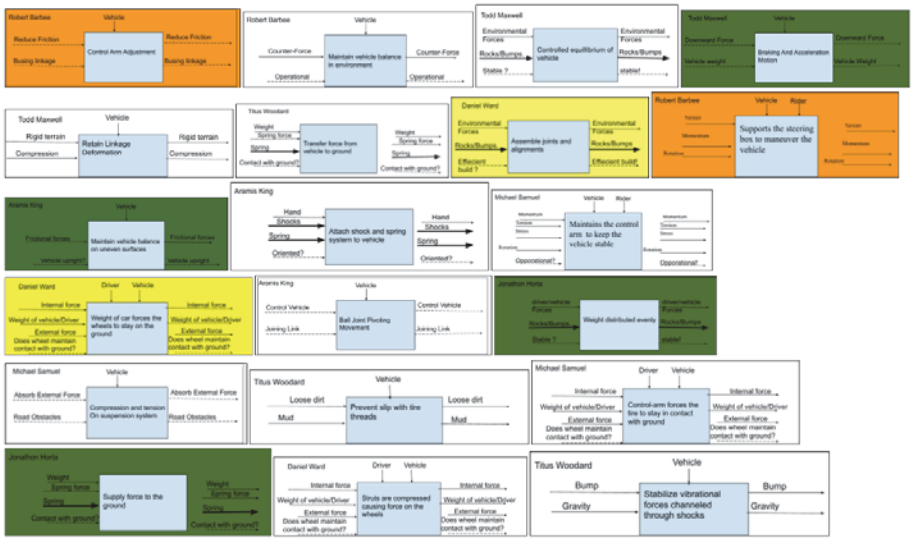


Figure 4.11 Sticky note system for the level two sub-function for sustaining the mobility of moving parts of the suspension system

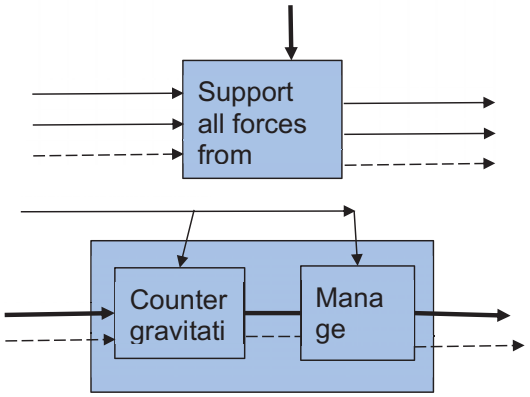


Figure 4.12 Diagrams breaking down of level one sub-function supporting all forces from environmental conditions

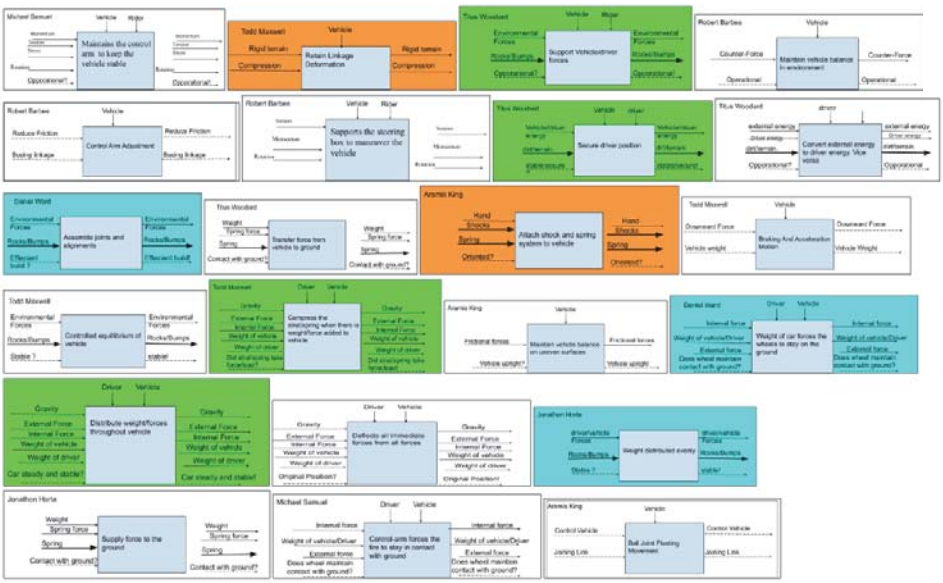


Figure 4.13 Sticky note system for level 2 subfunction distributing forces throughout suspension

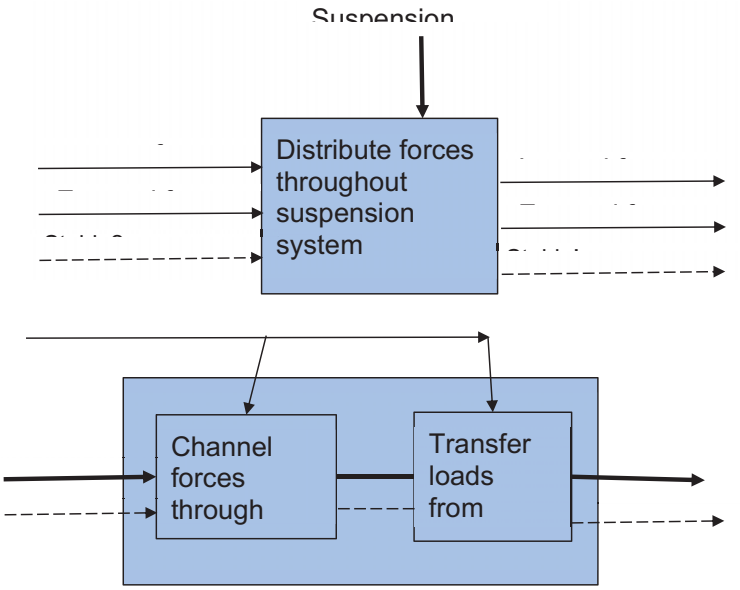


Figure 4.14 Diagrams breaking down of level one sub-function distributing forces throughout the suspension

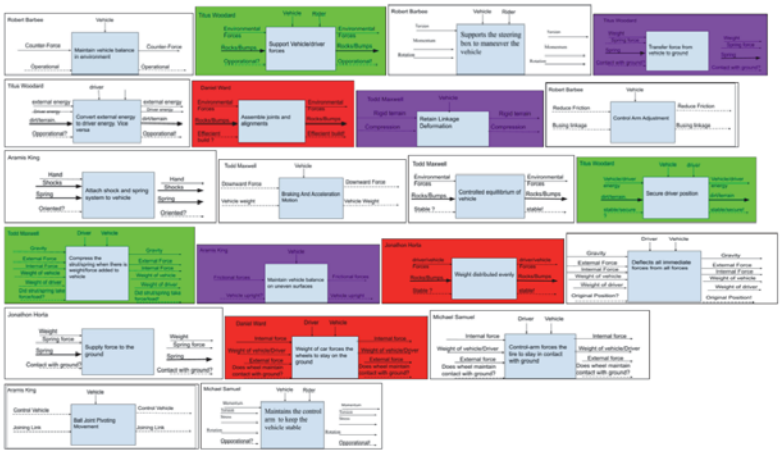


Figure 4.15 Sticky Note System for suspension sublevel 2 sustaining mobility of moving parts

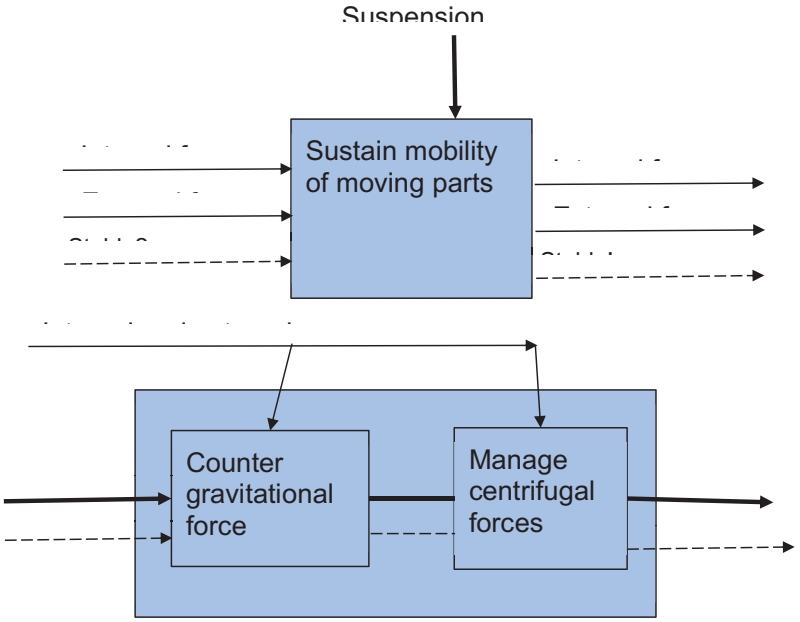


Figure 4.16 Diagrams breaking down of level one sub-function sustaining mobility of moving parts

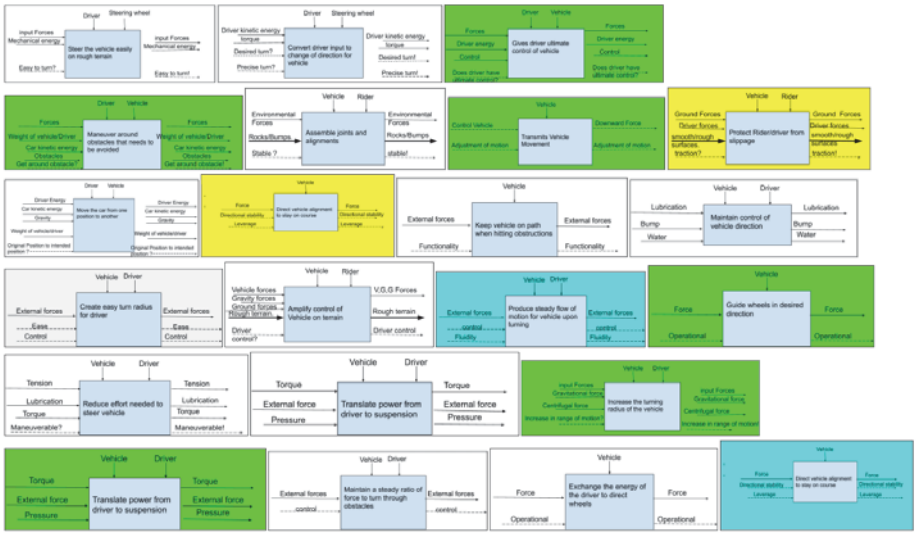


Figure 4.17: Sticky Note System for Steering Level 2 Subfunctions for transmitting motion of the vehicle

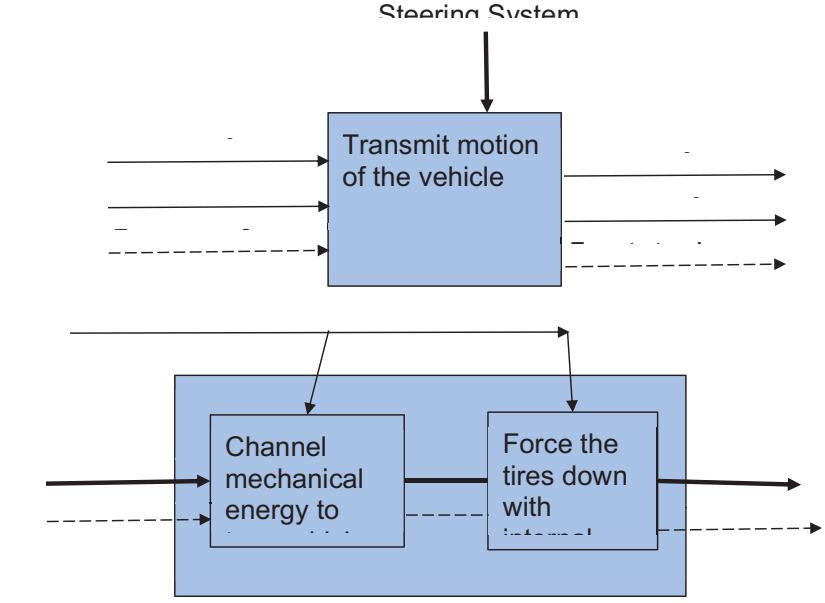


Figure 4.18 Diagrams breaking down of level one sub-function transmitting motion of the vehicle

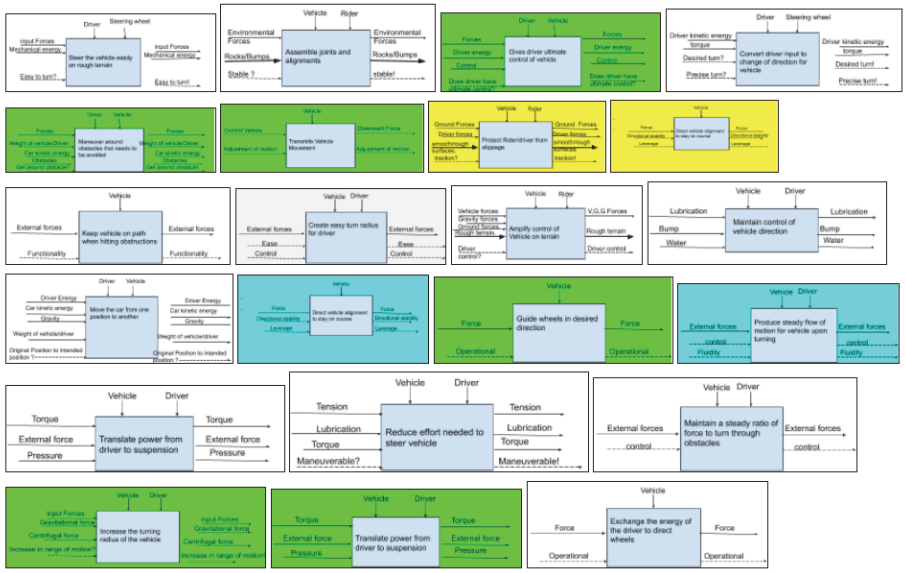


Figure 4.19: Sticky Note System for Steering Level 2 Subfunctions for maintaining control of the vehicle

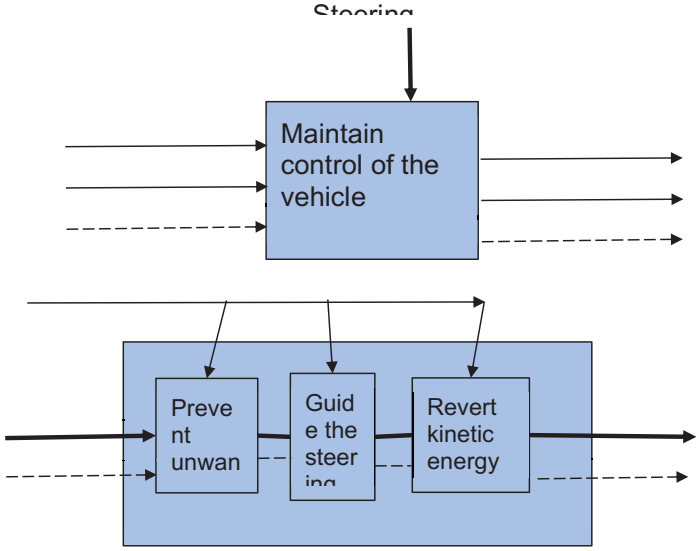


Figure 4.20 Diagrams breaking down of level one sub-function maintaining control of the vehicle

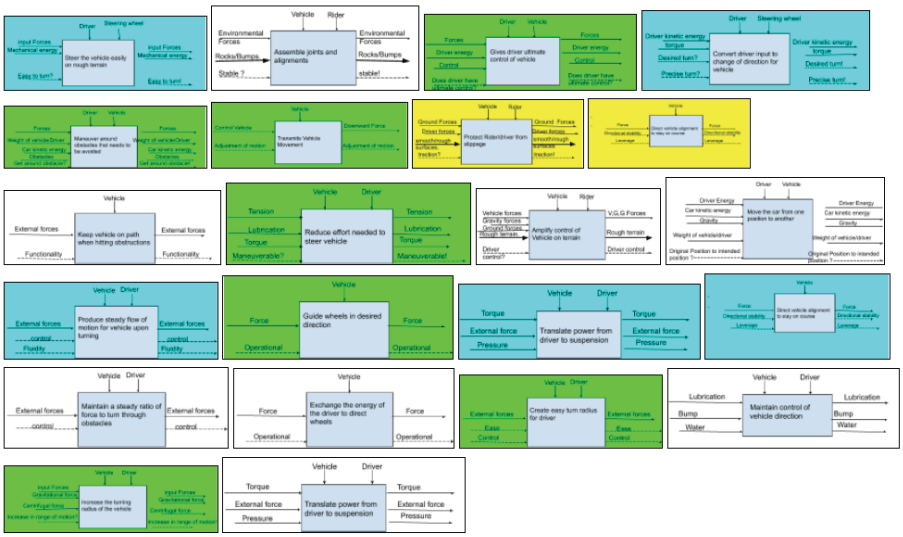


Figure 4.21: Sticky Note System for Steering Level 2 Sub-functions for Stabilization

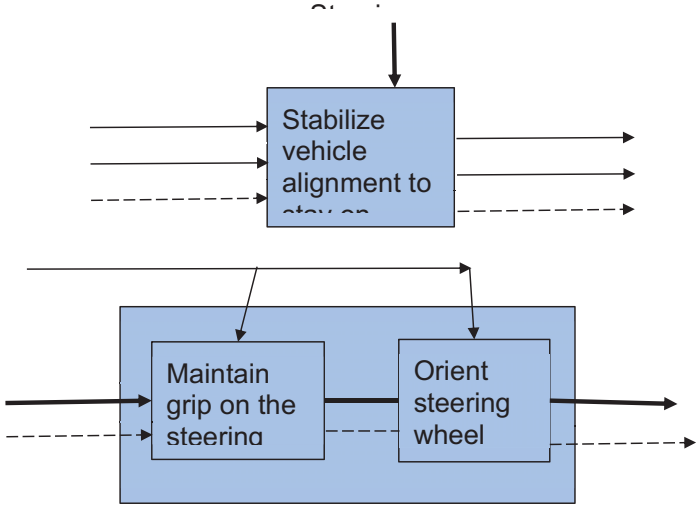


Figure 4.22 Diagrams breaking down of level one sub-function for stabilization

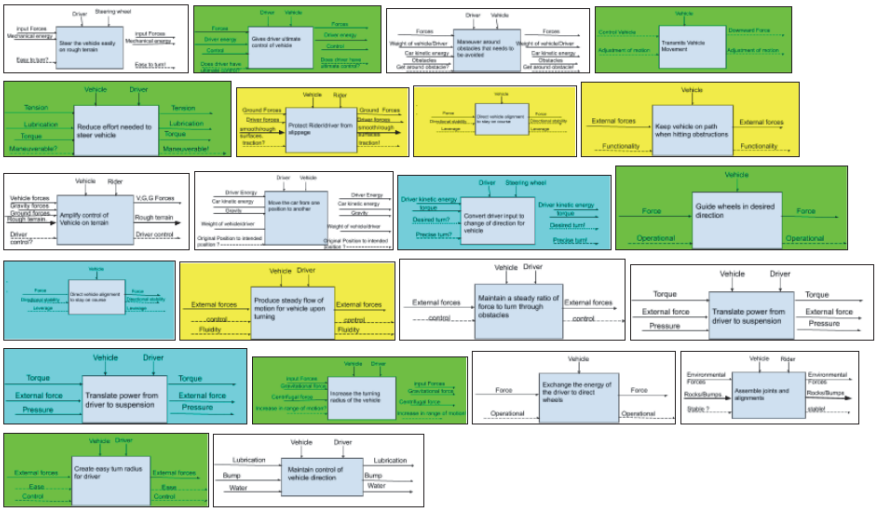


Figure 4.23: Sticky Note System for Steering Level 2 Sub-functions for Reducing Effort

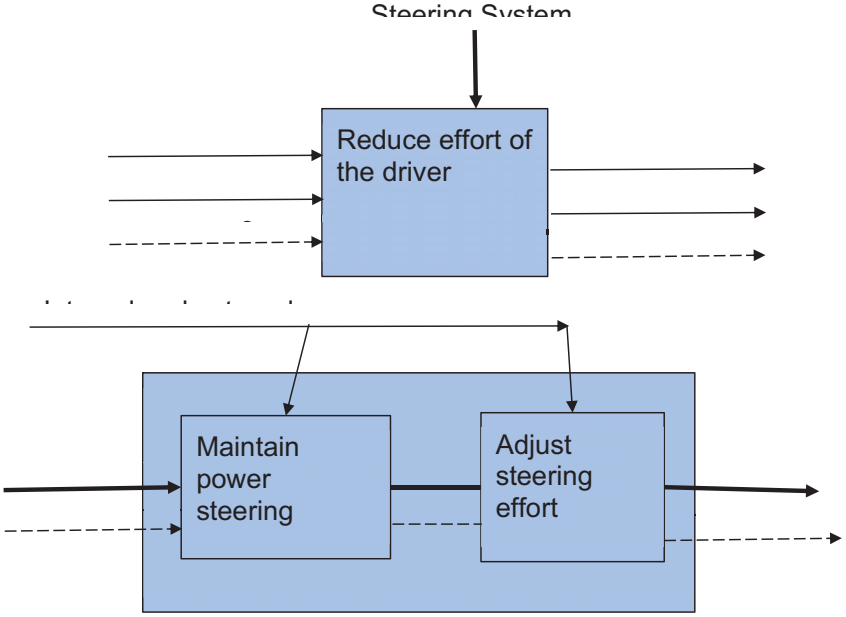


Figure 4.24 Diagrams breaking down of level one sub-function reducing effort

After all of the students created the level two sub functions, the group did not use the sticky note system to come up with the level three sub-function. The group instead had a meeting to discuss them verbally. This was sped of the process to generate the level three sub-functions. To organize everything, a morphology table was created for each suspension and steering system. Table 4.1 shows all of the functions and sub-functions for the suspension system Table 4.2 shows all of the functions and sub-functions for the steering system.

Table 4.1 Morphology Table for Suspension System

Overall Function	Level 1 Sub-functions	Level 2 Sub-functions	Level 3 Sub-functions
Absorb and withstand forces from off-road conditions and the vehicle	Maintain contact with the ground	Force tires down with internal components	Release force from coils to the ground
			Release energy from shocks to the tires
		Absorb All forces channeled from environment	Compress the springs from the external forces
			Compress the shocks from external forces
			Rotate the control arms to decrease force intake
	Sustain mobility of moving parts	Allow freedom of suspension components	Rotating of control arms to absorb excess forces
			Rotating of ball joints to absorb excess forces
			Compressing of shocks and springs from external forces
		Stabilize movement of vehicle	Absorb forces with shocks and springs
			Move control arms based off environment
			Rotate ball joints from contact of force
	Distribute forces throughout suspension system	Channel forces through multiple pathways	Collect force through the shocks
			Collect force through coils
			Transfer force through ball joint
		Transfers loads from components to wheels	Transfer load from control arms
			Transfer load from coils
			Transfer load from shocks
	Support external and internal forces from vehicle conditions	Counter Gravitational Force	Release force from spring to the ground
			Release force from shock to ground
		Manage centrifugal forces	Transfer vehicle load through shocks while turning
			Transfer vehicle load through coils while turning
			Rotate control arms while turning

Table 4.2 Morphology Table for Steering System

Overall Function	Level 1 Sub-functions	Level 2 Sub-functions	Level 3 Sub-functions
Convert driver input to change the direction of the vehicle	Maintain control of vehicle	Prevent unwanted motion due to external factors	Allow forces to be absorbed
			Rotate gears only from steering wheel
		Guide the steering wheel in direction desired	Hold the steering wheel firmly
			Turn the steering wheel when adjusting to external forces
			Allow horizontal motion with steering rod
		Revert kinetic energy into another direction	Allow gears to move in both directions
			Allow steering rod to move horizontally in both directions
	Transmit motion of the vehicle	Channel mechanical energy to turn vehicle	Transfer energy from steering wheel to Steering shaft
			Translate motion from gears to steering rod
			Move tires side to side from steering rod
		Grasp the steering wheel firmly	Contact the steering wheel tactfully
			Hold the steering wheel with hand
	Stabilize vehicle alignment to stay on course	Maintain grip on the steering wheel	Contact the steering wheel firmly
			Hold the steering wheel until leaving the vehicle
		Orient steering wheel based on drivers view	Avoid extreme conditions of the course
			Drive along calmer environmental conditions
	Reduce effort of driver	Maintain Power Steering	Apply pressure to reduce force input
			Absorb external force to reduce driver control
			Reduce the turn of the steering wheel to perform a sharp maneuver
		adjusting steering effort	Allow easy motion of gears
			Allow easy motion of steering rod
			Allow easy motion of steering wheel

4.2 Concept Generation

This section will dive deeper in the process that the group took to come up with the overall concept generation of each system and break them down all the way to level 3 sub-functions. This will include giving a brief description and a sketch for each variable of this project.

The roles were assigned alphabetically by the last name of each member. The names were inserted on the table in that order until all the sub-sections were covered on both tables. Once the tables were completed, they were observed by all members to verify sufficiency. The members then separated and completed the descriptions and sketches individually. Table ~~1~~ shows the final results of which member was assigned to which level 3 sub-function to create sketches and descriptions for the suspension system. Table ~~2~~ shows the results of which member was assigned to which level 3 sub-function to create sketches and descriptions for the steering system.

Table 4.3 Individual Assignment for Suspension Concept Generation

Overall function	Level 1 Sub-functions	Level 2 Sub-functions	Level 3 Sub-functions	Name	Name	Name	Name
Absorb and withstand forces from off-road conditions and the vehicle	Maintain contact with the ground	Force tires down with internal components	Release force from springs to the ground	Robert Barbee	Titus Woodard	Todd Maxwell	Daniel Ward
			Release energy from struts to the tires	Jonathon Horta	Daniel Ward	Michael Samuel	Titus Woodard
		Absorb All forces channeled from environment	Compress the springs from the external forces	Aramis King	Michael Samuel	Titus Woodard	Robert Barbee
			Compress the struts from external forces	Todd Maxwell	Aramis King	Daniel Ward	Jonathon Horta
			Rotate the control arms to decrease force intake	Michael Samuel	Todd Maxwell	Robert Barbee	Aramis King
	Sustain mobility of moving parts	Allow freedom of suspension components	Rotating of control arms to absorb excess forces	Daniel Ward	Jonathon Horta	Aramis King	Todd Maxwell
			Rotating of ball joints to absorb excess forces	Titus Woodard	Robert Barbee	Jonathon Horta	Michael Samuel
			Compressing of struts and springs from external forces	Robert Barbee	Titus Woodard	Todd Maxwell	Daniel Ward
		Stabilize movement of vehicle	Absorb forces with struts and springs	Jonathon Horta	Daniel Ward	Michael Samuel	Titus Woodard
			Move control arms based off environment	Aramis King	Michael Samuel	Daniel Ward	Robert Barbee
			Rotate ball joints from contact of force	Todd Maxwell	Aramis King	Titus Woodard	Jonathon Horta
	Distribute forces throughout suspension system	Channel forces through multiple pathways	Collect force through the struts	Michael Samuel	Jonathon Horta	Aramis King	Todd Maxwell
			Collect force through springs	Daniel Ward	Michael Samuel	Robert Barbee	Michael Samuel
			Transfer force through ball joint	Titus Woodard	Robert Barbee	Jonathon Horta	Daniel Ward

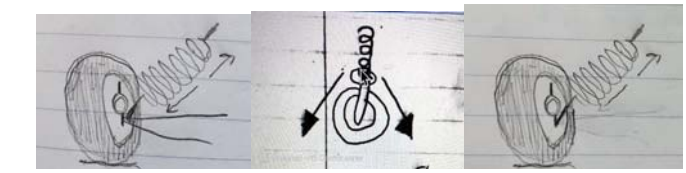
		Transfers loads from components to wheels	Transfer load from control arms	Robert Barbee	Titus Woodard	Todd Maxwell	Aramis King
			Transfer load from springs	Jonathon Horta	Daniel Ward	Michael Samuel	Todd Maxwell
			Transfer load from struts	Aramis King	Michael Samuel	Daniel Ward	Robert Barbee
	Support external and internal forces from vehicle conditions	Counter Gravitational Force	Release force from spring to the ground	Todd Maxwell	Aramis King	Titus Woodard	Michael Samuel
			Release force from struts to ground	Michael Samuel	Todd Maxwell	Aramis King	Jonathon Horta
		Ability to manage centrifugal forces	Transfer vehicle load through struts while turning	Daniel Ward	Jonathon Horta	Robert Barbee	Titus Woodard
			Transfer vehicle load through springs while turning	Titus Woodard	Robert Barbee	Jonathon Horta	Michael Samuel
			Rotate control arms while turning	Robert Barbee	Titus Woodard	Todd Maxwell	Daniel Ward

Table 4.4 Individual Assignment for Steering Concept Generation

overall function	Level 1 Sub-functions	Level 2 Sub-functions	Level 3 Sub-functions	Name	Name	Name	Name
Convert driver input to change the direction of the vehicle	Maintain control of vehicle	Prevent unwanted motion due to external factors	Allow forces to be absorbed	Robert Barbee	Titus Woodard	Todd Maxwell	Daniel Ward
			Rotate gears only from steering wheel	Jonathon Horta	Daniel Ward	Michael Samuel	Titus Woodard
		Guide the steering wheel in direction desired	Hold the steering wheel firmly	Aramis King	Michael Samuel	Titus Woodard	Robert Barbee
			Turn the steering wheel when adjusting to external forces	Todd Maxwell	Aramis King	Daniel Ward	Jonathon Horta
			Allow horizontal motion with steering rod	Michael Samuel	Todd Maxwell	Robert Barbee	Aramis King
		Revert kinetic energy into another direction	Allow gears to move in both directions	Daniel Ward	Jonathon Horta	Aramis King	Todd Maxwell
			Allow steering rod to move horizontally in both directions	Titus Woodard	Robert Barbee	Jonathon Horta	Michael Samuel
	Transmit motion of the vehicle	Channel mechanical energy to turn vehicle	Transfer energy from steering wheel to Steering shaft	Robert Barbee	Titus Woodard	Todd Maxwell	Daniel Ward
			Translate motion from gears to steering rod	Jonathon Horta	Daniel Ward	Michael Samuel	Titus Woodard
			Move tires side to side from steering rod	Aramis King	Michael Samuel	Daniel Ward	Robert Barbee

		Grasp the steering wheel firmly	Contact the steering wheel tactfully	Todd Maxwell	Aramis King	Titus Woodard	Jonatho n Horta
			Hold the steering wheel with hand	Michael Samuel	Jonathon Horta	Aramis King	Todd Maxwell
	Stabilize vehicle alignme nt to stay on course	Maintain grip on the steering wheel	Contact the steering wheel firmly	Daniel Ward	Michael Samuel	Robert Barbee	Michael Samuel
			Hold the steering wheel until leaving the vehicle	Titus Woodard	Robert Barbee	Jonathon Horta	Daniel Ward
		Orient steering wheel based on drivers view	Avoid extreme conditions of the course	Robert Barbee	Titus Woodard	Todd Maxwell	Aramis King
			Drive along calmer environmental conditions	Jonathon Horta	Daniel Ward	Michael Samuel	Todd Maxwell
	Reduce effort of driver	Maintain Power Steering	Apply pressure to reduce force input	Aramis King	Michael Samuel	Daniel Ward	Robert Barbee
			Absorb external force to reduce driver control	Todd Maxwell	Aramis King	Titus Woodard	Michael samuel
			Reduce the turn of the steering wheel to perform a sharp maneuver	Michael Samuel	Todd Maxwell	Aramis King	Jonatho n Horta
		adjusting steering effort	Allow easy motion of gears	Daniel Ward	Jonathon Horta	Robert Barbee	Titus Woodar d
			Allow easy motion of steering rod	Titus Woodard	Robert Barbee	Jonathon Horta	Michael Samuel
			Allow easy motion of steering wheel	Robert Barbee	Titus Woodard	Todd Maxwell	Daniel Ward

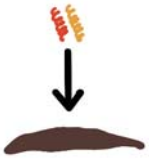
Once the group finished their individual concepts for the assigned level 3 subfunctions, the group combined the concepts to come up with four final concepts. For the first level 3 sub-function, release force from springs to the ground, the group came up with eight concepts and decided on four that would best fit the project. In Figure 4.25, all eight concepts from four different students for the first level 3 sub-functions. In table ~~3,~~ it shows the final four concepts for the level 3 sub-function release force from the springs to the ground.



(i) RB (ii) TW (iii) RB



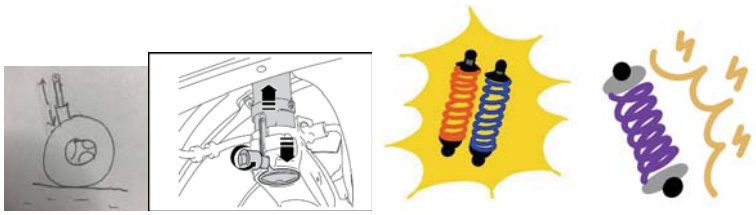
(iv) TM (v) DW (vi) TM



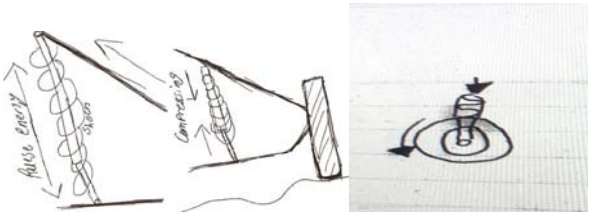
(vii) DW

Figure 4.25 Concepts for level 3 sub-function release force from the springs to the ground

For the next level 3 sub-function, releasing energy from the struts to the tires, the group came up with eight different concepts. In figure 4.26, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in ~~table 3~~.



(i)JH (ii) JH (iii) DW (iv) DW



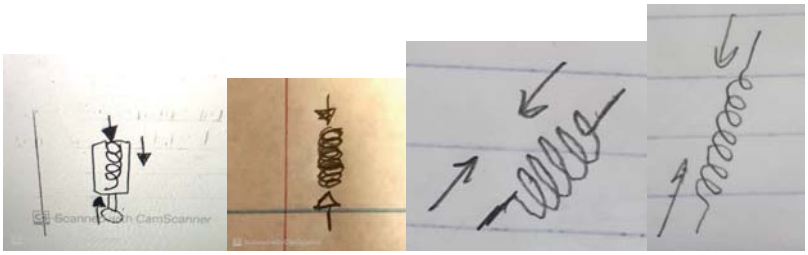
(v) MS (vi) MS (vii) TW

Figure 4.26: Concepts for level 3 sub-function release energy from struts to the tires

The next level 3 sub-function is compressing the springs from the external forces. The group created eight concepts that could work for this project. In table 3, it will have the final four concepts that will be considered for the design of this project. In Figure 4.27, it will show all concepts for this level 3 sub-function.



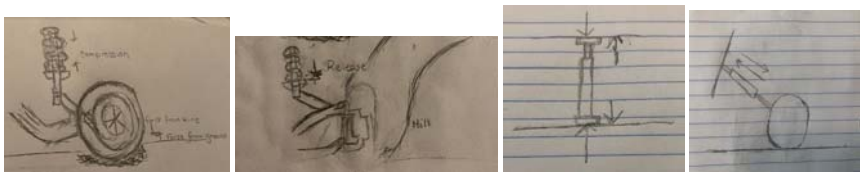
(i)AK (ii) AK (iii) MS (iv) MS



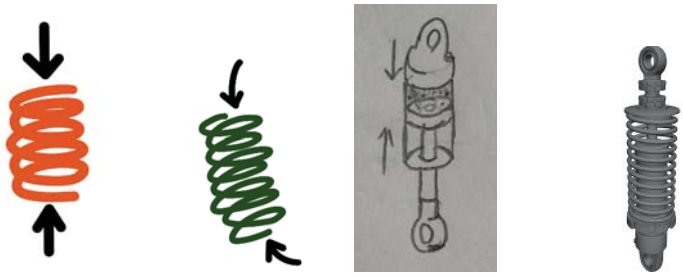
(v) TW (vi) TW (vii) RB (viii) RB

Figure 4.27: Concepts for level 3 sub-function compress the springs from the external forces

For the next level 3 sub-function, to compress the struts from external forces, the group came up with eight different concepts. In figure 4.28, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 3.



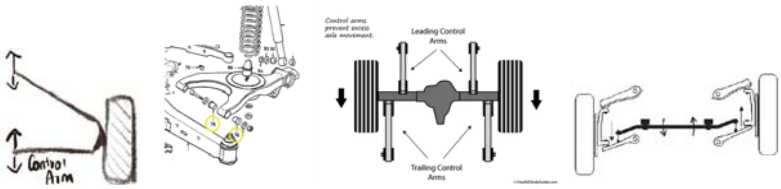
(i)TM (ii) TM (iii) AK (iv) AK



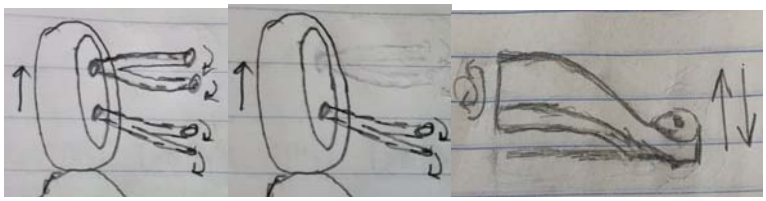
(v) DW (vi) DW (vii) JH (viii) JH

Figure 4.28: Concepts for level 3 sub-function compress the struts from external forces

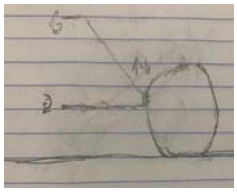
For the next level 3 sub-function, rotate the control arms to decrease force intake, the group came up with eight different concepts. In Figure 4.29, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 3.



(i)MS (ii) MS (iii) TM (iv) TM



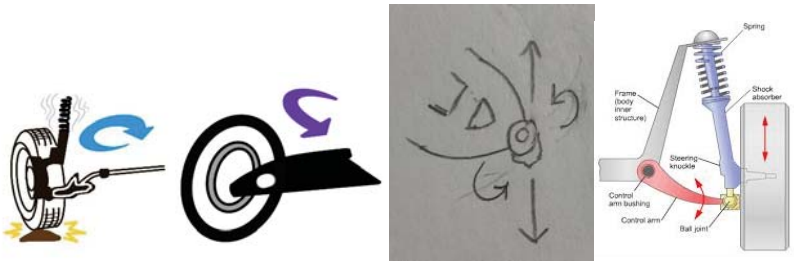
(v) RB (vi) RB (vii) AK



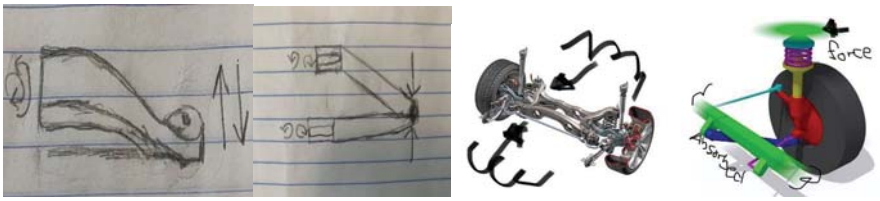
(viii) AK

Figure 4.29: Concepts for level 3 sub-function rotating the control arms to decrease force intake

For the next level 3 sub-function, rotating of control arms to absorb excess forces, the group came up with eight different concepts. In Figure 4.30, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 3.



(i)DW (ii) DW (iii)JH (iv) JH



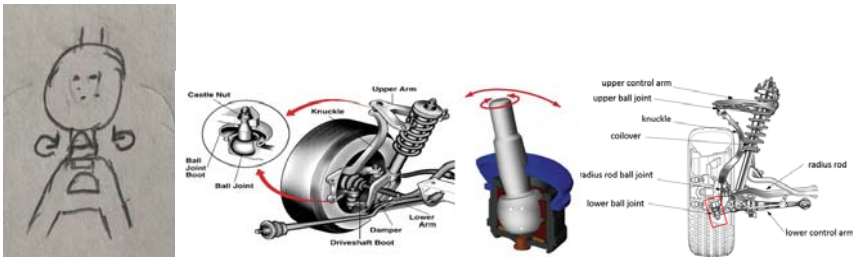
(v) AK (vi) AK (vii) TM (viii)

Figure 4.30: Concepts for level 3 sub-function rotating of control arms to absorb excess forces

For the next level 3 sub-function, rotating of ball joints to absorb excess forces, the group came up with eight different concepts. In Figure 4.31, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 3.



(i)TW (ii) RB (iii)RB

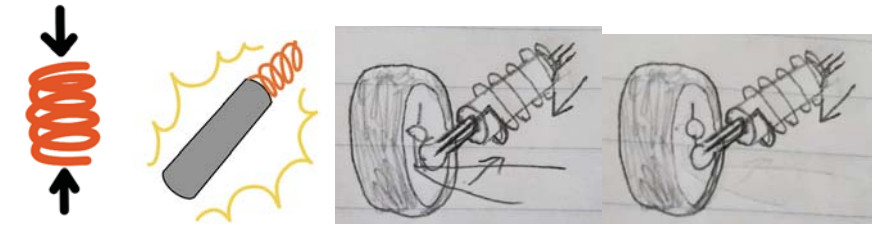


(iv) JH (v) JH (vi) MS (vii) MS

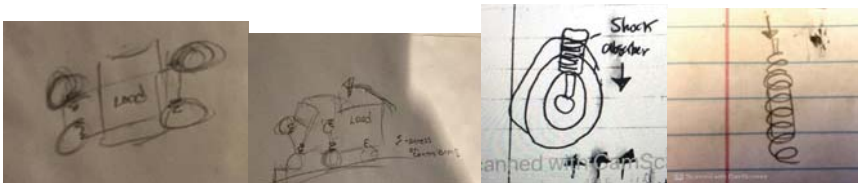
Figure 4.31: Concepts for level 3 sub-function rotating of ball joints to absorb excess forces

For the next level 3 sub-function, compressing struts and springs from external forces, the group came up with eight different concepts. In Figure 4.32, there are eight sketches from several

students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 3.



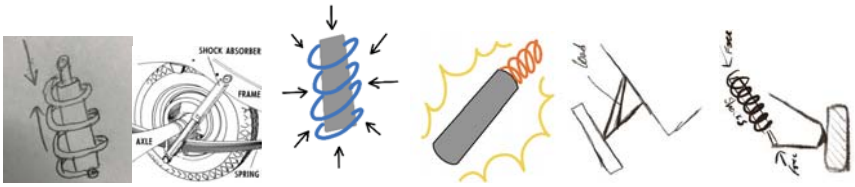
(i) DW (ii) DW (iii) RB (iv) RB



(v)TM (vi)TM (vii) TW (viii) TW

Figure 4.32: Concepts for level 3 sub-function compressing struts and springs from external forces

For the next level 3 sub-function, absorbing forces with struts and springs, the group came up with eight different concepts. In Figure 4.33, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 3.



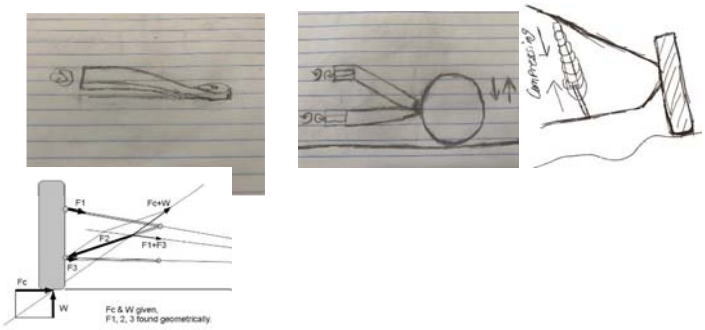
(i)JH (ii)JH (iii)DW (iv)DW (V) MS (Vi) MS



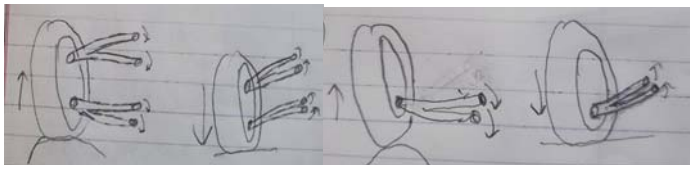
(vii) TW (vii) TW

Figure 4.33: Concepts for level 3 sub-function absorbing forces with struts and springs

For the next level 3 sub-function, move control arms based on the environment, the group came up with eight different concepts. In Figure 4.34, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 3.



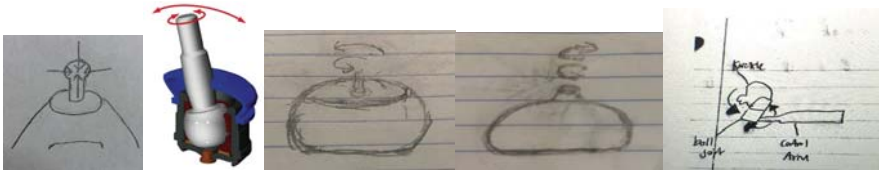
(i)AK (ii)AK (iii)MS (iV)MS



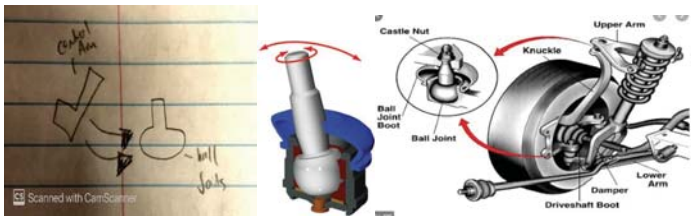
(v) RB (vi) RB

Figure 4.34: Concepts for level 3 sub-function move control arms based on the environments

For the next level 3 sub-function, rotate ball joints from contact of force, the group came up with eight different concepts. In Figure 4.35, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 3.



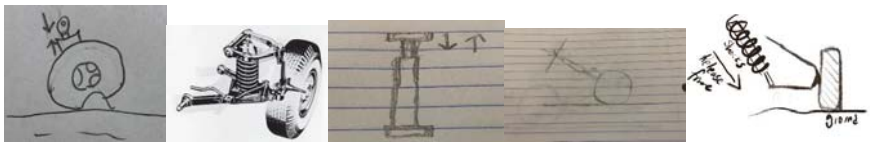
(i)JH (ii)JH (iii) AK (iv) AK (v) TW



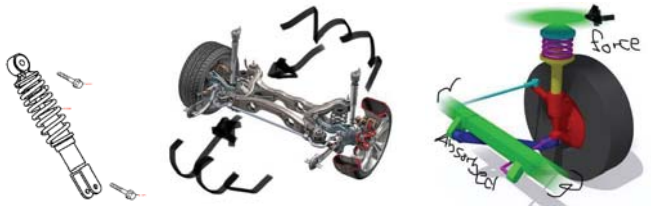
(vi) TW (vii)TM (viii)TM

Figure 4.35: Concepts for level 3 sub-function rotate ball joints from contact of force

For the next level 3 sub-function, to collect force through the struts, the group came up with eight different concepts. In Figure 4.36, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 3.



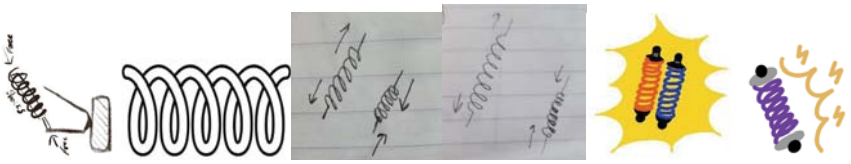
(i)JH (ii)JH (iii) AK (iv) AK (v)MS



(Vi)MS (vii)TM (viii)TM

Figure 4.36: Concepts for level 3 sub-function to collect force through the struts

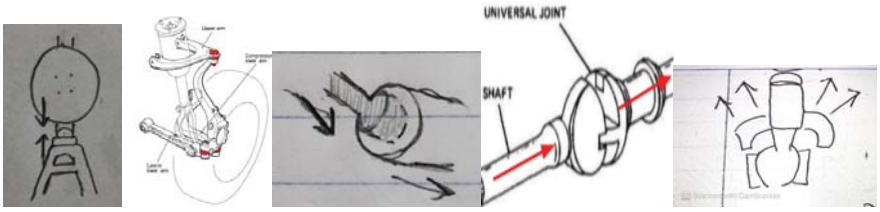
For the next level 3 sub-function, collect force through springs, the group came up with eight different concepts. In Figure 4.37, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 3.



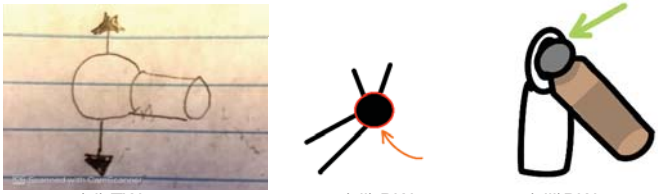
(i)MS (ii)MS (iii) RB (iv) RB (v) DW (vi) DW

Figure 4.37: Concepts for level 3 sub-function collect force through springs

For the next level 3 sub-function, transfer force through the ball joint, the group came up with eight different concepts. In Figure 4.38, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 3.



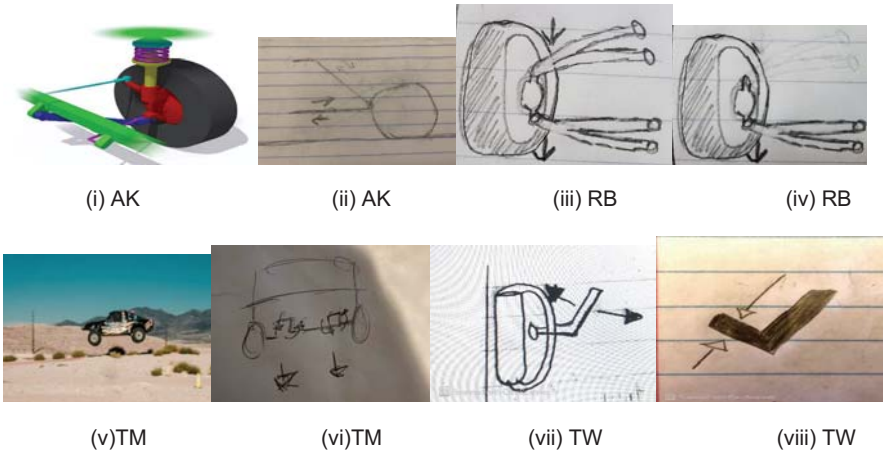
(i)JH (ii)JH (iii) RB (iv) RB (v) TW



(vi) TW (vii) DW (viii)DW

Figure 4.38: Concepts for level 3 sub-function transfer force through the ball joint

For the next level 3 sub-function, transfer load from control arms, the group came up with eight different concepts. In Figure 4.39, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 3.

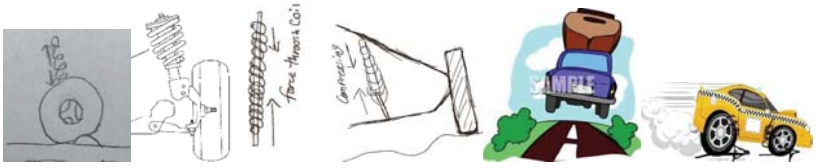


(i) AK (ii) AK (iii) RB (iv) RB

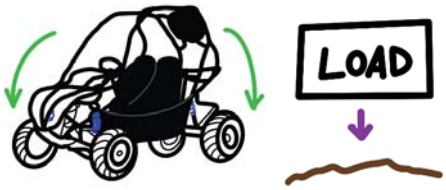
(v)TM (vi)TM (vii) TW (viii) TW

Figure 4.39: Concepts for level 3 sub-function transfer load from control arms

For the next level 3 sub-function, transfer load from springs, the group came up with eight different concepts. In Figure 4.40, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 3.



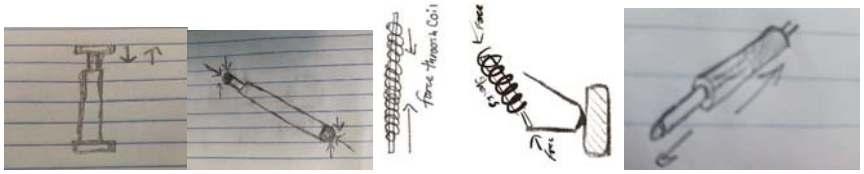
(i)JH (ii)JH (iii)MS (IV) MS (v)TM (vi)TM



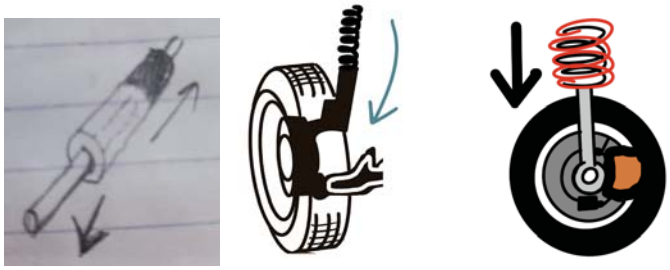
(vii) DW (viii) DW

Figure 4.40: Concepts for level 3 sub-function transfer load from springs

For the next level 3 sub-function, transfer load from struts, the group came up with eight different concepts. In Figure 4.41, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 3.



(i) AK (ii) AK (iii) MS (iV) MS (v) RB



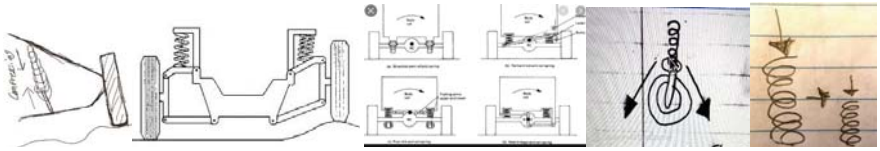
(vi) RB (vii) DW (viii) DW

Figure 4.41: Concepts for level 3 sub-function transfer load from struts

For the next level 3 sub-function, releasing force from the spring to the ground, the group came up with eight different concepts. In Figure 4.42, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 3.



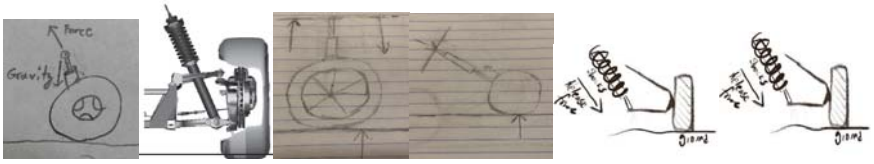
(i) DW (ii) DW (iii) AK (iv) AK (V)MS



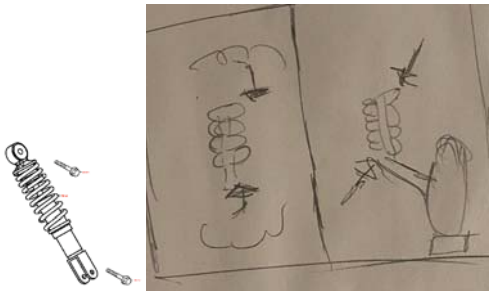
(vi) MS (vii)TM (viii)TM (ix) TW (x) TW

Figure 4.42: Concepts for level 3 sub-function releasing force from the spring to the ground

For the next level 3 sub-function, releasing force from the struts to ground, the group came up with eight different concepts. In Figure 4.43, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 3.



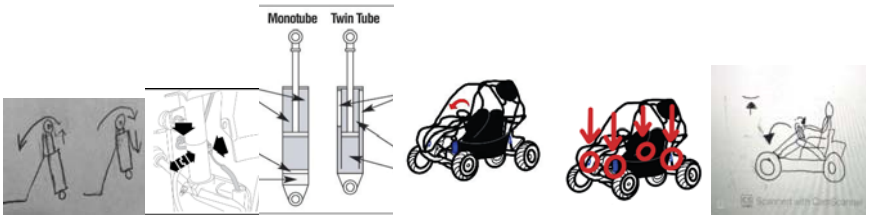
(i)JH (ii)JH (iii) AK (iv) AK (V)MS



(Vi)MS (vii)TM (viii)TM

Figure 4.43: Concepts for level 3 sub-function releasing force from the struts to ground

For the next level 3 sub-function, transfer vehicle load through struts while turning, the group came up with eight different concepts. In Figure 4.43, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 3.



(i)JH (ii)JH (iii) RB (iv) DW (v) DW (vi) TW

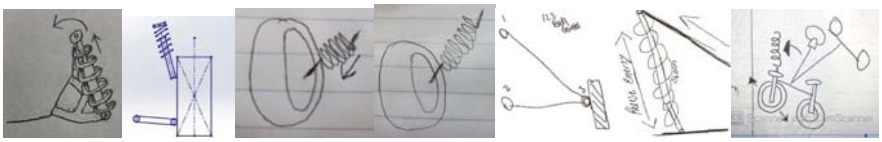


(vii) TW

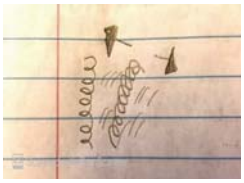
Figure 4.43: Concepts for level 3 sub-function transfer vehicle load through struts while turning

For the next level 3 sub-function, transfer vehicle load through springs while turning, the group came up with eight different concepts. In Figure 4.44, there are eight sketches from several

students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 3.



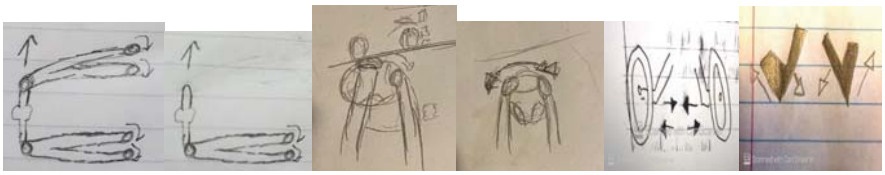
(i)JH (ii)JH (iii) RB (iv) RB (v) MS (vi) MS (vii) TW



(viii) TW

Figure 4.44: Concepts for level 3 sub-function transfer vehicle load through springs while turning

For the next level 3 sub-function, rotate control arms while turning, the group came up with eight different concepts. In Figure 4.45, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 3.



(i) RB (ii) RB (iii)TM (iv)TM (v) TW (vi)TW



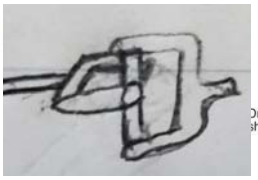
(vii) DW (viii) DW

Figure 4.45: Concepts for level 3 sub-function rotate control arms while turning

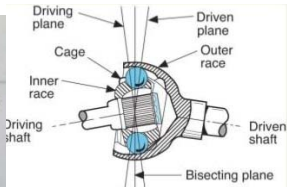
For steering, the first level 3 sub-function allows forces to be absorbed. The group came up with eight different concepts. In Figure 4.46, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in ~~table 4~~.



(i) DW



(ii) RB



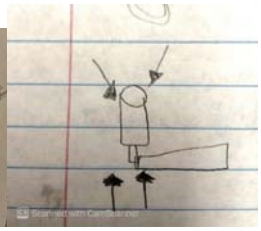
(iii) RB



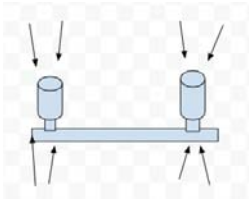
(iv)TM



(v)TM



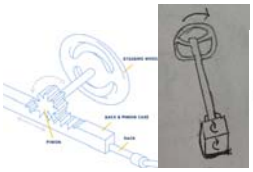
(vi) TW



(vii) TW

Figure 4.46: Concepts for level 3 sub-function allows forces to be absorbed

For the next level 3 sub-function, rotate gears only from the steering wheel, the group came up with eight different concepts. In Figure 4.47, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 4.

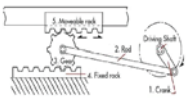


(i)JH

(ii)JH



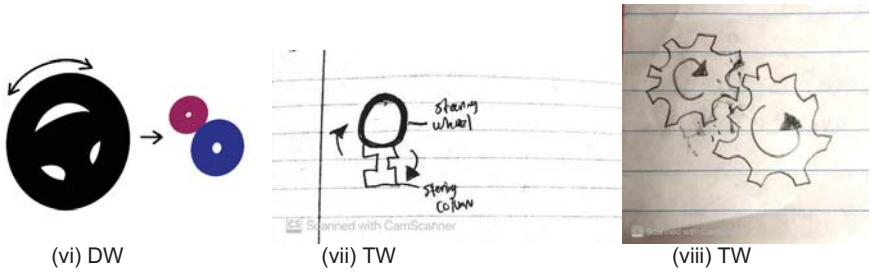
(iii)MS



(iv)MS



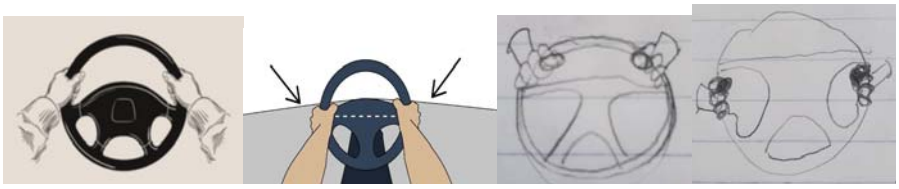
(v) DW



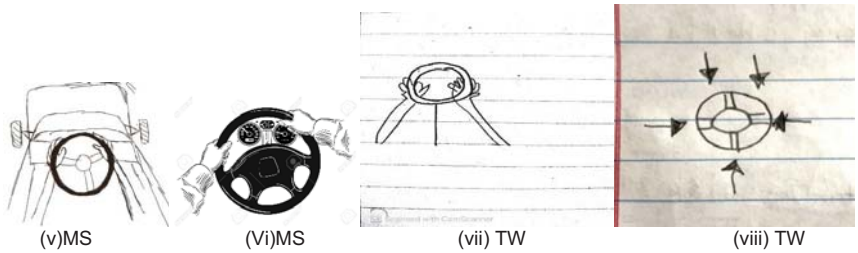
(vi) DW (vii) TW (viii) TW

Figure 4.47: Concepts for level 3 sub-function rotate gears only from the steering wheel

For the next level 3 sub-function, hold the steering wheel firmly, the group came up with eight different concepts. In Figure 4.48, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 4.



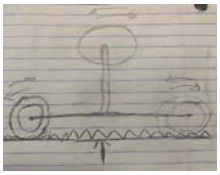
(i) AK (ii) AK (iii) RB (iv) RB



(v)MS (Vi)MS (vii) TW (viii) TW

Figure 4.48: Concepts for level 3 sub-function hold the steering wheel firmly

For the next level 3 sub-function, turn the steering wheel when adjusting to external forces, the group came up with eight different concepts. In Figure 4.49, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 4.



(i) AK



(ii) AK



(iii)JH



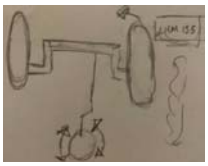
(iv)JH



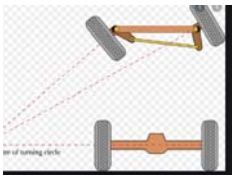
(v) DW



(vi) DW



(vii)TM



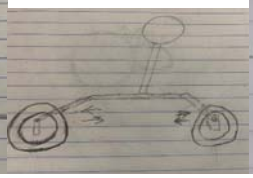
(viii)TM

Figure 4.49: Concepts for level 3 sub-function turn the steering wheel when adjusting to external forces

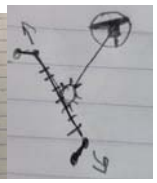
For the next level 3 sub-function, allowing horizontal motion with the steering rod, the group came up with eight different concepts. In Figure 4.50, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 4.



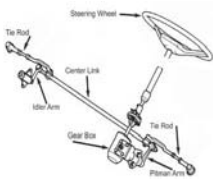
(i) AK



(ii) AK



(iii) RB



(iv) RB

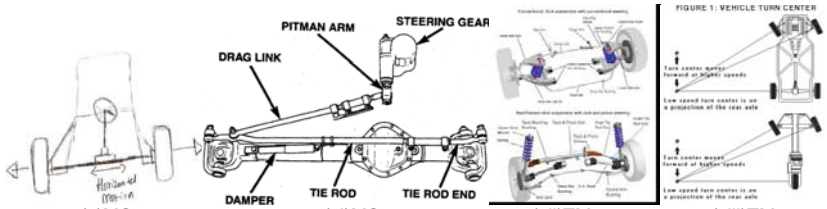


Figure 4.50: Concepts for level 3 sub-function allowing horizontal motion with the steering rod

For the next level 3 sub-function, allowing gears to move in both directions, the group came up with eight different concepts. In Figure 4.51, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 4.

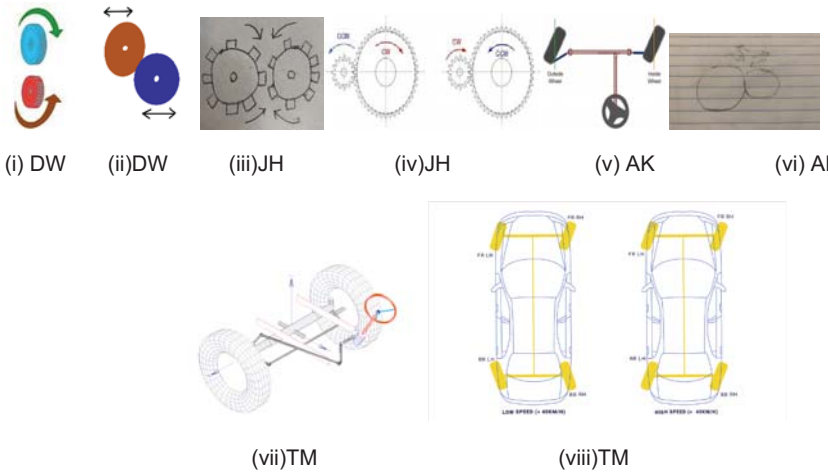
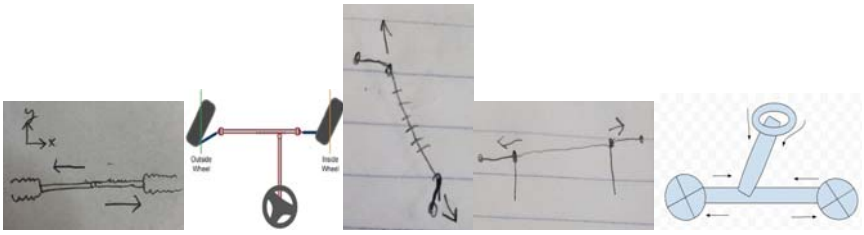
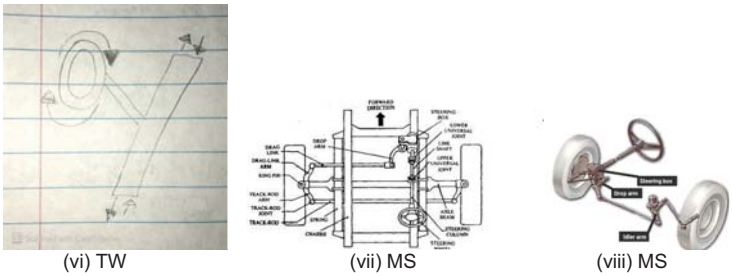


Figure 4.51: Concepts for level 3 sub-function allowing gears to move in both directions

For the next level 3 sub-function, allowing the steering rod to move horizontally in both directions, the group came up with eight different concepts. In Figure 4.52, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 4.



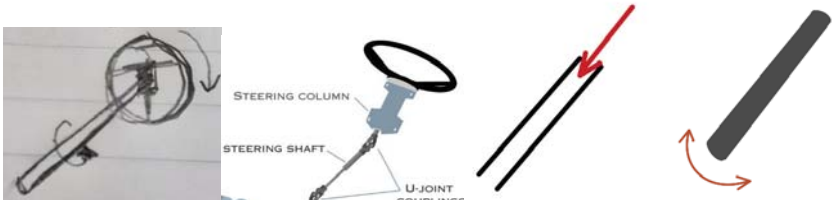
(i)JH (ii)JH (iii) RB (iv) RB (v) TW



(vi) TW (vii) MS (viii) MS

Figure 4.52: Concepts for level 3 sub-function allowing the steering rod to move horizontally in both directions

For the next level 3 sub-function, transferring energy from steering wheel to steering shaft, the group came up with eight different concepts. In Figure 4.53, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 4.



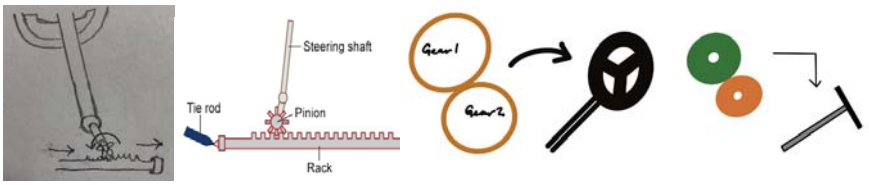
(i) RB (ii) RB (iii) DW (iv)DW



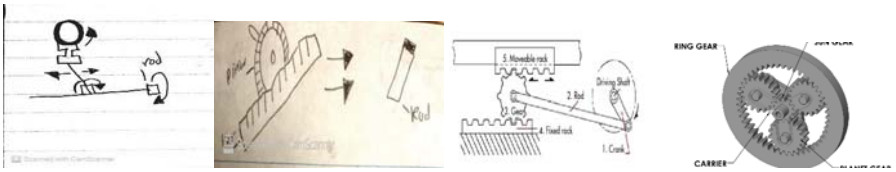
(V) TW (vi) TW (vii)TM (viii)TM

Figure 4.53: Concepts for level 3 sub-function transferring energy from steering wheel to steering shaft

For the next level 3 sub-function, which translates motion from gears to steering rod, the group came up with eight different concepts. In Figure 4.54, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 4.



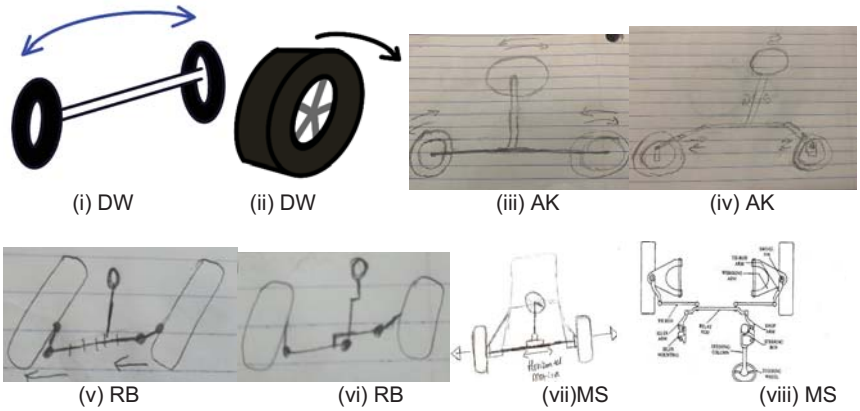
(i)JH (ii)JH (iii) DW (iv) DW



(v) TW (vi) TW (vii) MS (viii) MS

Figure 4.54: Concepts for level 3 sub-function which translates motion from gears to steering rod

For the next level 3 sub-function, moving tires side to side from the steering rod, the group came up with eight different concepts. In Figure 4.55, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 4.

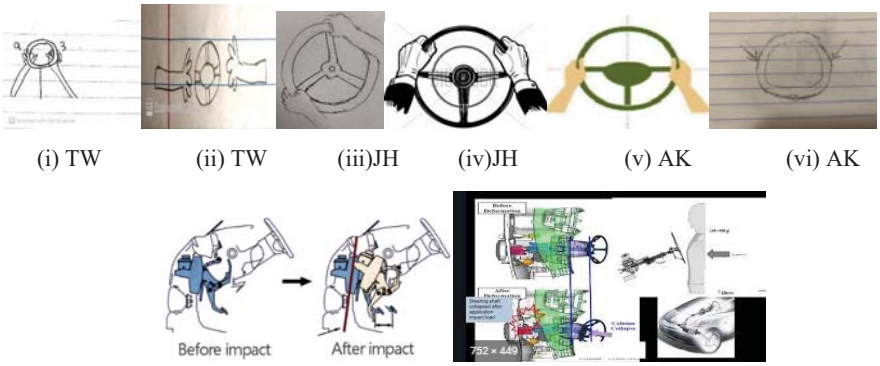


(i) DW (ii) DW (iii) AK (iv) AK

(v) RB (vi) RB (vii)MS (viii) MS

Figure 4.55: Concepts for level 3 sub-function moving tires side to side from the steering rod

For the next level 3 sub-function, contact the steering wheel tactfully, the group came up with eight different concepts. In Figure 4.56, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 4.



(i) TW (ii) TW (iii)JH (iv)JH (v) AK (vi) AK

(vii)TM (viii)TM

Figure 4.56: Concepts for level 3 sub-function contact the steering wheel tactfully

For the next level 3 sub-function, hold the steering wheel with hand, the group came up with eight different concepts. In Figure 4.57, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 4.



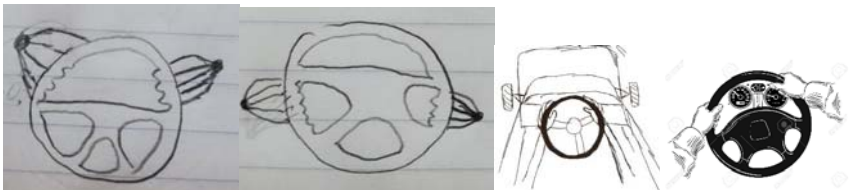
(i)JH (ii)JH (iii) AK (iv) AK (v)MS



(vi) MS (vii)TM (viii)TM

Figure 4.57: Concepts for level 3 sub-function hold the steering wheel with hand

For the next level 3 sub-function, contact the steering wheel firmly, the group came up with eight different concepts. In Figure 4.58, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 4.



(i) RB (ii) RB (iii)MS (iv)MS



(v) DW (vi) DW

Figure 4.58: Concepts for level 3 sub-function contact the steering wheel firmly

For the next level 3 sub-function, hold the steering wheel until leaving the vehicle, the group came up with eight different concepts. In Figure 4.59, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 4.



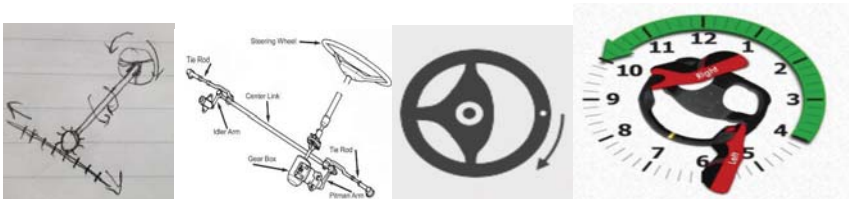
(i)JH (ii)JH (iii) RB (iv) RB (v) TW



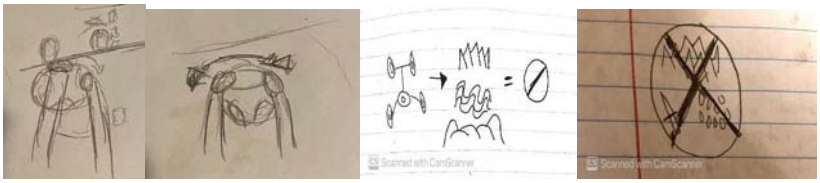
(vi) TW (vii) DW (viii) DW

Figure 4.59: Concepts for level 3 sub-function hold the steering wheel until leaving the vehicle

For the next level 3 sub-function, to avoid extreme conditions of the course, the group came up with eight different concepts. In Figure 4.60, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 4.



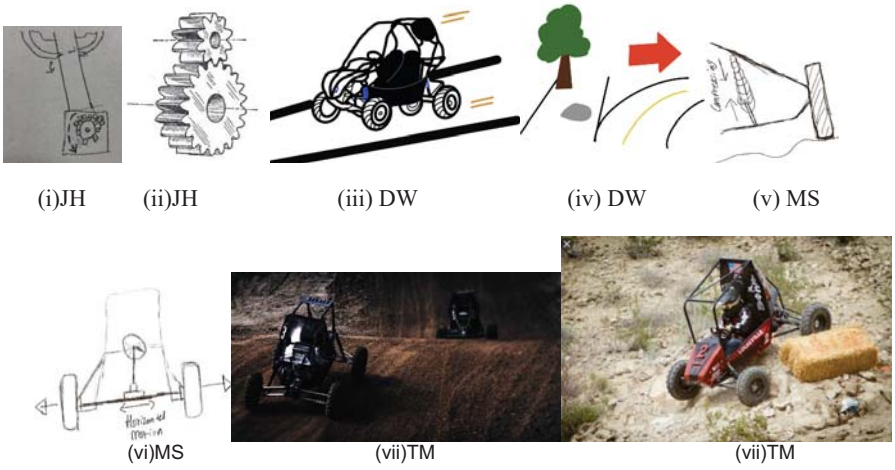
(i) RB (ii) RB (iii) AK (iv) AK



(v)TM (vi)TM (vii) TW (viii) TW

Figure 4.60: Concepts for level 3 sub-function to avoid extreme conditions of the course

For the next level 3 sub-function, driven along calmer environmental conditions, the group came up with eight different concepts. In Figure 4.61, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 4.

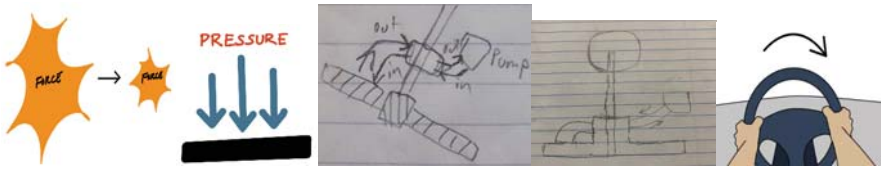


(i)JH (ii)JH (iii) DW (iv) DW (v) MS

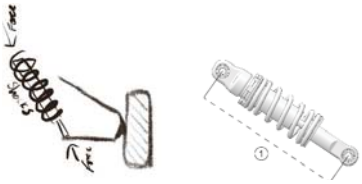
(vi)MS (vii)TM (vii)TM

Figure 4.61: Concepts for level 3 sub-function drive along calmer environmental conditions

For the next level 3 sub-function, applying pressure to reduce force input, the group came up with eight different concepts. In Figure 4.62, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 4.



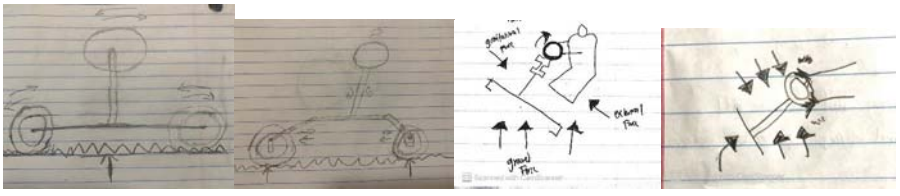
(i) DW (ii) DW (iii) RB (iv) AK (v) AK



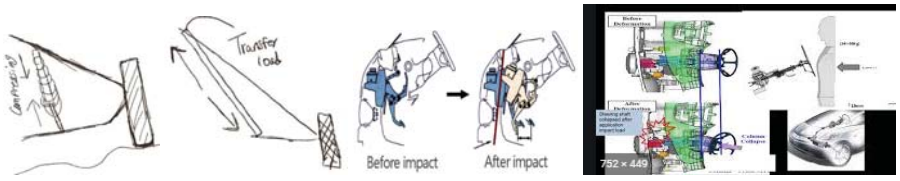
(Vi)MS (vii)MS

Figure 4.62: Concepts for level 3 sub-function applying pressure to reduce force input

For the next level 3 sub-function, to absorb external force to reduce driver control, the group came up with eight different concepts. In Figure 4.63, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 4.



(i) AK (ii) AK (iii) TW (iv) TW



(v) MS (vi) MS (vii) TM (viii) TM

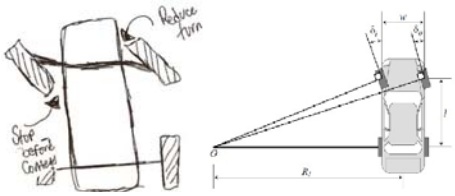
Figure 4.63: Concepts for level 3 sub-function to absorb external force to reduce driver control

For the next level 3 sub-function, reducing the turn of the steering wheel to perform a sharp maneuver, the group came up with eight different concepts. In Figure 4.64, there are eight

sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 4.



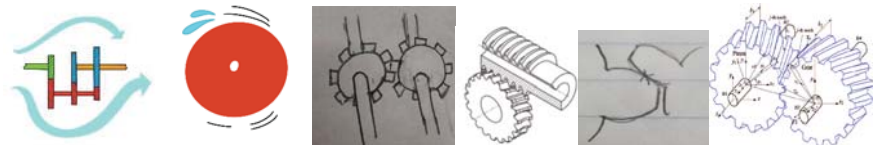
(i)JH (ii)JH (iii) AK (iv) AK



(v)MS (vi) MS

Figure 4.64: Concepts for level 3 sub-function reducing the turn of the steering wheel to perform a sharp maneuver

For the next level 3 sub-function, allowing easy motion of gears, the group came up with eight different concepts. In Figure 4.65, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 4.



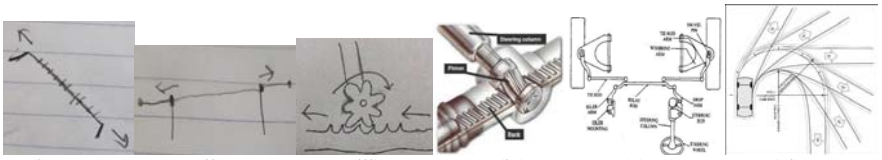
DW (ii) DW (iii)JH (iv)JH (v) RB (vi) RB (i)



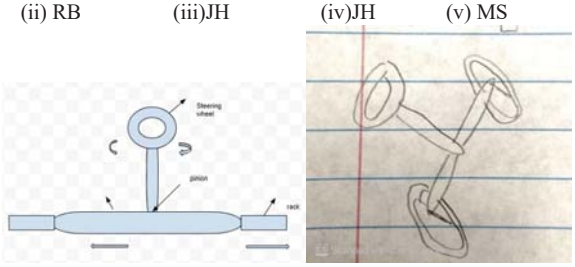
(vii) TW (viii) TW

Figure 4.65: Concepts for level 3 sub-function allowing easy motion of gears

For the next level 3 sub-function, allowing easy motion of the steering rod, the group came up with eight different concepts. In Figure 4.66, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 4.



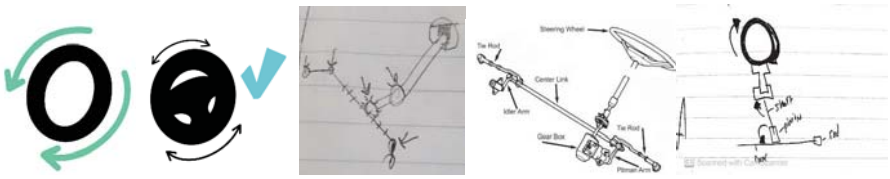
(i) RB (ii) RB (iii)JH (iv)JH (v) MS (vi) MS



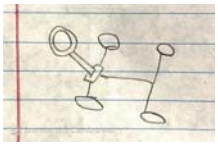
(vii) TW (viii) TW

Figure 4.66: Concepts for level 3 sub-function allowing easy motion of the steering rod

For the next level 3 sub-function, allowing easy motion of the steering wheel, the group came up with eight different concepts. In Figure 4.67, there are eight sketches from several students showing how the level 3 sub-function can be designed. The figure number from where the sketch is first shown is in table 4.



(i) DW (ii) DW (iii) RB (iv) RB (v) TW



(vi)TW

Figure 4.67: Concepts for level 3 sub-function allowing easy motion of the steering wheel

In Table 4.5, the table shows the level 3 sub functions for the suspension system. It also includes each concept created by a group member for their assigned subfunction. It also includes where the sketch is located and created by whom.

Table 4.5 Morphology Table for Suspension

Overall Function	Level 1 Sub-functions	Level 2 Sub-functions	Level 3 Sub-functions	Double Wishbone		MacPherson		Semi-Trailing		Trailing	
				Description	Sketch	Description	Sketch	Description	Sketch	Description	Sketch
Absorb and withstand forces from off-road conditions and the vehicle	Maintain contact with the ground	Force tires down with internal components	Release force from springs to the ground	Spring on control arm	Figure ~~7.1: (i)~~ RB	Force of spring exert to ground	Figure 7.1: (v) DW	Spring on knuckle	Figure 7~~.1: (iii)~~ RB	Spring applies force to ground	Figure ~~7.1:~~ (ii)TW
			Release energy from struts to the tires	Energy moves out of struts	Figure 7.2: (v) MS	Struts push toward tires	Figure 7.2: (ii) JH	Pressure exits strut	Figure 7.2: (i) JH	Energy transfered to tires	Figure 7.2: (iv) DW
		Absorb All forces channeled from environment	Compress the springs from the external forces	Springs absorb force	Figure 7.3: (vi) TW	Compression in springs	Figure 7.3: (i) AK	Force applied to both ends	Figure 7.3: (iii) MS	Compression in angles	Figure 7.3: (ii) AK
			Compress the struts from external forces	Absorb external force	Figure 7.4: (iv) AK	Compressing strut	Figure 7.4: (iii) AK	Struts connected to control arm	Figure 7.4: (i) TM	Struts freely compress	Figure 7.4: (vii) JH
			Rotate the control arms to decrease	Two control arms	Figure 7.5: (v) RB	Rotating control arm	Figure 7.5: (iv) TM	Allow movement	Figure 7.5: (i) MS	One control arm	Figure 7.5: (vi) RB

		force intake								
Sustain mobility of moving parts	Allow freedom of suspension components	Rotating of control arms to absorb excess forces	Better absorption of forces while rotating	Figure 7.6: (ii) DW	Rotates in positive and negative direction	Figure 7.6: (vi) AK	Control arm pivots	Figure 7.6: (iii) JH	Rotating control arm	Figure 7.6: (i) DW
		Rotating of ball joints to absorb excess forces	External force causes ball joint to rotate	Figure 7.7: (i) TW	Ball joint	Figure 7.7: (ii) RB	Universal joint	Figure 7.7: (iii) RB	Ability to move freely	Figure 7.7: (vi) MS
		Compressing of struts and springs from external forces	shocks and springs absorb external forces	Figure 7.8: (vii) TW	Two control arms	Figure 7.8: (iii) RB	load transfer force	Figure 7.8: (vi) TM	One control arm	Figure 7.8: (iv) RB
	Stabilize movement of vehicle	Absorb forces with struts and springs	struts and springs absorb forces	Figure 7.9: (iii) DW	System compresses to contain vibrations	Figure 7.9: (i) JH	shocks and springs absorb vibratons	Figure 7.9: (vii) TW	able to hold force	Figure 7.9: (vi) MS
		Move control arms based off environment	control arms adjust to environment	Figure 7.10: (iii) MS	external force moving the control arm	Figure 7.10: (iv) MS	Two control arms	Figure 7.10: (v) RB	One control arm	Figure 7.10: (vi) RB
		Rotate ball	forces rotate	Figure 7.11:	Ball joints	Figure 7.11: (i)	Ball joints	Figure 7.11:	Rotates and	Figure 7.11:

		joints from contact of force	& pivots ball joints	(v) TW	spin due to forces control arms	JH	rotate to absorb forces	(ii) JH	pivots	(iii) AK
Distribute forces throughout suspension system	Channel forces through multiple pathways	Collect force through the struts	Struts counter vibrations	Figure 7.12: (i) JH	Forces causes movement	Figure 7.12: (iii) AK	Forces absorbed	Figure 7.12: (iv) AK	Compressing to absorb	Figure 7.12: (v) MS
		Collect force through springs	Compressing to collect force	Figure 7.13: (i) MS	springs collect forces	Figure 7.13: (vi) DW	More coils	Figure 7.13: (iv) RB	Less coils	Figure 7.13: (iii) RB
		Transfer force through ball joint	Ball joints adjust to transfer force	Figure 7.14: (i) JH	Ball joint	Figure 7.14: (iii) RB	Forces are released	Figure 7.14: (v) TW	ball joints take on force	Figure 7.14: (viii) DW
	Transfers loads from components to wheels	Transfer load from control arms	Load to control arms	Figure 7.15: (vi) TM	Two control arms	Figure 7.15: (iii) RB	Forces absorbed	Figure 7.15: (ii) AK	One control arm	Figure 7.15: (iv) RB
		Transfer load from springs	Force moving through coils	Figure 7.16: (iv) MS	Transmitting force	Figure 7.16: (iii) MS	Springs transfer loads	Figure 7.16: (i) JH	load transfered from springs	Figure 7.16: (vii) DW
		Transfer load from struts	Force moving through struts	Figure 7.17: (iv) MS	compresses and releases	Figure 7.17: (ii) AK	Strut compresses and releases	Figure 7.17: (i) AK	load transfers from struts	Figure 7.17: (vii) DW
Support external and internal forces	Counter Gravitational Force	Release force from spring to the ground	ground force is a reactant force onto	Figure 7.18: (ix) TW	Spring compress release	Figure 7.18: (iii) AK	springs transfer force to ground	Figure 7.18: (i) DW	Forces transmit through ground	Figure 7.18: (v) MS

from vehicle conditions			spring							
		Release force from struts to ground	Compress and release	Figure 7.19: (iii) AK	Struts counter downward forces	Figure 7.19: (i) JH	force being decompressed	Figure 7.19: (v) MS	Release force to ground	Figure 7.19: (viii) TM
	Ability to manage centrifugal forces	Transfer vehicle load through struts while turning	load is transferred through vehicle to turn	Figure 7.20: (vi) TW	Struts transfer loads through inertia	Figure 7.20: (i) JH	vehicle load transfered through struts	Figure 7.20: (v) DW	Struts collect forces	Figure 7.20: (ii) JH
		Transfer vehicle load through springs while turning	Vehicle weight being distributed	Figure 7.21: (vi) MS	Springs transfer loads through inertia	Figure 7.21: (i) JH	More coils	Figure 7.21: (iv) RB	Less coils	Figure 7.21: (iii) RB
		Rotate control arms while turning	turning is done through rotation control arms	Figure 7.22: (v) TW	Two control arms	Figure 7.22: (i) RB	turning causes control arms to rotate	Figure 7.22: (vii) DW	One control arm	Figure 7.22: (ii) RB

In table 4.6, it shows all of the level 3 sub functions as well as each concept that each member created for their assigned subfunction. In the table it shows where the sketch is and who the sketch was created by.

Table 4.6 Morphology Table for Steering

Overall Function	Level 1 Sub-functions	Level 2 Sub-functions	Level 3 Sub-functions	Rack and pinion		Worm and sector		Recirculating Ball		Hydrostatic	
				Description	Sketch	Description	Sketch	Description	Sketch	Description	Sketch
Convert driver input to change the direction of the vehicle	Maintain control of vehicle	Prevent unwanted motion due to external factors	Allow forces to be absorbed	Absorb force through steering rod	Figure ~~7.23:~~ (vii) TW	Universal joint	Figure 7.23: (ii) RB	forces are absorbed	Figure 7.23: (i) DW	Absorbing forces	Figure 7.23: (v) TM
			Rotate gears only from steering wheel	Steering box allows rotation	Figure 7.24: (ii) JH	rotate the steering wheel to steer the car	Figure 7.24: (iv) MS	gears move only when steering occurs	Figure 7.24: (v) DW	Steering column	Figure 7.24: (vii) TW
		Guide the steering wheel in direction desired	Hold the steering wheel firmly	Hands grab wheel grips firmly	Figure 7.25: (i) AK	Hold Firmly	Figure 7.25:(iii) RB	A firm grip from both hands	Figure 7.25: (vii) TW	A Good grip on the steering wheel	Figure 7.25: (v) MS
			Turn the steering wheel when adjusting to external forces	adjustments made when steering due to external factors	Figure 7.26: (v) DW	Push and pull on steering wheel	Figure 7.26: (iii) JH	Wheel rotates in both directions	Figure 7.26: (i) AK	Steering wheel adjustments	Figure 7.26: (vii) TM
			Allow horizontal motion with steering rod	Rotation transfers forces	Figure 7.27: (i) AK	Rack and pinion	Figure 7.27: (iii) RB	Moving horizontally to allow steering	Figure 7.27: (v) MS	Easy horizontal path	Figure 7.27: (viii) TM
		Revert kinetic energy into another	Allow gears to move in both	Gears rotates simultaneousl	Figure 7.28: (vi) AK	gears move both directions	Figure 7.28: (i) DW	Driver gear directs turning directio	Figure 7.28: (iv) JH	gears move freely	Figure 7.28: (ii) DW

		directio n	directio ns	y				n			
			Allow steerin g rod to move horizon tally in both directio ns	Turn wheel to move left and right	Figure 7.29: (v) TW	Rack and pinion	Figure 7.29: (iii) RB	Worm and sector	Figure 7.29: (iv) RB	Steerin g rod moves in x-directio n	Figure 7.29: (i) JH
			Transfe r energy from steerin g wheel to Steerin g shaft	energy transfer red to shaft	Figure 7.30: (iii) DW	Steerin g column	Figure 7.30: (ii) RB	No steerin g column	Figure 7.30: (i) RB	Energy from steerin g wheel to shaft	Figure 7.30: (v) TW
			Transla te motion from gears to steerin g rod	Gears translat e motion betwee n two compo nents	Figure 7.31: (i) JH	Compo nents interpre t forces	Figure 7.31: (ii) JH	Rack and pinion	Figure 7.31: (vi) TW	Steerin g box system	Figure 7.31: (vii) MS
		Chann el mecha nical energy to turn vehicle	Move tires side to side from steerin g rod	Steerin g causes tires turn	Figure 7.32: (iv) AK	Worm and Sector	Figure 7.32: (vi) RB	Rack and Pinion	Figure 7.32: (v) RB	tires move when steerin g wheel moves	Figure 7.32: (i) DW
	Transm it motion of the vehicle	Grasp the steerin g wheel firmly	Contact the steerin g wheel tactfully	Maintai n contact with steerin g wheel	Figure 7.33: (iii) JH	9 to 3 hand placem ent	Figure 7.33: (i) TW	Grab wheel positio n and grip	Figure 7.33: (v) AK	Forces of hand positio n on wheel	Figure 7.33: (vi) Ak

		Hold the steering wheel with hand	Grab wheel position and grip	Figure 7.34: (iii) AK	Extend arm towards steering wheel	Figure 7.34: (i) JH	Firm grip on the wheel	Figure 7.34: (v) MS	Hold steering wheel	Figure 7.34: (vii) TM
		Contact the steering wheel firmly	grab steering wheel firmly	Figure 7.35: (v) DW	Firm grip on the wheel	Figure 7.35: (iii) MS	A Good grip on the steering wheel	Figure 7.35: (iv) MS	Higher hand placement	Figure 7.35: (i) RB
	Maintain grip on the steering wheel	Hold the steering wheel until leaving the vehicle	Hold steering with both hands at all times	Figure 7.36: (vi) TW	Maintain Contact	Figure 7.36: (iii) RB	properly grip steering wheel	Figure 7.36: (viii) DW	Leverage steering wheel	Figure 7.36: (i) JH
		Avoid extreme conditions of the course	Manuevering through obstacles	Figure 7.37: (v) TM	Worm and sector	Figure 7.37: (ii) RB	Rack and pinion	Figure 7.37: (i) RB	Move around trees	Figure 7.37: (vi) TM
Stablliz e vehicle alignm ent to stay on course	Orient steering wheel based on drivers view	Drive along calmer environmental conditions	Follwing the grounds pattern	Figure 7.38: (v) MS	easier ride	Figure 7.38: (iv) DW	Driving through safe areas	Figure 7.38: (vii) TM	steady drive due to reduced obstacles	Figure 7.38: (iii) DW
Reduce effort of driver	Maintain Power Steering	Apply pressure to reduce force input	force decreased when pressure applied	Figure 7.39: (i) DW	Slight rotation causes car to turn	Figure 7.39: (v) AK	Fluid/power flows from pump to steering rod	Figure 7.39: (iv) AK	Power steering pump	Figure 7.39: (iii) RB

			Absorb external force to reduce driver control	Absorbing forces for easier control	Figure 7.40: (vii) TM	wheel relieves excess forces	Figure 7.40: (ii) AK	using movement to reduce impact	Figure 7.40: (v) MS	Firm grip to maintain control	Figure 7.40: (iii) TW
			Reduce the turn of the steering wheel to perform a sharp maneuver	Align steering wheel	Figure 7.41: (i) JH	Wheels stop before contact with chassis	Figure 7.41: (v) MS	Small rotation causes wheels to turn	Figure 7.41:(iv) AK	rotation of wheel transfers force to wheels	Figure 7.41: (iii) AK
		adjusting steering effort	Allow easy motion of gears	Secure gear placement to transfer easily	Figure 7.42: (iii) JH	fluid motion	Figure 7.42: (ii) DW	Spur gear	Figure 7.42: (v) RB	motion of gears is easier	Figure 7.42: (i) DW
			Allow easy motion of steering rod	Components engage together perfectly	Figure 7.43: (iii) JH	Worm and sector	Figure 7.43: (ii) RB	Rack and pinion	Figure 7.43: (i) RB	No locking of joints	Figure 7.43: (vii) TW
			Allow easy motion of steering wheel	Proper connecting points	Figure 7.44: (v) TW	fluid motion of steering wheel	Figure 7.44: (i) DW	Rack and pinion	Figure 7.44: (iii) RB	easier handling	Figure 7.44: (ii) DW

4.3 Concept Evaluation

This selection will discuss the group evaluations for each level 3 sub-function concept. The group breaks down each concept and through a series of ratings the group was able to end on two concepts that would be considered for the system for the project. The group was also able to end on a final design for each level 3 sub-function.

4.3.1 Requirements/ Criteria for each Level 3 Sub-function

In this section, the group will break down a handful of questions that were given to them from the professors. The questions will be stated below with the group's responses that will be the requirements/ criteria of level 3 sub-functions.

- What customer requirements are related to the project? Make a list of all customer requirements
    1. Safety
    2. Is this reliable?
    3. Is it durable?
    4. Is this affordable?
    5. Is this high performance?
    6. Is it easy to use?
    7. Is this efficient?
    8. Is this high quality?
    9. Can this be used in other vehicles?
    10. Will this be low maintenance?
    11. Is it easy to turn?
    12. Can it handle all weather conditions?
- What operating environments are related to the project? Look at all of your operating environments.
    13. Can it withstand water?
    14. Can it operate in muddy conditions?
    15. Can it operate in off-road obstacles?
    16. Can it operate on concrete?
    17. Can it operate in hot/cold temperatures?
    18. Can it withstand unexpected external forces?
- What constraints can affect the project? List all of your project constraints.

    19. Can it hold the weight of the vehicle and driver?

- Can the technology/concept be manufactured with known processes?
    20. Can this be manufactured with known processes?
- Is there a need for experimentation to ascertain how well certain project function can be achieved?

21. What simulation software is used?
22. Options for prototype testing?

- What are the project objectives? Look at your list of objectives

23. Driver safety
24. Easy Repair
25. High range of motion
26. Withstand high speeds
27. Stability of vehicle
28. Sustainable
29. Able to adjust to different terrains
30. Is the alignment correct?

Table 4.7 below displays the suspension criteria identified by each subfunction. In a collaborative effort, the group decided the more efficient way to group our required criteria was to create nine available slots to show how each individual criteria affects a particular level 3 sub function. All nine slots for ~~table~~ 4.7 are numbered 1-~~36~~ for each sub function. The ~~36~~ requirements/criteria options are listed above.

Table 4.7 Criteria Affecting Previously identified Sub-functions for Suspension System

Overall Function	Level 1 Sub-functions	Level 2 Sub-functions	Level 3 Sub-functions	Requirements/Criteria Affecting Sub-Function								
				1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Absorb and withstand forces from off-road conditions and the vehicle	Maintain contact with the ground	Force tires down with internal components	Release force from springs to the ground	5	9	15	16	18	20	23	~~35~~	~~36~~
			Release energy from struts to the tires	1	2	3	7	18	24	33	34	35
		Absorb All forces channeled from environment	Compress the springs from the external forces	2	3	5	10	12	17	18	24	25
			Compress the struts from external forces	2	3	5	10	12	17	18	24	25
			Rotate the control arms to decrease force intake	2	3	9	15	16	18	28	31	35

Sustain mobility of moving parts	Allow freedom of suspension components	Rotating of control arms to absorb excess forces	3	5	8	9	10	18	23	30	35
		Rotating of ball joints to absorb excess forces	3	4	5	10	12	14	17	30	31
		Compressing of struts and springs from external forces	3	5	8	12	14	15	18	20	35
	Stabilize movement of vehicle	Absorb forces with struts and springs	1	3	5	10	12	14	15	17	20
		Move control arms based off environment	2	4	5	9	12	15	23	31	35
		Rotate ball joints from contact of force	1	2	4	10	13	14	15	24	31
Distribute forces throughout suspension system	Channel forces through multiple pathways	Collect force through the struts	3	4	5	12	18	24	30	33	35
		Collect force through springs	3	4	5	12	20	24	30	33	35
		Transfer force through ball joint	2	3	7	12	14	18	24	30	31
	Transfers loads from components to wheels	Transfer load from control arms	5	7	10	12	14	16	17	30	33
		Transfer load from springs	2	7	8	10	12	18	20	24	30
		Transfer load from struts	5	8	9	10	12	15	23	30	35
Support external	Counter Gravitation	Release force from spring to the ground	2	4	12	17	20	24	32	33	34

and internal forces from vehicle conditions	al Force	Release force from struts to ground	2	5	10	12	14	18	23	30	33
	Ability to manage centrifugal forces	Transfer vehicle load through struts while turning	2	4	5	12	15	28	31	33	34
		Transfer vehicle load through springs while turning	2	4	5	12	15	28	31	33	34
		Rotate control arms while turning	1	2	4	10	12	15	31	33	35

Table 4.8 below displays the steering criteria identified by each subfunction. In a collaborative effort, the group decided the more efficient way to group our required criteria was to create nine available slots to show how each individual criteria affects a particular level 3 sub function. At least 6 slots for Table 4.8 are numbered 1-~~36~~ for each sub function. The ~~36~~ requirements/criteria options are listed above.

Table 4.8 Criteria Affecting Previously identified Sub-functions for Steering System

Overall Function	Level 1 Sub-functions	Level 2 Sub-functions	Level 3 Sub-functions	Requirements/Criteria Affecting Sub-Function								
				1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Convert driver input to change the direction of the vehicle	Maintain control of vehicle	Prevent unwanted motion due to external factors	Allow forces to be absorbed	3	5	7	12	14	15	17	18	~~34~~
			Rotate gears only from steering wheel	1	2	5	10	11	14	15	18	30
		Guide the steering wheel in direction desired	Hold the steering wheel firmly	1	2	6	11	28	~~32~~			
			Turn the steering wheel when adjusting to external	1	2	6	11	12	15	18	32	35

			forces									
			Allow horizontal motion with steering rod	2	3	7	12	15	18	30	32	36
		Revert kinetic energy into another direction	Allow gears to move in both directions	2	3	4	7	10	12	14	24	30
			Allow steering rod to move horizontally in both directions	2	3	7	12	15	18	30	32	36
	Transmit motion of the vehicle	Channel mechanical energy to turn vehicle	Transfer energy from steering wheel to Steering shaft	2	4	5	7	11	12	15	18	24
			Translate motion from gears to steering rod	2	5	7	11	12	14	18	30	36
			Move tires side to side from steering rod	2	5	7	11	12	14	16	18	36
		Grasp the steering wheel firmly	Contact the steering wheel tactfully	1	2	6	11	28	32			
			Hold the steering wheel with hand	1	2	6	11	28	32			

Stabilize vehicle alignment to stay on course	Maintain grip on the steering wheel	Contact the steering wheel firmly	1	2	6	11	28	32			
		Hold the steering wheel until leaving the vehicle	1	2	6	11	28	32			
	Orient steering wheel based on drivers view	Avoid extreme conditions of the course	1	3	4	5	6	11	12	18	35
		Drive along calmer environmental conditions	1	2	6	7	11	12	31	34	35
Reduce effort of driver	Maintain Power Steering	Apply pressure to reduce force input	1	2	4	5	7	10	11	12	18
		Absorb external force to reduce driver control	3	5	7	11	12	18	28	29	35
		Reduce the turn of the steering wheel to perform a sharp maneuver	2	4	5	7	8	11	12	18	30
	adjusting steering effort	Allow easy motion of gears	1	2	7	8	11	30	31	32	34
		Allow easy motion of steering rod	1	2	7	8	11	30	31	32	34

			Allow easy motion of steering wheel	1	2	7	8	11	30	31	32	34

4.3.2 Evaluating Concepts with Requirements/ Criteria

The tables below present twenty-two GO-NO-GO tables created from the level 3 sub-functions the group created for the suspension system. The group collaboratively decided on the scores for the individual criterions pertaining to each level 3 function. Scores presenting "6" or above were considered GO's and scores presenting "5" or below were considered "NO-GO's." The group took all the GO's from these tables and pushed them forward for evaluations for the next section.

Table 4.9 GO-NO-GO Tables for Release force from springs to the ground

Release force from springs to the ground	Double Wishbone		Trailing		McPherson		Semi-Trailing	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Is it high performance?	10	GO	4	NO-GO	8	GO	6	GO
Is this efficient?	7	GO	7	GO	7	GO	9	GO
Can it withstand unexpected external forces?	9	GO	5	NO-GO	8	GO	5	NO-GO
Can it hold the weight of the vehicle and driver?	10	GO	5	NO-GO	9	GO	7	GO
Overall Decision		GO		NO-GO		GO		GO

Table 4.10 GO-NO-GO Table for Release energy from struts to the tires

Release energy from struts to the tires	Trailing		McPherson		Semi-Trailing		Double Wishbone	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Is this reliable?	5	NO-GO	8	GO	6	GO	10	GO
Is it durable?	8	GO	7	GO	5	NO-GO	9	GO
Can it withstand unexpected external forces?	7	GO	5	NO-GO	4	NO-GO	8	GO
Can it withstand unexpected external forces?	9	GO	7	GO	6	GO	9	GO
Overall Decision		GO		GO		NO-GO		GO

Table 4.11 GO-NO-GO Table for Compress the springs from the external forces

Compress the springs from the external forces	Semi-Trailing		Trailing		McPherson		Double Wishbone	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Is this reliable?	6	NO-GO	6	GO	8	GO	10	GO
Is it high performance?	8	GO	5	NO-GO	7	GO	9	GO
Can it withstand unexpected external forces?	7	GO	5	NO-GO	8	GO	8	GO
How are we going to test prototypes?	8	GO	5	NO-GO	9	GO	9	GO
Overall Decision		GO		NO-GO		GO		GO

Table 4.12 GO-NO-GO Table for Compress the springs from the external forces

Compress the struts from external forces	McPherson		Trailing		Double Wishbone		Semi-Trailing	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Can it withstand unexpected external forces?	7	GO	5	NO-GO	9	GO	5	NO-GO
Is it durable?	8	GO	7	GO	8	GO	6	GO
Is it reliable?	9	GO	6	GO	9	GO	6	GO
Is it high performance?	7	GO	8	GO	9	GO	4	NO-GO
Overall Decision		GO		GO		GO		NO-GO

Table 4.13 GO-NO-GO Table for Rotate the control arms to decrease force intake

Rotate the control arms to decrease force intake	Semi-Trailing		Trailing		Double Wishbone		McPherson	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Is it reliable?	7	GO	8	GO	9	GO	7	GO
High range of motion	6	GO	6	GO	8	GO	6	GO
Can it operate in off-road obstacles?	8	GO	7	GO	7	GO	5	NO-GO
Driver Safety	8	GO	9	GO	9	GO	5	NO-GO
Overall Decision		GO		GO		GO		NO-GO

Table 4.14 GO-NO-GO Table for Rotating of control arms to absorb excess forces

Rotating of control arms to absorb excess forces	Trailing	Double Wishbone	McPherson	Semi-Trailing

Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Is this high performance?	6	GO	9	GO	7	GO	7	GO
Able to adjust to different terrains	5	NO-GO	8	GO	6	GO	6	GO
Can this be manufactured with known processes?	5	NO-GO	9	GO	5	NO-GO	7	GO
Is it durable?	5	NO-GO	8	GO	6	GO	4	NO-GO
Overall Decision		NO-GO		GO		GO		GO

Table 4.15 GO-NO-GO Table for Rotating of control arms to absorb excess forces

Rotating of ball joints to absorb excess forces	Double Wishbone		McPherson		Trailing		Semi-Trailing	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Is it durable?	9	GO	9	GO	7	GO	4	NO-GO
Can it operate in muddy conditions?	7	GO	7	GO	8	GO	7	GO
High range of motion	8	GO	4	NO-GO	8	GO	5	NO-GO
Is it high performance?	9	GO	6	GO	5	NO-GO	6	GO
Overall Decision		GO		GO		GO		NO-GO

Table 4.16 GO-NO-GO Table for Compressing of struts and springs from external forces

Compressing of struts and springs from external forces	Trailing	McPherson	Semi-Trailing	Double Wishbone

Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Is it durable?	6	GO	4	NO-GO	6	GO	8	GO
Is this high quality?	9	GO	3	NO-GO	6	GO	9	GO
Can it operate in off-road obstacles?	8	GO	5	NO-GO	5	NO-GO	9	GO
Can it hold the weight of the vehicle and driver?	8	GO	9	GO	8	GO	7	GO
Overall Decision		GO		NO-GO		GO		GO

Table 4.17 GO-NO-GO Table for Absorb forces with struts and springs

Absorb forces with struts and springs	Double Wishbone		McPherson		Trailing		Semi-Trailing	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Is it durable?	9	GO	8	GO	7	GO	8	GO
Can it handle all weather conditions?	6	GO	7	GO	4	NO-GO	6	GO
Is it high performance?	5	NO-GO	9	GO	6	GO	4	NO-GO
Safety	7	GO	8	GO	4	NO-GO	7	GO
Overall Decision		GO		GO		NO-GO		GO

Table 4.18 GO-NO-GO Table for Move control arms based off environment

Move control arms based off environment	Double Wishbone		Semi-Trailing		McPherson		Trailing	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Is this high performance?	9	GO	4	NO-GO	8	GO	4	NO-GO

Able to adjust to different terrains	8	GO	6	GO	8	GO	4	NO-GO
Can it handle all weather conditions?	7	GO	6	GO	7	GO	5	NO-GO
High range of motion	9	GO	8	GO	6	GO	7	GO
Overall Decision		GO		GO		GO		NO-GO

Table 4.19 GO-NO-GO Table for Rotate ball joints from contact of force

Rotate ball joints from contact of force	McPherson		Semi-Trailing		Trailing		Double Wishbone	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Safety	6	GO	6	GO	4	NO-GO	7	GO
Is this reliable?	4	NO-GO	5	NO-GO	6	GO	9	GO
Can it operate on off-road obstacles?	8	GO	7	GO	5	NO-GO	8	GO
High range of motion	8	GO	9	GO	6	GO	9	GO
Overall Decision		GO		GO		NO-GO		GO

Table 4.20 GO-NO-GO Table for Collect force through the struts

Collect force through the struts	Double Wishbone		Trailing		Semi-Trailing		McPherson	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Is it durable?	9	GO	4	NO-GO	8	GO	7	GO
Is this high performance?	7	GO	8	GO	6	GO	5	NO-GO

Can it withstand unexpected external forces?	9	GO	7	GO	7	GO	6	GO
Able to adjust to different terrains	8	GO	6	GO	7	GO	4	NO-GO
Overall Decision		GO		GO		GO		NO-GO

Table 4.21 GO-NO-GO Table for Collect force through springs

Collect force through springs	Double Wishbone		Trailing		Semi-Trailing		McPherson	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Is it durable?	7	GO	4	NO-GO	8	GO	6	GO
Is this high performance?	9	GO	4	NO-GO	6	GO	7	GO
Stability of vehicle	8	GO	5	NO-GO	7	GO	5	NO-GO
Can it hold the weight of the vehicle and driver?	9	GO	7	GO	4	NO-GO	8	GO
Overall Decision		GO		NO-GO		GO		GO

Table 4.22 GO-NO-GO Table for Transfer force through ball joint

Transfer force through ball joint	Double Wishbone		McPherson		Semi-Trailing		Trailing	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Is this reliable?	8	GO	7	GO	5	NO-GO	5	NO-GO
Can it withstand unexpected external forces?	7	GO	7	GO	8	GO	4	NO-GO
High range of motion	9	GO	5	NO-GO	7	GO	6	GO

Is this efficient?	9	GO	8	GO	6	GO	7	GO
Overall Decision		GO		GO		GO		NO-GO

Table 4.23 GO-NO-GO Table for Transfer load from control arms

Transfer load from control arms	Semi-Trailing		McPherson		Trailing		Double Wishbone	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Is this high performance?	7	GO	8	GO	5	NO-GO	7	GO
Stability of vehicle	5	NO-GO	8	GO	5	NO-GO	9	GO
Is this efficient?	8	GO	6	GO	4	NO-GO	8	GO
Can it handle all weather conditions?	6	GO	5	NO-GO	8	GO	9	GO
Overall Decision		GO		GO		NO-GO		GO

Table 4.24 GO-NO-GO Table forTransfer load from springs

Transfer load from springs	McPherson		Trailing		Double Wishbone		Semi-Trailing	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Is this reliable?	7	GO	6	GO	7	GO	6	GO
What simulation software are we going to use?	6	GO	8	GO	9	GO	4	NO-GO
Is this efficient?	9	GO	5	NO-GO	8	GO	5	NO-GO
Can it hold the weight of the vehicle and driver?	7	GO	7	GO	9	GO	7	GO
Overall Decision		GO		GO		GO		NO-GO

Table 4.25 GO-NO-GO Table for Transfer load from struts

Transfer load from struts	Trailing		McPherson		Double Wishbone		Semi-Trailing	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Can it operate in off-road obstacles?	5	NO-GO	5	NO-GO	7	GO	5	NO-GO
Is this high performance ?	7	GO	8	GO	9	GO	7	GO
Is this high quality?	6	GO	6	GO	9	GO	4	NO-GO
Can it handle all weather conditions?	9	GO	9	GO	8	GO	6	GO
Overall Decision		GO		GO		GO		NO-GO

Table 4.26 GO-NO-GO Table for Release force from spring to the ground

Release force from spring to the ground	Trailing		McPherson		Semi-Trailing		Double Wishbone	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Can it hold the weight of the vehicle?	5	NO-GO	7	GO	4	NO-GO	7	GO
Sustainable	8	GO	6	GO	5	NO-GO	9	GO
Is this reliable?	6	GO	7	GO	5	NO-GO	8	GO
Can it handle all weather conditions?	7	GO	8	GO	6	GO	8	GO
Overall Decision		GO		GO		NO-GO		GO

Table 4.27 GO-NO-GO Table for Release force from struts to ground

Release force from struts to ground	Semi-Trailing		Double Wishbone		McPherson		Trailing	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Is this reliable?	5	NO-GO	7	GO	6	GO	6	GO
Can this withstand unexpected external forces?	9	GO	9	GO	8	GO	5	NO-GO
Stability of vehicle	7	GO	8	GO	8	GO	4	NO-GO
Is this high performance?	7	GO	9	GO	7	GO	7	GO
Overall Decision		GO		GO		GO		NO-GO

Table 4.28 GO-NO-GO Table for Transfer vehicle load through struts while turning

Transfer vehicle load through struts while turning	McPherson		Trailing		Semi-Trailing		Double Wishbone	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Stability of vehicle	8	GO	4	NO-GO	5	NO-GO	8	GO
Is this reliable?	7	GO	5	NO-GO	8	GO	7	GO
Can it handle all weather conditions?	5	NO-GO	3	NO-GO	7	GO	9	GO
Is this high performance?	6	GO	7	GO	6	GO	9	GO
Overall Decision		GO		NO-GO		GO		GO

Table 4.29 GO-NO-GO Table for Transfer vehicle load through springs while turning

Transfer vehicle load through springs while turning	Trailing		Semi-Trailing		McPherson		Double Wishbone	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Driver safety	7	GO	4	NO-GO	8	GO	10	GO
Stability of vehicle	8	GO	6	GO	7	GO	8	GO
Sustainable	6	GO	5	NO-GO	6	GO	9	GO
Is this high performance?	7	GO	3	NO-GO	8	GO	8	GO
Overall Decision		GO		NO-GO		GO		GO

Table 4.30 GO-NO-GO Table for Rotate control arms while turning

Rotate control arms while turning	Trailing		Semi-Trailing		Double Wishbone		McPherson	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Safety	7	GO	4	NO-GO	9	GO	6	GO
Is this reliable?	8	GO	3	NO-GO	7	GO	8	GO
Can it handle all weather conditions?	7	GO	5	NO-GO	8	GO	7	GO
High range of motion	9	GO	6	GO	10	GO	9	GO
Overall Decision		GO		NO-GO		GO		GO

The tables below present twenty-two GO-NO-GO tables created from the level 3 sub-functions the group created for the steering system. The group collaboratively decided on the scores for the individual criterions pertaining to each level 3 function. Scores presenting “6” or above were considered GO’s and scores presenting “5” or below were considered “NO-GO’s.” The group took all the GO’s from these tables and pushed them forward for evaluations for the next section.

Table 4.31 GO-NO-GO Tables for Allow forces to be absorbed

Allow forces to be absorbed	Recirculating Ball		Worm and Sector		Hydrostatic		Rack and Pinion	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Is it durable?	7	GO	8	GO	7	GO	9	GO
Is this high performance?	6	GO	7	GO	5	NO-GO	8	GO
Is this efficient?	4	NO GO	3	NO-GO	4	NO-GO	6	GO
Can it handle all weather conditions?	8	GO	8	GO	8	GO	8	GO
Overall Decision		GO		GO		NO-GO		GO

Table 4.32 GO-NO-GO Tables for Rotate gears only from steering wheel

Rotate gears only from steering wheel	Rack and Pinion		Hydrostatic		Worm and Sector		Recirculating Ball	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
safety	7	GO	6	GO	6	GO	6	GO
Is this reliable?	8	GO	7	GO	4	NO-GO	4	NO-GO
Is this high performance?	9	GO	7	GO	6	GO	6	GO
Will this be low maintenance?	8	GO	5	NO-GO	6	GO	5	GO
Overall Decision		GO		GO		GO		NO-GO

Table 4.33 GO-NO-GO Tables for Hold the steering wheel firmly

Hold the steering wheel firmly	Rack and Pinion		Hydrostatic		Recirculating Ball		Worm and Sector	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO

safety	9	GO	8	GO	7	GO	8	GO
Is this reliable?	7	GO	6	GO	4	NO-GO	7	GO
Is it easy to use?	8	GO	5	NO-GO	5	NO-GO	5	NO-GO
Is it easy to turn?	9	GO	7	GO	7	GO	7	GO
Overall Decision		GO		GO		NO-GO		GO

Table 4.34 GO-NO-GO Tables for Turn the steering wheel when adjusting to external forces

Turn the steering wheel when adjusting to external forces	Worm and Sector		Hydrostatic		Rack and Pinion		Recirculating Ball	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
safety	7	GO	7	GO	9	GO	7	GO
Is this reliable?	6	GO	5	NO-GO	8	GO	5	NO-GO
Is it easy to use?	4	NO-GO	7	GO	7	GO	4	NO-GO
Is it easy to turn?	7	GO	8	GO	8	GO	6	GO
Overall Decision		GO		GO		GO		NO-GO

Table 4.35 GO-NO-GO Tables for Allow horizontal motion with steering rod

Allow horizontal motion with steering rod	Rack and Pinion		Hydrostatic		Worm and Sector		Recirculating Ball	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Is this reliable?	8	GO	6	GO	6	GO	5	NO-GO
Is it durable?	7	GO	7	GO	5	GO	6	GO
Is this efficient?	8	GO	6	GO	4	NO-GO	4	NO-GO

Can it handle all weather conditions?	7	GO	5	NO-GO	6	GO	5	GO
Overall Decision		GO		GO		GO		NO-GO

Table 4.36 GO-NO-GO Tables for Allow gears to move in both directions

Allow gears to move in both directions	Hydrostatic		Recirculating Ball		Worm and Sector		Rack and Pinion	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Is this reliable?	6	GO	4	NO-GO	7	GO	9	GO
Is it durable?	5	NO-GO	5	NO-GO	7	GO	9	GO
Is this affordable?	7	GO	5	GO	6	GO	9	GO
Is this efficient?	8	GO	6	GO	5	NO-GO	9	GO
Overall Decision		GO		NO-GO		GO		GO

Table 4.37 GO-NO-GO Tables for Allow steering rod to move horizontally in both directions

Allow steering rod to move horizontally in both directions	Recirculating Ball		Worm and Sector		Hydrostatic		Rack and Pinion	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Is this reliable?	4	NO-GO	5	NO-GO	5	NO-GO	8	GO
Is it durable?	5	GO	6	GO	6	GO	8	GO
Is this efficient?	5	NO-GO	8	GO	7	GO	8	GO
Can it handle all weather conditions?	4	GO	8	GO	8	GO	9	GO
Overall Decision		NO-GO		GO		GO		GO

Table 4.38 GO-NO-GO Tables for Transfer energy from steering wheel to Steering shaft

Transfer energy from steering wheel to Steering shaft	Recirculating Ball		Worm and Sector		Rack and Pinion		Hydrostatic	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Is this reliable?	7	GO	8	GO	8	GO	6	GO
Is this affordable?	5	NO-GO	5	NO-GO	7	GO	5	NO-GO
Is this high performance?	6	GO	6	GO	8	GO	5	NO-GO
Is this efficient?	7	GO	6	GO	7	GO	4	NO-GO
Overall Decision		NO-GO		NO-GO		GO		NO-GO

Table 4.39 GO-NO-GO Tables for Translate motion from gears to steering rod

Translate motion from gears to steering rod	Rack and Pinion		Worm and Sector		Recirculating Ball		Hydrostatic	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Is this reliable?	8	GO	6	GO	4	NO-GO	5	GO
Is this high performance?	7	GO	5	NO-GO	6	GO	4	NO-GO
Is this efficient?	8	GO	6	GO	5	GO	4	NO-GO
Is it easy to turn?	9	GO	6	GO	6	GO	5	NO-GO
Overall Decision		GO		GO		GO		NO-GO

Table 4.40 GO-NO-GO Tables for Translate motion from gears to steering rod

Move tires side to side from steering rod	Recirculating Ball		Rack and Pinion		Hydrostatic		Worm and Sector	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Is this reliable?	6	GO	7	GO	4	NO-GO	4	NO-GO

Is this high performance?	6	GO	8	GO	5	GO	5	GO
Is this efficient?	5	NO-GO	8	GO	6	GO	6	GO
Is it easy to turn?	5	NO-GO	8	GO	6	GO	6	GO
Overall Decision		NO-GO		GO		GO		GO

Table 4.41 GO-NO-GO Tables for Contact the steering wheel tactfully

Contact the steering wheel tactfully	Hydrostatic		Rack and Pinion		Worm and Sector		Recirculating Ball	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
safety	6	GO	8	GO	7	GO	4	NO-GO
Is this reliable?	4	NO-GO	9	GO	6	GO	4	NO-GO
Is it easy to use?	6	GO	8	GO	3	NO-GO	5	NO-GO
Is it easy to turn?	4	NO-GO	9	GO	6	GO	5	NO-GO
Overall Decision		NO-GO		GO		GO		NO-GO

Table 4.42 GO-NO-GO Tables for Hold the steering wheel with hand

Hold the steering wheel with hand	Hydrostatic		Rack and Pinion		Worm and Sector		Recirculating Ball	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Is it easy to turn?	4	NO-GO	9	GO	7	GO	4	NO-GO
safety	6	GO	8	GO	6	GO	4	NO-GO
Is this reliable?	6	GO	9	GO	7	GO	5	GO
Is it easy to use?	5	GO	9	GO	5	NO-GO	5	NO-GO
Overall Decision		GO		GO		GO		NO-GO

Table 4.43 GO-NO-GO Tables for Hold the steering wheel with hand

Contact the steering wheel firmly	Recirculating Ball		Worm and Sector		Hydrostatic		Rack and Pinion	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
safety	4	NO-GO	7	GO	6	GO	9	GO
Is this reliable?	4	NO-GO	6	GO	6	GO	9	GO
Is it easy to use?	6	GO	6	GO	7	GO	8	GO
Is it easy to turn?	5	NO-GO	5	NO-GO	4	NO-GO	8	GO
Overall Decision		NO-GO		GO		GO		GO

Table 4.44 GO-NO-GO Tables for Hold the steering wheel until leaving the vehicle

Hold the steering wheel until leaving the vehicle	Recirculating Ball		Worm and Sector		Rack and Pinion		Hydrostatic	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
safety	7	GO	7	GO	8	GO	5	NO-GO
Is this reliable?	5	NO-GO	7	GO	8	GO	7	GO
Is it easy to use?	4	NO-GO	5	NO-GO	9	GO	8	GO
Is it easy to turn?	6	GO	7	GO	9	GO	7	GO
Overall Decision		NOGO		GO		GO		GO

Table 4.45 GO-NO-GO Tables for Avoid extreme conditions of the course

Avoid extreme conditions of the course	Hydrostatic		Worm and Sector		Rack and Pinion		Recirculating Ball	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
safety	7	GO	6	NO-GO	8	GO	7	GO
Is it durable?	7	GO	8	GO	9	GO	5	NO-GO

Is this affordable?	5	NO-GO	8	GO	9	GO	5	NO-GO
Is this high performance?	6	GO	7	GO	8	GO	4	NO-GO
Overall Decision		GO		GO		GO		NO-GO

Table 4.46 GO-NO-GO Tables for Drive along calmer environment

Drive along calmer environmental conditions	Recirculating Ball		Worm and Sector		Rack and Pinion		Hydrostatic	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
safety	5	NO-GO	8	GO	9	GO	4	NO-GO
Is this reliable?	4	NO-GO	5	NO-GO	9	GO	7	GO
Is it easy to use?	6	GO	7	GO	8	GO	7	GO
Is this efficient?	4	NO-GO	6	GO	8	GO	6	GO
Overall Decision		NO-GO		GO		GO		GO

Table 4.47 GO-NO-GO Tables for Apply pressure to reduce force input

Apply pressure to reduce force input	Rack and Pinion		Recirculating Ball		Worm and Sector		Hydrostatic	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
safety	8	GO	4	NO-GO	7	GO	6	GO
Is this reliable?	9	GO	5	NO-GO	7	GO	7	GO
Is this affordable?	9	GO	7	GO	8	GO	5	NO-GO
Is this high performance?	8	GO	4	NO-GO	5	NO-GO	6	GO
Overall Decision		GO		NO-GO		GO		GO

Table 4.48 GO-NO-GO Tables for Absorb external force to reduce driver control

Absorb external force to reduce driver control	Hydrostatic		Recirculating Ball		Worm and Sector		Rack and Pinion	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Is it durable?	7	GO	4	NO-GO	8	GO	9	GO
Is this high performance?	7	GO	6	GO	7	GO	9	GO
Is this efficient?	4	NO-GO	5	NO-GO	7	GO	8	GO
Is it easy to turn?	6	GO	4	NO-GO	5	NO-GO	9	GO
Overall Decision		GO		NO-GO		GO		GO

Table 4.49 GO-NO-GO Tables for Reduce the turn of the steering wheel to perform a sharp maneuver

Reduce the turn of the steering wheel to perform a sharp maneuver	Rack and Pinion		Recirculating Ball		Hydrostatic		Worm and Sector	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
Is this reliable?	9	GO	6	GO	7	GO	8	GO
Is this affordable?	9	GO	5	NO-GO	7	GO	7	GO
Is this high performance?	9	GO	4	NO-GO	5	NO-GO	5	NO-GO
Is this efficient?	8	GO	4	NO-GO	6	GO	7	GO
Overall Decision		GO		NO-GO		GO		GO

Table 4.50 GO-NO-GO Tables for Allow easy motion of gears

Allow easy motion of gears	Hydrostatic	Worm and Sector	Rack and Pinion	Recirculating Ball

Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
safety	5	NO-GO	8	GO	9	GO	8	GO
Is this reliable?	5	NO-GO	7	GO	9	GO	6	GO
Is this efficient?	6	GO	7	GO	9	GO	6	GO
Is this high quality?	4	NO-GO	5	NO-GO	8	GO	5	NO-GO
Overall Decision		NO-GO		GO		GO		GO

Table 4.51 GO-NO-GO Tables for Allow easy motion of steering rod

Allow easy motion of steering rod	Hydrostatic		Worm and Sector		Rack and Pinion		Recirculating Ball	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
safety	6	GO	7	GO	8	GO	4	NO-GO
Is this reliable?	7	GO	5	NO-GO	9	GO	5	NO-GO
Is this efficient?	4	NO-GO	7	GO	9	GO	4	NO-GO
Is this high quality?	8	GO	7	GO	9	GO	6	GO
Overall Decision		GO		GO		GO		NO-GO

Table 4.52 GO-NO-GO Tables for Allow easy motion of steering wheel

Allow easy motion of steering wheel	Worm and Sector		Recirculating Ball		Hydrostatic		Rack and Pinion	
Criteria/Requirements	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO	Score	GO-NO-GO
safety	7	GO	4	NO-GO	6	GO	9	GO
Is this reliable?	8	GO	4	NO-GO	7	GO	9	GO
Is this reliable?	7	GO	6	GO	7	GO	8	GO
Is this reliable?	5	NO-GO	4	NO-GO	4	NO-GO	8	GO

Overall Decision		**GO**		**NO-GO**		**GO**		**GO**

After the GO-NO-GO tables were completed by the group, the next round of tables were created to end with two concepts that can be the design for each level 3 sub-function. At the beginning, the group created a list of requirements that each level 3 sub-function will be rated by and the tables below show each concept being rated by at least 6 requirements for that sub-function. Each requirement/criteria was weighted based on how important the requirement/ criteria was for each level 3 sub-function.

The group held a meeting and collaborated on each concept and rated the concepts. Table 4.53 shows all of the scoring for the three concepts for the suspension system that passed the GO-NO-GO scoring. In the end, the two highest scores are highlighted and were passed on to the next section.

Table 4.53 Decision matrices for Release force from springs to the ground

Release force from springs to the ground		~~Concept 1~~		~~Concept 3~~		~~Concept 4~~	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
~~Criterion 1~~	8	10	80	8	64	6	48
~~Criterion 2~~	9	7	63	7	63	9	81
~~Criterion 3~~	9	9	81	8	72	5	45
Criterion 4	5	10	50	9	45	7	35
Criterion 5	9	9	81	6	54	5	45
Criterion 6	8	8	64	7	56	6	48
Criterion 7	8	9	72	8	64	5	40
Criterion 8	8	7	56	6	48	8	64
~~Criterion 9~~	7	8	56	8	56	5	35
Total Weighted Score			603		522		441

Table 4.54 Decision matrices for Release energy from struts to the tires

Release energy from struts to the tires		Concept 1		Concept 2		Concept 4	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	10	5	50	8	80	10	100

Criterion 2	9	8	72	7	63	9	81
Criterion 3	9	7	63	5	45	8	72
Criterion 4	9	9	81	7	63	9	81
Criterion 5	9	7	63	9	81	9	81
Criterion 6	7	6	42	8	56	7	49
Criterion 7	9	7	63	6	54	9	81
Criterion 8	9	8	72	7	63	9	81
Criterion 9	8	7	56	8	64	9	72
Total Weighted Score			562		569		698

Table 4.55 Decision matrices for Compress the springs from the external forces

Compress the springs from the external forces		Concept 1		Concept 3		Concept 4	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	9	6	54	8	72	10	90
Criterion 2	9	8	72	7	63	9	81
Criterion 3	8	7	56	8	64	8	64
Criterion 4	7	8	56	9	63	9	63
Criterion 5	7	7	49	8	56	8	56
Criterion 6	6	8	48	9	54	9	54
Criterion 7	9	8	72	8	72	9	81
Criterion 8	7	6	42	7	49	9	63
Criterion 9	8	5	40	8	64	9	72
Total Weighted Score			489		557		624

Table 4.56 Decision matrices for Compress the struts from external forces

Compress the struts from external forces		Concept 1		Concept 2		Concept 3	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score

Criterion 1	9	7	63	5	45	9	81
Criterion 2	9	8	72	7	63	8	72
Criterion 3	8	9	72	6	48	9	72
Criterion 4	7	7	49	8	56	9	63
Criterion 5	7	6	42	8	56	9	63
Criterion 6	6	5	30	9	54	8	48
Criterion 7	8	7	56	7	56	7	56
Criterion 8	7	6	42	6	42	9	63
Criterion 9	8	6	48	7	56	9	72
Total Weighted Score			474		476		590

Table 4.57 Decision matrices for Rotate the control arms to decrease force intake

Rotate the control arms to decrease force intake		Concept 1		Concept 2		Concept 3	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	9	7	63	8	72	9	81
Criterion 2	9	6	54	6	54	8	72
Criterion 3	4	8	32	7	28	7	28
Criterion 4	9	8	72	9	81	9	81
Criterion 5	5	7	35	9	45	7	35
Criterion 6	9	7	63	8	72	8	72
Criterion 7	10	8	80	9	90	9	90
Criterion 8	8	6	48	7	56	9	72
Criterion 9	8	9	72	8	64	9	72
Total Weighted Score			519		562		603

Table 4.58 Decision matrices for Rotate the control arms to decrease force intake

Rotating of control arms to absorb excess forces		Concept 2		Concept 3		Concept 4	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	9	9	81	7	63	7	63
Criterion 2	8	8	64	6	48	6	48
Criterion 3	8	9	72	5	40	7	56
Criterion 4	4	8	32	6	24	4	16
Criterion 5	7	7	49	7	49	6	42
Criterion 6	9	9	81	8	72	5	45
Criterion 7	8	8	64	6	48		0
Criterion 8	9	9	81	7	63	7	63
Criterion 9	8	8	64	8	64	6	48
Total Weighted Score			588		471		381

Table 4.59 Decision matrices for Rotating of ball joints to absorb excess forces

Rotating of ball joints to absorb excess forces		Concept 1		Concept 2		Concept 3	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	9	9	81	9	81	7	63
Criterion 2	7	7	49	7	49	8	56
Criterion 3	8	8	64	4	32	8	64
Criterion 4	7	9	63	6	42	5	35
Criterion 5	7	9	63	7	49	6	42
Criterion 6	7	7	49	8	56	7	49
Criterion 7	6	6	36	6	36	5	30
Criterion 8	9	9	81	7	63	6	54
Criterion 9	8	8	64	9	72	6	48

Total Weighted Score			550		480		441

Table 4.60 Decision matrices for Compressing of struts and springs from external forces

Compressing of struts and springs from external forces		Concept 1		Concept 3		Concept 4	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	9	6	54	6	54	8	72
Criterion 2	8	9	72	6	48	9	72
Criterion 3	8	8	64	5	40	9	72
Criterion 4	7	8	56	8	56	7	49
Criterion 5	7	7	49	4	28	8	56
Criterion 6	9	8	72	6	54	9	81
Criterion 7	9	7	63	7	63	7	63
Criterion 8	9	8	72	5	45	8	72
Criterion 9	8	9	72	4	32	9	72
Total Weighted Score			574		420		609

Table 4.61 Decision matrices for Absorb forces with struts and springs

Absorb forces with struts and springs		Concept 1		Concept 2		Concept 4	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	10	9	90	8	80	8	80
Criterion 2	9	6	54	7	63	6	54
Criterion 3	8	5	40	9	72	4	32
Criterion 4	7	7	49	8	56	7	49
Criterion 5	7	7	49	8	56	5	35
Criterion 6	7	7	49	9	63	6	42
Criterion 7	9	8	72	8	72	5	45

Criterion 8	6	8	48	9	54	5	30
Criterion 9	9	8	72	9	81	7	63
Total Weighted Score			523		597		430

Table 4.62 Decision matrices for Move control arms based off environment

Move control arms based off environment		Concept 1		Concept 2		Concept 3	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	9	9	81	4	36	8	72
Criterion 2	7	8	56	6	42	8	56
Criterion 3	8	7	56	6	48	7	56
Criterion 4	4	9	36	8	32	6	24
Criterion 5	7	9	63	7	49	7	49
Criterion 6	9	9	81	6	54	7	63
Criterion 7	8	8	64	8	64	8	64
Criterion 8	8	7	56	7	56	9	72
Criterion 9	8	8	64	7	56	7	56
Total Weighted Score			557		437		512

Table 4.63 Decision matrices for Rotate ball joints from contact of force

Rotate ball joints from contact of force		Concept 1		Concept 2		Concept 4	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	10	6	60	6	60	7	70
Criterion 2	9	4	36	5	45	9	81
Criterion 3	7	8	56	7	49	8	56
Criterion 4	7	8	56	9	63	9	63
Criterion 5	7	7	49	8	56	8	56

Criterion 6	7	8	56	9	63	9	63
Criterion 7	9	7	63	8	72	8	72
Criterion 8	7	8	56	7	49	9	63
Criterion 9	8	7	56	8	64	9	72
Total Weighted Score			488		521		596

Table 4.64 Decision matrices for Collect force through the struts

Collect force through the struts		Concept 1		Concept 2		Concept 3	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	9	9	81	4	36	8	72
Criterion 2	7	7	49	8	56	6	42
Criterion 3	8	9	72	7	56	7	56
Criterion 4	7	8	56	7	49	7	49
Criterion 5	9	8	72	7	63	8	72
Criterion 6	7	9	63	8	56	8	56
Criterion 7	9	8	72	6	54	7	63
Criterion 8	9	6	54	7	63	9	81
Criterion 9	8	9	72	8	64	8	64
Total Weighted Score			591		497		555

Table 4.65 Decision matrices for Collect force through springs

Collect force through springs		Concept 1		Concept 3		Concept 4	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	9	7	63	8	72	6	54
Criterion 2	7	9	63	6	42	7	49
Criterion 3	8	8	64	7	56	5	40

Criterion 4	7	9	63	4	28	8	56
Criterion 5	9	7	63	6	54	7	63
Criterion 6	7	8	56	7	49	6	42
Criterion 7	9	9	81	8	72	7	63
Criterion 8	9	9	81	7	63	8	72
Criterion 9	8	8	64	6	48	9	72
Total Weighted Score			598		484		511

Table 4.66 Decision matrices for Transfer force through ball joint

Transfer force through ball joint		Concept 1		Concept 2		Concept 3	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	9	8	72	7	63	5	45
Criterion 2	9	7	63	7	63	8	72
Criterion 3	9	9	81	5	45	7	63
Criterion 4	7	9	63	8	56	6	42
Criterion 5	7	9	63	7	49	5	35
Criterion 6	9	7	63	9	81	6	54
Criterion 7	7	8	56	8	56	7	49
Criterion 8	9	9	81	8	72	6	54
Criterion 9	8	7	56	7	56	8	64
Total Weighted Score			598		541		478

Table 4.67 Decision matrices for Transfer load from control arms

Transfer load from control arms		Concept 1		Concept 2		Concept 4	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score

Criterion 1	8	7	56	8	64	7	56
Criterion 2	9	5	45	8	72	9	81
Criterion 3	7	8	56	6	42	8	56
Criterion 4	7	6	42	5	35	9	63
Criterion 5	7	7	49	8	56	9	63
Criterion 6	5	7	35	9	45	8	40
Criterion 7	6	8	48	8	48	9	54
Criterion 8	9	7	63	7	63	8	72
Criterion 9	9	8	72	6	54	9	81
Total Weighted Score			466		479		566

Table 4.68 Decision matrices for Transfer load from springs

Transfer load from springs		Concept 1		Concept 2		Concept 3	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	9	7	63	6	54	7	63
Criterion 2	9	6	54	8	72	9	81
Criterion 3	8	9	72	5	40	8	64
Criterion 4	7	7	49	7	49	9	63
Criterion 5	7	6	42	7	49	9	63
Criterion 6	9	7	63	7	63	9	81
Criterion 7	9	8	72	8	72	8	72
Criterion 8	7	5	35	8	56	8	56
Criterion 9	9	8	72	7	63	7	63
Total Weighted Score			522		518		606

Table 4.69 Decision matrices forTransfer load from struts

Transfer load from struts		Concept 1		Concept 2		Concept 3	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	6	5	30	5	30	7	42
Criterion 2	8	7	56	8	64	9	72
Criterion 3	4	6	24	6	24	9	36
Criterion 4	7	9	63	9	63	8	56
Criterion 5	7	7	49	8	56	9	63
Criterion 6	9	6	54	8	72	9	81
Criterion 7	8	8	64	9	72	8	64
Criterion 8	9	7	63	7	63	9	81
Criterion 9	8	7	56	8	64	9	72
Total Weighted Score			459		508		567

Table 4.70 Decision matrices for Release force from spring to the ground

Release force from spring to the ground		Concept 1		Concept 2		Concept 4	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	9	5	45	7	63	7	63
Criterion 2	7	8	56	6	42	9	63
Criterion 3	7	6	42	7	49	8	56
Criterion 4	6	7	42	8	48	8	48
Criterion 5	9	6	54	8	72	9	81
Criterion 6	7	7	49	7	49	9	63
Criterion 7	7	7	49	8	56	8	56
Criterion 8	9	7	63	8	72	8	72
Criterion 9	9	8	72	7	63	7	63
Total Weighted Score			472		514		565

Table 4.71 Decision matrices for Release force from struts to ground

Release force from struts to ground		Concept 1		Concept 2		Concept 3	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	9	5	45	7	63	6	54
Criterion 2	8	9	72	9	72	8	64
Criterion 3	7	7	49	8	56	8	56
Criterion 4	7	7	49	9	63	7	49
Criterion 5	7	8	56	9	63	7	49
Criterion 6	9	7	63	9	81	6	54
Criterion 7	8	7	56	8	64	7	56
Criterion 8	9	7	63	8	72	7	63
Criterion 9	9	8	72	7	63	7	63
Total Weighted Score			525		597		508

Table 4.72 Decision matrices for Transfer vehicle load through struts while turning

Transfer vehicle load through struts while turning		Concept 1		Concept 3		Concept 4	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	9	8	72	5	45	8	72
Criterion 2	7	7	49	8	56	7	49
Criterion 3	8	5	40	7	56	9	72
Criterion 4	7	6	42	6	42	9	63
Criterion 5	9	6	54	7	63	9	81
Criterion 6	10	7	70	7	70	9	90
Criterion 7	8	7	56	8	64	8	64
Criterion 8	9	8	72	7	63	7	63
Criterion 9	9	6	54	7	63	8	72

Total Weighted Score			509		522		626

Table 4.73 Decision matrices for Transfer vehicle load through springs while turning

Transfer vehicle load through springs while turning		Concept 1		Concept 3		Concept 4	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	9	7	63	8	72	10	90
Criterion 2	7	8	56	7	49	8	56
Criterion 3	8	6	48	6	48	9	72
Criterion 4	7	7	49	8	56	8	56
Criterion 5	9	8	72	7	63	10	90
Criterion 6	10	8	80	7	70	9	90
Criterion 7	8	7	56	8	64	9	72
Criterion 8	9	6	54	8	72	8	72
Criterion 9	9	8	72	7	63	9	81
Total Weighted Score			550		557		679

Table 4.74 Decision matrices for Rotate control arms while turning

Rotate control arms while turning		Concept 1		Concept 3		Concept 4	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	10	7	70	9	90	6	60
Criterion 2	9	8	72	7	63	8	72
Criterion 3	7	7	49	8	56	7	49
Criterion 4	7	9	63	10	70	9	63
Criterion 5	7	7	49	8	56	6	42
Criterion 6	9	6	54	9	81	7	63
Criterion 7	8	7	56	9	72	8	64

Criterion 8	9	5	45	7	63	8	72
Criterion 9	8	7	56	9	72	7	56
Total Weighted Score			514		623		541

The group held a meeting and collaborated on each concept and rated the concepts. Table ~~4.6~~ shows all of the scoring for the three concepts for the steering system that passed the GO-NO-GO scoring. Just like the table 4.5, the two highest scoring concepts are passed on to the next section.

Table 4.75 Decision matrices for Allow forces to be absorbed

Allow forces to be absorbed		Concept 1		Concept 2		Concept 4	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	9	7	63	8	72	9	81
Criterion 2	8	6	48	7	56	8	64
Criterion 3	9	4	36	3	27	6	54
Criterion 4	7	8	56	8	56	8	56
Criterion 5	7	7	49	6	42	7	49
Criterion 6	6	8	48	7	42	8	48
Criterion 7	6	7	42	8	48	9	54
Criterion 8	9	9	81	6	54	7	63
Criterion 9	9	8	72	7	63	7	63
Total Weighted Score			495		460		532

Table 4.76 Decision matrices for Rotate gears only from steering wheel

Rotate gears only from steering wheel		Concept 1		Concept 2		Concept 3	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score

Criterion 1	10	7	70	6	60	6	60
Criterion 2	9	8	72	7	63	4	36
Criterion 3	8	9	72	7	56	6	48
Criterion 4	7	8	56	5	35	6	42
Criterion 5	8	7	56	5	40	5	40
Criterion 6	7	8	56	6	42	4	28
Criterion 7	9	6	54	4	36	6	54
Criterion 8	9	7	63	5	45	5	45
Criterion 9	9	8	72	5	45	4	36
Total Weighted Score			571		422		389

Table 4.77 Decision matrices for Hold the steering wheel firmly

Hold the steering wheel firmly		Concept 1		Concept 2		Concept 4	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	10	9	90	8	80	8	80
Criterion 2	9	7	63	6	54	7	63
Criterion 3	7	8	56	5	35	5	35
Criterion 4	8	9	72	7	56	7	56
Criterion 5	10	8	80	6	60	5	50
Criterion 6	7	9	63	5	35	4	28
		8		4		5	
		7		4		4	
		7		5		6	
Total Weighted Score			424		320		312

Table 4.78 Decision matrices for Turn the steering wheel when adjusting to external forces

Turn the steering wheel when adjusting to external forces		Concept 1		Concept 2		Concept 3	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score

Criterion 1	10	7	70	7	70	9	90
Criterion 2	9	6	54	5	45	8	72
Criterion 3	7	4	28	7	49	7	49
Criterion 4	8	7	56	8	64	8	64
Criterion 5	7	6	42	7	49	7	49
Criterion 6	9	4	36	6	54	8	72
Criterion 7	9	5	45	5	45	6	54
Criterion 8	7	4	28	7	49	7	49
Criterion 9	8	5	40	5	40	8	64
Total Weighted Score			399		465		563

Table 4.79 Decision matrices for Allow horizontal motion with steering rod

Allow horizontal motion with steering rod		Concept 1		Concept 2		Concept 3	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	9	8	72	6	54	6	54
Criterion 2	9	7	63	7	63	5	45
Criterion 3	9	8	72	6	54	4	36
Criterion 4	7	7	49	5	35	6	42
Criterion 5	9	7	63	4	36	5	45
Criterion 6	9	8	72	5	45	6	54
Criterion 7	9	7	63	6	54	7	63
Criterion 8	7	8	56	7	49	4	28
Criterion 9	9	6	54	5	45	4	36
Total Weighted Score			564		435		403

Table 4.80 Decision matrices for Allow gears to move in both directions

Allow gears to move in both directions		Concept 1		Concept 3		Concept 4	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score

Criterion 1	9	6	54	7	63	9	81
Criterion 2	9	5	45	7	63	9	81
Criterion 3	7	7	49	6	42	9	63
Criterion 4	9	8	72	5	45	9	81
Criterion 5	7	8	56	6	42	8	56
Criterion 6	7	6	42	7	49	7	49
Criterion 7	7	7	49	5	35	9	63
Criterion 8	7	5	35	8	56	8	56
Criterion 9	9	5	45	7	63	7	63
Total Weighted Score			447		458		593

Table 4.81 Decision matrices for Allow gears to move in both directions

Allow steering rod to move horizontally in both directions		Concept 2		Concept 3		Concept 4	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	9	5	45	5	45	8	72
Criterion 2	9	6	54	6	54	8	72
Criterion 3	9	8	72	7	63	8	72
Criterion 4	7	8	56	8	56	9	63
Criterion 5	9	7	63	6	54	8	72
Criterion 6	9	4	36	5	45	9	81
Criterion 7	9	5	45	5	45	7	63
Criterion 8	7	6	42	4	28	7	49

Criterion 9	9	4	36	6	54	6	54
Total Weighted Score			449		444		598

Table 4.82 Decision matrices for Transfer energy from steering wheel to Steering shaft

Transfer energy from steering wheel to Steering shaft		Concept 1		Concept 2		Concept 3	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	9	7	63	8	72	8	72
Criterion 2	7	5	35	5	35	7	49
Criterion 3	8	6	48	6	48	8	64
Criterion 4	9	7	63	6	54	7	63
Criterion 5	8	5	40	5	40	7	56
Criterion 6	7	6	42	4	28	8	56
Criterion 7	9	6	54	5	45	6	54
Criterion 8	9	7	63	4	36	8	72
Criterion 9	7	5	35	5	35	7	49
Total Weighted Score			443		393		535

Table 4.83 Decision matrices for Translate motion from gears to steering rod

Translate motion from gears to steering rod		Concept 1		Concept 2		Concept 3	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	9	8	72	6	54	4	36
Criterion 2	8	7	56	5	40	6	48
Criterion 3	9	8	72	6	54	5	45
Criterion 4	8	9	72	6	48	6	48
Criterion 5	7	8	56	5	35	5	35
Criterion 6	7	8	56	6	42	6	42
Criterion 7	5	9	45	7	35	5	25
Criterion 8	9	8	72	6	54	6	54

Criterion 9	9	7	63	7	63	5	45
Total Weighted Score			564		425		378

Table 4.84 Decision matrices for Move tires side to side from steering rod

Move tires side to side from steering rod		Concept 2		Concept 3		Concept 4	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	9	7	63	4	36	4	36
Criterion 2	8	8	64	5	40	5	40
Criterion 3	9	8	72	6	54	6	54
Criterion 4	8	8	64	6	48	6	48
Criterion 5	7	7	49	5	35	5	35
Criterion 6	7	8	56	4	28	6	42
Criterion 7	5	7	35	6	30	6	30
Criterion 8	9	7	63	6	54	4	36
Criterion 9	9	8	72	4	36	5	45
Total Weighted Score			538		361		366

Table 4.85 Decision matrices for Contact the steering wheel tactfully

Contact the steering wheel tactfully		Concept 1		Concept 2		Concept 3	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	10	6	60	8	80	7	70
Criterion 2	9	4	36	9	81	6	54
Criterion 3	7	6	42	8	56	3	21
Criterion 4	8	4	32	9	72	6	48
Criterion 5	10	5	50	8	80	5	50
Criterion 6	7	4	28	9	63	4	28

Total Weighted Score			248		432		271

Table 4.86 Decision matrices for Hold the steering wheel with hand

Hold the steering wheel with hand		Concept 1		Concept 2		Concept 3	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	10	4	40	9	90	7	70
Criterion 2	9	6	54	8	72	6	54
Criterion 3	7	6	42	9	63	7	49
Criterion 4	8	5	40	9	72	5	40
Criterion 5	10	5	50	8	80	5	50
Criterion 6	7	4	28	7	49	4	28
Total Weighted Score			281		426		291

Table 4.87 Decision matrices for Contact the steering wheel firmly

Contact the steering wheel firmly		Concept 2		Concept 3		Concept 4	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	10	7	70	6	60	9	90
Criterion 2	9	6	54	6	54	9	81
Criterion 3	7	6	42	7	49	8	56
Criterion 4	8	5	40	4	32	8	64
Criterion 5	10	4	40	4	40	7	70
Criterion 6	7	5	35	5	35	9	63
Total Weighted Score			281		270		424

Table 4.88 Decision matrices for Contact the steering wheel firmly

Hold the steering wheel until leaving the vehicle		Concept 2		Concept 3		Concept 4	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score

Criterion 1	10	7	70	8	80	5	50
Criterion 2	9	7	63	8	72	7	63
Criterion 3	7	5	35	9	63	8	56
Criterion 4	8	7	56	9	72	7	56
Criterion 5	10	6	60	8	80	6	60
Criterion 6	7	5	35	9	63	5	35
Total Weighted Score			319		430		320

Table 4.89 Decision matrices for Avoid extreme conditions of the course

Avoid extreme conditions of the course		Concept 1		Concept 2		Concept 3	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	10	7	70	6	60	8	80
Criterion 2	9	7	63	8	72	9	81
Criterion 3	7	5	35	8	56	9	63
Criterion 4	8	6	48	7	56	8	64
Criterion 5	7	5	35	6	42	9	63
Criterion 6	8	4	32	5	40	7	56
Criterion 7	7	5	35	6	42	8	56
Criterion 8	9	6	54	7	63	7	63
Criterion 9	8	5	40	5	40	6	48
Total Weighted Score			412		471		574

Table 4.90 Decision matrices for Drive along calmer environmental conditions

Drive along calmer environmental conditions		Concept 2		Concept 3		Concept 4	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score

Criterion 1	10	8	80	9	90	4	40
Criterion 2	9	5	45	9	81	7	63
Criterion 3	7	7	49	8	56	7	49
Criterion 4	9	6	54	8	72	6	54
Criterion 5	8	9	72	7	56	4	32
Criterion 6	7	7	49	8	56	6	42
Criterion 7	8	7	56	7	56	8	64
Criterion 8	9	9	81	9	81	7	63
Criterion 9	8	8	64	8	64	9	72
Total Weighted Score			550		612		479

Table 4.91 Decision matrices for Apply pressure to reduce force input

Apply pressure to reduce force input		Concept 1		Concept 3		Concept 4	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	10	8	80	7	70	6	60
Criterion 2	9	9	81	7	63	7	63
Criterion 3	7	9	63	8	56	5	35
Criterion 4	8	8	64	5	40	6	48
Criterion 5	9	7	63	5	45	5	45
Criterion 6	7	6	42	7	49	4	28
Criterion 7	8	8	64	8	64	5	40
Criterion 8	7	9	63	6	42	4	28
Criterion 9	9	7	63	8	72	8	72
Total Weighted Score			583		501		419

Table 4.92 Decision matrices for Absorb external force to reduce driver control

Absorb external force to reduce driver control		Concept 1	Concept 3	Concept 4

Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	9	7	63	8	72	9	81
Criterion 2	8	7	56	7	56	9	72
Criterion 3	9	4	36	7	63	8	72
Criterion 4	8	6	48	5	40	9	72
Criterion 5	7	7	49	8	56	8	56
Criterion 6	9	8	72	6	54	9	81
Criterion 7	10	6	60	7	70	8	80
Criterion 8	5	4	20	8	40	7	35
Criterion 9	8	8	64	8	64	9	72
Total Weighted Score			468		515		621

Table 4.93 Decision matrices for Reduce the turn of the steering wheel to perform a sharp maneuver

Reduce the turn of the steering wheel to perform a sharp maneuver		Concept 1		Concept 3		Concept 4	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	9	9	81	7	63	8	72
Criterion 2	7	9	63	7	49	7	49
Criterion 3	8	9	72	5	40	5	40
Criterion 4	9	8	72	6	54	7	63
Criterion 5	8	8	64	5	40	7	56
Criterion 6	8	7	56	7	56	6	48
Criterion 7	7	6	42	7	49	8	56
Criterion 8	9	9	81	9	81	7	63
Criterion 9	9	8	72	5	45	8	72
Total Weighted Score			603		477		519

Table 4.94 Decision matrices for Allow easy motion of gears

Allow easy motion of gears		Concept 2		Concept 3		Concept 4	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	10	8	80	9	90	8	80
Criterion 2	9	7	63	9	81	6	54
Criterion 3	9	7	63	9	81	6	54
Criterion 4	8	5	40	8	64	5	40
Criterion 5	8	6	48	7	56	7	56
Criterion 6	9	7	63	6	54	6	54
Criterion 7	8	5	40	8	64	5	40
Criterion 8	7	9	63	9	63	8	56
Criterion 9	9	6	54	9	81	9	81
Total Weighted Score			514		634		515

Table 4.95 Decision matrices for Allow easy motion of steering rod

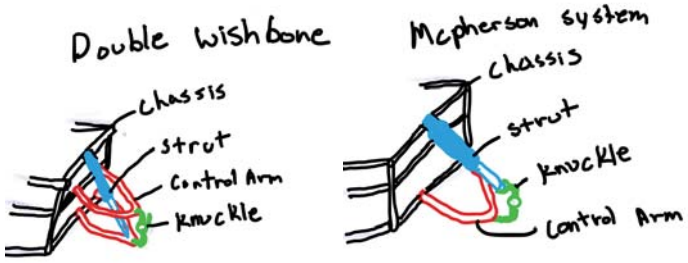
Allow easy motion of steering rod		Concept 1		Concept 2		Concept 3	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	10	6	60	7	70	8	80
Criterion 2	9	7	63	5	45	9	81
Criterion 3	9	4	36	7	63	9	81
Criterion 4	8	8	64	7	56	9	72
Criterion 5	8	4	32	8	64	7	56
Criterion 6	9	6	54	5	45	8	72
Criterion 7	8	5	40	8	64	6	48
Criterion 8	7	9	63	6	42	9	63
Criterion 9	9	7	63	7	63	9	81
Total Weighted Score			475		512		634

Table 4.96 Decision matrices for Allow easy motion of steering wheel

Allow easy motion of steering wheel		Concept 1		Concept 3		Concept 4	
Criteria/Requirements	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Criterion 1	10	7	70	6	60	9	90
Criterion 2	9	8	72	7	63	9	81
Criterion 3	9	7	63	7	63	8	72
Criterion 4	8	5	40	4	32	8	64
Criterion 5	8	7	56	6	48	7	56
Criterion 6	9	8	72	7	63	7	63
Criterion 7	8	6	48	8	64	8	64
Criterion 8	7	7	49	7	49	9	63
Criterion 9	9	9	81	9	81	7	63
Total Weighted Score			551		523		616

4.4 System Sketches and Descriptions for Two Final Designs

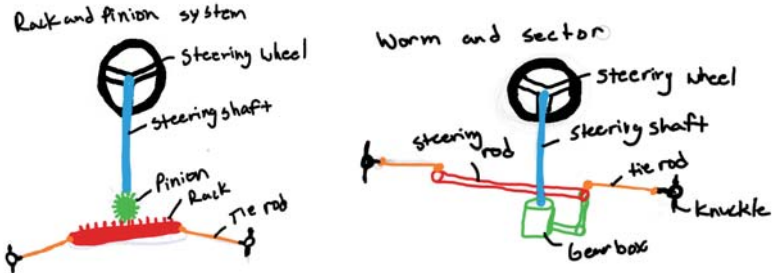
This section will provide detailed sketches of the final two designs of the suspension system. In Figure 4.68, it shows the double wishbone and the mcpherson suspension systems that the group has broken the concepts down to. The double wishbone system has two control arms providing more support for the suspension system. This system works by the control arms moving up or down based on the environmental conditions. The struts compress at the same time to absorb the forces to provide a stable drive for the driver and the vehicle. The other suspension system in Figure 4.69 is the McPherson suspension design. This system works the same way as the double wishbone system but only has one control arm. The McPherson system allows for the vehicle to sit higher but there is less support for the suspension system. With extremely harsh operating conditions, the group decided to go with the double wishbone design because it provides the most support and decreases the chances of buckling by having two control arms.



(i) **(ii)**

Figure 4.68: Two designs for the suspension system

In figure 4.2, it shows the two design concepts that the group has rated as the best possible designs for this project. The image labeled (i) shows the rack and pinion steering design. This system works by the driver turning the wheel that is connected to the steering shaft. This then turns the pinion that acts on the rack. The rack then pushes and pulls on the tie rods which will then turn the tires. This system has the least amount of moving parts and minimizes the loss of range in motion in the steering system. The image labeled (ii) shows the worm and sector steering system. The system is similar but the gear set acts on a linkage that will push and pull on the steering rod. This system has a lot more linkages and joints which can lead to more locked connection points and increased loss in range of motion. The group chose the rack and pinion steering system because it has the least amount of moving parts. This system is more precise in turning the vehicle then the worm and sector design.



(i) (ii)

Figure 4.69 Two designs for the steering system

5. DETAILED SYSTEM DESIGN

This chapter will dive deeper in the analysis needed to come up with the design. The group broke each system down into individual components and then the group focused on calculations needed to design the best component for optimized performance.

5.1 Identification and Plans for Types of Analysis Needed for the Design

This section will provide all the components that are needed for the suspension and steering system. Going through ~~table~~ 5.1, each component will have the description of the analysis that will be done for each component. Also, the table will contain the subject area for where the subject focus is for each component as well as the source from where we found equations needed. Majority of the equations were found mainly from textbooks the students had from their previous classes such as machine design, kinematics, dynamics, and geometry. For the suspension system, the components are mainly to absorb external forces and apply them back to the ground. For the steering system, the components are mainly for transferring forces from driver input to the turning of the tires.

Table 5.1 Summary of System Components, Types of Analysis needed, Subject Areas and Reference Sources used for the Design Analysis of the Components

Item #	System Component or part description	Description of analysis needed for the design, sizing, specifying or selecting component	Subject Area	Reference Source for Analysis
1	Control Arms	Range of motion in wheels	Kinematics /Geometry	Design of Machinery
2	Knuckle	Transfer force to the control arms/ accept force from the tie rods to turn tires	Kinematics	Design of Machinery
3	Struts	Support of total weight of the vehicle and driver/ calculate total external forces the struts will experience	Dynamics	System dynamics for engineering students
4	Revolute joints	Allow range of motion in control arms	Kinematics	Design of Machinery
5	Steering wheel	Driver input to turn the steering wheel	Force analysis	Mechanical engineering Design
6	Steering shaft	Torsional force transfer from steering wheel to rack and pinion	Force analysis	Mechanical engineering Design
7	Rack and pinion	Gear design and force analysis from gears meshing	Gear design	Mechanical engineering Design
8	Steering rod	Transfer force to the tires from the rack and pinion	Force analysis	Mechanical engineering Design
9	Universal joint	Transfer force from steering shaft to rack and pinion	Force analysis	Mechanical engineering Design
10	tie rods	Allow geometry to line up as ackerman/ transfer force to the knuckle to turn the tires	Kinematics / force analysis	Design of Machinery
11	Ball joints	Allow some motion in connections to reduce overbearing components	kinematics	Design of Machinery

Approval by Project owner: Name Lai Jiang Signature Lai Jiang DocuSigned by: 6C1C88553B964F9...

5.2 Detailed Engineering Analysis and Simulation for Designing, Sizing, Specifying and Selecting Parts for the Design.

In this section, an overall analysis was performed in order to determine the design and specifications of the components that will be utilized in the Baja vehicle steering and suspension systems. Specifically, a kinematic, strength of materials and power and energy analysis was compiled into the further research and development of all components. The forces and equations needed for design and operation were to be calculated and provided in the findings. The sections below will break down each component into free body diagrams, equations and variables used, and known and computed variables.

5.2.1 **Analysis for control arm sizes/range in motion**

Range of motion in the four bar linkage is created by the upper and lower control arm. the control arm connects the wheel hub and steering knuckle to the frame of the vehicle. a four bar linkage consists of four rigid bar or rods in a plane that are connected by a pin joint. In this case it will be our control arm, which has four bars that have a vertical range of motion. Given

position, velocity, acceleration, and inertia properties such as mass and mass moment of inertia for each moving link of a four-bar linkage, we are able to perform force analysis for the linkage.

Free Body Diagram (FBD)

Figure 5.1 shows the free body diagram of the front upper and lower control arms. Figure 5.2 shows the free body diagram of the rear upper and lower control arms.

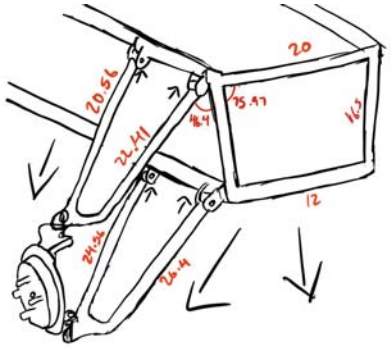


Figure 5.1 Free Body Diagram of The Front Control Arms

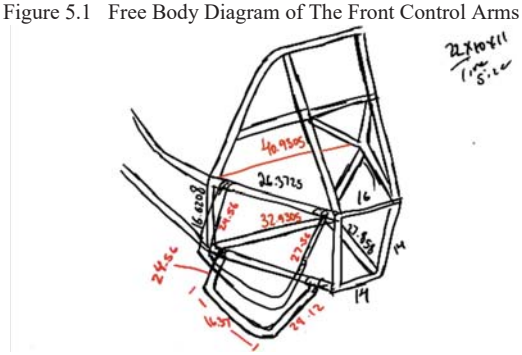


Figure 5.2 Free Body Diagram of The Rear Control Arms

Analysis Equations

These analysis equations were used to determine chassis dimensions utilized for the control arms based on previous chassis designs that were recently shared with the group by Society of Automotive Engineers. Some lengths and angles were given, but some important lengths and angles were also missing. These equations assisted the group in determining the range of motion in the linkages between the upper and lower control arms, chassis, and knuckle.

A sketch of the area from above the upper control arm was drawn based on Figure 5.3. Then, lower case letters were used to identify lengths and upper case letters were used to identify angles in the area drawn. Figure 5.3 below presents the dimensions between the mid chassis section and knuckle.

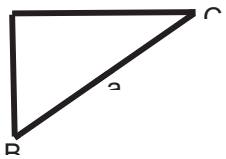


Figure 5.3 Dimensions between mid chassis section and knuckle

Using the law of sines, a general expression was derived to come up with an equation to find the angle between the upper control arm and the knuckle.

$$\frac{sin(A)}{a} = \frac{sin(B)}{b} \quad (1)$$

then, the known and unknown variables were moved to opposite sides

$$B = \arcsin(\frac{sin(A)\ x\ b}{a}) \quad (2)$$

knowing that all triangles add up to the same degree

$$A + B + C = 180° \quad (3)$$

A sketch of the area between the upper and lower control arms was drawn based on Figure 5.2. Then, lower case letters were used to identify lengths and upper case letters were used to identify angles in the area drawn. Figure 5.4 below presents the dimensions between the upper and lower control arms referencing the chassis.

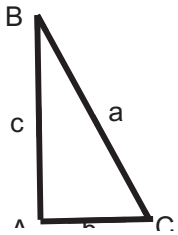


Figure 5.4 Dimensions between the upper and lower control arms

Using the law of sines, a general expression was derived to come up with an equation to find the angle referencing the chassis between the upper and lower control arms.

$$\frac{a}{sin(A)} = \frac{b}{sin(B)} \quad (4)$$

then, the known and unknown variables were moved to opposite sides

$$b = \frac{a}{sin(A)}\ x\ sin(B) \qquad (5)$$

Knowing that all triangles add up to the same degree

$$A + B + C = 180° \qquad (6)$$

Values of known variables
For Figure 5.3:
The angle between the extended outline of the mid section of the chassis and the knuckle, **A = 90°**
The length of the upper control arm, **a = 22.41in**
The horizontal length between the control arm and the knuckle, **b = 12in**

For Figure 5.4:
The angle between the extended outline of the mid section of the chassis and the lower chassis section, **A = 90°**
The diagonal length between the upper and lower control arms where they're connected to revolute joints, **a = 22.41in**
The angle between the vertically extended outline of the mid section of the chassis and the diagonal line drawn between both control arm connections, **B =14.3°**

Values of computed variables
For Figure 5.3:
With these values, the angle was computed using equation (2), to be **B=32.376°**
The remaining angle in the triangle was computed using equation (3), to be **C=57.624°**

For Figure 5.4:
With these values, the length between the vertically extended midsection of the chassis and the horizontally extended base of the chassis was computed using equation (5), to be **b=4in**
The remaining angle for the triangle was computed using equation (6), to be **C=75.97°**

Camber angle is the inclination of the vehicle tire with the vertical axis when viewed from the Front section. In case the top of tire leans in towards the centre of the car this is the condition of negative camber. we will be including a Positive camber on our vehicle to compensate for the weight of the vehicle and the driver. this will neutralize the camber to a neutral vertical position. Figure 5.5 shows the camber angles.

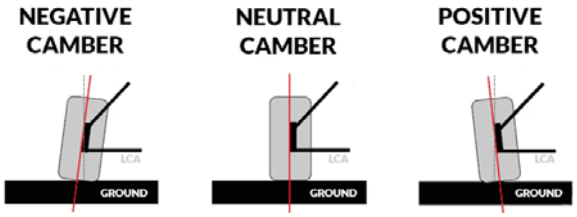


Figure 5.5 Camber angles: Negative camber, Neutral camber, & Positive camber

5.2.2 **Analysis for knuckle size/stress**

The main forces in which the knuckle will experience is torsional and axial loads. Because this component is dependent upon a variation of other components within the system it can be assumed that its range of motion will be very minimal, yet still plays a major factor in the overall functionality of the suspension and steering system. Below is a free body diagram showing how the component is analyzed and how the forces and loads are implemented.

Free Body Diagram (FBD)

The free body diagram for the knuckle shows the fixed supports where the control arms connect to. In ~~figure~~ 5.6, the forces are applied to the center of the knuckle to allow rotation of the tire.

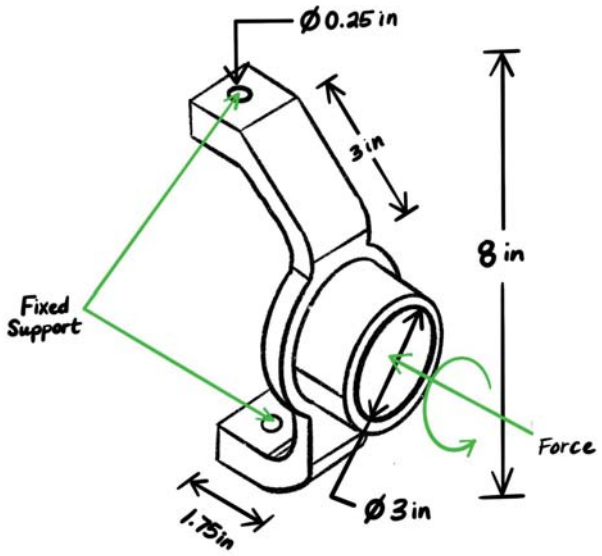


Figure 5.6 Free Body Diagram of Knuckle

Analysis Equations

This specific component proved to be very tedious to design due to the other major components that it links to. Several iterations were drafted up and constructed to fit the design of the control arms, however, this is one of the few designs that the team may seek to update later on down the road in order to fit properly within the given system. The dimensions and specifications of the knuckle design were drawn up based on an already established component and again, constructed to fit the specifications of the team's overall design structure.

The following equations were utilized to design and calculate the forces and possible loads that the knuckle would endure as it collaborated with the other components in the system. As seen in the sketch of the free

body diagram in Figure 5.3, there are critical areas in which there needs to be a main focus. The formulas and equations below will assist with the overall understanding of how this component works and analyze the necessary steps to take in order to calculate this component as a whole

Various forces are calculated in the analysis of the Knuckle of a Steering system. These forces are calculated through three major separation of loads and two major stresses. These equations demonstrated are Axial loads (Compressive and Tensile), Inertia Loads, Bending Loads. Axial Stress and Torsional Stress.

Calculations of Loads

Tensile Load (Pt) = Tensile Stress X Area (1)
Compressive Load (Pc) = Compressive Stress X Area

Inertia load (Fa) = $w^2\ R\ (cos\ \Theta + R/L\ cos\ (2\theta)$

Bending Load (Total inertia bending force)=>

=$Fb = PAiL^2\ sin\ (\theta + o)/2\ (N)$

where,

Tensile Stress = σ = F/A

Compressive Stress= F/A

F= load a point of failure

A= initial cross sectional area = τ =V/a

Calculation of the Stresses

Axial Stress = $\sigma a\ = Fe/As\ + \sigma$b

Torsional Stress = τ = $T(d/2)/\pi d^4/32$

$T = (\tau)\ J/r$

where as,

Fe=effective tension and compression (2)

As= cross sectional Area= τ =V/a

σb= bending stress= σx = - My/I

I= interia = L/W

L= angular momentum , W = angular velocity

Y= young's modulus of elasticity = (FL0)/A(Ln − L0).

T= torsion

d= diameter

π= pie

The equations given above are tools used to measure the various forces and stresses applied to the knuckle of the system. (3)

Values of known variables

There are a few known variables within the knuckle of the system. The height of the overall knuckle is 8in. The knuckle consists of 4 separate extended linkages broken in two 3 in linkages connected to the opening of the knuckle set at a diameter of 3in. Following would be two more linkages at 1.75in at the fixed supports with a diameter of .25in.

Values of computed variables

Axial loads (Compressive and Tensile), Inertia Loads, Bending Loads. Axial Stress and Torsional Stress

5.2.3 **Analysis for determining Struts**

The struts are a critical part of the suspension system. They take a large amount of forces throughout the course. It is important that suitable shocks are chosen to handle the rough terrain and various obstacles that the Baja car will encounter. During extensive research and analysis a strut was chosen that uses air and nitrogen instead of traditional springs.

Free Body Diagram (FBD)

Below in Figure 5.7 is the free body diagram of the strut showing the absorbed forces.

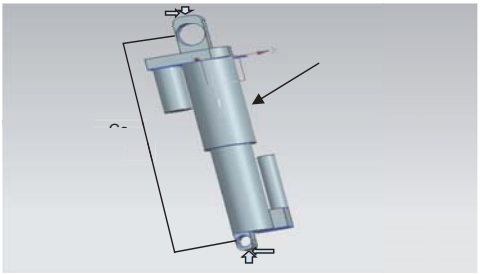


Figure 5.7 Free Body Diagram of Strut

Analysis Equations

The struts main chamber has control of the vehicle's sag height. The SAG height is the height at which a motionless vehicle sits with a driver in the vehicle in relation to the vehicle's full extension.

F_ext-h_r= SAG (1)

Struts are most efficient when at a vertical position. Due to the design of the chassis, clearance issues may occur. An assumption of a 20 degree angle from the vertical position is made.

$$\cos(A) = a \qquad (2)$$

The calculations of the spring rate with max stiffness and the highest pressures in both chambers is shown with strut mounted vertically.

$$k_v = W/SAG \qquad (3)$$

where,

F_ext is the vehicle's full extension
h_r is the height with rider
A is the assumed angle
a is the angle of strut

Knowing the vertical spring rate and angle of strut, the spring rate at a 20 degree angle is calculated.

$$k_{20} = k_v/a \qquad (4)$$

where k_20 is the spring rate at 20 degrees

Values of known variables
The full extension of vehicle is estimated, F_ext=14"
The ride height of vehicle with driver is estimated, h_r= 12"
A reasonable estimated angle, A= 20 degrees is used to calculate angle of strut.
The weight of the driver and vehicle, W=700lb is assumed.

Values of computed variables
With these values the SAG was calculated using equation (1) to be SAG= 2"
The angle of the strut was calculated using equation (2) to be a=.94
The vertical spring rate was calculated using equation (3) to be k_v= 350 lbs/in
The spring rate at an angle of 20 degree was calculated using equation (4) to be k_20= 372.3 lbs/in

Specification of part if part is selected

Upon research and design the Fox Float 3 EVOL series were chosen for the Baja car. The struts are built using 6061-T6 aluminum for light weight and strength. The struts have an extra chamber that uses air as springs, instead of coil springs which makes them lightweight and a suitable option. The struts also contain high pressure nitrogen gas and high viscosity index shock oil separated by an internal floating piston system. Figure 5.8 shows an image of the Fox Float 3 EVOL RC2 struts.



Figure 5.8 Fox Float 3 EVOL RC2

Figure 5.9 shows the specifications of the Fox float EVOL struts that were chosen for the baja vehicle.

Technical Details

Manufacturer	**Fox Racing Shox**
Brand	**Fox** Racing
Model	**Float 3 EVOL RC2 Shocks**
Item Weight	13.5 pounds
Product Dimensions	30.5 x 13.2 x 5.7 inches

Figure 5.9 Strut Specifications

Figure 5.10 shows the flexibility of adjustments that can be made to the main and evol chamber on the struts depending on terrain and obstacles.

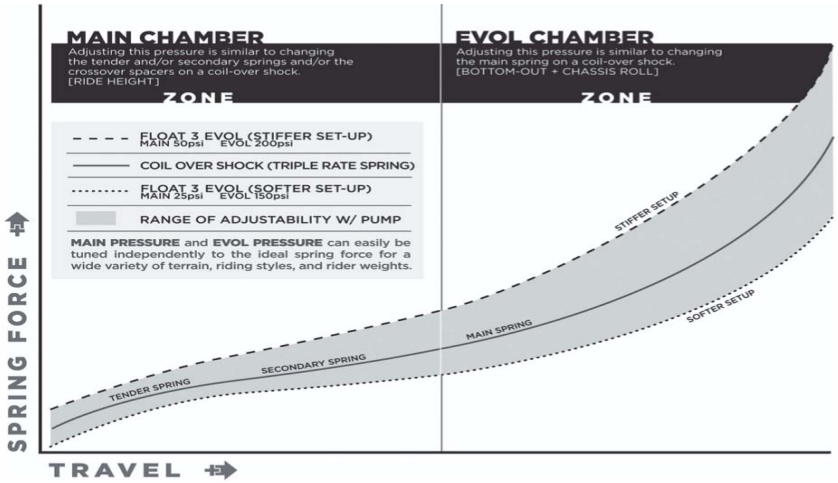


Figure 5.10 Flexibility of Struts

Figure 5.11 shows the recommended air pressures for the EVOL chamber and main chamber for various driver weights.

Reference Air Pressures

Rider Weight	EVOL Air Chamber	Main Air Chamber
100-140LB	100-195PSI	25-45PSI
141-199LB	110-210PSI	25-50PSI
200-250LB	120-225PSI	30-55PSI

Figure 5.11 Reference Air Pressures

Figure 5.12 shows the effects of adjusting the pressure in the EVOL and main chamber on the struts. The figure shows the relationship of the Force vs Distance traveled.

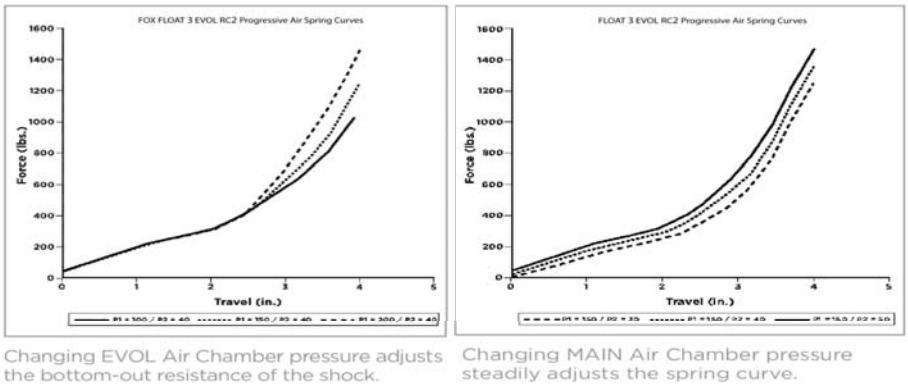


Figure 5.12 Force Vs Distance Traveled

5.2.4 **Analysis for determining the range in motion in the revolute joint**

Revolute joint is a joint between two nodes in which the rotations of the nodes differ by a relative rotation about an axis that is fixed in and, therefore, rotates with the joint. A simple example is a hinge. The Revolute joint is implemented in this system to make the rotational motion simple and quick responsive. This system introduces an additional degree of freedom.

Free Body Diagram (FBD)

Figure 5.13, below shows the motion movement of a revolute joint. which provide a simple rotational motion. one degree of freedom kinematic pair frequently used in mechanisms and machines. This joint constrains the motion of two bodies to pure rotation along a common axis.

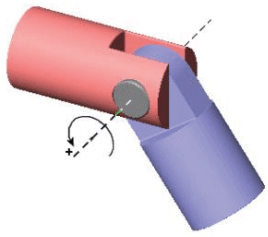


Figure 5.13 Free Body Diagram of revolute joint

5.2.5 **Analysis for determining size of the steering wheel**

The steering wheel is a simple component of the vehicle and is used to steer the vehicle. The driver input starts the process for the steering system. The driver turns the steering wheel with a certain amount of force that is transferred to the steering shaft. That transferred force is used all the way to the gears which then pushes and pulls the tires to steering the vehicle. The inner design of the steering wheel is up to the group but the important thing is the size of the steering wheel. The larger the steering wheel the more torque can be produced. Standard steering wheels for baja vehicles are around 5 inches.If more force needs to be created by the driver then the group can increase the radius of the steering wheel to 6 inches. The sterling system has to overcome the weight of the vehicle and the driver in order to turn. In figure 5.14, it shows the forces involved with the steering wheel and how the steering wheel moves. In the equations down below it will discuss the torque being generated by the driver and how the radius is involved. The goal is to achieve a steering ratio of 12:1 which allows the driver to turn the wheel 30 degrees to turn the vehicle a total 360 degrees at a certain turning radius.

Free Body Diagram (FBD)

The free body diagram in figure 5.14 shows the forces involved with the steering wheel. First, the driver places their hands in a safe and comfortable position. Then, the driver will push on one side of the steering wheel and pull with the other hand with about the same amount of force. The force causes a torque which is transferred to the steering shaft which is the blue circle in figure 5.14. As mentioned before, the goal is to have a steering ratio of 12:1 so the steering wheel will have a max turn radius of 30 degrees to turn the vehicle a total of 360 degrees.

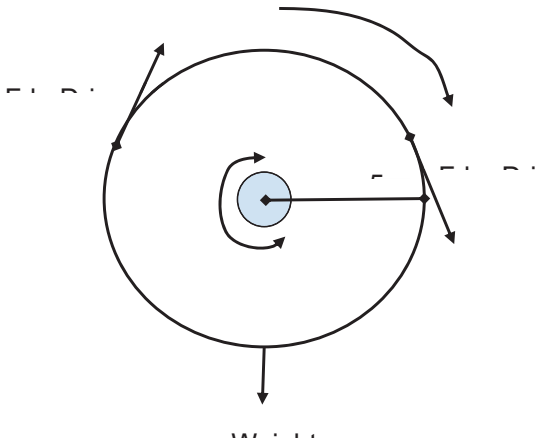


Figure 5.14 Free Body Diagram of the steering wheel

Analysis Equations

The equation for computing the force that will be transferred to the other components is below. The torque is the force driving the other components. If the torque needed to be higher than the driver can apply more force or the radius of the steering wheel can be increased. The opposite would need to happen if the torque is too much for the other components.

$$T_d = F_d * r_d \quad \text{or} \quad F_d = \frac{T_d}{r_d} \quad (1)$$

where,

T_d is the torque created by the force from the driver
F_d is the input force from the driver
r_d is the radius of the steering wheel

Values of known variables

Based on the standard steering wheel sizes, the radius is known to be .127 m. The torque from the driver input was computed by the pinion to overcome the force from the tires which is 22.12 N*m. These variables are used to find the force of the driver to turn the car.

Values of computed variables

The force the driver needs to input in order to turn the car is 174.17 N. This is approximately 39 lbs in total. To split it up by each hand the driver will have to approximately push and pull 19.5 lbs per hand in order to turn the vehicle. If this is too much for the driver the group can increase the diameter of the pinion which will make it easier for the driver. Also, the group can increase the size of the steering wheel.

The only downside to increasing the radius of the steering wheel, it will increase the max shear stress. By having low stress on the steering shaft now, this will not be a problem.

5.2.6 **Analysis for max shear stress on steering shaft**

The steering shaft is the direct connection from the steering wheel to the pinion. This component needs to transport the force from the driver input to the pinion with enough force in order to move the tires to turn the vehicle. In ~~figure~~ 5.15, the forces are shown that are acting on the steering shaft. The material that is chosen for this component is critical because a lot of torque is being applied causing a lot of shear stress.

Free Body Diagram (FBD)

The free body diagram in ~~figure~~ 5.15, is to show the torque being applied to one end travels through the shaft to the other end. The weight of the steering shaft is a force applied to the steering shaft.

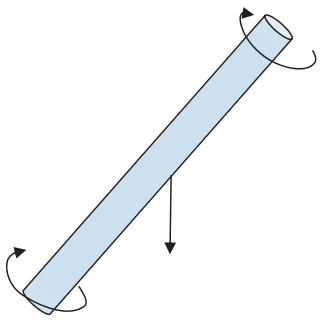


Figure 5.15 Free Body Diagram of the steering shaft

Analysis Equations

The analysis equations will break down the force analysis of the shaft as well as the max shear stress the component can take.

$$J = \frac{\pi d^{4}}{32} \qquad (1)$$

After the polar second moment of area was calculated, the max shear stress was found.

$$\tau_{max} = \frac{T_d r}{J} \qquad (2)$$

where,

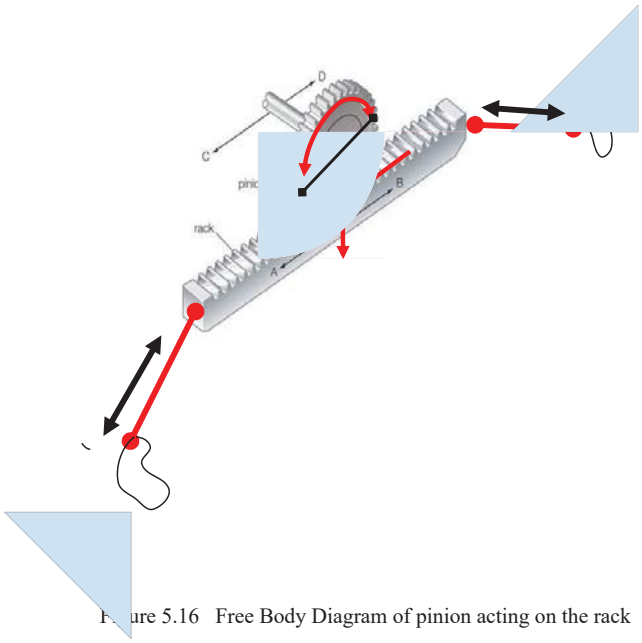
J is the polar second moment of area
d is the diameter of the steering shaft
τ_{max} is the max shear stress
T_d is the torque that was created by the driver
r is the radius of the other surface

Values of known variables
The diameter of the steering shaft is 0.254 m and that is a little above the standard in the industry today. The torque from the driver is going to be 22.12 N*m. The radius is known to be 0.127 m. The length of the steering shaft is known to be 0.52267104 m based on placement inside the vehicle.

Values of computed variables
The values to be computed is the max shear stress the material is going to go through when steering the vehicle. The polar second moment of area is calculated to be 4.09 E -4 m^4. The max shear stress of the steering shaft is calculated to be 6868.56 Pa. The material will have to have a yield strength of at least double the max shear stress because of the safety factor of two.

5.2.7 **Analysis for determining the size of the pinion and the torque on pinion**
The rack and pinion is the main component that does all of the work to move the tires from side to side. The pinion needs to apply more force to the rack then the force from the tires to the tie rods. To achieve a greater force, the diameter of the pinion and the steering wheel need to have a radius that will reduce the effort for the driver. The goal of the design for the rack and pinion is to allow for fast change in direction from the driver for better maneuverability.

Free Body Diagram (FBD)
The free body diagram has a visual of how the forces flow through the pinion and the general size of the gear. The main components are the torque on the pinion to the rack that was transferred from the driver and the weight. In ~~figure~~ 5.16, it shows the free body diagram of the pinion and the size of the pinion.



F ure 5.16 Free Body Diagram of pinion acting on the rack

Analysis Equations

The equations for the pinion are mainly for the forces involved to turn the vehicle. The size of the diameter was determined by the group and is used to determine the amount of force generated by the driver to turn the vehicle. First the amount of force to overcome the force from the tires was determined. Then the force is multiplied to the radius of the pinion to calculate the torque of the pinion that is applied to the steering rod.

$$T_p = F_p * r_p \quad (1)$$

The torque on the pinion is the same as the torque of the steering wheel so it can be stated that

$$T_p < T_d \quad (2)$$

(3)

where,

T_p is the torque on the pinion
F_p is the force from the pinion on the rack
r_p is the radius of the pinion

Knowing the diameter of the pinion and assuming a module the pinion specs can be calculated.

$$P = \frac{N}{d} \quad (4)$$

$$N = \frac{d}{m} \quad (5)$$

$$p = \pi m \quad (6)$$

where,

P is the diametral pitch
N is the number of teeth for the gear
d is the diameter of the gear
m is the module
p is the circular pitch

These equations are used to find basic information on the gears. Once the relations are found for the pinion, the thickness can be found using the following equation.

Values of known variables
There were several known variables for the pinion gear. The diameter of the gear was chosen to be 44 mm. The module was chosen to be 2 mm/tooth. The radius of the pinion is set to be 22 mm due to the diameter being 44 mm. The sizes were found online through common sizes for a rack and pinion. The Force acting on the pinion based on the steering rod is 502.44 N. The driver needs to input more torque than the torque needed to turn the pinion that will turn the tires. By using a factor of 2, the assumed value for the force to turn the tires is 1004.88 N.

Values of computed variables
The Torque of the pinion was calculated to be 22.12 N*m. The force the driver needs to input is calculated in the steering wheel section. The number of teeth came out to be 22 for the pinion and diametral pitch was .5 teeth/in. The thickness of the teeth was .25 in and the circular pitch is 2π.

5.2.8 **Analysis for determining the force applied to the steering rod**

The steering rod is used to push the tires left and right from the desired direction the driver wants to go. The rack is placed on the steering rod that is forced side to side from a pinion. The steering rod was placed 12 inches from the front axle. The length of the steering rod was determined by geometry and the force needed to be applied to push the steering rod side to side was calculated based on the force needed to turn the tires.

(a) Free Body Diagram (FBD)
The free body diagram shows the forces from the pinion on the rack to push the steering rod side to side. In the figure 5.17, the steering rod has a few places the forces affect it. One place being where the rack is being pushed by the pinion and the force from the tie rods.

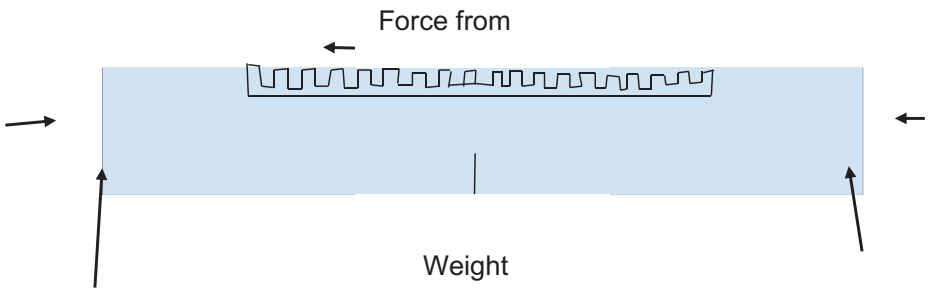


Figure 5.17 Free Body Diagram of the steering rod

Analysis Equations
The equations involved with the steering rod include the total force needed to push the tires side to side. The force from one tie rod was already calculated so to find the total force acted on the steering rod is double the force from one tie rod. The steering system will need to provide more force then the total force from the tie rods in order to steer the vehicle. The length of the steering rod found through

$$f_{total} = f_f * 2 \qquad (1)$$

where,
f total is the total amount of force on the steering rod from the tie rods

Values of known variables
The known variable in this equation is the force from one tie rod. The value of f_f was found from doing analysis from the tie rods. The value for f_f is 251.22 N.

Values of computed variables
To find the total force acting on the steering rod the group doubled the amount of force from one tie rod. Since the tie rod will push and pull with about the same amount of force, the group was able to find the total amount of force from the tie rods was 502.44 N. This means the driver and the steering system will have to provide more force than the tie rods.

5.2.9 **Analysis for determining the force applied from tie rods**
The tie rods are responsible for connecting the knuckle to the steering rod. This connection is used for transferring force to the tires from the steering input. Also, the geometry of the tie rods will determine if the steering system is an ackerman steering system. In figure 5.19, it shows the geometry of the tie rods and how it aligns to be an ackerman system. The dimensions for the tie rods are based on chassis. The dimensions of the axles were provided from the baja club from their designs.

Free Body Diagram (FBD)

The forces shown on the tie rod are from the tires and the steering rod. The forces from the tire include the external forces and the friction forces of the ground. The forces from the steering rod are from the driver's input that either pushes or pulls depending on the desired direction the driver wants to go. In figure 5.18, it shows the free body diagram for the tie rods.

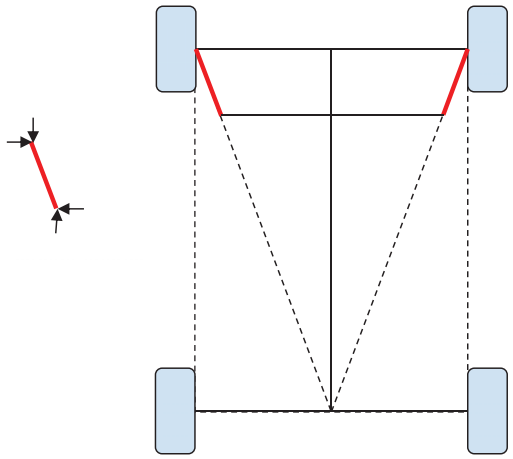


Figure 5.18 Free Body Diagram of the tie rod as well as the geometry of the tie rods

Analysis Equations

The equations below will help determine the amount of force that is acting on the tie rods. The first equation determines the amount of force of friction that the tires will have to overcome to turn. Then that will be used to determine the torque due to frictional force. To determine the force action on one tie rod, the T_ff is divided by the distance to the kingpin axis. This value will then be multiplied by two to determine the amount of force acting on the steering rod based off the tie rods to turn the wheels.

$$F_f = \boldsymbol{\mu} * F_{ft} * g \quad (1)$$

$$T_{ff} = F_f * r_s \quad (2)$$

$$f_f = T_{ff}/d_k \quad (3)$$

where,

F_f is the force of friction

μ is the friction coefficient
F_ft is the force on each front tire
T_ff is the torque due to friction force
r_s is the scrub radius
f_f force on the tie rod
d_k distance to the kingpin axis
g is the gravitational force constant

Values of known variables
The value for μ is used at 0.8 for a safety factor to allow the vehicle to overcome a high friction surface. The value for F_ft was given from the baja club and it is the amount of force acting on each tire based on the center of gravity which is 34.02 kg. The value for the scrub radius was given to us by the baja club which was 0.0889 m. The scrub radius is a dimension based on the tire's dimensions which was chosen by the baja club. The value for *d_k* is the distance from the kingpin axis and the tire. This value is from the geometry of the tire which was given from the baja club at 0.0945 m.

Values of computed variables
The value of *F_f* is computed to find the force of friction acting on the tires. With the known variables, the amount of friction force is 266.99 N. Then that value is multiplied by the scrub radius to find the torque due to frictional force which was 23.74 N*m. When that value is divided by the kingpin axis the value is 251.22 N. This is the force acting on the steering rod from one tie rod.

5.2.10 **Analysis for determining the size of the ball joint and the range of motion**

Ball joint allows for a flexible movement using a ball joint. This is for front suspension assembly of links, joints, bushings and bearings that allow your front wheels to move up and down independently and turn left or right together. the motions of the suspension is maximized and the tire contact with the road for optimum vehicle control and tire wear.

Free Body Diagram (FBD)
The ball joint on the front suspension provides pivoting movement between the steering knuckles and control arms to provide a safe, smooth ride and allow precise control to the vehicle. In figure 5.19, it shows the ball joint.

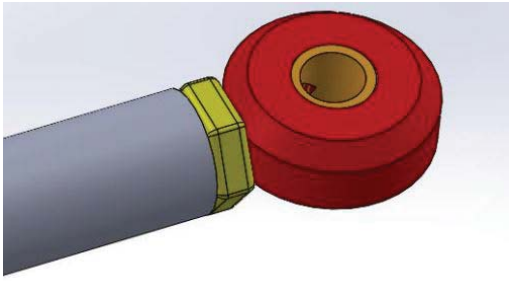


Figure 5.19 Free Body Diagram of ball joint and the range of motion

5.3 ~~Suspension 3D CAD models with labels~~

This section will show and break down the overall design for each component as well as the assembly to the vehicle.

Figure 5.20 presents a 3D model of the upper control arm for the front of the vehicle. This model is used for the right and left sides of the vehicle in the front. This component is used to limit the vertical and horizontal motion of the knuckle at the top.

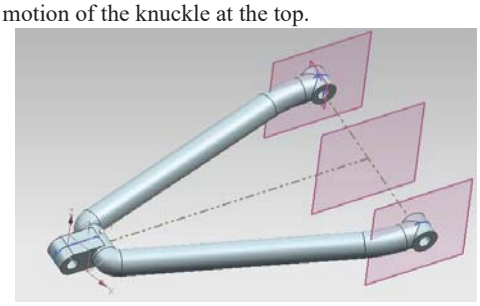


Figure 5.20 Front Upper Control Arm

Figure 5.21 presents a 3D model of the upper control arm for the rear side of the vehicle. This model is used for the right and left sides of the vehicle in the back. This component is used to limit the vertical and horizontal motion of the knuckle at the top.

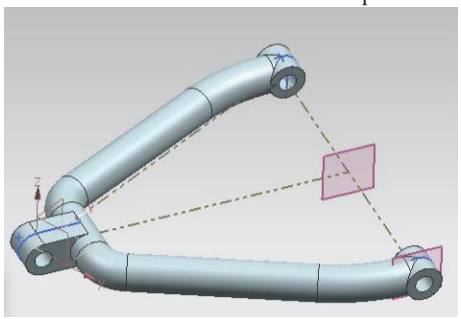


Figure 5.21 Rear Upper Control Arm

Figure 5.22 presents a 3D model of the lower control arm for the front of the vehicle. This model is used for the right and left sides of the vehicle in the back. This component is used to limit the vertical and horizontal motion of the knuckle at the bottom.

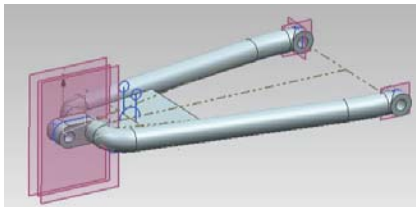


Figure 5.22 Front Lower Control Arm

Figure 5.23 presents a 3D model of the lower control arm for the back of the vehicle. This model is used for the right and left sides of the vehicle in the back. This component is used to limit the vertical and horizontal motion of the knuckle at the bottom.

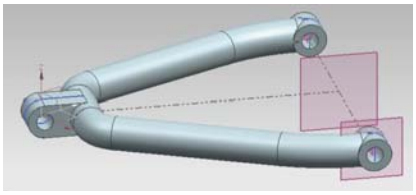


Figure 5.23 Rear Lower Control Arm

Figure 5.24 presents a 3D model of the knuckle for the front of the vehicle. This model is used for the right and left sides of the vehicle in the front. This component is used to transfer horizontal motion from the steering rod and also to keep the hub assembly perpendicular to the ground.

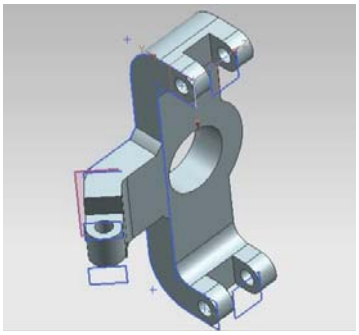


Figure 5.24 Front Knuckle

Figure 5.25 presents a 3D model of the knuckle for the rear end of the vehicle. This model is used for the right and left sides of the vehicle in the back. This component is used to keep the hub assembly perpendicular to the ground.

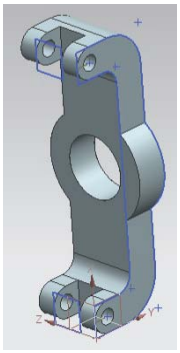


Figure 5.25 Rear Knuckle

~~5.4~~ Suspension 2-D sketches

Figure 5.26 presents the drawings and dimensions of the upper control arm for the front of the vehicle. The drawings show the front, top, and right views of the control arm. A 3-D isometric view was also included to grasp a better understanding of the full component.

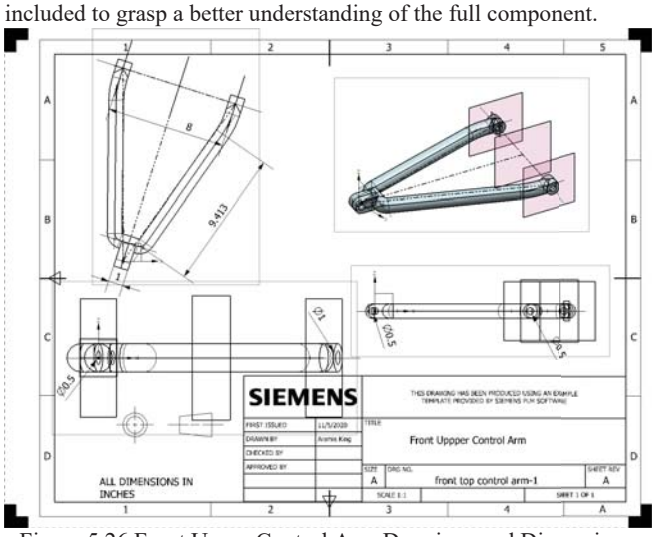


Figure 5.26 Front Upper Control Arm Drawings and Dimensions

Figure 5.27presents the drawings and dimensions of the upper control arm for the back of the vehicle. The drawings show the front, top, and right views of the control arm. A 3-D isometric view was also included to grasp a better understanding of the full component.

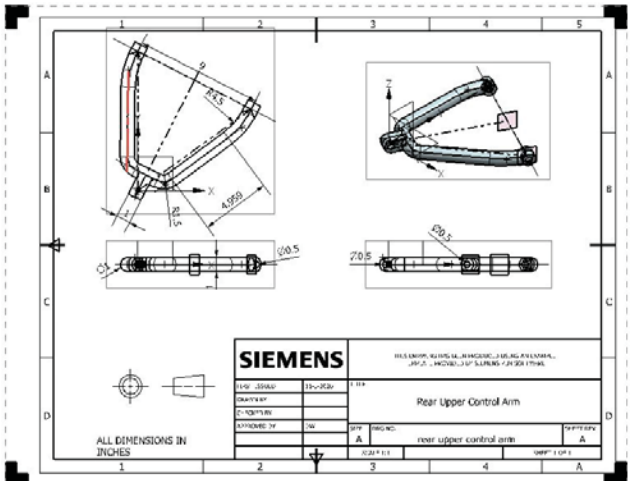


Figure 5.27 Rear Upper Control Arm Drawings and Dimensions

Figure 5.28 presents the drawings and dimensions of the lower control arm for the front of the vehicle. The drawings show the front, top, and right views of the control arm. A 3-D isometric view was also included to grasp a better understanding of the full component.

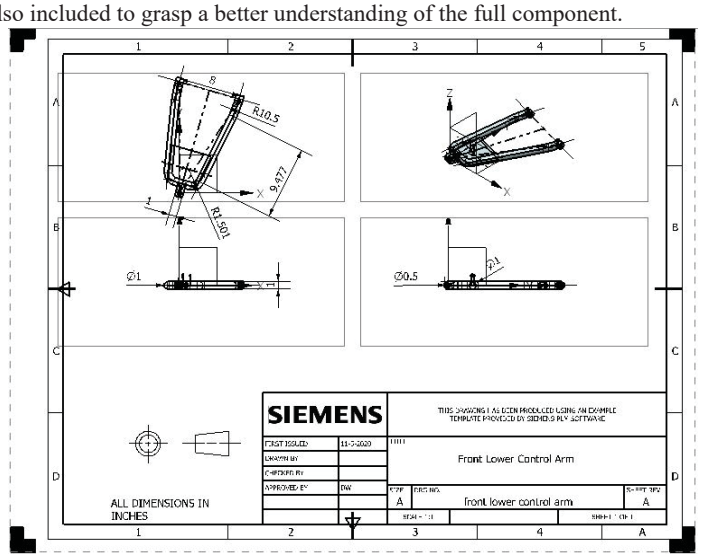


Figure 5.28 Front Lower Control Arm Drawings and Dimensions

Figure 5.29 presents the drawings and dimensions of the lower control arm for the back of the vehicle. The drawings show the front, top, and right views of the control arm. A 3-D isometric view was also included to grasp a better understanding of the full component.

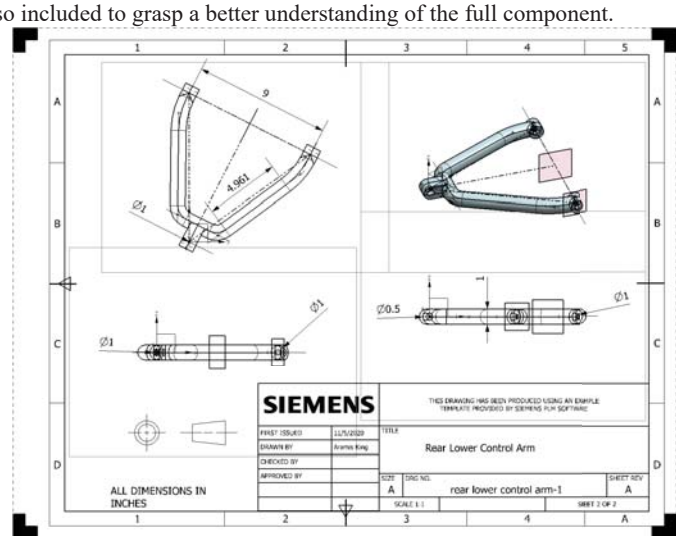


Figure 5.29 Rear Lower Control Arm Drawings and Dimensions

Figure 5.30 presents the drawings and dimensions of the knuckle for the back of the vehicle. The drawings show the front, top, and right views of the control arm. A 3-D isometric view was also included to grasp a better understanding of the full component.

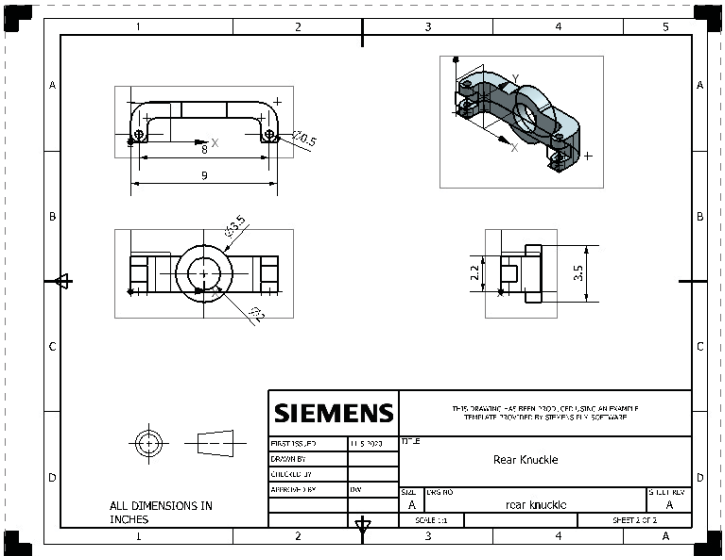


Figure 5.30 Rear Knuckle Drawings and Dimensions

Figure 5.31 presents the drawings and dimensions of the knuckle for the front of the vehicle. The drawings show the front, top, and right views of the control arm. A 3-D isometric view was also included to grasp a better understanding of the full component.

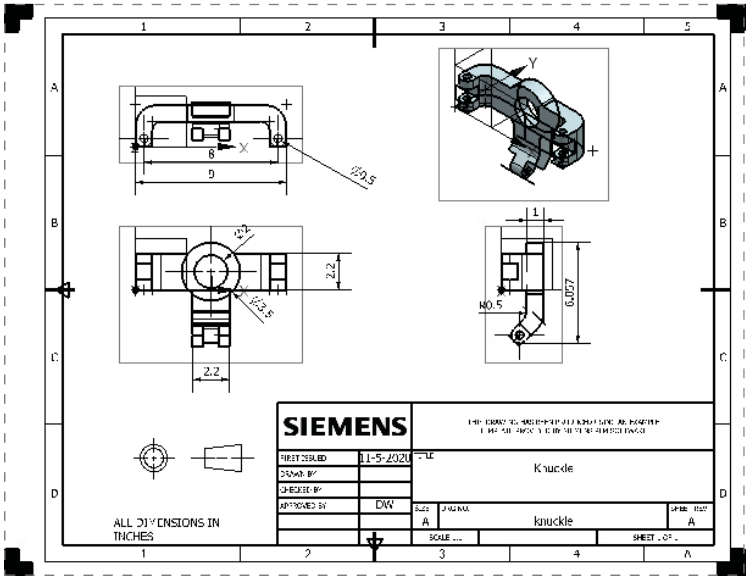


Figure 5.31 Front Knuckle Drawings and Dimensions

~~5.5~~ Steering 3D CAD models with labels

The steering wheel was a cushion design that the group created. In figure 5.32, the final steering wheel design is shown. The diameter is 10 inches which is standard for off-road vehicles. The steering wheel is directly connected to the steering rod.

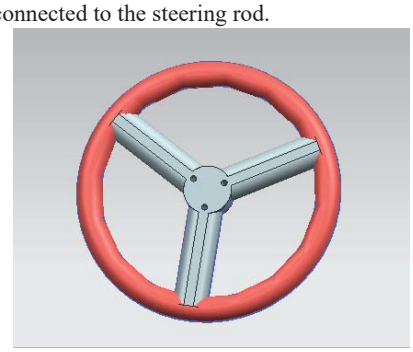


Figure 5.32 Steering Wheel

Figure 5.33 presents the steering shaft and pinion, which connects to the steering wheel at the top and connects to the rack at the bottom. This component transfers torque from the steering wheel to the rack.



Figure 5.33 Steering Shaft and Pinion

Figure 5.34 presents the rack for the steering system, which transfers rotational motion to horizontal motion from the pinion to the tie rods respectfully.

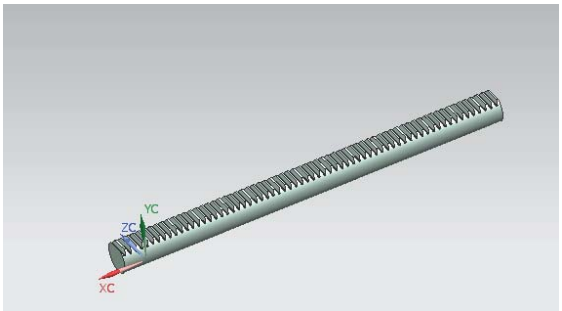


Figure 5.34 Rack/Steering Rod

~~5.6~~ Steering 2-D sketches

Figure 5.35 presents the drawings and dimensions of the steering wheel. The drawings only show the front and top views of the steering wheel due to it being symmetrical and the front view looking just like the top view. A 3-D isometric view was also included to grasp a better understanding of the full component.

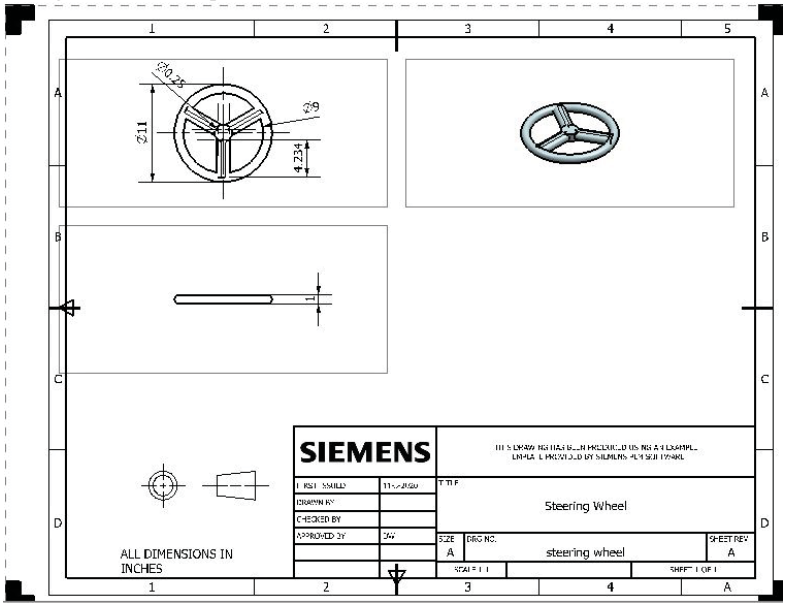


Figure 5.35 Steering Wheel Drawings and Dimensions

~~5.7~~ Assemblies and Subassemblies

The full assembly of the suspension and steering system is shown connected to the vehicle in Figure 5.36. The suspension system and the steering system work together in absorbing forces and turning the vehicle.

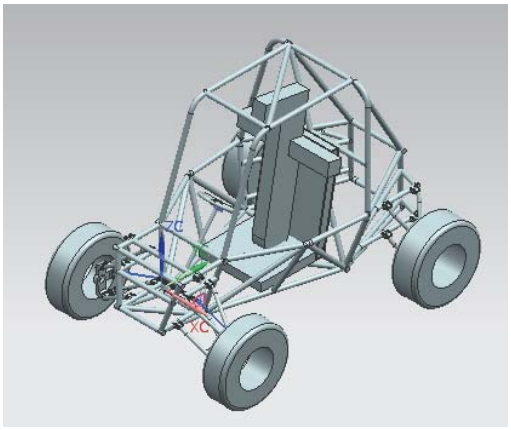


Figure 5.36 Full Assembly of Suspension & Steering Systems

Figure 5.37 presents the sub-assembly of the steering and suspension systems. The cross figure represents the driver sitting in the driver seat.

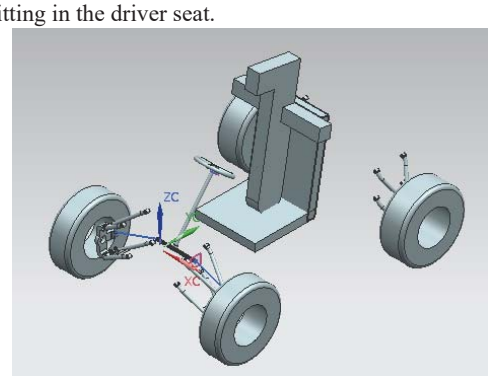


Figure 5.37 Sub-assembly of Suspension & Steering System

~~5.8 Standards used~~

From a technical standpoint, it is now possible to add dimensions, tolerances, and notes to 3D geometric models in a generally agreed way. Driven by the aerospace and automotive industries, the American Society of Mechanical Engineers (ASME) issued, in 2003, the ASME Y14.41 standard in response to the need to utilize 3D CAD data as manufacturing and/or inspection sources; thus, allowing 2D drawings to be phased out.

~~5.9 Summary/Calculations/Cost~~

~~ANSYS was used to determine the sizes to pass allowable stresses of stainless steel 4130 when using a safety factor of 2. A safety factor of 2 was chosen because safety factors for the~~

automotive industry typically range between 1.5 and 2.25. The given dimensions of the chassis were used to determine how each part was sized.

$$\text{Allowable Stress} = \frac{Yield\ Strength}{Safety\ Factor} = \frac{631000\ psi}{2} = 31550\ \text{psi} \qquad (1)$$

5.10 Economic Analysis in Table Form

This section will talk about the price for the components for both systems. The status will be the only part that is outsourced from a vendor. The other components are going to be manufactured from a vendor with our models. The vendors have not been found yet but that is something the group will need to do during the break to find the budget for this project. Table 10.1 shows the components for the steering and suspension system as well as the pricing for each. This table was supposed to tell the group how much everything costs.

Table 5.2 Economic Analysis

Part #	Part Name	Part Specification/ Description	Quantity Needed	Unit Price	Extended Price	Vendor Name	Vendor Phone #	Web-address
1	Front Control Arm	Maintains vertical motion in the front knuckle and minimizes horizontal motion	2					
2	Rear Control Arm	Maintains vertical motion in the rear knuckle and minimizes horizontal motion	2					
3	Fox Strut	Absorb forces of impact.	4	$547.50	$2190	Fox		ridefox.com
4	Front Knuckle	Connects to the control arms and the	2					

		steering rod. Allows for turning of the wheels.						
5	Rear Knuckle	Connects to the wheel hub assembly and allows for vertical motion in the back.	2					
6	Tie Rod	Connects to the front knuckle and the steering shaft. This is what pushes and pulls on the front knuckle.	2					
					Total			

6. RESULTS & DISCUSSION

This chapter will contain the results of the project so far as well as any discussions. This chapter dives deeper into the results that were found during all of the research that has been conducted so far.

6.1 Summary of Goals and Objectives

In designing and analyzing the steering and suspension of the baja car there are a few key goals and objectives that were defined. For the design of the suspension it is critical that we choose a suspension system that allows for easy maintenance and repair. It also needs to be designed where the suspension is of high performance so that the vehicle and driver is safe while navigating through given obstacles of the Baja competition. In designing the steering it is critical the design gives the driver total control and allows for easy but precise driving.

6.2 Discussion of Completed Work

In chapter 1, the group has successfully defined the problems and needs of this project. The group fully understands what needed to be done to reach a final design. In chapter 2, the group was able to plan out the entire semester as well as next semester. In chapter 3, the group was able to provide a detailed literature review that contains what each system was responsible for and other relevant information with this project. In chapter 4, the group successfully broke down the project into several level 3 sub-functions as well as provide concepts for each level 3 sub-function. Also, the group was able to rate each design to reach a final design for each system. In chapter 5, the group was able to do analysis to fulfill the designs that were chosen for the project such as sizing, stress test and motion tests. The group was also able to provide models for each component as well as assemblies.

6.3 Summary of Constraints and Codes Identified for Project

The main constraints and codes that were identified for this specific project includes the necessary applications based on the SAE rules and regulations. The latter constraints were created by the group itself; taking into consideration the overall task. It was understood that SAE would oversee the Baja competition with guidelines as far as: vehicle width and weight, no utilization of kits and prohibiting the assistance from professionals. Functional constraints include but are not limited to: the steering being compatible with the suspension.

7. CONCLUSIONS AND RECOMMENDATIONS

This chapter is going to conclude the report. This chapter will discuss what we have gotten from our research and give recommendations for those interested in this project.

7.1 Conclusions

From doing all of the research on suspension and steering systems, there are many options when creating these systems. This report covers the simple systems that can be chosen for suspension and steering. By having a simpler system, the math part will not be as bad as the complex ones. The cost analysis still needs to be done by the group and the group will reach out to vendors to find the cheapest price to manufacture the parts. The motion of the systems are finalized and the material choice needs to be finalized. 4130 Stainless steel is too heavy so the group needs to find a strong material but that is lighter and around the same price.

7.2 Recommendations

When it comes to off-road vehicles, the steering geometry should be the Ackerman steering geometry. It is perfect for having a great turning radius. For the suspension system of an off road vehicle, the double wishbone is preferred due to supporting the vehicle more and preventing any damage to the driver or the vehicle. When it comes to choosing the material if the money part is the problem then it is okay to go with a heavier material.

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APPENDIX A

A.1
Project Selection and Team Formation

Mechanical Engineering Department
Senior Design I
Fall 2020 Semester
Project Selection Assignment
Status Report 1 on Project Selection

Assigned: 08/27/2020 Due: 08/31/2020 (by 5:00 PM on e-course)

Name: _Daniel Ward__Phone:_281-771-9167____ email__dward13@student.pvamu.edu__

1. Review the project statements distributed and rank them according to your 1st, 2nd, 3rd, 4th, ... 9th choices on Table 1 (Please type in information directly in the table).

Table 1. Project Selection Ranking

Project number	Project Title	Preference Ranking
1	Enhancing Thermal Resistance of Building Walls By Utilizing Fluid Flow in Microchannel within the Wall(Dr. Shafiee)	6
2	Design, Fabricate and Test a Condenser Train for Condensing Biogas to Bio-oil During Pyrolysis of Biomass (Dr. Biney)	9
3	Design of experiment to measure heat transfer coefficient and effective thermal conductivity in nanofluids under different boundary conditions. (Dr. Shafiee)	7
4	Design and Fabrication of Exoskeleton-based Hybrid Human Rehabilitation Robot (Dr. Park & Dr. Duan)	2
5	Optimized Design of Satellite Thermal Radiator for Space-based Applications (Ball Aerospace)	5
6	Low Shock Restraint and Deployment Device for Deployable Satellite Appendages (Ball Aerospace)	4
7	Design, Fabrication, and Testing of an Automated Oil Recovering Skimm (Dr. Zhou & Dr. Park)	8
8	Design and Fabricate the Suspension and Steering for Off-Road Vehicle (Dr. Jiang)	1
9	Design, Fabricate and Test a fully instrumented laboratory set-up that could be used to study the performance of the major types of heat exchangers used in the industry.(Dr. Biney)	3

2. For your **first** and **second** choices, conduct a brief background work to
   (a) show that you have read about the project and that you understand the problem and that you have some basic knowledge to contribute to the project,
   (b) show the experience that you have that makes you interested in this project and
   (c) justify why those selections should be assigned to you.

(Repeat a, b, c for second choice also)
(To make sure you have answered each question, copy the question and each sub-question before you provide your answer below it).

Grading Scheme

Item	Description	Maximum Points	Your Score
1	Ranking of Projects	10	
2a	Background review for understanding project choices 1 & 2	20	
2b	Stated experience in choices 1 & 2	10	
2c	Justification of why project should be assigned to you	10	
	Total	50	

1. Off Road Vehicle
    a. Background review–After reviewing Project 8: Design and Fabricate the Suspension and Steering for Off-Road Vehicle, I found this was a task I could stand behind and actually enjoy. Derek Marshall, a good friend of mine and recent PV graduate, grasped my attention with the Baja competition, going in depth with the overall details of the project and how captivating it was to be a part of something that is not only great engineering experience but intriguingly fun, especially for a person like myself who has been working on vehicles since I was young. I understand that the project has been in place since the 2019-2020 school year and needs updating so the vehicle can be even better than it was before with the installation of a new suspension and steering system. I also am aware that aside from the overall fabrication, there is a need for a redesign and testing to solidify the quality and best performance of the vehicle. The goal is to successfully make it through an entire off-road obstacle course in which the suspension and steering system should hold true to the landscape and increase the durability of the vehicle as a whole.
    b. Stated experience – Not only have I been working on vehicles for a quite a long time, but I've also had previous internships where I've been exposed to the car industry, modeling, design, testing and integration. I worked for Dimensional Engineering Summer 2019 as our team held a contract with General Motors, completing metrology reports utilizing laser trackers and CAD modeling to reverse engineer specified parts and also calibrated vibration testing and analysis on various popular vehicles. This past summer I worked for Northrop Grumman as a mechanical test engineer, overseeing various projects including mechanical release devices, vibration and environmental testing, as well as writing procedures for the floor where major installations were made, finalizing the testing and integration phase of the 20-year project. Machine Design 2 with Dr. Park also adds value to my experience from a research and design point of view. The project we were assigned as a class increased my overall excitement and interest in the car industry and how the smallest parts can make the biggest difference when it comes to performance. Aside from my internship and classroom experience, I've worked on plenty of vehicles in my lifetime as I've had to

continuously upkeep and maintain my own truck and family cars, as well as ATVs, go karts and other off-road vehicles, both mechanical and electrical components.

c. Justification – All in all, this project is right up my ally as I've been exposed to these systems and utilize my experience and knowledge on a daily basis. Not only do I have the background, but I also bring a strong work ethic. Especially since this is a project that I feel like I will deeply enjoy, I will be genuinely ecstatic to put my effort into it and make sure that I will be an asset to my team as I have been to the companies who have hired me over the past 4-5 years. I know that the knowledge and experience I have can deeply impact this project and know that the final product will be successful and represent the College of Engineering and the University as a whole. This is the main reason I wanted to become an engineer in the first place, so being a part of this project will be a blessing.

2. Rehabilitation Robot
    a. Background review – I understand that Project 4 entails the design and fabrication of an exoskeleton for a rehabilitation robot hybrid that will assist the elderly with daily functions in which they will be more independent and equipped for daily practical situations. The hybrid robot will be used to generate a functioning system for those in need. It is also known that there are already such various systems in place and models that have been created and put to use to help with this effort, however, there is always room for improvement. This is where we come into play, identifying the faults and inefficiencies in order to build something much better, marketable, consumer friendly and overall better quality.
    b. Stated experience – Multiple internships and classes have equipped me with the tools necessary to make an impact on this project. This is not only a mechanical based project but also electrical, which will require coding and a knack for linking electrical components with mechanical. My high school was partnered with Texas A&M's E12 program where we conducted various robotic based projects. With this program I was exposed to coding, soldering and many other applications that allowed me to build my skills. Dr. Kirby also played a role in my understanding of computer aided technology through C++, networking and circuit design. Kinematics has also been a course that has increased my overall knowledge and understanding of vectors, how components work with each other synonymously and the basic movements of mechanical parts.
    c. Justification – I'm extremely confident that I will be an asset to my team and will learn a lot on this project. I've always had an interest in bioengineering and the medical field in general and would love to be a part of something that helps people thrive in an advanced society without any limits. As I've stated above, my various internships and activities have definitely prepared me for this challenge,

and I'll be very interested in the task and make sure I add value and bring in-house experience to the team in any way possible.

A.2
Team Organization and Agreement

COLLEGE OF ENGINEERING

SENIOR DESIGN & PROFESSIONALISM I

FALL 2020 SEMESTER

Status Report on Project Agreement

Due: 09/09/2020

1. Group Leader Selection: Develop and describe a process used to select a group leader [6]. Provide the name, phone number and email of the leader selected as shown below [4].
    1. Name of member selected as group leader: Robert Barbee
    2. Phone number of group leader: 832-461-3958
    3. e-mail address of group leader: rbarbee80@gmail.com
2. Technical & Non-technical Roles: Develop and describe a process used to assign technical and non-technical roles to each member [5]. See the notes at the ends of this assignment on possible team roles.

    Then complete the table below to document the roles assigned to each team member [5].

- The process that will be used to assign members to possible roles will begin by deciding by first figuring out how to distribute technical and non-technical roles as evenly as possible. After that, every member will have the opportunity to describe their experiences in a way relatable to the roles available. Lastly, the members will vote on who they believe would fit best to the roles based on the member's backgrounds. Members wouldn't be able to vote on themselves.

	Name of Group Member	Assigned Role	Phone Number	e-mail Address

1	**Robert Barbee**	**Group Leader/ Organizer**	**832-461-3958**	**rbarbee80@gmail.com**
2	**Jonathon Horta**	**Recorder/ Budgeter/ Ideas Facilitator**	**469-735-2830**	**hortajonathon@gmail.com**
3	**Todd Maxwell**	**Technical Writer/ Idea Facilitator**	**713-398-2866**	**Tmaxwell0001@gmail.com**
4	**Daniel Ward**	**Manufacturing & Testing Leader**	**281-771-9167**	**ward.daniel97@gmail.com**
5	**Aramis King**	**Manufacturing & Testing Leader/Proof Reader**	**832-713-1542**	**Aramisking23@gmail.com**
6	**Michael Samuel**	**Presentation Manager/Design Analysis Leader**	**(832)955-5196**	**msamuel4@student.pvamu.edu**
7	**Titus Woodard**	**Graphics/Models Leade/ Proof Reader**	**713-201-0343**	**tituswoodard21@gmail.com**

3. Group Meeting Times & Location: Develop and describe how the group selected the group meeting times and meeting locations suitable to all member [3].

Complete the table below to document the meeting times and location [7].

Each group should meet **at least** 6 hours per week to work on the project outside of class time [3].

- The group selected meeting times and locations by everyone laying out their weekly schedules to figure out a time that best works for everyone.

Day of the Week	Meeting Times Start time & End time	Total meeting hours for day	Meeting Location (Location, Building, Room) Or How group plans to meet Provide link, etc. if Zoom or other electronic meeting forms being used
Tuesday	**12PM - 2PM**	**2hrs**	**Zoom:** **ID: 987 671 2507** **PW: 310102020**
Thursday	**12PM - 2PM**	**2hrs**	**Zoom:** **ID: 987 671 2507** **PW: 310102020**
Friday	**10:40AM - 12:40AM**	**2hrs**	**Zoom:** **ID: 987 671 2507** **PW: 310102020**

Total Meeting Hours for the week (outside class period)		**6hrs**	

4. Faculty Advisor Meeting Times: Develop and describe how the group selected the common times for the group to meet with the faculty project advisor [2].

   Complete the table below to document the meeting times and location for the advisor meeting. Part of the class time on Thursdays between 3 PM to 5 PM can be used for this meeting.

   [2] The group selected the common times to meet with the professor by Jonathon Horta reaching out to the professor to figure out his free times throughout his day.

Meeting times with Project Faculty Owner [3]

Day of the Week	**Meeting Times** **Start time & End time**	**Meeting Location** **(Location, Building, Room)** **Or How group plans to meet** **Provide link, etc. if Zoom or other electronic meeting forms being used**
Wednesday 9/9/20	**Start: 3:30pm**	**Zoom** **Meeting ID: 981 404 1458** **Passcode: 041458**

	End: 4pm	

Faculty Advisor's Signature:_____ Date:_____

5. Write up a simple meeting time and other responsibility agreement using appropriate legal terms that would be binding on each member (*Need to do some research on how to write legal agreements since this may be new to you all*). Include the following statement as part of the agreement [6]:

   I have read and understood the requirements of the course and the grading policies as stated in the final course syllabus.

   I agree to abide by the university's policy on scholastic dishonesty.

   I hereby assign all of my intellectual property rights on the project to the sponsor of the project [4].

   Printed names, signatures and dates on agreement.

	Printed Name	Signature	Date
1	Robert Barbee		
2	Michael Samuel		
3	Aramis King		
4	Titus Woodard		
5	Daniel Ward		
6	Jonathon Horta		
7	Todd Maxwell		

The agreement signed is binding on each student until the end of the semester, and violating the agreement may require you to drop the course.

Note: All signatures must be obtained through DocuSign)

Note: Attach a copy of this status report sheet to your work (placed after the cover sheet) [2]

Note: Assignment for Outcome 5 in the syllabus

NOTES ON TEAM ROLES

Technical Team Roles may include but not limited to

1. Organizer

Leads in developing, maintaining task scheduling, and reviews progress on project schedule and refocuses efforts to meet deadlines in project schedule.

2. Ideas Facilitator

Leads in generating, collecting and organizing ideas.

3. Graphics/Models Leader

Oversees developing of models, drawings, and simulations.

4. Design analysis leader

Oversees the various analysis needed for the design and ensures designated members present accurate design analysis and integrate analysis into the design report.

5. Manufacturing and Testing Leader

Oversees the fabrication, assembly, manufacture and testing of the system designed.

Non-Technical Roles may include but not limited to

1. Budgeter /Purchaser

Prepares detailed budget and coordinates purchasing of parts for the design

2. Presentation Manager
Leads in the organization, preparation and oversees presentation roles of team members.

3. Technical Writer
Leads in organizing, structuring and writing of the report using contributions from designated members.

4. Proof Reader
Responsible for ensuring the report has no grammatical or spelling errors and that the report is written using acceptable clear English language.

5. Recorder

Takes minutes and documents all meeting and design activities for the group. Short video clips can be used to catalog the group's activities.

Note: Group can add more roles if needed.

Grading Scheme for Group Agreement

Project Group #__8__

Item	Description	Maximum Points	Your Score
1	Development and description of group leader selection process Information provided on group leader	6 4	
2	Development and description of process for assigning roles Assignment of Proper Roles to team members	5 5	
3	Development and description of process for selecting meeting times Meeting times (days of the week, time) selected	3 4	
4	Total meeting hours/week (>=6 hours)	3	
5	Grouping meeting location specified	3	
6	Development and description of process for setting up meeting with project owner Meeting schedule with faculty project owner(s) fixed & Signed by advisor	2 3	

7	Properly legally phrased agreement that shows students did research to put in appropriate legal terms. *Included College statements in agreement and signed by each member*	6 4	
8	Homework cover page used and copy of assignment attached	2	
	Total	50	

A.3
Record of Meeting Minutes

Meeting Minutes 1

SENIOR DESIGN & PROFESSIONALISM II
FALL 2020 SEMESTER
REPORT ON GROUP DYNAMICS

Week #3 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 9/10/20 Meeting Time: 12PM-2PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Remind everyone on what can be done in the meantime
- Discuss what will be covered at next meeting
- Complete project report

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Remind everyone on what can be done in the meantime
12pm - 12:22pm

Jonathon Horta suggested doing research on the off-road vehicle and obstacle course.
Daniel Ward shared a video of previous a Baja competition
Michael Samuel suggested paying attention to wheels based of the video shared

Discuss what will be covered at next meeting
12:23pm - 12:28pm

Robert Barbee mentioned what would be covered at the next meeting and that SAE Baja would be joining our next meeting at 11am.
Robert Barbee brought up dues for people interested in joining the organization.

Complete project report
12:29pm - 2pm

Robert Barbee suggested everyone focussing on the suspension instead of the whole vehicle.
Aramis King and Titus Woodard suggested using an off-road course near Houston outskirts.
Todd Maxwell suggested coming back to topics in the future when it's less difficult to discuss them.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

We encountered a problem finding main tasks to focus on with the project. Robert Barbee suggested reducing the number of tasks to better break down subtasks, and this something the group agreed on to help resolve this problem. We also encountered a problem finding a measurement basis on the safety subject. Michael Samuel helped resolve this problem by mentioning that we could figure that out as we go, which the group had agreed on.

Name	**Task Assigned to team members at this meeting**	**Deliverables completed & submitted from tasks assigned in previous meeting(s)**	**Actions taken by group on non-performing member**
Robert Barbee	Send the completed project report to Dr. Jiang for a review. Find an article about the suspension or the Baja competition to share at the next meeting.	Get together with PV SAE to clarify tasks that need to be done and agenda.	

Jonathon Horta	Complete meeting minutes before the next meeting. Find an article about the suspension or the Baja competition to share at the next meeting.	Turn in meeting minutes and project agreement.	
Aramis King & Daniel Ward	Find an article about the suspension or the Baja competition to share at the next meeting.	Complete section 1.3.2 from project report	
Michael Samuel & Titus Woodard	Find an article about the suspension or the Baja competition to share at the next meeting.	Find a location for putting our prototype to the test.	
Todd Maxwell	Find an article about the suspension or the Baja competition to share at the next meeting.		

SENIOR DESIGN & PROFESSIONALISM II
FALL 2020 SEMESTER
REPORT ON GROUP DYNAMICS

Week #3 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 9/11/20 Meeting Time: 10:40AM-12:40PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Find mistakes of previous graded submission of report.
- Discuss examples of off road suspension/vehicles.
- Meet with Baja Club leaders.
- Discuss/Start on status report 3.

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)
Everyone discussed what mistakes were made on previous report

10:40-10:50

Jonathan Horta presented feedback from Dr.Peng.

Robert Barbee suggested a diagram for deliverables and tasks assignments.

10:50-11:25

Discuss examples of off road suspension/vehicles

Robert Barbee introduced chassis design and off road vehicle competition video.

Michael Samuel had suggestions on chassis design and driver of vehicle in competition.

Titus Woodard had question concerning suspension systems being used, and suggested shock refinements to enhance suspensions.

Aramis King found information about the baja competition to get a better idea of designing features.

Daniel Ward stated design concerns and introduced problems that could arise with the overall stability of the vehicle when taking to the course

11:25-12:25

Met with leaders of Baja Club

Baja Club leaders spoke with the team about joining the competition committee and how competition will be assembled.

Majority of the group created SAE membership.

All of the group are now Baja Club members.

12:25-12:40

Discuss Status Report 3

As a group we decided to add more a descriptive status report.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

Majority of our meeting was constructed to get to know more about the Baja Club and its leaders. As a team we all agreed to join the Club so that our understanding of designing and competition of the off road vehicle will enhance. The only real problem we ran into was the last submission of the status report. Jonathan Horta informed the team of our mistakes, while Robert Barbee suggested a unique approach with organizing our report using diagrams/charts. Titus Woodard, Daniel Ward, Todd Maxwell and Aramis King all provided questions and suggestions regarding design and competition.

Name	Task Assigned to team members at this meeting	Deliverables completed & submitted from tasks assigned in previous meeting(s)	Actions taken by group on non-performing member
Robert Barbee	Complete charts and diagrams for status report 3.	Introduce team to Baja club leaders.	
Jonathon Horta	Complete charts and diagrams for status report 3.	Provided feedback from graded status report.	
Aramis King & Daniel Ward	Complete 1.4 section of status report	Provided questions and suggestions from articles and videos researched.	
Michael Samuel & Titus Woodard	Complete 1.4 section of status report	Provided questions and suggestions from articles and videos researched.	
Todd Maxwell	Complete 1.4 section of status report	Provided questions and suggestions from articles and videos researched.	

SENIOR DESIGN & PROFESSIONALISM II

FALL 2020 SEMESTER

REPORT ON GROUP DYNAMICS

Week #4 MINUTES OF GROUP MEETINGS

Group #8

Meeting Date: 9/15/20 Meeting Time: 12:00AM-2:00PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Meet with Baja Club leaders.
- Discuss and begin on status report 4.
- Prepare the Gantt Chart
- Find mistakes of previous graded submission of report.
- Discussion of the designs brought forward by the group members.

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Everyone discussed what mistakes were made on previous report

12:00-12:30

Met with leaders of Baja Club

Group 8 met with the BAJA organization to discuss the roles for the different team members.

Reiterated what we discussed on friday from the different ideas and designs. Also making sure we were following the guidelines for this year's competition.

Lastly what updates have been made to the suspension, and what are the next steps taken for that to be fully completed.

12:30-1:05

Discussing the key objectives

With meeting the BAJA team we were able to better understand what areas we need to move forward with and what areas need minor modifications.

1:05-1:25

Break off into Sections for Report

Robert and Johnathan began working on Table 1 with provided information from the BAJA team.

Michael began working on the Microsoft Project Software to create a successful Gantt chart.

Aramis and Daniel began working on Table 2.1 of the report

Titus and Todd began working on Table 2.2 of the report

1:25-2:00

Discuss Status Report 4

As a group we then came together to collaborate and observe one another's work to make any corrections if needed. Also, the planning of ideas for the upcoming meetings, to better prepare for the next steps in the project.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

The first part of our meeting was constructed to get to know more about our roles and necessary contributions to the Baja Club and its leaders. We next were given the necessary steps the organization wanted to and how we should move forward. After meeting with Baja we disbanded

into our senior design group, coming on the problem of the Gantt chart. Continuously having minor malfunctions until we were able to play and get better with the software, to successfully complete the results. We then decided to collective pair up to complete the task for the upcoming report, as we were able to contribute to the assignment. Robert Barbee and Johnathon Horta started on the objectives and design. Michael Samuel worked on the creation of the Gantt Chart. Aramis King and Daniel Ward worked on the Task Identification, Table 2.1 . Todd Maxwell and Titus Woodard worked on the timeline, Table 2.2.

Name	**Task Assigned to team members at this meeting**	**Deliverables completed & submitted from tasks assigned in previous meeting(s)**	**Actions taken by group on non-performing member**
Robert Barbee	Complete charts and diagrams for status report 4.Complete Table 1 and Stress Analysis for Suspension.	Confirmed meeting days with Dr. Jiang	

Jonathon Horta	Complete charts and diagrams for status report 4 .Complete Table 1 and Engineering Codes and Standards.	Provided feedback from graded status reports.	
Aramis King & Daniel Ward	Complete 2.1 section of status report. Aramis- Stress Analysis of Suspension Daniel- Previous design of suspension and steering	Provided questions and suggestions from articles and videos researched.	
Todd Maxwell & Titus Woodard	Complete 2.2 section of status report. ™-Kinematic Design of Suspension and Meeting Minutes Titus-Design of previous Suspension and steering.	Provided questions and suggestions from articles and videos researched.	
Michael Samuel	Complete Gantt Chart section of status report. Previous Design of Suspension and Steering	Provided questions and suggestions from articles and videos researched.	

Meeting Minutes 2

SENIOR DESIGN & PROFESSIONALISM II
FALL 2020 SEMESTER
REPORT ON GROUP DYNAMICS

Week #4 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 9/17/20 Meeting Time: 12PM-2PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Reviewed Progress on status report 4
- Continued to work on status report 4
- Review of previous status report and upcoming objectives

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Reviewed Progress on status report 4
12:00PM-12:23
Robert Barbee asked about progress of tasks that needed to be completed from the previous meeting, and mentioned that he spoke with Dr. Jiang about meeting times. Aramis King and Daniel Ward mentioned that they completed the first section of status report 4. Todd and Titus noted that they were completing section two in status report 4.

Continued to work on status report 4
12:23PM-1:26PM
Robert Barbee discussed the timeline with Todd Maxwell and how it should be completed. Jonathon Horta and Robert Barbee continued to work on the detailed table. Aramis King and Daniel Ward continued to work on the task identification section. Todd Maxwell and Titus Woodard continued to work on the timeline. Michael Samuel shared his screen of Gantt Chart and Robert Barbee and Jonathon Horta discussed time durations of objectives and Michael Samuel edited time in Microsoft Project.

Review of previous status report and upcoming objectives
1:26-2:00PM
Jonathon Horta and Robert Barbee discussed feedback from the previous status report. Robert Barbee and Michael Samuel both shared screens to adjust dates for future objectives in Microsoft Project. Robert Barbee discussed assigning tasks for upcoming objectives and discussed progress of current tasks.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

We kept running into issues when scheduling objectives in the Gantt Chart. Michael Samuel shared his screen and made some edits with dates. Robert Barbee made suggestions then shared his screen and made more edits to dates.

Name	**Task Assigned to team members at this meeting**	**Deliverables completed & submitted from tasks assigned in previous meeting(s)**	**Actions taken by group on non-performing member**
Robert Barbee	Complete the detailed table in status report 4.	Complete charts and diagrams for status report 4.Complete Table 1 and Stress Analysis for Suspension.	
Jonathon Horta	Complete the detailed table in status report 4.	Complete charts and diagrams for status report 4.Complete Table 1 and Stress Analysis for Suspension.	
Aramis King	Complete task identification section in status report 4.	Complete charts and diagrams for status report 4 .Complete Table 1 and Engineering Codes and Standards.	
Daniel Ward	Complete task identification section in status report 4.	Complete 2.1 section of status report. Aramis- Stress Analysis of Suspension Daniel- Previous design of suspension and steering	

Michael Samuel	Finish edits on Gantt Chart in status report 4.	Complete 2.2 section of status report. ™-Kinematic Design of Suspension and Meeting Minutes Titus-Design of previous Suspension and steering.	
Titus Woodard	Complete the timeline section in status report 4.	Complete Gantt Chart section of status report. Previous Design of Suspension and Steering	
Todd Maxwell	Complete the timeline section in status report 4.	Complete Gantt Chart section of status report. Previous Design of Suspension and Steering	

SENIOR DESIGN & PROFESSIONALISM II
FALL 2020 SEMESTER
REPORT ON GROUP DYNAMICS

Week #4 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 9/18/20 Meeting Time: 10:40AM-12:40PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Reviewed Progress on status report 4

- Continued to work on status report 4 and made corrections to status report 3
- Review of previous status report and upcoming objectives

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Reviewed Progress on status report 4
10:40AM-11:00AM
Michael Samuel updated the group on his status on the Gantt Chart. Jonathan Horta and Robert Barbee updated the group with their progress on the Detailed Table in status report 4. Aramis King and Daniel Ward updated the group with their progress with the Task Identification section. Titus Woodard and Todd Maxwell updated the group with their progress on the Timeline section.

Continued to work on status report 4 and made corrections to status report 3
11:00AM-12:00PM
Michael Samuel continued to work on Gantt chart and made corrections to the status report 3. Jonathan Horta and Robert Barbeee continued to work on the Detailed Table in status report 4 and made corrections to the status report. Aramis King and Daniel Ward completed the Task Identification section and made modifications to status report 3. Titus Woodard and Todd Maxwell continued to work on the Timeline section.

Review of previous status report and upcoming objectives
12:00PM-12:40PM
Jonathon Horta and Robert Barbee discussed feedback from the status report 3 and changes that still need to be made. Aramis King and Daniel Ward updated the group on the completion of the Task Identification section. Titus Woodard and Todd Maxwell updated the group on their progress of the Timeline section. Michael Samuel updated the group on the completion of edits on the Gantt Chart.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

This meeting was a continuation of the previous meeting so all problems were resolved in the previous meeting.

Name	Task Assigned to team members at this meeting	Deliverables completed & submitted from tasks assigned in previous meeting(s)	Actions taken by group on non-performing member

Robert Barbee	Complete the detailed table in status report 4.	Complete a portion of the detailed table in status report 4.	
Jonathon Horta	Complete the detailed table in status report 4.	Complete a portion of the detailed table in status report 4.	
Aramis King	Make corrections to status report 3.	Complete a portion of the task identification section in status report 4.	
Daniel Ward	Make corrections to status report 3.	Complete task identification section in status report 4.	
Michael Samuel	Make corrections to status report 3.	Finish edits on Gantt Chart in status report 4.	
Titus Woodard	Complete the timeline section in status report 4.	Complete the timeline section in status report 4.	
Todd Maxwell	Complete the timeline section in status report 4.	Complete the timeline section in status report 4.	

SENIOR DESIGN & PROFESSIONALISM II
FALL 2020 SEMESTER
REPORT ON GROUP DYNAMICS

Week #5 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 9/22/20 Meeting Time: 12PM-2PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard, Carrie Conton (Organization President)

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Meet with organization needing project done
- Discuss project updates and next steps
- Complete ¾ of Status Report 4

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Meet with organization needing project done
12M-12:20PM
Carrie Conton gave the group an ideal time frame of when things should be completed. Robert Barbee suggested touching base with the organization again Friday after the senior design group meeting. Carrie Conton gave Michael Samuel clarification on how the Gantt Chart should look.

Discuss project updates and next steps
12:21M-12:43PM
Michael Samuel gave the group an update on the process for approvals towards university project assistance. Robert Barbee suggested a few additions on the Gantt Chart. Robert Barbee suggested for Jonathon Horta to continue where Todd Maxwell and Titus Woodard left off on the timeline. Todd Maxwell mentioned his discussion with Titus Woodard and needed clarification on the timeline portion.

Complete ¾ of Status Report 4
12:44PM-2PM
Todd Maxwell suggested sharing status report 4 with Dr. Jiang and Dr. Peng at the same time. Michael Samuel completed the Gantt Chart and presented it to the entire group. Jonathon Horta interpreted all subtasks from the project planning portion onto the timeline. Robert Barbee continued to complete Table 1 on the report. Robert Barbee suggested splitting the majority of the subtasks evenly across the group. Robert Barbee suggested Todd Maxwell, Titus Woodard, and Jonathon Horta completing 2.2 and 2.3 of the report.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

There was minor confusion about the Gantt Chart and the timeline, but Carrie Conton and Robert Barbee were able to clear up the confusion..

Name	Task Assigned to team members at this meeting	Deliverables completed & submitted from tasks assigned in previous meeting(s)	Actions taken by group on non-performing member
Robert Barbee	Complete the detailed table for status report 4.	Completed more than half of the table on status report 4.	
Jonathon Horta	Complete the timeline for status report 4.	Revise everything that has been completed on the table for status report 4.	
Aramis King	Complete corrections to status report 3.	Corrected a portion of status report 3.	
Daniel Ward	Complete corrections to status report 3.	Corrected a portion of status report 3.	
Michael Samuel	Make corrections to the Gantt Chart and complete.	Updated Gantt Chart.	
Titus Woodard	Complete the timeline for section 3 to 13.	Completed the timeline for the project formulation portion.	
Todd Maxwell	Complete the timeline for section 3 to 13.	Completed the timeline for the project formulation portion.	

Meeting Minutes 3

SENIOR DESIGN & PROFESSIONALISM II
FALL 2020 SEMESTER
REPORT ON GROUP DYNAMICS

Week #5 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 9/24/20 Meeting Time: 12PM-2PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Cover recommendations
- Go through an introduction for status report 5
- Begin research

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Cover recommendations
12:00PM-12:25PM
Robert Barbee started the meeting setting the purpose behind the meeting today. Robert Barbee brought to attention that the suspension for this project is completely different from the suspension for a regular vehicle, and that he needs to do deeper research on steering. Robert Barbee suggested getting a solid audience for the project.

Go through an introduction for status report 5
12:25PM-1:04PM
Titus Woodard asked for clarification on sections 3.1 and 3.2 on the report. Robert Barbee presented 6 topics we could target on section 3.1. All group members selected a topic to do research on, and Robert Barbee gave everyone major points to focus on towards each topic. Michael Samuel suggested cleaning up the drive and organizing items into folders. Aramis King asked Michael Samuel for clarification on their research collaboration. Robert Barbee gave Todd Maxwell clarification on their research collaboration. Robert Barbee suggested only recording sources for now.

Begin research
1:04PM-2:00PM
The entire group did research on their topic and recorded their sources.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

There were a few times that group members such as Titus Woodard, Aramis King, and Todd Maxwell needed clarification, but all confusion was cleared up by group members such as Robert Barbee and Michael Samuel.

Name	**Task Assigned to team members at this meeting**	**Deliverables completed & submitted from tasks assigned in previous meeting(s)**	**Actions taken by group on non-performing member**
Robert Barbee	Complete research on steering and math equations to provide the sources at the next meeting.	Complete the first half of the detailed table for status report 4.	
Jonathon Horta	Complete research on general information and provide sources at the next meeting.	Complete the second half of the detailed table for status report 4.	
Aramis King	Complete research on suspension parts and provide sources at the next meeting.	Complete and review all subtasks updated under task identification.	
Daniel Ward	Complete research on target audience and provide sources at the next meeting.	Complete subtasks left under identification and review previous subtasks created from the previous meeting.	
Michael Samuel	Complete research on suspension parts and provide sources at the next meeting.	Make minor date corrections to the Gantt Chart and update report 4 with the final chart.	
Titus Woodard	Complete research on safety and provide sources at the next meeting.	Complete the essay format portion of the timeline status report 4.	

Todd Maxwell	Complete research on math equations and provide sources at the next meeting.	Complete the subtask portion involving deliverables of the timeline section on status report 4.	

SENIOR DESIGN & PROFESSIONALISM II
FALL 2020 SEMESTER
REPORT ON GROUP DYNAMICS

Week #5 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 9/25/20 Meeting Time: 10:40AM-12:40PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Cover recommendations
- Literature Review/Status Report 5
- Research Analysis

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Cover recommendations
10:40PM-11:25PM
Robert Barbee addressed the meeting with a brief overview of what criteria needs to be covered in the report. Robert also addressed the next steps by assigning roles for the Literature Review that we need to research for the weekend and bring back updated information to the meeting on tuesday.Jonathan Horta next displayed the additional information and sections we need to break down in order to meet the goals our audience/clients are looking for. Finally we set a deadline in order to finish the task we were given.

Literature Review/ Status Report 5

11:25PM-12:00PM
Status Report:
Robert Barbee established that he along with Jonathon Horta and Michael Samauel would be working on 3.1 as it would clear up any miscommunication between the group members. These members are set out to identify all information needed in moving forward with the project, such as diagrams for the suspension and steering, safety measures needed put in place as well as what type of system is in place. Jonathan Horta, Robert Barbee and Michael Samuel were given task 3.2 identifying the source, by displaying references and giving the group a better understanding of what they are looking to accomplish. Lastly Todd Maxwell, Aramis King and Titus Woodard were given task 3.3 the overall composition of the Literature Review.
Literature Review:
Section 3.1 we broke down into six different parts and split between group members to have researched from the task given on Thursday by Robert Barbee. The sections given were general overviews. steering, math equations, back and front suspension, audience/clients and safety. During this section of the meeting displays the information that we researched and presented the information to the group.
Robert Barbee worked on the Steering and Math equations, while Michael samauel worked on the front suspension and Aramis King worked on the back suspension. Jonathan Horta gave a general overview, Daniew Ward displayed the audience/clientele we should aim for,Titus Woodard researched the safety measures and requirements, Finally Todd Maxwell researched the math equations that it is need in the different areas implemented in section 3.1

Titus Woodard asked for clarification on sections 3.1 and 3.2 of the report. Robert Barbee presented 6 topics we could target on section 3.1. All group members selected a topic to do research on, and Robert Barbee gave everyone major points to focus on towards each topic. Michael Samuel suggested cleaning up the drive and organizing items into folders. Aramis King asked Michael Samuel for clarification on their research collaboration. Robert Barbee gave Todd Maxwell clarification on their research collaboration. Robert Barbee suggested only recording sources for now.

Research Analysis
12:00PM-12:40PM
Continue on with research and gain more knowledge within the section for 3.1 to bring and discuss better for tuesday's meeting. For the second half of the meeting we meet with the Baja team to discuss what the expectations are for the future assignments for the car. Also Robert addressed the research that the group has endured thus far and the measures we are taking moving forward.The entire group did research on their topic and recorded their sources.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

There were a few times that group members such as Titus Woodard, Aramis King, and Todd Maxwell needed clarification, but all confusion was cleared up by group members such as Robert Barbee and Michael Samuel.

Name	Task Assigned to team members at this meeting	Deliverables completed & submitted from tasks assigned in previous meeting(s)	Actions taken by group on non-performing member
Robert Barbee	Complete research for section 3.1 on steering and Math equation.Start assigned section of literature review and bring the information to the next meeting.	Complete research on steering and math equations to provide the sources at the next meeting.	
Jonathon Horta	Complete research for section 3.1 on general information.Start assigned section of literature review and bring the information to the next meeting.	Complete research on general information and provide sources at the next meeting.	
Aramis King	Complete research for section 3.1 on Suspension.Start assigned section of literature review and bring the information to the next meeting.	Complete research on suspension parts and provide sources at the next meeting.	
Daniel Ward	Complete research for section 3.1 on Audience/clientele. Start assigned section of literature review and bring the information to the next meeting.	Complete research on target audience and provide sources at the next meeting.	
Michael Samuel	Complete research for section 3.1 on suspension.Start assigned section of literature review and bring the information to the next meeting.	Complete research on suspension parts and provide sources at the next meeting.	
Titus Woodard	Complete research for section 3.1 on Safety..Start assigned section of literature review and bring the information to the next meeting.	Complete research on safety and provide sources at the next meeting.	
Todd Maxwell	Complete research for section 3.1 on Math equation.Start assigned section of literature review and bring the information to the next meeting.	Complete research on math equations and provide sources at the next meeting.	

SENIOR DESIGN & PROFESSIONALISM II
FALL 2020 SEMESTER
REPORT ON GROUP DYNAMICS

Week #5 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 9/29/20 Meeting Time: 12PM-1:40PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Cover requirements
- Literature Review/ Status Report 5
- Detailed Research Analysis

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Cover requirements
12:00PM-12:25PM
Robert started off the meeting giving a brief overview of what we discussed in the last meeting as well as what is on today's agenda.

Literature Review/Status report 5
12:25PM-1:04PM
Status Report 5:
Robert Barbee, Jonathon Horta and Michael Samuel have been working on 3.1 and have received a specified deadline of when that section should be finished. Johnathan horta Robert Barbee and Daniel Ward begin discussing what audiences they want to add to the report as we are looking to aim for as many companies and distributors as possible working on section 3.2. Titus Woodard, Aramis King and Todd Maxwell were given the task of completing the Literature Review by Wednesday finalizing section 3,3 and Status Report 5.

Detailed Research Analysis
1:04PM-2:00PM
Research from 3.1 should be added to the folder. For the second half of the meeting we meet with the Baja team to discuss what the expectations are for the future assignments

for the car. Also Robert addressed the research that the group has endured thus far and the measures we are taking moving forward.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

There were a few times that group members such as Titus Woodard, Aramis King, and Todd Maxwell needed clarification, but all confusion was cleared up by group members such as Robert Barbee and Michael Samuel.

Name	Task Assigned to team members at this meeting	Deliverables completed & submitted from tasks assigned in previous meeting(s)	Actions taken by group on non-performing member
Robert Barbee	Complete section 3.1/3.2 .Start on status report 5.	Complete research for section 3.1 on steering and Math equation.Start assigned section of literature review and bring the information to the next meeting.	
Jonathon Horta	Complete research for section 3.⅓.2 .Start on status report 5.	Complete research for section 3.1 on general information.Start assigned section of literature review and bring the information to the next meeting.	
Aramis King	Complete section 3.3 .Start on status report 5.	Complete research for section 3.1 on Suspension.Start assigned section of literature review and bring the information to the next meeting.	
Daniel Ward	Complete section 3.2 .Start on status report 5.	Complete research for section 3.1 on Audience/clientele. Start assigned section of literature review and bring the information to the next meeting.	
Michael Samuel	Complete section 3.1.Start on status report 5.	Complete research for section 3.1 on suspension.Start assigned section of literature review and bring the information to the next meeting.	
Titus Woodard	Complete section 3.3.Start onstatus report 5.	Complete research for section 3.1 on Safety..Start assigned section of	

		literature review and bring the information to the next meeting.	
Todd Maxwell	Complete section 3.3 on suspension.Start on status report 5. assigned section of literature review and bring the information to the next meeting.	Complete research for section 3.1 on Math equation.Start assigned section of literature review and bring the information to the next meeting.	

Meeting Minutes 4

SENIOR DESIGN & PROFESSIONALISM II
FALL 2020 SEMESTER
REPORT ON GROUP DYNAMICS

Week #6 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 10/5/20 Meeting Time: 10PM-11:15PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Update team on progress
- Update team on what's left
- Assign tasks to group members and work on individual tasks

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Update team on progress
10:00PM-10:18PM
Jonathon Horta stated that he corrected ⅓ of status report 3. Daniel Ward stated that he completed a few corrections on status report 4. Daniel Ward stated that the gantt chart and the milestone needed some attention due to confusion. Jonathon Horta stated what the previous grades are looking like. Robert Barbee gave clarification on the milestone portion of status report 4.

Update team on what's left
10:19PM-10:32PM
Robert Barbee gave the group a heads up on what's to be expected for the next meeting. Robert Barbee stated that he will begin putting together the midterm report. Jonathon Horta explained what's left to correct on status report 3. Daniel Ward explained in detail what's left to correct on status report 4.

Assign tasks to group members and work on individual tasks
10:33PM-11:15PM
Aramis King, Michael Samuel, and Daniel Ward agreed on correcting the rest of status report 4 together. Robert Barbee, Jonathon Horta, and Todd Maxwell agreed to correct status report 3 together. The members worked towards correcting their parts for the rest of the meeting.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

There was minor confusion in the milestone section of status report 4, but Robert Barbee assisted in clearing up the confusion with some clarification.

Name	Task Assigned to team members at this meeting	Deliverables completed & submitted from tasks assigned in previous meeting(s)	Actions taken by group on non-performing member
Robert Barbee	Correct the project list description and reorganize the project list for status report 3.	Complete section 3.1/3.2 and start on status report 5.	
Jonathon Horta	Identify table 1.1 and figure 1.1 with brief descriptions and section introductions for status report 3.	Complete research for section 3.⅓.2 and start on status report 5.	
Aramis King	Correct a few sections in status report 4 from where Daniel Ward left.	Complete section 3.3 and start on status report 5.	
Daniel Ward	Correct all deliverables missing in section 2.1.1 for status report 4.	Complete section 3.2 and start on status report 5.	
Michael Samuel	Correct the missing dates for the gantt chart and create a milestone for status report 4.	Complete section 3.1 and start on status report 5.	
Titus Woodard		Complete section 3.3 and start on status report 5.	Group split evenly members work and reached out to understand member's schedule
Todd Maxwell	Correct and add onto table 1.2, and constraints and operating environment for status report 3.	Complete section 3.3 on suspension and start on status report 5. Interpret a section of literature review and bring the information to the next meeting.	

SENIOR DESIGN & PROFESSIONALISM I

FALL 2020 SEMESTER

REPORT ON GROUP DYNAMICS

Week #7 MINUTES OF GROUP MEETINGS Group #8

Meeting Date: 10/06/20 Meeting Time: 12PM-2:00PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Michael Samuel, Aramis King, Titus Woodard

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Cover function Decomposition Powerpoint
- Assign Everyone to create Black box for Suspension and steering
- Report back at the end of the day with our ideas

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Cover requirements 12:00PM-12:25 PM

Robert started off the meeting giving a brief overview of what we discussed in the last meeting as well as what is on today's agenda. Also briefly went over future important dates.

Function Decomposition 12:25PM-1:20PM

Status Report 5:

Robert Barbee Started off with the powerpoint from canvas to review lecture 5 for status report 6: Function Decomposition. Then after reviewing this information, he assigned everyone to come up with ideas for the function decomposition.

Individual function decomposition 1:20PM-2:00PM

We took this time to create our black box for suspension. Which we reported back at the end of the meeting to put our ideas together.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

There were a few times that group members such as Titus Woodard, Aramis King, and Michael Samuel needed clarification, but all confusion was cleared up by group members such as Robert Barbee and Michael Samuel.

Name	Task Assigned to team members at this meeting	Deliverables completed & submitted from tasks assigned in previous meeting(s)	Actions taken by group on non-performing member
Robert Barbee	Complete Functional Decomposition black box for statues report 6. Bring in 3 ideas for suspension overall main function	Reviewed over Lecture 5 Status report 6 Functional Decomposition with the group. Completed individual assignment (creating black box with 3 ideas for suspension)	
Jonathon Horta	Complete Functional Decomposition black box for statues report 6. Bring in 3 ideas for suspension overall main function	Completed individual assignment (creating black box with 3 ideas for suspension)	
Aramis King	Complete Functional Decomposition black box for statues report 6. Bring in 3 ideas for suspension overall main function	Completed individual assignment (creating black box with 3 ideas for suspension)	
Daniel Ward	Complete Functional Decomposition black box for statues report 6. Bring in 3 ideas for suspension overall main function	Was not in meeting but still completed individual assignment (creating black box with 3 ideas for suspension).	
Michael Samuel	Complete Functional Decomposition black box for statues report 6. Bring in 3 ideas for suspension overall main function	Clarified missing information from lecture 5 and Completed individual assignment (creating black box with 3 ideas for suspension)	
Titus Woodard	Complete Functional Decomposition black box for statues report 6. Bring in 3 ideas for suspension overall main function	Completed individual assignment (creating black box with 3 ideas for suspension)	

Todd Maxwell	Complete Functional Decomposition black box for statues report 6. Bring in 3 ideas for suspension overall main function	Was not in meeting but still completed individual assignment (creating black box with 3 ideas for suspension)	

SENIOR DESIGN & PROFESSIONALISM II
FALL 2020 SEMESTER
REPORT ON GROUP DYNAMICS

Week #7 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 10/6/20-10/7/20 Meeting Time: 11PM-1:55AM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Update group on timeline up till midterm presentation
- Have members present all work from previous meeting
- Work towards completing black boxes for the suspension

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Update group on timeline up till midterm presentation
11PM-11:22PM
Robert Barbee updated the group on the meeting would consist of. Jonathon Horta gave an update on the grade given for status report 5. Jonathon Horta mentioned what was corrected on status report 3. Robert Barbee proceeded to inform the group on what needs to be completed by each individual for status report 6.

Have members present all work from previous meeting
11:23PM-11:58PM
Each individual presented the black boxes they created for the first major decomposition towards the suspension. Aramis King stated that there was confusion for the black boxes. Everyone agreed on clarification being needed for black boxes on status report 6.

Work towards completing black boxes for the suspension
11:58PM-1:58AM
Robert Barbee stated that he would present what Dr. Biney went through the previous class for clarification. After the presentation, the group proceeded and agreed on

understanding what is being asked before continuing with status report 6. Robert Barbee stated that there were some issues with putting all the black boxes on one page. Titus Woodard and Daniel Ward gave some suggestions on joining all black boxes in a simpler way. The entire group agreed on what black boxes overall should move onto the next level. Information from these black boxes were extracted and combined into a larger black box. Robert Barbee assigned tasks to all group members and informed the group on what the timeline would be looking like for the following day.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

There was confusion among the entire group as far as what the materials, energies, and forces entering and exiting the boxes should look like. Robert Barbee went over the presentation presented by Dr.Biney during the previous class to get clarification on what should be inputs and outputs on black boxes.

Name	**Task Assigned to team members at this meeting**	**Deliverables completed & submitted from tasks assigned in previous meeting(s)**	**Actions taken by group on non-performing member**
Robert Barbee	Complete 3 layer 1 Functional Decomposition black boxes about absorbing forces from off road conditions for statues report 6.	Complete Functional Decomposition black box for statues report 6. Bring in 3 ideas for suspension overall main function.	
Jonathon Horta	Complete 3-layer 1 Functional Decomposition black boxes about absorbing forces from off road conditions for statues report 6. Post literature review feedback.	Complete Functional Decomposition black box for statues report 6. Bring in 3 ideas for suspension overall main function.	
Aramis King	Complete 3-layer 1 Functional Decomposition black boxes about absorbing forces from off road conditions for statues report 6.	Complete Functional Decomposition black box for statues report 6. Bring in 3 ideas for suspension overall main function	
Daniel Ward	Complete 3-layer 1 Functional Decomposition black boxes about absorbing forces from off road conditions for statues report 6.	Complete Functional Decomposition black box for statues report 6. Bring in 3 ideas for suspension overall main function.	

Michael Samuel	Complete 3-layer 1 Functional Decomposition black boxes about absorbing forces from off road conditions for statues report 6. Begin putting presentation together.	Complete Functional Decomposition black box for statues report 6. Bring in 3 ideas for suspension overall main function.	
Titus Woodard	Complete 3 layer 1 Functional Decomposition black boxes about absorbing forces from off road conditions for statues report 6.	Complete Functional Decomposition black box for statues report 6. Bring in 3 ideas for suspension overall main function.	
Todd Maxwell	Complete 3-layer 1 Functional Decomposition black boxes about absorbing forces from off road conditions for statues report 6.	Complete Functional Decomposition black box for statues report 6. Bring in 3 ideas for suspension overall main function.	

Meeting Minutes 5

SENIOR DESIGN & PROFESSIONALISM II
FALL 2020 SEMESTER
REPORT ON GROUP DYNAMICS

Week #6 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 10/5/20 Meeting Time: 10PM-11:15PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Update team on progress
- Update team on what's left
- Assign tasks to group members and work on individual tasks

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Update team on progress
10:00PM-10:18PM
Jonathon Horta stated that he corrected ⅓ of status report 3. Daniel Ward stated that he completed a few corrections on status report 4. Daniel Ward stated that the gantt chart and the milestone needed some attention due to confusion. Jonathon Horta stated what the previous grades are looking like. Robert Barbee gave clarification on the milestone portion of status report 4.

Update team on what's left
10:19PM-10:32PM
Robert Barbee gave the group a heads up on what's to be expected for the next meeting. Robert Barbee stated that he will begin putting together the midterm report. Jonathon Horta explained what's left to correct on status report 3. Daniel Ward explained in detail what's left to correct on status report 4.

Assign tasks to group members and work on individual tasks
10:33PM-11:15PM
Aramis King, Michael Samuel, and Daniel Ward agreed on correcting the rest of status report 4 together. Robert Barbee, Jonathon Horta, and Todd Maxwell agreed to correct status report 3 together. The members worked towards correcting their parts for the rest of the meeting.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

There was minor confusion in the milestone section of status report 4, but Robert Barbee assisted in clearing up the confusion with some clarification.

Name	Task Assigned to team members at this meeting	Deliverables completed & submitted from tasks assigned in previous meeting(s)	Actions taken by group on non-performing member
Robert Barbee	Correct the project list description and reorganize the project list for status report 3.	Complete section 3.1/3.2 and start on status report 5.	
Jonathon Horta	Identify table 1.1 and figure 1.1 with brief descriptions and section introductions for status report 3.	Complete research for section 3.⅓.2 and start on status report 5.	
Aramis King	Correct a few sections in status report 4 from where Daniel Ward left.	Complete section 3.3 and start on status report 5.	
Daniel Ward	Correct all deliverables missing in section 2.1.1 for status report 4.	Complete section 3.2 and start on status report 5.	
Michael Samuel	Correct the missing dates for the gantt chart and create a milestone for status report 4.	Complete section 3.1 and start on status report 5.	
Titus Woodard		Complete section 3.3 and start on status report 5.	Group split evenly members work and reached out to understand member's schedule
Todd Maxwell	Correct and add onto table 1.2, and constraints and operating environment for status report 3.	Complete section 3.3 on suspension and start on status report 5. Interpret a section of literature review and bring the information to the next meeting.	

SENIOR DESIGN & PROFESSIONALISM I

FALL 2020 SEMESTER

REPORT ON GROUP DYNAMICS

Week #7 MINUTES OF GROUP MEETINGS Group #8

Meeting Date: 10/06/20 Meeting Time: 12PM-2:00PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Michael Samuel, Aramis King, Titus Woodard

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Cover function Decomposition Powerpoint
- Assign Everyone to create Black box for Suspension and steering
- Report back at the end of the day with our ideas

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Cover requirements 12:00PM-12:25 PM

Robert started off the meeting giving a brief overview of what we discussed in the last meeting as well as what is on today's agenda. Also briefly went over future important dates.

Function Decomposition 12:25PM-1:20PM

Status Report 5:

Robert Barbee Started off with the powerpoint from canvas to review lecture 5 for status report 6: Function Decomposition. Then after reviewing this information, he assigned everyone to come up with ideas for the function decomposition.

Individual function decomposition 1:20PM-2:00PM

We took this time to create our black box for suspension. Which we reported back at the end of the meeting to put our ideas together.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

There were a few times that group members such as Titus Woodard, Aramis King, and Michael Samuel needed clarification, but all confusion was cleared up by group members such as Robert Barbee and Michael Samuel.

Name	Task Assigned to team members at this meeting	Deliverables completed & submitted from tasks assigned in previous meeting(s)	Actions taken by group on non-performing member
Robert Barbee	Complete Functional Decomposition black box for statues report 6. Bring in 3 ideas for suspension overall main function	Reviewed over Lecture 5 Status report 6 Functional Decomposition with the group. Completed individual assignment (creating black box with 3 ideas for suspension)	
Jonathon Horta	Complete Functional Decomposition black box for statues report 6. Bring in 3 ideas for suspension overall main function	Completed individual assignment (creating black box with 3 ideas for suspension)	
Aramis King	Complete Functional Decomposition black box for statues report 6. Bring in 3 ideas for suspension overall main function	Completed individual assignment (creating black box with 3 ideas for suspension)	
Daniel Ward	Complete Functional Decomposition black box for statues report 6. Bring in 3 ideas for suspension overall main function	Was not in meeting but still completed individual assignment (creating black box with 3 ideas for suspension).	
Michael Samuel	Complete Functional Decomposition black box for statues report 6. Bring in 3 ideas for suspension overall main function	Clarified missing information from lecture 5 and Completed individual assignment (creating black box with 3 ideas for suspension)	
Titus Woodard	Complete Functional Decomposition black box for statues report 6. Bring in 3 ideas for suspension overall main function	Completed individual assignment (creating black box with 3 ideas for suspension)	
	Complete Functional Decomposition black box	Was not in meeting but still completed individual assignment	

Todd Maxwell	for statues report 6. Bring in 3 ideas for suspension overall main function	(creating black box with 3 ideas for suspension)	

SENIOR DESIGN & PROFESSIONALISM II
FALL 2020 SEMESTER
REPORT ON GROUP DYNAMICS

Week #7 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 10/6/20-10/7/20 Meeting Time: 11PM-1:55AM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Update group on timeline up till midterm presentation
- Have members present all work from previous meeting
- Work towards completing black boxes for the suspension

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Update group on timeline up till midterm presentation
11PM-11:22PM
Robert Barbee updated the group on the meeting would consist of. Jonathon Horta gave an update on the grade given for status report 5. Jonathon Horta mentioned what was corrected on status report 3. Robert Barbee proceeded to inform the group on what needs to be completed by each individual for status report 6.

Have members present all work from previous meeting
11:23PM-11:58PM
Each individual presented the black boxes they created for the first major decomposition towards the suspension. Aramis King stated that there was confusion for the black boxes. Everyone agreed on clarification being needed for black boxes on status report 6.

Work towards completing black boxes for the suspension
11:58PM-1:58AM
Robert Barbee stated that he would present what Dr. Biney went through the previous class for clarification. After the presentation, the group proceeded and agreed on understanding what is being asked before continuing with status report 6. Robert Barbee stated that there were some issues with putting all the black boxes on one page. Titus Woodard and Daniel Ward gave some suggestions on joining all black boxes in a simpler way. The entire group agreed on what black boxes overall should move onto the next

level. Information from these black boxes were extracted and combined into a larger black box. Robert Barbee assigned tasks to all group members and informed the group on what the timeline would be looking like for the following day.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

There was confusion among the entire group as far as what the materials, energies, and forces entering and exiting the boxes should look like. Robert Barbee went over the presentation presented by Dr.Biney during the previous class to get clarification on what should be inputs and outputs on black boxes.

Name	Task Assigned to team members at this meeting	Deliverables completed & submitted from tasks assigned in previous meeting(s)	Actions taken by group on non-performing member
Robert Barbee	Complete 3-layer 1 Functional Decomposition black boxes about absorbing forces from off road conditions for statues report 6.	Complete Functional Decomposition black box for statues report 6. Bring in 3 ideas for suspension overall main function.	
Jonathon Horta	Complete 3-layer 1 Functional Decomposition black boxes about absorbing forces from off road conditions for statues report 6. Post literature review feedback.	Complete Functional Decomposition black box for statues report 6. Bring in 3 ideas for suspension overall main function.	
Aramis King	Complete 3-layer 1 Functional Decomposition black boxes about absorbing forces from off road conditions for statues report 6.	Complete Functional Decomposition black box for statues report 6. Bring in 3 ideas for suspension overall main function	
Daniel Ward	Complete 3-layer 1 Functional Decomposition black boxes about absorbing forces from off road conditions for statues report 6.	Complete Functional Decomposition black box for statues report 6. Bring in 3 ideas for suspension overall main function.	
Michael Samuel	Complete 3-layer 1 Functional Decomposition black boxes about absorbing forces from off road conditions for statues report 6. Begin putting presentation together.	Complete Functional Decomposition black box for statues report 6. Bring in 3 ideas for suspension overall main function.	

Titus Woodard	Complete 3-layer 1 Functional Decomposition black boxes about absorbing forces from off road conditions for statues report 6.	Complete Functional Decomposition black box for statues report 6. Bring in 3 ideas for suspension overall main function.	
Todd Maxwell	Complete 3-layer 1 Functional Decomposition black boxes about absorbing forces from off road conditions for statues report 6.	Complete Functional Decomposition black box for statues report 6. Bring in 3 ideas for suspension overall main function.	

Meeting Minutes 6

SENIOR DESIGN & PROFESSIONALISM II
FALL 2020 SEMESTER
REPORT ON GROUP DYNAMICS

Week #7 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 10/8/20 Meeting Time: 12PM-2PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Add additional information to presentation slides needing it
- Run through brief information on slides for each member
- Do a couple dry runs and adjust presentation based on the timing

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Add additional information to presentation slides needing it
12:00PM-12:38PM
Robert Barbee stated that there isn't a limit on the amount of slides we can have on the presentation. Robert Barbee suggested fixing the flow of the math equations section of the presentation. All members added finishing touches to the report after bouncing ideas off each other.

Run through brief information on slides for each member
12:39PM-1:08PM
Michael Samuel shared his screen and did a quick runthrough on the presentation allowing all the members to get a quick glance at the completed presentation. All members were asked to give a quick summary on the slides they created. Daniel Ward made some suggestions on what could be included in the introduction. Michael Samuel stated that he would be changing the slides for the presentation during class. Every individual went in and fixed all the issues detected on their slides during the quick run through.

Do a couple dry runs and adjust presentation based on the timing
1:09PM-2PM
The group proceeded to do a presentation dry run, which took over 15 minutes. Aramis King stated that less time would be spent once every member speaks about their presentation at a faster rate. Jonathon Horta suggested not focussing too much on the details of the research done for the report. The group made minor tweaks to the

presentation and proceeded to do a second dry run, which took a little over 12 minutes. Robert Barbee suggested all members to look over the presentation one last time before presenting.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

The group as a whole had an issue regarding timing because the dry run of the presentation turned out to go past 15 minutes. This was resolved by each member going less in depth on the information presented on the slides. This cut the total presentation down to less than 12 minutes.

Name	Task Assigned to team members at this meeting	Deliverables completed & submitted from tasks assigned in previous meeting(s)	Actions taken by group on non-performing member
Robert Barbee	Run through the midterm presentation portion one last time and review status report 5 feedback.	Completed introduction, steering, functional decomposition, and conclusion slides for midterm presentation.	
Jonathon Horta	Run through the midterm presentation portion one last time and review status report 5 feedback.	Completed general information slides and add needs to project goals slide on for midterm presentation.	
Aramis King	Run through the midterm presentation portion one last time and review status report 5 feedback.	Complete the slide covering types of suspension systems on the midterm presentation.	
Daniel Ward	Run through the midterm presentation portion one last time and review status report 5 feedback.	Interpret the audience and how they would benefit from the design onto the midterm presentation.	
Michael Samuel	Run through the midterm presentation portion one last time and review status report 5 feedback.	Structure the overall midterm presentation, complete project constraints slide, and assist Aramis King on suspension parts slide on midterm presentation.	
Titus Woodard	Run through the midterm presentation portion one last time and review status report 5 feedback.	Complete the literature review introduction and safety slides of the midterm presentation.	

Todd Maxwell	Run through the midterm presentation portion one last time and review status report 5 feedback.	Complete the math equations slides of the midterm presentation.	

SENIOR DESIGN & PROFESSIONALISM I

FALL 2020 SEMESTER

REPORT ON GROUP DYNAMICS

Week #7 MINUTES OF GROUP MEETINGS Group #8

Meeting Date: 10/09/20 Meeting Time: 10:40AM-12:40PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Michael Samuel, Aramis King, Titus Woodard, Todd Maxwell, Daniel Ward

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Meet with Baja Club.
- Identify mistakes of previous reports.
- Fix mistakes for completed Midterm Report.

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Meet with Baja Club

Each group member updated Carrie Conton on components researched from past weekend. Each group member made sure to research a different area of design for Baja Club.

10:40AM-11:00AM

Identify mistakes on previous reports

Robert Barbee suggested that each group member fix their previous mistakes in previous reports and literature review. Aramis King and Daniel Ward reminded the group of certain report formats, based on Dr. Peng's comments.

11:00AM-11:40AM

Fix mistakes for completed Midterm report

Jonathon Horta suggested that we format the report a certain way to avoid points off. Daniel Ward Formatted midterm report. Todd Maxwell fixed the key part from the

previous status report. Aramis king updated deliverables from the previous status report to improve mistakes. Titus Woodard questioned and finished the acknowledgement section for report.

11:40AM-12:40AM

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

In a collective discussion, our group focused on minor mistakes is previous reports that would affect our final midterm report. Based on everyone's schedule, we all agreed to have all mistakes fixed by the end of 10/10/20, so that on 10/11/20 we would have our group overview day to make final submission.

Name	Task Assigned to team members at this meeting	Deliverables completed & submitted from tasks assigned in previous meeting(s)	Actions taken by group on non-performing member
Robert Barbee	Fix previous reports mistakes, based on feedback comments. Cited all tables and figures.	Read and fix Status Report 5, based on feedback from Dr.Peng	
Jonathon Horta	Format midterm report Fix previous reports mistakes, based on feedback comments. Create a Letter of transmittal.	Read and fix Status Report 5, based on feedback from Dr.Peng	
Aramis King	Fix previous reports mistakes, based on feedback comments. Update deliverables on each status report.	Read and fix Status Report 5, based on feedback from Dr.Peng	
Daniel Ward	Fix previous reports mistakes, based on feedback comments. Format midterm report.	Read and fix Status Report 5, based on feedback from Dr.Peng	
Michael Samuel	Fix previous reports mistakes, based on feedback comments	Read and fix Status Report 5, based on feedback from Dr.Peng	
Titus Woodard	Fix previous reports mistakes, based on feedback comments. Provide acknowledgements for midterm reports.	Read and fix Status Report 5, based on feedback from Dr.Peng	

Todd Maxwell	Fix previous reports mistakes, based on feedback comments	Read and fix Status Report 5, based on feedback from Dr.Peng	

SENIOR DESIGN & PROFESSIONALISM I

FALL 2020 SEMESTER

REPORT ON GROUP DYNAMICS

Week #8 MINUTES OF GROUP MEETINGS Group #8

Meeting Date: 10/13/20 Meeting Time: 12:00pm-2:00pm__ Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Michael Samuel, Aramis King, Titus Woodard, Todd Maxwell, Daniel Ward

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Baja Club Agenda
- Status Report 7a:7b Breakdown
- Beginning Process of Status Report

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Baja Club Agenda
12:00PM-12:38PM
To start off this meeting our group members met with Carie Conton the president of the Baja club to discuss what further plans she had in mind for the vehicle. Also Miss Conton displayed a new literature review that she would like us to research and familiarize ourselves with the knowledge we gain. Robert Barbee then intervened asking about the process of the information given and the deadline for our research analysis of the topics.

Status Report 7a:7b Breakdown
12:39PM-1:10PM
Johnathon Horta started off our meeting with our usual feedback of previous reports as our group better prepares for our next Status Report. Robert Barbee asks who's taking the meeting then brings a twist to the group as we were able change the format of the meeting by putting Michael Samuel over the background and forefront. Todd Maxwell volunteers for the meeting minutes. Michael Samuel shared his screen and began to run through the description and requirements for the upcoming Status Reports. Robert Barbee then interjects with his own synopsis of what the report is telling us. Daniel Ward and

Aramis King asked for a reference to get a better and detailed understanding of what the report is asking for. Michael Samuel then gives further input from what he is viewing from the information he has received from canvas.

Beginning Process of Status Report
1:11PM-2PM
Michael Samuel and Robert Barbee sorted material of the following Status Reports to best even out the workload. As we began in the next steps Titus Woodard asked when the deadline for the first production of the sketches would be. Michael Samuel gave us the opportunity to finish the first part of sketches by 5pm later that day. Aramis King and Johnathon horta then go on to ask the requirements for the first half of work. Robert barbee then says we should try to do at least twelve sketches by the next meeting time.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

In a collective discussion, our group focused on first the areas we needed to correct from previous reports and bring what we've learned to the newest report. Next we were able to evenly divide our work into sections to focus on. We were able to generate a deadline for the material that needs to be finished in a timely manner.

Name	Task Assigned to team members at this meeting	Deliverables completed & submitted from tasks assigned in previous meeting(s)	Actions taken by group on non-performing member
Robert Barbee	Complete given section of Status Report 7a:7b	Fix previous reports mistakes, based on feedback comments. Cited all tables and figures.	
Jonathon Horta	Complete given section of Status Report 7a:7b	Format midterm report Fix previous reports mistakes, based on feedback comments. Create a Letter of transmittal.	
Aramis King	Complete given section of Status Report 7a:7b	Fix previous reports mistakes, based on feedback comments. Update deliverables on each status report.	
Daniel Ward	Complete given section of Status Report 7a:7b	Fix previous reports mistakes, based on feedback comments. Format midterm report.	

Michael Samuel	Complete given section of Status Report 7a:7b	Fix previous reports mistakes, based on feedback comments	
Titus Woodard	Complete given section of Status Report 7a:7b	Fix previous reports mistakes, based on feedback comments. Provide acknowledgements for midterm reports.	
Todd Maxwell	Complete given section of Status Report 7a:7b	Fix previous reports mistakes, based on feedback comments	

Meeting Minutes 7

SENIOR DESIGN & PROFESSIONALISM II
FALL 2020 SEMESTER
REPORT ON GROUP DYNAMICS

Week #8 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 10/15/20 Meeting Time: 12PM-2PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Update group on progress
- Combine work based off previous tasks given
- Begin finalizing report 7

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Update group on progress
12:00PM-12:22PM
Robert Barbee updated the group on new due dates. Robert Barbee asked the group for an update on previous tasks given to the group members. Michael Samuel suggested finding out which file works best for uploading pictures for sketches. Titus Woodard suggested converting pictures for sketches into pdfs.

Combine work based off previous tasks given
12:23PM-1:05PM
The group began skimming through status report 7 to have a better understanding. After skimming through report 7, the group began combining their individual level 3 function descriptions onto a table. Robert Barbee suggested changing the word shocks to the word struts across the table. The group continued to put all their level 3 function descriptions into the table.

Begin finalizing report 7
1:06PM-2PM
The group began to fill out status report 7. There was confusion on what was being asked for in the individual portion of the report, but Robert Barbee gave some clarification after reading through what was being asked a few times. Jonathon Horta asked about sketches needing to be put into tables. Robert Barbee explained why the group should hold off on the sketches. Robert Barbee suggested for everyone to dive deeper into understanding the knuckles in the suspension better.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

Aramis King needed clarification on the function on the control arm. The whole group assisted in breaking down the control arm to its smallest possible functions for better clarification of the function of the entire control arm.

Name	Task Assigned to team members at this meeting	Deliverables completed & submitted from tasks assigned in previous meeting(s)	Actions taken by group on non-performing member
Rrbert Barbee	Do some research to better understand the knuckles in a suspension.	Complete given section of Status Report 7a:7b	
Jonathon Horta	Do some research to better understand the knuckles in a suspension.	Complete given section of Status Report 7a:7b	
Aramis King	Do some research to better understand the knuckles in a suspension.	Complete given section of Status Report 7a:7b	
Daniel Ward	Do some research to better understand the knuckles in a suspension.	Complete given section of Status Report 7a:7b	
Michael Samuel	Do some research to better understand the knuckles in a suspension.	Complete given section of Status Report 7a:7b	
Titus Woodard	Do some research to better understand the knuckles in a suspension.	Complete given section of Status Report 7a:7b	
Todd Maxwell	Do some research to better understand the knuckles in a suspension.	Complete given section of Status Report 7a:7b	

SENIOR DESIGN & PROFESSIONALISM II
FALL 2020 SEMESTER
REPORT ON GROUP DYNAMICS

Week #8 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 10/16/20 Meeting Time: 10:40AM-12:40PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard, Carrie Conton, Viccassee Paul

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Update Organization on progress
- Present literature review on research done by members
- Present a presentation for students interested in joining the organization

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Update Organization on progress
10:40AM-11AM
Carrie Conton informed the group on how this meeting will play out. Carrie Conton updated the group on some portions of the vehicle will be due. Jonathon Horta suggested getting in touch with Dr. Jiang about registration fees for the competition. Viccassee Paul informed the group on how exactly the professional gear for the organization will look and about how long it will take to arrive.

Present literature review on research done by members
11AM-12PM
Carrie Conton presented her literature review on the drivetrain of the vehicle. Michael Samuel presented his literature review on transmission. Aramis King presented his literature review on the drivetrain. Jonathon Horta presented his literature review on the transmission. Todd Maxwell presented his literature review on the drivetrain. Vicaassee Paul presented his literature review on tires. Robert Barbee presented his literature review on steering.Daniel Ward presented his literature review on transmission. Titus Woodard presented his literature review on safety.

Present a presentation for students interested in joining the organization
12PM-12:40PM
The group chose specific slides to cover during the presentation. The group presented a brief presentation involving the background behind the organization, competition, and different teams for each system on the vehicle. Carrie Conton gave next steps for anyone interested in being a part of the projects and the organization. Robert Barbee gave tasks to the senior design group and asked for them to be completed before the next meeting.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

There were no problems encountered during this meeting, and all transitions occurred smoothly between agendas for this meeting.

Name	Task Assigned to team members at this meeting	Deliverables completed & submitted from tasks assigned in previous meeting(s)	Actions taken by group on non-performing member
Robert Barbee	Complete remaining 25 sketches and descriptions for assigned level 3 subfunctions.	Do some research to better understand the knuckles in a suspension.	
Jonathon Horta	Complete remaining 24 sketches and descriptions for assigned level 3 subfunctions.	Do some research to better understand the knuckles in a suspension.	
Aramis King	Complete remaining 24 sketches and descriptions for assigned level 3 subfunctions.	Do some research to better understand the knuckles in a suspension.	
Daniel Ward	Complete remaining 24 sketches and descriptions for assigned level 3 subfunctions.	Do some research to better understand the knuckles in a suspension.	
Michael Samuel	Complete remaining 24 sketches and descriptions for assigned level 3 subfunctions.	Do some research to better understand the knuckles in a suspension.	
Titus Woodard	Complete remaining 24 sketches and descriptions for assigned level 3 subfunctions.	Do some research to better understand the knuckles in a suspension.	
Todd Maxwell	Complete remaining 24 sketches and descriptions for assigned level 3 subfunctions.	Do some research to better understand the knuckles in a suspension.	

SENIOR DESIGN & PROFESSIONALISM II
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REPORT ON GROUP DYNAMICS

Week #8 MINUTES OF GROUP MEETINGS
Group #9

Meeting Date: 10/20/20 Meeting Time: 12PM-2PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard, Carrie Conton, Vicaassee Paul

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Meet with organization needing the project
- Explain correct formatting for individual tables
- Assign tasks for the next meeting

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Meet with organization needing the project
12PM-12:44PM
Robert Barbee and Jonathon Horta updated the organization on the recent progress with the suspension and steering. Carrie Conton mentioned that the group members would all have to register on two different websites since the group is assisting the organization with a portion of the vehicle. Carrie Conton shared these two websites with the group and gave everyone step by step instructions on how to go about registering. Carrie Conton assigned every two members to focus on individual portions of the vehicle.

Explain correct formatting for individual tables
12:45PM- 1:48PM
Robert Barbee created a descriptions and sketches table template for the steering and suspension systems individual report. Michael Samuel suggested that every group member should have a folder including all tables and their individual report under the Status Report 7 folder. Robert Barbee proceeded to run through examples of correct formatting for the individual reports.

Assign tasks for the next meeting
1:49PM-2PM
Jonathon Horta asked what the members felt comfortable having completed by the next class. Robert Barbee did a quick run through on what the results on the tables should look like, and explained what should be done before the next class and its importance.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

There was a problem with Titus Woodard, Daniel Ward, and Todd Maxwell trying to understand how all figures should be cited. Robert Barbee had to go through multiple examples as he shared his screen to resolve this problem.

Name	Task Assigned to team members at this meeting	Deliverables completed & submitted from tasks assigned in previous meeting(s)	Actions taken by group on non-performing member
Robert Barbee	Complete individual tables with correct citation format for assigned level 3 functions before the next class.	Complete remaining 25 sketches and descriptions for assigned level 3 subfunctions.	
Jonathon Horta	Complete individual tables with correct citation format for assigned level 3 functions before the next class.	Complete remaining 24 sketches and descriptions for assigned level 3 subfunctions.	
Aramis King	Complete individual tables with correct citation format for assigned level 3 functions before the next class.	Complete remaining 24 sketches and descriptions for assigned level 3 subfunctions.	
Daniel Ward	Complete individual tables with correct citation format for assigned level 3 functions before the next class.	Complete remaining 24 sketches and descriptions for assigned level 3 subfunctions.	
Michael Samuel	Complete individual tables with correct citation format for assigned level 3 functions before the next class.	Complete remaining 24 sketches and descriptions for assigned level 3 subfunctions.	
Titus Woodard	Complete individual tables with correct citation format for assigned level 3 functions before the next class.	Complete remaining 24 sketches and descriptions for assigned level 3 subfunctions.	
Todd Maxwell	Complete individual tables with correct citation format for assigned level 3 functions before the next class.	Complete remaining 24 sketches and descriptions for assigned level 3 subfunctions.	

Meeting Minutes 8

SENIOR DESIGN & PROFESSIONALISM II
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REPORT ON GROUP DYNAMICS

Week #9 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 10/22/20 Meeting Time: 12PM-2PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Group update
- Go over specific tasks per individual
- Brought report 7 to a close

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Group Update
12:00PM-12:16PM
The group received necessary updates and information from group leader, Robert Barbee, as the previously distributed tasks were looking toward getting completed. Jonathan Horta discussed his thoughts on the tables and answered on-the-spot questions by Titus Woodard and Aramis King.

Go over specific tasks per individual
12:17PM-12:37PM
Robert Barbee continued to answer questions and specify tasks in which each member was to get done for the day, giving the group a deadline and continued to elaborate on the concepts if their posed any trouble or confusion.

Brought report 7 to a close
12:38PM-2:00PM
Group members worked together to get the final details of the report together. Figures and tables were updated by each member, in which Robert Barbee, Michael Samuel and Daniel Ward continued to look over each draft and make sure each concept was evaluated effectively.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

There were no issues needing to be resolved and there wasn't any major confusion by the members during this meeting.

Name	Task Assigned to team members at this meeting	Deliverables completed & submitted from tasks assigned in previous meeting(s)	Actions taken by group on non-performing member
Robert Barbee	Complete figures and descriptions	Complete individual report	
Jonathon Horta	Complete figures and descriptions	Complete individual report	
Aramis King	Complete figures and descriptions	Complete individual report	
Daniel Ward	Complete figures and descriptions	Complete individual report	
Michael Samuel	Complete figures and descriptions	Complete individual report	
Titus Woodard	Complete figures and descriptions	Complete individual report	
Todd Maxwell	Complete figures and descriptions	Complete individual report	

SENIOR DESIGN & PROFESSIONALISM II
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REPORT ON GROUP DYNAMICS

Week #9 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 10/23/20 Meeting Time: 10:40AM-12:40PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard,

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Baja Organization
- Adjustments to Reports
- General Introduction to Status Report 8

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

10:40-11:30

As we do generally every Friday we met with Carrie Conton and the Baja Organization for a brief moment as she was able to give the group her thoughts on what the next steps of operation were. Robert Barbee then chimed in with the progress of our Senior Design Project as well as the class. Robert Barbee and John Horta gave the feedback of how they feel the separation of information should go through experience and group members. As parts were given to research more in depth Titus Woodard and Aramis King began to ask questions for a better understanding. Michael Samuel gave his thoughts on how he felt the topics. Daniel Ward then asked everyone if we were in understanding and all in agreement.

11:31-12:05

The next order of business was breaking off and making sure our individual assignments were complete in efforts to turn in our Status Report 7 Group Project. Robert Barbee started off by asking each group member their status within the individual reports to begin collaboration. Each group member was then able to respond back with feedback on their progress. As the majority of group members were completing the assignment within this period, Michael Samuel suggested a time to thoroughly be complete. Titus gave his input on the time as well as Daniel Ward. Jonathan Horta had completed the assignment and began creating the formatt of the group assignment with Aramis King and Robert BArbee. Todd Maxwell then confirmed the time the group would finish and moved to the next steps.

12:06-12:40

In the final segment of our meeting we also wanted to get a better understanding of what is ahead for our next assignment. Robert Barbee then begins to share the screen and show the through layout of what is to come next in Status Report 8. With this Jonathan Horta begins to ask questions about what are intentionally supposed to do. Michael Samuel and Daniel Ward gave their feedback on their personal understanding from Robert's description. Todd Maxwell asks when the assignment is due and what next steps should be taken to complete this. Robert Barbee replies with his thoughts on the Status Report 8 , while Titus Woodard said we should break down the segments and discuss this portion further in the next meeting.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

Each part was broken up evenly throughout the group members to have equal contribution. As

team contribution is key in our group we were able to get feedback from all group members on the task we were given.

Name	Task Assigned to team members at this meeting	Deliverables completed & submitted from tasks assigned in previous meeting(s)	Actions taken by group on non-performing member
Robert Barbee	Corrections and minor adjustments made to individual/ group report for final submission	Complete figures and descriptions	
Jonathon Horta	Corrections and minor adjustments made to individual/ group report for final submission	Complete figures and descriptions	
Aramis King	Corrections and minor adjustments made to individual/ group report for final submission	Complete figures and descriptions	
Daniel Ward	Corrections and minor adjustments made to individual/ group report for final submission	Complete figures and descriptions	
Michael Samuel	Corrections and minor adjustments made to individual/ group report for final submission	Complete figures and descriptions	
Titus Woodard	Corrections and minor adjustments made to individual/ group report for final submission	Complete figures and descriptions	
Todd Maxwell	Corrections and minor adjustments made to individual/ group report for final submission	Complete figures and descriptions	

SENIOR DESIGN & PROFESSIONALISM II
FALL 2020 SEMESTER
REPORT ON GROUP DYNAMICS

Week #10 MINUTES OF GROUP MEETINGS

Group #9

Meeting Date: 10/27/20 Meeting Time: 12PM-2PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard, Carrie Conton, Vicaassee Paul

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Meet with organization for an update
- Discuss improvements or suggestions towards the project
- Work on tables needed for status report 8

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Meet with organization for an update

12PM-12:30PM

Carrie Conton stated what all would be covered during this meeting. Robert Barbee updated the organization on progress towards the suspension and steering systems. Carrie Conton suggested for Jonathon Horta to contact Toyota for funding distribution for the project. The group went through organization applications. Carrie Conton suggested resending applications and having them submitted by Friday. Vicaassee Paul suggested for the board to conduct personal interviews for recruiting. Carrie Conton mentioned what would be the agenda for interviews at the next meeting.

Discuss improvements or suggestions towards the project

12:31PM-1PM

Robert Barbee suggested that the group should meet more often and work on having better communication if issues occur. Jonathon Horta suggested for each member to be more productive during the times the group meets. Daniel Ward suggested for the group to continue staying encouraged and helping each other out throughout the project. Titus Woodard suggested the group members to be more transparent and not afraid to ask questions in times of confusion.

Work on tables needed for status report 8

1:01PM-2PM

Robert Barbee stated the importance of the GO-NO-GO tables and how to properly fill them out. Jonathon Horta and Todd Maxwell began creating and properly formatting the GO-NO-GO and Decision Matrix tables. Daniel Ward, Aramis King, Michael Samuel, and Titus Woodard all began identifying which concepts on Table 3 were better based on the level 3 functions connected. Robert Barbee transitioned the better concepts onto the GO-NO-GO tables based on the group's agreements.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

The group didn't come across any issues or confusions within the meeting. There was good verbal communication and team dynamics during the meeting as well.

Name	Task Assigned to team members at this meeting	Deliverables completed & submitted from tasks assigned in previous meeting(s)	Actions taken by group on non-performing member
Robert Barbee	Transition the rest of the GO-NO-GO decisions made during the meeting onto the GO-NO-GO tables.	Corrections and minor adjustments made to individual/ group report for final submission	
Jonathon Horta	Complete formatting the GO-NO-GO and Decision Matrix tables. Transition all level three functions onto these tables.	Corrections and minor adjustments made to individual/ group report for final submission	
Aramis King	Identify good concepts listed throughout the description and sketches tables for the rest of the steering and suspension systems.	Corrections and minor adjustments made to individual/ group report for final submission	
Daniel Ward	Identify good concepts listed throughout the description and sketches tables for the rest of the steering and suspension systems.	Corrections and minor adjustments made to individual/ group report for final submission	
Michael Samuel	Assist in transitioning the rest of the GO-NO-GO decisions made during the meeting onto the GO-NO-GO tables.	Corrections and minor adjustments made to individual/ group report for final submission	
Titus Woodard	Identify good concepts listed throughout the description and sketches tables for the rest of the steering and suspension systems.	Corrections and minor adjustments made to individual/ group report for final submission	
Todd Maxwell	Complete formatting the GO-NO-GO and Decision Matrix tables. Transition all level three functions onto these tables.	Corrections and minor adjustments made to individual/ group report for final submission	

Meeting Minutes 9

SENIOR DESIGN & PROFESSIONALISM II
FALL 2020 SEMESTER
REPORT ON GROUP DYNAMICS

Week #10 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 10/29/20 Meeting Time: 12PM-2PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Weigh and fill criterion table
- review criterion list
- Discuss roles to complete status report 8

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Review criterion list
12:00pm-12:30pm
Jonathan Horta mentioned adding more specific criterion. As a group we added more to the list, while reviewing the ones already on the list. Daniel Ward had questions concerning efficiency criterion. Titus Woodard questioned the weather condition criterion. Todd Maxwell explained terms of weather conditions. Robert Barbee explained economic criterion.

Weigh and fill criterion table
12:30pm-1:45pm
Collectively we discussed a certain weight parameter. To complete the table, work was equally distributed between members. Jonathan Horta, Daniel Ward, Robert Barbee and Aramis King worked on filling suspension/steering table descriptions. Titus Woodard, Mike Sam and Todd Maxwell worked on filling suspension/steering table weights.

Discuss Roles to complete status report 8
1:45pm-2:00pm
Robert Barbee identified what completed tasks needed to be done.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)
The only slight problem was making sure the criterion list wasn't missing ideas.

Name	Task Assigned to team members at this meeting	Deliverables completed & submitted from tasks assigned in previous meeting(s)	Actions taken by group on non-performing member
Robert Barbee	Finish status report 8	Completed figures and descriptions	
Jonathon Horta	Finish status report 8	Completed figures and descriptions	
Aramis King	Finish status report 8	Completed figures and descriptions	
Daniel Ward	Finish status report 8	Completed figures and descriptions	
Michael Samuel	Finish status report 8	Completed figures and descriptions	
Titus Woodard	Finish status report 8	Completed figures and descriptions	
Todd Maxwell	Finish status report 8	Completed figures and descriptions	

SENIOR DESIGN & PROFESSIONALISM II
FALL 2020 SEMESTER
REPORT ON GROUP DYNAMICS

Week #10 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 10/30/20 Meeting Time: 12PM-2PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard, Carrie Conton, Vicaassee Paul, Zion Brown

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Update organization needing the project completed
- Members participate in giving feedback
- Look over status report 9

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Update organization needing the project completed
10:40AM-11:12AM
Carrie Conton updated the group on what would be the agenda for next week. The new member introduced himself to the rest of the team. All members got their small questions about registering under the organization out the way. Vicaassee Paul suggested for the members to find different ways to break down the drivetrain. Carrie Conton mentioned a few members possibly syncing up with Toyota to give them an update on the progress.

Members participate in giving feedback
11:13AM-12PM
Robert Barbee mentioned that the efficiency of the group the past week has been a lot better than the previous weeks. Daniel Ward suggested continuing to work together the way the group did the following week. Aramis King mentioned that everyone has to continue cooperating well since the virtual setting limits the amount of comments being able to be heard during a meeting. Robert Barbee suggested for the members to continue the great level of communication when issues occur during a member's schedule.

Look over status report 9
12:01PM-12:40PM
Robert Barbee instructed all the group members to skim through the report. All group members went through the report individually and had a chance to go through the classroom slides for status report 9. Robert Barbee instructed all members to do a little research and bring what they believe the systems should be split into, to the next meeting.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

There was no confusion or issues in understanding what the focus should be for the next week. The members were all transparent with the group leader when giving feedback.

Name	**Task Assigned to team members at this meeting**	**Deliverables completed & submitted from tasks assigned in previous meeting(s)**	**Actions taken by group on non-performing member**
Robert Barbee	Do research on what parts the suspension and steering systems could be broken down to. Present information during the meeting.	Finalize all formatting for specific sections assigned for status report 8.	
Jonathon Horta	Do research on what parts the suspension and steering systems	Finalize all formatting for specific sections assigned for status report 8.	

	could be broken down to. Present information during the meeting.		
Aramis King	Do research on what parts the suspension and steering systems could be broken down to. Present information during the meeting.	Finalize all formatting for specific sections assigned for status report 8.	
Daniel Ward	Do research on what parts the suspension and steering systems could be broken down to. Present information during the meeting.	Finalize all formatting for specific sections assigned for status report 8.	
Michael Samuel	Do research on what parts the suspension and steering systems could be broken down to. Present information during the meeting.	Finalize all formatting for specific sections assigned for status report 8.	
Titus Woodard	Do research on what parts the suspension and steering systems could be broken down to. Present information during the meeting.	Finalize all formatting for specific sections assigned for status report 8.	
Todd Maxwell	Do research on what parts the suspension and steering systems could be broken down to. Present information during the meeting.	Finalize all formatting for specific sections assigned for status report 8.	

SENIOR DESIGN & PROFESSIONALISM II
FALL 2020 SEMESTER
REPORT ON GROUP DYNAMICS

Week #11 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 11/3/20 Meeting Time: 12PM-2PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard, Carrie Conton, Garrett Warren, DeShawn Houston, Ethan Phillips, Zion Brown

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Update organization on progress
- Give a scope on Report 9
- Assign tasks and work towards completing tasks

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Update organization on progress
12PM-12:33PM
Carrie Conton updated the group on what has been received by the organization. The new couple members had the opportunity to introduce themselves. All members at the meeting selected which specific drivetrain group they'd like to be a part of. Carrie Conton suggested for all members to present a literature review on analysis and details based on their drivetrain components.

Give a scope on Report 9
12:34PM-1PM
Robert Barbee gave the group a scope on what Report 9 is about. Robert Barbee mentioned some parts needing serious attention based on the terrain, and the areas needing to be broken down for Report 9. Robert Barbee suggested breaking each system down into 3-4 parts. Aramis King suggested including control arms and ball joints as one joined part. Robert Barbee suggested having more teeth on the gears for the steering system to improve efficiency. Daniel Ward suggested having the group focussing on one system at a time.

Assign tasks and work towards completing tasks
1:01PM-2PM
Each member selected which part of the suspension system they'd like to work on. The group agreed to have their suspension part completed by Friday. Robert Barbee suggested all group members to focus on the design, placement, and calculations for the specific part each member selected. Robert Barbee stated that he will set up a time with Jonathon Horta and Michael Samuel to discuss weight distribution when the time comes. The group worked on their specific suspension part for the rest of the meeting.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)
Robert Barbee repeated himself multiple times throughout the meeting, so there was no confusion in the group members comprehending what was being asked to be completed by the group leader.

Name	**Task Assigned to team members at this meeting**	**Deliverables completed & submitted from tasks assigned in previous meeting(s)**	**Actions taken by group on non-performing member**
Robert Barbee	Gather information for the design, part placement, and calculations needed for the springs and struts.	Do research on what parts the suspension and steering systems could be broken down to. Present information during the meeting.	

Jonathon Horta	Gather information for the design, part placement, and calculations needed for the control arms and ball joints.	Do research on what parts the suspension and steering systems could be broken down to. Present information during the meeting.	
Aramis King	Gather information for the design, part placement, and calculations needed for the springs and struts.	Do research on what parts the suspension and steering systems could be broken down to. Present information during the meeting.	
Daniel Ward	Gather information for the design, part placement, and calculations needed for the knuckles.	Do research on what parts the suspension and steering systems could be broken down to. Present information during the meeting.	
Michael Samuel	Gather information for the design, part placement, and calculations needed for the control arms and ball joints.	Do research on what parts the suspension and steering systems could be broken down to. Present information during the meeting.	
Titus Woodard	Gather information for the design, part placement, and calculations needed for the springs and struts.	Do research on what parts the suspension and steering systems could be broken down to. Present information during the meeting.	
Todd Maxwell	Gather information for the design, part placement, and calculations needed for the knuckles.	Do research on what parts the suspension and steering systems could be broken down to. Present information during the meeting.	

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SENIOR DESIGN & PROFESSIONALISM II
FALL 2020 SEMESTER
REPORT ON GROUP DYNAMICS

Week #11 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 11/5/20 Meeting Time: 12PM-2PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Meeting with Baja Organization
- Information gathered from Specific Parts
- Efficiency within the Design

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Meeting with Baja Organization
12PM-12:30PM
Our group members carried out a meeting with Carrie Conton and the rest of the organization members. Ms. Conton initial remarks regarding the update from the previous meetings as the requirements for the group/ organization members. Next instructions were to gain more knowledge and detail within your drivetrain components. Gain a better understanding of the specified material, the efficiency of the parts and etc. Group members then began to ask the necessary details needed as we began to wrap up the meeting for the day.

Information gathered from Specific Parts
12:31PM-1:15PM
Robert Barbee instructed the meeting, addressing the criteria of what the meeting will consist of . Jonathon Horta addressed the group with the previous reports and meeting minutes with the feedback given by the professors. Group members discussed the efforts that needed to be made as well as the problems that had been shown from the report. Robert Barbee then instructed group members to give a brief statement on the information gathered about their specific parts. Jonathon Horta and Michael Samuel started off by addressing the control arms of the suspension system. Aramis King and Titus Woodard were next in discussing the suspension systems and springs. Todd Maxwell and Daniel Ward discussed the Knuckles of the suspension. And finally Robert Barbee discussed the gears.

Efficiency within the Design
1:16PM-2:00PM
All group members began discussing what the dimensions of the Baja Kart would be. Research from previous groups and other organizations were brought to attention to be research for better measurement understanding. Group members then broke off into their pairs to begin establishing their specified parts. After about 15 min Robert Barbee addressed the group in brief feedback, Michael Samuel and Jonathon Horta intervened with their knowledge of their research. Michael Samuel begans a brief sketch as we see some various dimensions of the system. Titus Woodard and Aramis King also chime in to display the information they have gathered. Daniel Ward and Todd Maxwell were the last to chime in as their part is based on the dimensions of the other group members.Robert Barbee then gave a brief overview of what needs to be addressed in the next meet as well as becoming more detailed within our specified parts.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)
Group members were able to collectively collarabe in the research and analysis of specified parts within the system. At which dimensions were by group members to begin the construction and design of the project.

Name	Task Assigned to team members at this meeting	Deliverables completed & submitted from tasks assigned in previous meeting(s)	Actions taken by group on non-performing member
Robert Barbee	Gather information from previous groups and organizations on the most efficient result of the specified parts. NX Model of the gears.	Gather information for the design, part placement, and calculations needed for the springs and struts.	
Jonathon Horta	Gather information from previous groups and organizations on the most efficient result of the specified parts. NX Model of the control arms.	Gather information for the design, part placement, and calculations needed for the control arms and ball joints.	
Aramis King	Gather information from previous groups and organizations on the most efficient result of the specified parts. NX Model of the suspension/springs.	Gather information for the design, part placement, and calculations needed for the springs and struts.	
Daniel Ward	Gather information from previous groups and organizations on the most efficient result of the specified parts. NX Model of the knuckle.	Gather information for the design, part placement, and calculations needed for the knuckles.	
	Gather information from previous groups and organizations on the most	Gather information for the design, part placement,	

Michael Samuel	efficient result of the specified parts. NX Model of the control arms.	and calculations needed for the control arms and ball joints.	
Titus Woodard	Gather information from previous groups and organizations on the most efficient result of the specified parts. NX Model of the suspension/springs.	Gather information for the design, part placement, and calculations needed for the springs and struts.	
Todd Maxwell	Gather information from previous groups and organizations on the most efficient result of the specified parts. NX Model of the knuckles.	Gather information for the design, part placement, and calculations needed for the knuckles.	

SENIOR DESIGN & PROFESSIONALISM II
FALL 2020 SEMESTER
REPORT ON GROUP DYNAMICS

Week #11 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 11/6/20 Meeting Time: 10:40AM-12:40PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Meeting with Baja organization
- Modification Within the Design
- Further information gathered and implemented
-

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Meeting with Baja Organization
10:40AM-11:20AM
Our group members carried out a meeting with Carrie Conton and the rest of the organization members. Ms. Conton initial remarks regarding the update from the previous meetings as the requirements for the group/ organization members. Within our selected drivetrain groups, a member was asked to give research on the component's members. Group members were then able to express their input on several parts and ideas. Expressing specifications and information they gathered from research. Carie Conton finished off with closing remarks instructing preparations for the next meeting.

Modification Within the Design
11:21AM-12:00PM

Robert Barbee instructed the meeting, addressing the criteria of what the meeting will consist of from last meeting.. Robert Barbee then instructed group members to give a brief statement on the more detailed information regarding the specific parts. Jonothon Horta and Michael Samuel started off by addressing the control arms of the suspension system. Aramis King and Titus Woodard were next in discussing the suspension systems and springs. Todd Maxwell and Daniel Ward discussed the Knuckles of the suspension. And finally Robert Barbee discussed the gears. Group members were methods and specifications other organizations used to become successful at this competition.

Further information gathered and implemented
12:01PM-12:40PM
Through collaboration from group members we were able to make changes in the necessary parts that we felt would put our group in the best chance to be successful. Michael Samuel and Robert Barbee began the modifications to the design in Nx. John Horta and Aramis King gave input on the preference they had found in common through research. As Titus Woodard makes specifications to the spring model that it may adjust better to the new design and speculations given through research. Todd Maxwell and Daniel Ward waited in regard to the new dimensions to recreate a new design specification. Working on Status Report 9 along the way.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)
Group members worked collectively to assemble new found parts and design gathered through research to display the most efficient model. Also working on Status Report 9.

Name	Task Assigned to team members at this meeting	Deliverables completed & submitted from tasks assigned in previous meeting(s)	Actions taken by group on non-performing member
Robert Barbee	Continue with improvements to Nx Model and Understanding and Modification of Status Report 9	Gather information from previous groups and organizations on the most efficient result of the specified parts. NX Model of the gears.	
Jonathon Horta	Continue with improvements to Nx Model and Understanding and Modification of Status Report 9	Gather information from previous groups and organizations on the most efficient result of the specified parts. NX Model of the control arms.	
Aramis King	Continue with improvements to Nx Model and Understanding and Modification of Status Report 9	Gather information from previous groups and organizations on the most efficient result of the specified parts. NX Model of the suspension/springs.	

Daniel Ward	Continue with improvements to Nx Model and Understanding and Modification of Status Report 9	Gather information from previous groups and organizations on the most efficient result of the specified parts. NX Model of the knuckle.	
Michael Samuel	Continue with improvements to Nx Model and Understanding and Modification of Status Report 9	Gather information from previous groups and organizations on the most efficient result of the specified parts. NX Model of the control arms.	
Titus Woodard	Continue with improvements to Nx Model and Understanding and Modification of Status Report 9	Gather information from previous groups and organizations on the most efficient result of the specified parts. NX Model of the suspension/springs.	
Todd Maxwell	Continue with improvements to Nx Model and Understanding and Modification of Status Report 9	Gather information from previous groups and organizations on the most efficient result of the specified parts. NX Model of the knuckles.	

SENIOR DESIGN & PROFESSIONALISM II
FALL 2020 SEMESTER
REPORT ON GROUP DYNAMICS

Week #12 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 11/10/20 Meeting Time: 12:00AM-2:00PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard, Carrie Conton, Garrett Warren, DeShawn Houston, Ethan Phillips, Zion Brown

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Meet with organization and update on progress
- Go through Status Report 9 final layout

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Meet with organization and update on progress

12PM-1:13PM

Carie Conton updated the team on what was discussed last weekend with Toyota, and the competitions to choose between in 2021. Carrie Conton mentioned that registration opens up for Luisville, Kentucky and Arizona on November 17th. Michael Samuel presented

his literature review on tires. Carrie Conton mentioned how to calculate torque on tires and what issues can occur with tires. Jonathon Horta presented his literature review on differential materials. Zion Brown presented his literature review on differentials. Ethan Phillips presented a literature review on transmission. Vicaassee Paul suggested strongly considering the terrain when considering the transmission. Carrie Conton mentioned what would be the next focusses for the team till the next meeting.

Go through Status Report 9 final layout
1:14PM-2PM
Robert Barbee ran through the complete layout of Status Report 9. Robert Barbee suggested for the group members to add their parts on table 1.5 and complete the numbering in sequential order. Michael Samuel was confused on how the free body diagrams should be presented on the report. Robert Barbee gave clarification on how exactly the free body diagrams should look for each part for each system. Jonathon Horta needed clarification about the "subject area" portion of table 5.1. Robert Barbee gave clarification on the "subject area" portion of table 5.1. Robert Barbee suggested the group members to reach out in the group chat around 10:30pm if anyone has any questions.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

There was confusion for Michael Samuel towards the free body diagrams, and confusion for Jonathon Horta towards table 5.1. Robert Barbee broke down both items, so the members could better understand the main focus in both areas.

Name	Task Assigned to team members at this meeting	Deliverables completed & submitted from tasks assigned in previous meeting(s)	Actions taken by group on non-performing member
Robert Barbee	Assist with completing all areas of the suspension system for the report. Begin the designs for the steering system for the report.	Continue with improvements to Nx Model and Understanding and Modification of Status Report 9	
Jonathon Horta	Complete ¾ of the control arms dimension calculations portion of the report.	Continue with improvements to Nx Model and Understanding and Modification of Status Report 9	
Aramis King	Complete ¾ of the springs and struts dimension calculations portion of the report.	Continue with improvements to Nx Model and Understanding and Modification of Status Report 9	

Daniel Ward	Complete ¾ of the knuckles free body diagrams portion of the report.	Continue with improvements to Nx Model and Understanding and Modification of Status Report 9	
Michael Samuel	Complete ¾ of the control arms free body diagrams portion of the report.	Continue with improvements to Nx Model and Understanding and Modification of Status Report 9	
Titus Woodard	Complete ¾ of the springs and struts free body diagrams portion of the report.	Continue with improvements to Nx Model and Understanding and Modification of Status Report 9	
Todd Maxwell	Complete ¾ of the knuckles calculations portion of the report.	Continue with improvements to Nx Model and Understanding and Modification of Status Report 9	

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SENIOR DESIGN & PROFESSIONALISM II
FALL 2020 SEMESTER
REPORT ON GROUP DYNAMICS

Week #12 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 11/12/20 Meeting Time: 12PM-2PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Present progress on Report 9
- Share suggestions
- Work on Report 9 individually

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Present progress on Report 9
12PM-12:25PM
Robert Barbee shared the changes made to the knuckle and control arm NX models. The group agreed to the changes Robert Barbee made on the NX models. Jonathon Horta mentioned the calculations used for creating the control arm dimensions.

Share suggestions
12:26PM-1:05PM
Robert Barbee suggested for the group to present results to Dr. Peng to determine if two reports could be generated. The group agreed on the idea of presenting the results to Dr. Peng. The group added their input on what they thought could be the issue for designing the front control arms. Titus Woodard suggested for all the group members to download VMware to utilize NX more effectively. Robert Barbee demonstrated the movement of links using the NX tool.

Work on Report 9 individually
1:06PM-2PM
Aramis King mentioned the struts and springs being purchased instead of manufactured for the off road vehicle. Jonathon Horta suggested for the group members not working on anything to fix the issues on previous reports based on feedback. Daniel Ward and Todd Maxwell continued to work on the calculations and model for the knuckle. Jonathon

Horta and Michael Samuel shared calculation methods used with Robert Barbee and continued working on control arms. Aramis King and Titus Woodard continued doing research on the struts and spring design.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)
There was confusion on how to get accurate dimensions for the control arms and knuckles since the part NX models haven't been finalized yet. Robert Barbee assisted Michael Samuel, Jonathon Horta, Daniel Ward, and Todd Maxwell with the suggestion of presenting this issue to Dr. Peng.

Name	**Task Assigned to team members at this meeting**	**Deliverables completed & submitted from tasks assigned in previous meeting(s)**	**Actions taken by group on non-performing member**
Robert Barbee	Complete ¼ of the steering dimensions and calculations for status report 9.	Assist with completing all areas of the suspension system for the report. Begin the designs for the steering system for the report.	
Jonathon Horta	Research on better dimensions for the front and rear suspension systems.	Complete ¾ of the control arms dimension calculations portion of the report.	
Aramis King	Research on better dimensions for the springs and struts and bring suggestions to the group.	Complete ¾ of the springs and struts dimension calculations portion of the report.	
Daniel Ward	Research on better dimensions for the knuckles and bring suggestions to the group.	Complete ¾ of the knuckles free body diagrams portion of the report.	
Michael Samuel	Complete ¾ of the control arms free body diagrams portion of the report.	Complete ¾ of the control arms free body diagrams portion of the report.	
Titus Woodard	Determine the maximum weight that each strut and spring and hold.	Complete ¾ of the springs and struts free body diagrams portion of the report.	
Todd Maxwell	Determine a reasonable total length for the knuckle.	Complete ¾ of the knuckles calculations portion of the report.	

FALL 2020 SEMESTER
REPORT ON GROUP DYNAMICS

Week #12 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 11/13/20 Meeting Time: 10:40AM-12:40PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard, Carrie Conton, Zion Brown, Vicaassee Paul

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Update Organization
- Run through feedback for previous reports
- Assign tasks to members

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Update Organization
10:40AM-11:38AM
Carrie Conton mentioned that a poll would be created to assist with deciding on what competition would make more sense for the team to attend. Zion Brown suggested for the team to attend the competition that isn't around the team where finals are expected to be starting. Carrie Conton mentioned that Toyota is proceeding with giving the team an additional $20,000 to assist in extra expenses. Vicaassee Paul mentioned that the gear that was ordered for the team has arrived. Robert Barbee updated the organization on what our timeline looks like for the rest of the semester. Carrie Conton showed the team how to get to the new resources that have been gathered to assist in designing the vehicle. Carrie Conton suggested for the team to look into placement of the drivetrain by the next meeting.

Run through feedback for previous reports
11:39AM-12:23PM
Jonathon Horta mentioned that all the feedback for previous reports have been posted for everyone to access. Robert Barbee mentioned his ideas on the amount of work it would take to design the steering system. Jonathon Horta proceeded to show the group how exactly to access the feedback. The group ran through the feedback for Status Report 7 and identified everything that had to be fixed. Robert Barbee suggested for the group to create two new concepts for each system. Michael Samuel suggested for the group to be detailed as possible when fixing issues identified on the feedback.

Assign tasks to members
12:24PM-12:40PM

Todd Maxwell and Daniel Ward suggested for the group to comment on areas that have been fixed. Jonathon Horta suggested for the group to focus on fixing Status Reports 7 this week. The group agreed on everything not having to be fixed today. Michael Samuel suggested for the team to focus on Table 3 and Table 4 for Report 7. Jonathon Horta assigned all members to a start point and end point for fixing Status Report 7.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

Aramis King wasn't understanding how the layout of Table 2 and Table 3 of Status Report 7 should look when it's corrected. Jonathon Horta went through a few corrections on Table 2 to show the team an example of how the corrected tables should look as each level 3 sub-function gets corrected.

Name	Task Assigned to team members at this meeting	Deliverables completed & submitted from tasks assigned in previous meeting(s)	Actions taken by group on non-performing member
Robert Barbee	Complete ½ of the steering dimensions and calculations for status report 9.	Complete ¼ of the steering dimensions and calculations for status report 9.	
Jonathon Horta	Add additional concepts for Tables 3 & 4 and post information about these concepts in the group chat.	Research on better dimensions for the front and rear suspension systems.	
Aramis King	Fix the top 11 suspension system level 3 sub-functions on Table 3 for Status Report 7.	Research on better dimensions for the springs and struts and bring suggestions to the group.	
Daniel Ward	Begin fixing the sketches and descriptions having issues on Status Report 7.	Research on better dimensions for the knuckles and bring suggestions to the group.	
Michael Samuel	Fix the top 11 steering system level 3 sub-functions on Table 4 for Status Report 7.	Complete ¾ of the control arms free body diagrams portion of the report.	
Titus Woodard	Fix the bottom 11 suspension system level 3 sub-functions on Table 3 for Status Report 7.	Determine the maximum weight that each strut and spring and hold.	

Todd Maxwell	Fix the bottom 11 steering system level 3 sub-functions on Table 4 for Status Report 7.	Determine a reasonable total length for the knuckle.	

SENIOR DESIGN & PROFESSIONALISM II
FALL 2020 SEMESTER
REPORT ON GROUP DYNAMICS

Week #13 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 11/17/20 Meeting Time: 12:00AM-2:00PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard,

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Baja Meeting
- Changes made to Specs.and ideals
- Status Report 9

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

12:00pm -1:00pm

Meeting with Carrie Conton and the Baja Organization with efforts for updates and ideal plans for the Baja Kart. As a team we were able to collaborate with the organizations on the designs and research we've created previously. Robert Barbee and Jonathon Horta were able to first discuss the status moving forward within our group being previous title holding members in the group. As each group member followed with details from their different design sections. Next we were able to go over the alternative assignments provided by the organization discussing various parts.

1:01pm-1:30pm

To start off the meeting Robert Barbee stated the errors were having in the overall design.Stating parts of the dimensions needed to be changed to create a fully connected, showing a gap within the chassis and control arms. Jonathan Horta and Michael Samuel chime in with ideas on what modifications could be made to address the issue. Todd Maxwell then makes a suggestion of what he thinks could happen. Robert Barbee responds to the group with the attempts made in modification efforts to the design. Next Robert addresses the possible modifications that need to be made from the different sections.

1:31pm-2:00pm

Aramis King and Titus Woodard discusses a time to make the modifications to the struts and springs. Robert Barbee addresses Daniel Ward on the modifications of the Knuckle and Todd Maxwell on the dimensional analysis of the knuckle as well as a time to meet. Michael Samuel and Jonathon Horta discuss a time to meet for modifications to the suspension and control arms. Jonathan Horta then addresses Status Report 9 breaking down what needs to be done to complete the report. Robert Barbee breaks the report down in sections per group member.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

As a group we were able to collaborate to make modifications to our overall designs to prepare for Status Report 9.

Name	**Task Assigned to team members at this meeting**	**Deliverables completed & submitted from tasks assigned in previous meeting(s)**	**Actions taken by group on non-performing member**
Robert Barbee	Complete Modifications to Gears and Steering. Complete Status Report 9	Complete ½ of the steering dimensions and calculations for status report 9.	
Jonathon Horta	Complete Modifications to Suspension and Control Arms. Complete Status Report 9	Add additional concepts for Tables 3 & 4 and post information about these concepts in the group chat.	
Aramis King	Complete Modifications to Struts/Springs. Complete Status Report 9	Fix the top 11 suspension system level 3 sub-functions on Table 3 for Status Report 7.	
Daniel Ward	Complete Modifications to Knuckle. Complete Status Report 9	Begin fixing the sketches and descriptions having issues on Status Report 7.	
Michael Samuel	Complete Modifications to Suspension and Control Arms . Complete Status Report 9	Fix the top 11 steering system level 3 sub-functions on Table 4 for Status Report 7.	
Titus Woodard	Complete Modifications to Struts/Springs. Complete Status Report 9	Fix the bottom 11 suspension system level 3 sub-functions on Table 3 for Status Report 7.	
Todd Maxwell	Complete Modifications to Knuckle. Complete Status Report 9	Fix the bottom 11 steering system level 3 sub-functions on Table 4 for Status Report 7.	

Meeting Minutes 12

SENIOR DESIGN & PROFESSIONALISM II
FALL 2020 SEMESTER
REPORT ON GROUP DYNAMICS

Week #13 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 11/19/20 Meeting Time: 12PM-2PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Go over correct report 9 layout
- Update on changes or progress
- Assign tasks

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Go over correct report 9 layout
12PM-12:23PM
Robert Barbee opened up Status Report 9 and went through the correct layout as he compared it to the class presentation for that report. Jonathon Horta asked why sections 5.3 to 5.5 was being excluded from the report. Robert Barbee explained that the professor instructed students to not worry about sections 5.3 to 5.5 on the report.

Update on changes or progress
12:24PM-2:53PM
Aramis King presented his new research on the struts and he suggested a change to our design on the struts. Robert Barbee presented his new research on the control arms and suggested a slight change to be done to the chassis for suspension improvement. Michael Samuel and Jonathon Horta presented their research on the tires and suggested some top brands for tires. Titus Woodard mentioned an update on spec changes for the knuckle. Daniel Ward mentioned what would be the next plans for knuckle. Michael Samuel mentioned an estimated weight of the front tires. Robert Barbee mentioned estimating the tire coefficient of friction for future purposes. Aramis King mentioned not being able to get forces till a program is utilized. Robert Barbee suggested for everyone to assume the driver of the vehicle will weigh 200lbs. Robert Barbee asked the group for the amount of work needing to be done. Robert Barbee assisted Jonathon Horta in understanding what changes need to be done to the control arms and why. Robert Barbee updated the group on what's left with the steering system as far as the model and calculations.

Assign tasks
2:54PM-2PM
Group quickly discussed what would be covered at the next meeting and what needs to be done before the meeting.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

Jonathon Horta needed clarification on why changes needed to be made to the control arms. Robert Barbee pulled up a NX model and some examples to help Jonathon Horta understand why the previous control arm design would cause issues.

Name	**Task Assigned to team members at this meeting**	**Deliverables completed & submitted from tasks assigned in previous meeting(s)**	**Actions taken by group on non-performing member**
Robert Barbee	Complete calculations needed for the steering system and identify all parts included.	Complete Modifications to Gears and Steering.	
Jonathon Horta	Recalculate lengths for control arms based on new modifications	Complete Modifications to Suspension and Control Arms.	
Aramis King	Update weight/ force calculations for the struts including the adjusted weight of the driver.	Complete Modifications to Struts/Springs.	
Daniel Ward	Update calculations for the knuckle based on adjustments to the control arm.	Complete Modifications to Knuckle.	
Michael Samuel	Resketch a new model for the control arms based on updates from the meeting.	Complete Modifications to Suspension and Control Arms.	
Titus Woodard	Create a new sketch or find a representation of the new struts discussed.	Complete Modifications to Struts/Springs.	
Todd Maxwell	Create a new design based on dimension changes to the knuckle.	Complete Modifications to Knuckle.	

SENIOR DESIGN & PROFESSIONALISM II
FALL 2020 SEMESTER
REPORT ON GROUP DYNAMICS

Week #13 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 11/19/20 Meeting Time: 8PM-10PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard,

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Discus what's left for Status report
- Combine all necessary information onto Status Report 9
- Assign final tasks for Report 9

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Discus what's left for Status report
8PM-8:26AM
Jonathon Horta mentioned that formatting is something that has a large impact on the report. Robert Barbee did a runthrough on Status Report 9. Michael Samuel suggested adding all figures to the report before beginning to number the figures.

Combine all necessary information onto Status Report 9
8:27PM-9:47PM
The group began to attach all free body diagrams onto Status Report 9. Jonathon Horta suggested for all members to notify the group once they have almost finished adding the information about their part. The members that completed calculations began to interpret their calculations onto the report. Aramis King asked if all the equations had to be in an equation format or if they could just be typed in. Robert Barbee suggested for everyone to use equation format with proper units for all equations. All members continued working towards completing their parts on the report.

Assign final tasks for Report 9
9:48PM-10PM
Robert Barbee instructed each member on what specifically to complete and to notify Jonathon Horta once their part is completed and ready for submission.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

Jonathon Horta was having issues understanding what to add under a figure that didn't involve any calculations. Robert Barbee showed a steering system part as an example to help Jonathon Horta understand how a section involving a part that doesn't have calculations should look.

Name	Task Assigned to team members at this meeting	Deliverables completed & submitted from tasks assigned in previous meeting(s)	Actions taken by group on non-performing member
Robert Barbee	Share completed steering designs and calculations with Jonathon Horta for submitting.	Complete calculations needed for the steering system and identify all parts included.	
Jonathon Horta	Review the formatting for the control arms section of Report 9 and submit the report.	Recalculate lengths for control arms based on new modifications	
Aramis King	Share completed strut calculations with Jonathon Horta for submitting.	Update weight/ force calculations for the struts including the adjusted weight of the driver.	
Daniel Ward	Share completed knuckle calculations with Jonathon Horta for submitting.	Update calculations for the knuckle based on adjustments to the control arm.	
Michael Samuel	Share completed control arm design with Jonathon Horta for submitting.	Resketch a new model for the control arms based on updates from the meeting.	
Titus Woodard	Share completed strut design with Jonathon Horta for submitting.	Create a new sketch or find a representation of the new struts discussed.	
Todd Maxwell	Share completed knuckle design with Jonathon Horta for submitting.	Create a new design based on dimension changes to the knuckle.	

SENIOR DESIGN & PROFESSIONALISM II
FALL 2020 SEMESTER
REPORT ON GROUP DYNAMICS

Week #14 MINUTES OF GROUP MEETINGS
Group #8

Meeting Date: 11/24/20 Meeting Time: 12:00PM-2:00PM Meeting Location: Zoom ID: 987 671 2507 PW: 310102020

Members Present: Robert Barbee, Jonathon Horta, Todd Maxwell, Michael Samuel, Aramis King, Daniel Ward, Titus Woodard, Carie Conton, Vicaassee Paul, Zion Brown

Agenda for Meeting (Items to be discussed or discussed at the meeting)

- Update organization on progress
- Run through assignments due today
- Inform group on agenda for next couple meetings

Detailed Minutes: (should include name of speaker and summary of what he/she suggested)

Update organization on progress
12PM-12:48PM
Carrie Conton mentioned a few key points that shouldn't be missed when designing the hub assembly. Vicaassee Paul suggested using stainless steel as a material. Robert Barbee suggested for the team to use cheaper materials for bolts. Vicaassee Paul mentioned that it would be a good idea to have more money budgeted to use in more beneficial areas such as transportation. Vicaassee Paul suggested adding a skid plate for the drive shaft. Zion Brown was confused on the placement of the shaft. Jonathon Horta presented on the differential. Robert Barbee presented on CVT transmissions. Robert Barbee mentioned pulleys transferring torque from the transmission. Jonathon Horta gave an update on the grant application for Toyota.

Run through assignments due today
12:49PM-1:43PM
Robert Barbee began going through the taskstream assignments. Robert Barbee created a template for section 1.4 a taskstream assignment. Jonathon Horta needed clarification on how there our design could be beneficial on a local level. Michael Samuel mentioned the taskstream assignments being due at 2pm for him. Jonathon Horta mentioned the taskstream assignments being due at midnight for him. The group worked towards completing the taskstreams.

Inform group on agenda for next couple meetings
1:44PM-2PM
Robert Barbee mentioned that corrections would be the focus of the next meeting. Jonathon Horta mentioned what has been fixed on status report 7.

Brief statement on individual participation and or problems encountered with specific group members and how group resolved problem(s)

Zion Brown needed clarification on where exactly the placement of the driveshaft would go, so Jonathon Horta presented some pictures and gave a better explanation on the placement on the drivetrain.

Name	Task Assigned to team members at this meeting	Deliverables completed & submitted from tasks assigned in previous meeting(s)	Actions taken by group on non-performing member
Robert Barbee	Work towards fixing mistakes on status reports 7 and 8.	Share completed steering designs and calculations with Jonathon Horta for submitting.	
Jonathon Horta	Work towards fixing mistakes on status reports 7 and 8.	Review the formatting for the control arms section of Report 9 and submit the report.	
Aramis King	Work towards fixing mistakes on status reports 7 and 8.	Share completed strut calculations with Jonathon Horta for submitting.	
Daniel Ward	Work towards fixing mistakes on status reports 7 and 8.	Share completed knuckle calculations with Jonathon Horta for submitting.	
Michael Samuel	Work towards fixing mistakes on status reports 7 and 8.	Share completed control arm design with Jonathon Horta for submitting.	
Titus Woodard	Work towards fixing mistakes on status reports 7 and 8.	Share completed strut design with Jonathon Horta for submitting.	
Todd Maxwell	Work towards fixing mistakes on status reports 7 and 8.	Share completed knuckle design with Jonathon Horta for submitting.	

SENIOR DESIGN AND PREFESIONALISM I
FALL 2020

Status Report 1

TOPICS COVERED IN Status Report 1

1. Project Selection

Mechanical Engineering Department
Senior Design I
Fall 2020 Semester
Project Selection Assignment
Status Report 1 on Project Selection

Are you a US Citizen?
Circle one

YES

NO

Assigned: 08/27/2020 Due: 08/31/2020 (by 5:00 PM on e-course)

Name:_____ **Phone:**_____ **email**_____

1. Review the project statements distributed and rank them according to your 1st, 2nd, 3rd, 4th, ... 9th choices on Table 1 (Please type in information directly in the table).

Table 1. Project Selection Ranking

Project number	Project Title	Preference Ranking
1	Enhancing Thermal Resistance of Building Walls By Utilizing Fluid Flow in Microchannel within the Wall (Dr. Shafiee)	
2	Design, Fabricate and Test a Condenser Train for Condensing Biogas to Bio-oil During Pyrolysis of Biomass (Dr. Biney)	
3	Design of experiment to measure heat transfer coefficient and effective thermal conductivity in nanofluids under different boundary conditions. (Dr. Shafiee)	
4	Design and Fabrication of Exoskeleton-based Hybrid Human Rehabilitation Robot (Dr. Park & Dr. Duan)	
5	Optimized Design of Satellite Thermal Radiator for Space-based Applications (Ball Aerospace)	
6	Low Shock Restraint and Deployment Device for Deployable Satellite Appendages (Ball Aerospace)	
7	Design, Fabrication, and Testing of an Automated Oil Recovering Skimm (Dr. Zhou & Dr. Park)	
8	Design and Fabricate the Suspension and Steering for Off-Road Vehicle (Dr. Jiang)	
9	Design, Fabricate and Test a fully instrumented laboratory set-up that could be used to study the performance of the major types of heat exchangers used in the industry.(Dr. Biney)	

2. For your **first** and **second** choices, conduct a brief background work to
   (a) show that you have read about the project and that you understand the problem and that you have some basic knowledge to contribute to the project,
   (b) show the experience that you have that makes you interested in this project and
   (c) justify why those selections should be assigned to you.

(Repeat a, b, c for second choice also)

(To make sure you have answered each question, copy the question and each sub-question before you provide your answer below it).

Grading Scheme

Item	Description	Maximu	Your
1	Ranking of Projects	10	
2a	Background review for understanding project choices 1 & 2	20	
2b	Stated experience in choices 1 & 2	10	
2c	Justification of why project should be assigned to you	10	
	Total	50	

ABOVE AVERAGE

SENIOR DESIGN & PROFESSIONALISM I

FALL 2020

PROJECT PROGRESS REPORT COVER SHEET

PROJECT TITLE:___Project Selection Assignment

GROUP NUMBER _____

Progress Report Title:___Status Report 1

Due Date:___08/31/2020_____

No	Group Member Name Group Member signature	Brief Description of Work Assigned to Member	% Completed by Member*	Your Score
1	Caleb Riggins C Ri	Ranked project selections from 1-9 while emphasizing my top two choices through extended background information and expression of interest.		
2				
3				
4				
5				
6				
7				
8				

*100% means the member completed his/her assigned work*By signing this assignment cover sheet, I agree that the percentages stated in the % completed column reflect the contribution made by me and the other members of the group.*

Mechanical Engineering Department
Senior Design I
Fall 2020 Semester
Project Selection Assignment
Status Report 1 on Project Selection

Are you a US Citizen?
Circle one

YES

NO

Assigned: 08/27/2020 Due: 08/31/2020 (by 5:00 PM on e-course)

Name:____Caleb Riggins_____Phone:_832-207-2815_____
email:_criggins1@student.pvamu.edu_____

1. Review the project statements distributed and rank them according to your 1st, 2nd, 3rd, 4th, ... 9th choices on Table 1 (Please type in information directly in the table).

Table 1. Project Selection Ranking

Project number	Project Title	Preference Ranking
1	Enhancing Thermal Resistance of Building Walls By Utilizing Fluid Flow in Microchannel within the Wall (Dr. Shafiee)	8
2	Design, Fabricate and Test a Condenser Train for Condensing Biogas to Bio-oil During Pyrolysis of Biomass (Dr. Biney)	5
3	Design of experiment to measure heat transfer coefficient and effective thermal conductivity in nanofluids under different boundary conditions. (Dr. Shafiee)	9
4	Design and Fabrication of Exoskeleton-based Hybrid Human Rehabilitation Robot (Dr. Park & Dr. Duan)	1
5	Optimized Design of Satellite Thermal Radiator for Space-based Applications (Ball Aerospace)	6
6	Low Shock Restraint and Deployment Device for Deployable Satellite Appendages (Ball Aerospace)	4
7	Design, Fabrication, and Testing of an Automated Oil Recovering Skimm (Dr. Zhou & Dr. Park)	2
8	Design and Fabricate the Suspension and Steering for Off-Road Vehicle (Dr. Jiang)	3
9	Design, Fabricate and Test a fully instrumented laboratory set-up that could be used to study the performance of the major types of heat exchangers used in the industry.(Dr. Biney)	7

2. For your **first** and **second** choices, conduct a brief background work to
   (a) show that you have read about the project and that you understand the problem and that you have some basic knowledge to contribute to the project,
   (b) show the experience that you have that makes you interested in this project and
   (c) justify why those selections should be assigned to you.

(Repeat a, b, c for second choice also)

(To make sure you have answered each question, copy the question and each sub-question before you provide your answer below it).

Grading Scheme

Item	Description	Maximu	Your
1	Ranking of Projects	10	
2a	Background review for understanding project choices 1 & 2	20	
2b	Stated experience in choices 1 & 2	10	
2c	Justification of why project should be assigned to you	10	
	Total	50	

Choice #1 DESIGN AND FABRICATION OF EXOSKELETON- BASED HYBRID REHABILITATION ROBOT

(a) show that you have read about the project and that you understand the problem and that you have some basic knowledge to contribute to the project,
Given the current data pertaining to the increase in the average age of Americans, there will an increase in the need for mobility accommodations in the near future. Currently there has been some attempts at exoskeleton models in medical field to help with mobility disorders, but they are quite bulky, and do not accommodate well to personal needs. Ergonomically they work well, but they are less to be desired in comfortability which ultimately defeats the purpose. Naturally as we get older, our bodies begin to deteriorate. Depending on our different experiences in life along with genetics and family history, some of our health and bodies will deteriorate faster than others. Also, with the many growing human advances in technology and the pace of our world today, our health and our bodies must endure life at a faster pace than past generations. Although technology makes life easier, the advances also may cause us to neglect our health. According to the Bureau of Labor and Statistics, the average American works 44 hours a week. Work can affect our physical, emotional, and mental health. Prolonged, all these aspects have been associated with difficulty in overall mobility and climbing stairs and STS mobility in nondisabled elderly. The objectives of this project require the design and production of an exoskeleton that will need to meet an appropriate stiffness for a hybrid human assistive robot that will also identify locations where softer components can locate and reduce acute pressure areas. A control algorithm of actuators will then need to be created to adequately support the STS motion. This project will allow for an engineering advancement in the biomedical engineering field as well as a great way for biomedical engineering studies to flourish at PVAMU. In previous years I started as a Pre-veterinarian major, and I also own horses. A lot of scientific advances begin with study in animals, and I have seen and observed structural likeness in most animals in relation to humans as they endure similar health conditions as we do. With this along with a Nanotechnology research internship I participated in this past summer, I believe I can provide additional knowledge and insight to this project.

(b) show the experience that you have that makes you interested in this project.
This past Summer I was given the opportunity by Dr. Rayegan and Dr. Xu to participate in an Undergraduate Research internship with UT Austin's NASCENT REU program. In this program, we were given the opportunity to conduct research based upon advances in nanotechnology in relation to engineering. Within the research and different professional seminars, we were given a grand challenge and got to research about materials like silicones, aerogels, polymers, and the application of shape memory alloys into devices while also getting to present our research. My research ultimately allowed me to gain insight of how nanotechnology is vastly incorporated into mechanical engineering through material science applications. For this project, there is need for a soft component that will allow for comfortability as well as durability and functionalism for this robotic mechanism. This is a grand challenge for engineers because there can be difficulties with incorporating soft components with rigid components while also offering functional ability. In the previous semester, in my thermal science lab, I would write the majority of my group's lab codes as well as tutor my peers with code manuscript throughout the semester in the Pace lab. This was also true for my Measurements class. My

knowledge and ability to adapt to learning and writing code would be beneficial to project as well. In my personal life, my father has had two patella tendon tears on separate occasions in the early 2000's. To this day, he still struggles standing up and sitting as well as going up and down stairs caused from wear and tear on his knees along with growing age. Sentimentally this project has personal connection within my interests as well. Along with this, I am also currently an Assistant Service Manager at HEB in Fairfield. Many elderly or handicapped customers choose to have assistance shopping within the store due to medical issues with mobility and moving around the store. Currently there are not a lot of public accessibilities or accommodations for elderly or handicapped persons. This project could serve as a gateway to many more advancements in the medical and engineering field that could improve public places and make them accommodable to all from primarily improving STS mobility.

(c) justify why those selections should be assigned to you.

This semester I may be given the opportunity to help Dr. Xu conduct research in combustion design for biofuels. The ability to do research and design with him may also help give insight in design theory for this project as well even though they are different topics. I also have earned excellent grades in Machine Design 1 as well as Kinematics and am currently taking Finite Elements and Machine Design 2. I believe that my interactions with the project advisors will also help me to be successful in my Machine Design 2 class as well as help me with greater understandings of Finite Element and design. Upon graduation, I am hoping to enter into a career within manufacturing and machine design, and this project will help me to gain insight on real world engineering ethical applications that are even more crucial in this project because of the medical applications as well. With an open and flexible mind, I believe that I can offer a lot of insight to this available project.

CHOICE #2 DESIGN,FABRICATION,AND TESTING OF AN AUTOMATED OIL RECOVERING SKIMMER

(a) show that you have read about the project and that you understand the problem and that you have some basic knowledge to contribute to the project

There are many negative contributions that human mistakes make to the environment. Contributions like plastic pollution, poor waste management, air pollution and accidental occurrences like oil spills. These contributions along with natural changes and phenomena in the environment cause many underlying environmental changes that affect the earth. Out of these factors, oil spills are probably the quickest in environmental destruction because it directly effects its environment in an instant. Oil containment booms help to provide a vast area of oil to be captured and contained, but don't offer efficiency in collection. Skimmers have been used, but most of them today do not seem to offer a good percentage of oil collection to area ratio. With the fluctuations of oil spills yearly, there needs to be an adequate way to capture and remove oil at an acceptable rate. As more oil enters these environments, marine life is at risk along with air pollution caused by oil evaporating off the water's surface. Not only will the environment suffer, so will the economy due to damage to businesses like fisheries and mariculture sites getting contaminated. This project will require the research and study of today's industrial oil skimmer and their deficiencies in order to design a new automated skimmer which considers the current industrial skimmer drawbacks. Given a domain and parameters of 5ft by 5 ft, this project will involve testing on different thicknesses of calm oil slick and observing its collection ratio percentage in comparison to the current industrial oil skimmer based from a created

control algorithm. As of now I believe that there is a way to combine an oil skimmer idea with an oil containment boom of some sort. Benefits of this project would allow advancement in engineering technology in a way that allows us as engineers to be environmentally conscious not only as engineers but as human beings.

(b) show the experience that you have that makes you interested in this project

As stated before, this past Summer, I was given the opportunity to conduct research as an REU participant in UT Austin's NASCENT program. One of the projects that was researched and proposed involved a way for power plants and other industries to properly expose of excess plastic wastes. Currently, according to the PEW Charitable Trusts Organization, 11 million metric tons of plastics enter the ocean per year. Plastics, just like oil affect our environment at an exponential rate. Within the research in the program, what was concluded is that nano organisms could be used "dissolve" or get rid of plastics similarly to an organism called a wax worm. The enzymes within the worms intestine can dissolve plastics at some given rate. This sparked my interest due to the growing issue of human- factor waste management. I believe that some ideas from this study could possibly be incorporated within the Oil skimmer project. Maybe some sort of harmful biproduct could be used to dissolve oil within the skimmer. Living near the Gulf of Mexico my entire life, I have also seen the affects of water pollution in recent events like the Deepwater Horizon Oil Spill back in 2010. There is also a 14+ year oil spill currently leaking in the gulf of Mexico that has been averaging 200-300 barrels a day. With events like this, an urgent plan is greatly needed.

(c) justify why those selections should be assigned to you.

As I become closer to graduating, there are many real-world issues that will need to be handled by my generation as well as future generations. Environmental health is something that is going to affect everyone's lives much more later if there is no solution now. This project requires knowledge in Fluid Mechanics as well as Machine Design. In a previous semester I received an "A" in my Fluid Mechanics class as well as an "A" in my Machine Design 1 class. As stated before, currently I am taking Machine Design 2 and Finite Elements. This project would again allow me to indulge in greater study of machine design as well as fluid mechanics while also guiding me with my abilities in finite element design. I believe that I have a very high environmental consciousness and understand the urgencies needed to be taken to ensure a better equilibrium of our environment around us. The skimmer will also require a small amount of coding ability for the automation and sensor component of this project, and I do believe I could provide insight in this aspect. Overall, this project would help me to gain more insight in the relationship between engineering and the ethics behind contributing engineering into the environment.

AVERAGE

Mechanical Engineering Department
Senior Design I
Fall 2020 Semester
Project Selection Assignment
Status Report 1 on Project Selection

Are you a US Citizen?
Circle one

YES

NO

Assigned: 08/27/2020 Due: 08/31/2020 (by 5:00 PM on e-course)

Name:_ Demetrious Sandford_ Phone:__(409) 934-4270_
email:_dsandford@student.pvamu.edu___

1. Review the project statements distributed and rank them according to your 1st, 2nd, 3rd, 4th, ... 9th choices on Table 1 (Please type in information directly in the table).

Table 1. Project Selection Ranking

Project number	Project Title	Preference Ranking
1	Enhancing Thermal Resistance of Building Walls By Utilizing Fluid Flow in Microchannel within the Wall (Dr. Shafiee)	5
2	Design, Fabricate and Test a Condenser Train for Condensing Biogas to Bio-oil During Pyrolysis of Biomass (Dr. Biney)	6
3	Design of experiment to measure heat transfer coefficient and effective thermal conductivity in nanofluids under different boundary conditions. (Dr. Shafiee)	8
4	Design and Fabrication of Exoskeleton-based Hybrid Human Rehabilitation Robot (Dr. Park & Dr. Duan)	1
5	Optimized Design of Satellite Thermal Radiator for Space-based Applications (Ball Aerospace)	9
6	Low Shock Restraint and Deployment Device for Deployable Satellite Appendages (Ball Aerospace)	3
7	Design, Fabrication, and Testing of an Automated Oil Recovering Skimm (Dr. Zhou & Dr. Park)	2
8	Design and Fabricate the Suspension and Steering for Off-Road Vehicle (Dr. Jiang)	4
9	Design, Fabricate and Test a fully instrumented laboratory set-up that could be used to study the performance of the major types of heat exchangers used in the industry.(Dr. Biney)	7

2. For your **first** and **second** choices, conduct a brief background work to
   (a) show that you have read about the project and that you understand the problem and that you have some basic knowledge to contribute to the project,
   (b) show the experience that you have that makes you interested in this project and
   (c) justify why those selections should be assigned to you.

(Repeat a, b, c for second choice also)
(To make sure you have answered each question, copy the question and each sub-question before you provide your answer below it).

Grading Scheme

Item	Description	Maximu	Your
1	Ranking of Projects	10	
2a	Background review for understanding project choices 1 & 2	20	
2b	Stated experience in choices 1 & 2	10	
2c	Justification of why project should be assigned to you	10	
	Total	50	

Sandford, Demetrious
MCEG 4472 Y02
Report 1

Project Selection Assignment

Choice 1

(a) show that you have read about the project and that you understand the problem and that you have some basic knowledge to contribute to the project,

For my first choice I choose **Design and Fabrication of Exoskeleton-based Hybrid Human Rehabilitation Robot** (project number 4). There are three objects of this project, the first is to design and create an exoskeleton capable of providing a strong, stiff foundation for the robot. The next objective is to identify locations where there should be soft components on the robot that reduce acute pressure for the user. This is because previous exoskeletons have been reported as uncomfortable or even painful which defeats the purpose. Then finally a control algorithm must be created for the actuators so that it supports the STS motion (sit-to-stand).

(b) show the experience that you have that makes you interested in this project

With the knowledge I received in robotics class I was able to help during a robotics competition where students were asked to design and program a robot capable of lifting objects and transporting them to another location. I've always had an interest in robotic design and learning how to use multiple software and machinery has help me develop a better understanding as to what it takes to evolve from lifting and transporting robots to upper and lower body robotic limbs.

(c) justify why those selections should be assigned to you.

With what I have learned and still in the process of learning, I believe that I stand a good chance at completing this project. This project will also give me more of an understanding and experience with exoskeleton-based hybrid human rehabilitation and allowing me to help

Choice 2

(a) show that you have read about the project and that you understand the problem and that you have some basic knowledge to contribute to the project

For my second choice I choose **Design, Fabrication, and Testing of an Automated Oil Recovering Skimm** (project number 7). With the unpredictable climate conditions, increasing strength of currents and underwater pressure, etc., offshore oil productions have been placed in unstable environments. Recognizing the importance of environmental issues, understanding the necessary functionalities of the oil recovering skimmers, familiarizing with the state-of-the-art technology in oil recovery field, and fabricating and validating the innovative skimmer design have become the objectives of this project.

(b) show the experience that you have that makes you interested in this project

I believe that this is something that is overlooked. With the changes going on in the world I believe that we should prioritize offshore oil recovery. Finding a new way to efficiently do this would create an environment changing cycle. Recovering the oil more accurately and quickly would in turn allow the environment to be restored which would also help prevent more spills.

(c) justify why those selections should be assigned to you

With what I have discovered and learned from studying at Prairie View A&M I believe I can help turn this project into a beneficial tool in the oil recovery field.

BELOW AVERAGE

Mechanical Engineering Department
Senior Design I
Fall 2020 Semester
Project Selection Assignment
Status Report 1 on Project Selection

Are you a US Citizen?
Circle one

YES

NO

Assigned: 08/27/2020 Due: 08/31/2020 (by 5:00 PM on e-course)

Name:__Darryl Geyen_____Phone:832-407-8574_____
email: darrylgeyen@gmail.com_____

1. Review the project statements distributed and rank them according to your 1st, 2nd, 3rd, 4th, ... 9th choices on Table 1 (Please type in information directly in the table).

Table 1. Project Selection Ranking

Project number	Project Title	Preference Ranking
1	Enhancing Thermal Resistance of Building Walls By Utilizing Fluid Flow in Microchannel within the Wall (Dr. Shafiee)	#3
2	Design, Fabricate and Test a Condenser Train for Condensing Biogas to Bio-oil During Pyrolysis of Biomass (Dr. Biney)	#9
3	Design of experiment to measure heat transfer coefficient and effective thermal conductivity in nanofluids under different boundary conditions. (Dr. Shafiee)	#5
4	Design and Fabrication of Exoskeleton-based Hybrid Human Rehabilitation Robot (Dr. Park & Dr. Duan)	#2
5	Optimized Design of Satellite Thermal Radiator for Space-based Applications (Ball Aerospace)	#6
6	Low Shock Restraint and Deployment Device for Deployable Satellite Appendages (Ball Aerospace)	#8
7	Design, Fabrication, and Testing of an Automated Oil Recovering Skimm (Dr. Zhou & Dr. Park)	#4
8	Design and Fabricate the Suspension and Steering for Off-Road Vehicle (Dr. Jiang)	#1
9	Design, Fabricate and Test a fully instrumented laboratory set-up that could be used to study the performance of the major types of heat exchangers used in the industry.(Dr. Biney)	#7

2. For your **first** and **second** choices, conduct a brief background work to
   (a) show that you have read about the project and that you understand the problem and that you have some basic knowledge to contribute to the project,
   (b) show the experience that you have that makes you interested in this project and
   (c) justify why those selections should be assigned to you.

(Repeat a, b, c for second choice also)
(To make sure you have answered each question, copy the question and each sub-question before you provide your answer below it).

Grading Scheme

Item	Description	Maximu	Your
1	Ranking of Projects	10	
2a	Background review for understanding project choices 1 & 2	20	
2b	Stated experience in choices 1 & 2	10	
2c	Justification of why project should be assigned to you	10	
	Total	50	

First Choice: Design and Fabricate the Suspension and Steering for Off-Road Vehicle (Dr. Jiang)

a) With the opportunity to work on this project, I will have a great experience designing an off road vehicle that will not only be drivable, but be able to withstand various conditions that will affect the vehicle. Working in an internship with DuPont this past summer they deal with creating specific products that deal with the automobile industry and deal with working on mechanical systems in order to make sure their products are efficient enough to withstand various atmospheric conditions in operation.
b) From the internship and dealing with my own personal car on a daily basis I have developed a knowledge to understand how automobile mechanical systems work and have an understanding of how to operate vehicles under specific conditions within the given constraints.
c) I believe this selection for this project should be assigned to me because I have already discussed with a group of students already about proposing this project in the first place and I'm very excited to have the opportunity to work with the team in contributing to the overall success of this project.

Second Choice: Design and Fabrication of Exoskeleton-based Hybrid Human Rehabilitation Robot (Dr. Park & Dr. Duan)

a) This project is very interesting in that it deals with robot and human interaction based on sensor results.
b) In the same DuPont internship, although I had little time to work with the robotic Engineer for specific projects at the company, he was able to guide me on what he did at work on a day to day basis which ultimately lead me to become interested in robotic engineering. He explained how the human and robot interaction came about for specific roles on the job and I was able to get a slight firsthand knowledge on how the robotic systems were operated.
c) Although I have already discussed on my first choice that I have already been speaking with a group about working on the "Design and Fabricate the Suspension and Steering for Off-Road Vehicle", this second choice would be interesting as well.

For both my first and second choice I have discussed the following:

(a) show that you have read about the project and that you understand the problem and that you have some basic knowledge to contribute to the project,
(b) show the experience that you have that makes you interested in this project and
(c) justify why those selections should be assigned to you.

SENIOR DESIGN AND PREFESIONALISM I
FALL 2020

STATUS REPORT 2

TOPICS COVERED IN STATUS REPORT 2

Group Leader Selection and Meeting Time/location Agreement

COLLEGE OF ENGINEERING
SENIOR DESIGN & PROFESSIONALISM I
FALL 2020 SEMESTER

Status Report on Project Agreement

Due: 09/09/2020

1. Group Leader Selection: Develop and describe a process used to select a group leader [6]. Provide the name, phone number and email of the leader selected as shown below [4].
    a. Name of member selected as group leader:
    b. Phone number of group leader:
    c. e-mail address of group leader:

2. Technical & Non-technical Roles: Develop and describe a process used to assign technical and non-technical roles to each member [5]. See the notes at the ends of this assignment on possible team roles.
   Then complete the table below to document the roles assigned to each team member [5].

	Name of Group Member	Assigned Role	Phone Number	e-mail Address
1				
2				
3				
4				
5				
6				
7				

3. Group Meeting Times & Location: Develop and describe how the group selected the group meeting times and meeting locations suitable to all member [3].
   Complete the table below to document the meeting times and location [7].
   Each group should meet **at least** 6 hours per week to work on the project outside of class time [3].

Day of the Week	Meeting Times Start time & End time	Total meeting hours for day	Meeting Location (Location, Building, Room) Or How group plans to meet Provide link, etc. if Zoom or other electronic meeting forms being used
Total Meeting Hours for the week (outside class period)			

4. Faculty Advisor Meeting Times: Develop and describe how the group selected the common times for the group to meet with the faculty project advisor [2].
   Complete the table below to document the meeting times and location for the advisor meeting. Part of the class time on Thursdays between 3 PM to 5 PM can be used for this meeting.

Meeting times with Project Faculty Owner [3]

Day of the Week	Meeting Times Start time & End time	Meeting Location (Location, Building, Room) Or How group plans to meet Provide link, etc. if Zoom or other electronic meeting forms being used

Faculty Advisor's Signature:_____ Date:_____

5. Write up a simple meeting time and other responsibility agreement using appropriate legal terms that would be binding on each member (*Need to do some research on how to write legal agreements since this may be new to you all*). Include the following statement as part of the agreement [6]:

   I have read and understood the requirements of the course and the grading policies as stated in the final course syllabus.
   I agree to abide by the university's policy on scholastic dishonesty.
   I hereby assign all of my intellectual property rights on the project to the sponsor of the project [4].

Printed names, signatures and dates on agreement.

	Printed Name	Signature	Date
1			
2			
3			
4			
5			
6			
7			

The agreement signed is binding on each student until the end of the semester, and violating the agreement may require you to drop the course.

Note: All signatures must be obtained through DocuSign
Note: Attach a copy of this status report sheet to your work (placed after the cover sheet) [2]
Note: Assignment for Outcome 5 in the syllabus

NOTES ON TEAM ROLES

Technical Team Roles may include but not limited to

1. **Organizer**
   Leads in developing, maintaining task scheduling, and reviews progress on project schedule and refocuses efforts to meet deadlines in project schedule.

2. **Ideas Facilitator**
   Leads in generating, collecting and organizing ideas.

3. **Graphics/Models Leader**
   Oversees developing of models, drawings, and simulations.

4. **Design analysis leader**
   Oversees the various analysis needed for the design and ensures designated members present accurate design analysis and integrate analysis into the design report.

5. **Manufacturing and Testing Leader**
   Oversees the fabrication, assembly, manufacture and testing of the system designed.

Non-Technical Roles may include but not limited to

1. **Budgeter /Purchaser**
   Prepares detailed budget and coordinates purchasing of parts for the design

2. **Presentation Manager**
   Leads in the organization, preparation and oversees presentation roles of team members.

3. **Technical Writer**
   Leads in organizing, structuring and writing of the report using contributions from designated members.

4. **Proof Reader**
   Responsible for ensuring the report has no grammatical or spelling errors and that the report is written using acceptable clear English language.

5. **Recorder**
   Takes minutes and documents all meeting and design activities for the group. Short video clips can be used to catalog the group's activities.
   Note: Group can add more roles if needed.

Grading Scheme for Group Agreement

Project Group #_____

Item	Description	Maximum Points	Your Score
1	Development and description of group leader selection process Information provided on group leader	6 4	
2	Development and description of process for assigning roles Assignment of Proper Roles to team members	5 5	
3	Development and description of process for selecting meeting times Meeting times (days of the week, time) selected	3 4	
4	Total meeting hours/week (>=6 hours)	3	
5	Grouping meeting location specified	3	
6	Development and description of process for setting up meeting with project owner Meeting schedule with faculty project owner(s) fixed & Signed by advisor	2 3	
7	Properly legally phrased agreement that shows students did research to put in appropriate legal terms. *Included College statements in agreement and signed by each member*	6 4	
8	Homework cover page used and copy of assignment attached	2	
	Total	50	

ABOVE AVERAGE

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SENIOR DESIGN & PROFESSIONALISM I
FALL 2020
PROJECT PROGRESS REPORT COVER SHEET

45/50

PROJECT TITLE: Design of experiment to measure heat transfer coefficient and effective thermal conductivity in nanofluids under different boundary conditions

GROUP NUMBER 3

Submit work in Word Format

Progress Report Title: Status Report 2

Due Date: 9/9/2020

No	Group Member Name Group Member signature	Brief Description of Work Assigned to Member	% Completed by Member*	Your Score
1	Fanta Kaba DocuSigned by: 5806806D584B4EA...	Contributed to formulation of report ideas, created the legal document, and proofread, discussion of roles and voting.	100 %	
2	Yemboado Brayan Yonli DocuSigned by: Yemboado Brayan Yonli 4CB8696A9EE91FE...	Created and shared the meeting room. Designed the process by ich technical and non technical roles were assigned.	100%	
3	Diana Morales DocuSigned by: Diana Morales 6E3A002-0997D8...	Proofread the report, and contributed to content of the report for parts 1 discussion of roles and voting	100%	
4	Abdullah EL Aker DocuSigned by: Abdullah El Aker F97896015DBC4B9...	contributed to the report content and established the DocuSign. roofread, discussion of roles and voting.	100%	
5	Marcelo Epam Ona DocuSigned by: Marcelo Epam Ona 32DFDFB1803D43D...	Make sure that each group member did his or her part so that overall assignment was done. Set up a meeting with the project's wner so that we can establish a ne where we could meet every week. Creating a list of legal agreements so that as a group we could be on the same terms.	100%	
6	Christian White DocuSigned by: 0EF77D6FBA39156...	Contributed to part 4 and 1in writing and proofreading document, discussion of roles and voting	100 %	

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COLLEGE OF ENGINEERING
SENIOR DESIGN & PROFESSIONALISM I
FALL 2020 SEMESTER

Status Report on Project Agreement

Due: 09/09/2020

1. Group Leader Selection: Develop and describe a process used to select a group leader [6].

To select the group leader, each member in the group was allowed to voluntarily come forward and voice their desire in becoming the group leader. It was then asked for each candidate to express what qualities they had to offer in order to ensure the success of the team. After each candidate expressed their skills and why they should be the leader for our group, each member of the group took the time to reflect on what they felt they needed from their leader. Each member took some time to express their individual thoughts on what they felt was important to receive from the team leader for the successful completion of this project. In summary, it was concluded that someone with great organizational skills was important as well as project understanding (based on grades obtained in the different classes that would have a direct impact on the project execution), motivation, and availability. Based on these qualities, Marcelo Epam Ona was unanimously chosen, as he was believed to be the right person for the position. This was done by using an online voting poll.

6/6

Provide the name, phone number and email of the leader selected as shown below [4].

a. Name of member selected as group leader: Marcelo Epam Ona
b. Phone number of group leader: 832-614-2426
c. e-mail address of group leader: mepam@student.pvamu.edu

4/4

2. Technical & Non-technical Roles: Develop and describe a process used to assign technical and non-technical roles to each member [5]. See the notes at the ends of this assignment on possible team roles.

Technical and non technical roles were assigned based on each member's skills and interests about the role. Each group member took the time to analyze and review the roles, then each member reflected on their own skills. The group leader was automatically assigned the role of Organizer, as it is in parallel to his role as Group Leader. After reflecting on the roles, one at a time, each member announced the role they would be willing to take. For the members that wanted to work on the same roles, a discussion was initiated on who was more suited for the role and the team leader chose who would take that role. Based on that, the following table presents each student with their different roles and contact information.

5/5

Then complete the table below to document the roles assigned to each team member [5].

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	Name of Group Member	Assigned Role	Phone Number	e-mail Address
1	Fanta Kaba	Writer & Recorder	832-762-1173	fantakaba50@gmail.com
2	Yemboado Brayan Yonli	Design Analysis Leader & Budgeter/Burchaser	713-894-4648	yyonli@student.pvamu.edu
3	Diana Morales	Proof Reader and Ideas Facilitator	281-236-0581	dmorales4@student.pvamu.edu
4	Abdullah EL Aker	Manufacturing & Testing Leader	832-421-0808	aelaker@student.pvamu.edu
5	Marcelo Epam Ona	Group Leader & Organizer	832-614-2426	mepam@student.pvamu.edu
6	Christian White	Graphics & Presentation	713-517-1509	cwhite52@student.pvamu.edu

5/5

3. Group Meeting Times & Location: Develop and describe how the group selected the group meeting times and meeting locations suitable to all members [3].

The details of each member class schedules and work schedules was reviewed in order to choose appropriate weekly meeting times. Each member shared their availability and Marcelo gathered the information as he heard it. He then confirmed with each member the dates, that he saw fit for the weekly meetings and then the members agreed. The meetings time were decided to be Tuesday's and Friday's for 3 hours in order to meet for a minimum of 6 hours per week, and some time was also set aside on Saturday's for 2 hours just in case extra time was needed on the weekly assignments and weekly discussions. Marcelo would be in charge of setting up the zoom meeting for us to attend for future meetings.

3/3

Complete the table below to document the meeting times and location [7].
Each group should meet **at least** 6 hours per week to work on the project outside of class time [3].

Avoid splitting table across two pages.

Day of the Week	Meeting Times Start time & End time	Total meeting hours for day	Meeting Location (Location, Building, Room) Or How group plans to meet Provide link, etc. if Zoom or other electronic meeting forms being used
Tuesday	12pm - 3pm	3	https://us04web.zoom.us/j/8188851036?pwd=M083VG9mdGgzNklvUGNNS1lCRndhQT09
Friday	11am - 2pm	3	https://us04web.zoom.us/j/8188851036?pwd=M083VG9mdGgzNklvUGNNS1lCRndhQT09
Saturday	10am - 12am	2	https://us04web.zoom.us/j/8188851036?pwd=M083VG9mdGgzNklvUGNNS1lCRndhQT09

7/7

3/3

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Total Meeting Hours for the week (outside class period)	8 hrs	

3/3

4. Faculty Advisor Meeting Times: Develop and describe how the group selected the common times for the group to meet with the faculty project advisor [2].
Complete the table below to document the meeting times and location for the advisor meeting. Part of the class time on Thursdays between 3 PM to 5 PM can be used for this meeting.

The group leader emailed the Project owner asking for his specific office hours and what time he would be available for the remaining semester and the Spring semester. He replied immediately with his office hours and the leader chose the time that worked best for the group as whole based on each member's schedule. He confirmed it with the team and then scheduled it with the project owner as a set time. It would be Tuesday's from 11:00 am to 12:00 pm.

2/2

Meeting times with Project Faculty Owner [3]

Day of the Week	Meeting Times Start time & End time	Meeting Location (Location, Building, Room) Or How group plans to meet Provide link, etc. if Zoom or other electronic meeting forms being used
Tuesday	11am - 12pm	https://pvpanther.zoom.us/j/8487601860?pwd=TVdIVFpKZ0JHa1NoRWNpWENuNWRqQT09

3/3

Faculty Advisor's Signature:_____ DocuSigned by: D3C71690369B4B8... :_____

5. Write up a simple meeting time and other responsibility agreement using appropriate legal terms that would be binding on each member (*Need to do some research on how to write legal agreements since this may be new to you all*). Include the following statement as part of the agreement [6]:

I have read and understood the requirements of the course and the grading policies as stated in the final course syllabus.
I agree to abide by the university's policy on scholastic dishonesty.
I hereby assign all of my intellectual property rights on the project to the sponsor of the project [4].

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Dear Group 3 Members,

This letter (the "Agreement") summarizes my understanding of the agreement that we reached on September 8, 2020 after our zoom conference. If this Agreement is acceptable to you, please sign below in the space in the space designated for your signature.

As I understand it, we have agreed as follows:

Legal agreement not comprehensive enough and not enough legal terms used

1. Agreement

It is my understanding we have agreed to the following in regards to: Group 3.

- *I have read and understood the requirements of the course and the grading policies as stated in the final course syllabus*
- *I agree to abide by the university's policy on scholastic dishonesty*
- *I hereby assign all of my intellectual property rights on the project to the sponsor of the project*
- *I agree to attend every single meeting established by the group and the project adviser unless we had a valid reason such as being in class, sick or work.*
- *Each group member agrees to be penalized by the group leader if they do not complete the part of the project that has been assigned to them.*
- *Each group member agrees to be respectful to other group members when it comes to communicating their ideas and suggestions to the group.*

2/6

4/4

2. Term

The term of this Agreement ("Term") will commence as of September 8, 2020, and will continue in effect until the end of the senior design project. No part of this Letter of the Agreement may be changed, modified, amended or supplemented. I have read and understood the requirements of the agreement.

Printed names, signatures and dates on agreement.

	Printed Name	**Signature**	**Date**
1	Fanta Kaba	DocuSigned by:	9/5/2020
2	Yemboado Brayan Yonli	DocuSigned by: Yemboado Brayan Yonli	9/5/2020
3	Diana Morales	DocuSigned by: Diana Morales	
4	Christian White	DocuSigned by:	9/5/2020
5	Abdullah EL Aker	DocuSigned by: Abdullah El Aker	9/5/2020
6	Marcelo Epam Ona	DocuSigned by: Marcelo Epam Ona	9/5/2020

The agreement signed is binding on each student until the end of the semester, and violating the agreement may require you to drop the course.

Note: All signatures must be obtained through DocuSign
Note: Attach a copy of this status report sheet to your work (placed after the cover sheet) [2]
Note: Assignment for Outcome 5 in the syllabus

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NOTES ON TEAM ROLES

Technical Team Roles may include but not limited to

1. **Organizer**

Leads in developing, maintaining task scheduling, and reviews progress on project schedule and refocuses efforts to meet deadlines in project schedule.

2. **Ideas Facilitator**

Leads in generating, collecting and organizing ideas.

3. **Graphics/Models Leader**

Oversees development of models, drawings, and simulations.

4. **Design analysis leader**

Oversees the various analysis needed for the design and ensures designated members present accurate design analysis and integrate analysis into the design report.

5. **Manufacturing and Testing Leader**

Oversees the fabrication, assembly, manufacture and testing of the system designed.

Non-Technical Roles may include but not limited to

1. **Budgeter /Purchaser**

Prepares detailed budget and coordinates purchasing of parts for the design

2. **Presentation Manager**

Leads in the organization, preparation and oversees presentation roles of team members.

3. **Technical Writer**

Leads in organizing, structuring and writing of the report using contributions from designated members.

4. **Proof Reader**

Responsible for ensuring the report has no grammatical or spelling errors and that the report is written using acceptable clear English language.

5. **Recorder**

Takes minutes and documents all meeting and design activities for the group. Short video clips can be used to catalog the group's activities.

Note: Group can add more roles if needed.

Grading Scheme for Group Agreement

Project Group #_____

Item	Description	Maximum Points	Your Score
1	Development and description of group leader selection process Information provided on group leader	6 4	10
2	Development and description of process for assigning roles Assignment of Proper Roles to team members	5 5	10
3	Development and description of process for selecting meeting times Meeting times (days of the week, time) selected	3 4	7
4	Total meeting hours/week (>=6 hours)	3	3
5	Grouping meeting location specified	3	3
6	Development and description of process for setting up meeting with project owner Meeting schedule with faculty project owner(s) fixed & Signed by advisor	2 3	5

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7	Properly legally phrased agreement that shows students did research to put in appropriate legal terms. *Included College statements in agreement and signed by each member*	6 4	2 4
8	Homework cover page used and copy of assignment attached	2	1
	Total	50	45

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AVERAGE

BELOW AVERAGE

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COLLEGE OF ENGINEERING

SENIOR DESIGN & PROFESSIONALISM I

FALL 2020 SEMESTER

Status Report on Project Agreement

Due: 09/09/2020

1. Group Leader Selection: Develop and describe a process used to select a group leader [6]. Provide the name, phone number and email of the leader selected as shown below [4].
    1. Name of member selected as group leader: Robert Barbee
    2. Phone number of group leader: 832-461-3958
    3. e-mail address of group leader: rbarbee80@gmail.com
2. Technical & Non-technical Roles: Develop and describe a process used to assign technical and non-technical roles to each member [5]. See the notes at the ends of this assignment on possible team roles.

    Then complete the table below to document the roles assigned to each team member [5].

	Name of Group Member	**Assigned Role**	**Phone Number**	**e-mail Address**
1	**Robert Barbee**	**Group Leader/ Organizer**	**832-461-3958**	**rbarbee80@gmail.com**
2	**Jonathon Horta**	**Recorder/ Budgeter/ Ideas Facilitator**	**469-735-2830**	**hortajonathon@gmail.com**

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3	**Todd Maxwell**	**Technical Writer/ Idea Facilitator**	**713-398-2866**	**Tmaxwell0001@gmail.com**
4	**Daniel Ward**	**Manufacturing & Testing Leader**	**281-771-9167**	**ward.daniel97@gmail.com**
5	**Aramis King**	**Manufacturing & Testing Leader/Proof Reader**	**832-713-1542**	**Aramisking23@gmail.com**
6	**Michael Samuel**	**Presentation Manager/Design Analysis Leader**	**(832)955-5196**	**msamuel4@student.pvamu.edu**
7	**Titus Woodard**	**Graphics/Models Leade/ Proof Reader**	**713-201-0343**	**tituswoodard21@gmail.com**

3. Group Meeting Times & Location: Develop and describe how the group selected the group meeting times and meeting locations suitable to all member [3].

   Complete the table below to document the meeting times and location [7].

   Each group should meet **at least** 6 hours per week to work on the project outside of class time [3].

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Day of the Week	Meeting Times Start time & End time	Total meeting hours for day	Meeting Location (Location, Building, Room) Or How group plans to meet Provide link, etc. if Zoom or other electronic meeting forms being used
Tuesday	**12PM - 2PM**	**2hrs**	**Zoom:** **ID: 987 671 2507** **PW: 310102020**
Thursday	**12PM - 2PM**	**2hrs**	**Zoom:** **ID: 987 671 2507** **PW: 310102020**
Friday	**10:40AM - 12:40AM**	**2hrs**	**Zoom:** **ID: 987 671 2507** **PW: 310102020**
Total Meeting Hours for the week (outside class period)		**6hrs**	

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4. Faculty Advisor Meeting Times: Develop and describe how the group selected the common times for the group to meet with the faculty project advisor [2].

   Complete the table below to document the meeting times and location for the advisor meeting. Part of the class time on Thursdays between 3 PM to 5 PM can be used for this meeting.

Meeting times with Project Faculty Owner [3]

Day of the Week	Meeting Times Start time & End time	Meeting Location (Location, Building, Room) Or How group plans to meet Provide link, etc. if Zoom or other electronic meeting forms being used
Wednesday 9/9/20	**Start: 3:30pm** **End: 4pm**	**Zoom** **Meeting ID: 981 404 1458** **Passcode: 041458**

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Faculty Advisor's Signature: DocuSigned by: Lai Jiang 6C1C88553B961F9... Date: 9/9/2020 | 3:50 PM CDT

5. Write up a simple meeting time and other responsibility agreement using appropriate legal terms that would be binding on each member (*Need to do some research on how to write legal agreements since this may be new to you all*). Include the following statement as part of the agreement [6]:

   I have read and understood the requirements of the course and the grading policies as stated in the final course syllabus.

   I agree to abide by the university's policy on scholastic dishonesty.

   I hereby assign all of my intellectual property rights on the project to the sponsor of the project [4].

Printed names, signatures and dates on agreement.

	Printed Name	**Signature**	**Date**
1	**Robert Barbee**	DocuSigned by: 72C2E0EB6FA2411...	9/9/2020
2	**Michael Samuel**	DocuSigned by: 2AEB00F9972C469...	9/9/2020
3	**Aramis King**	DocuSigned by: Aramis King 21BEBD3183334F3...	9/9/2020

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4	**Titus Woodard**	DocuSigned by: Titus Woodard 5B99C2B6D09148E...	9/9/2020
5	**Daniel Ward**	DocuSigned by: 73D9C89EE35D495...	9/9/2020
6	**Jonathon Horta**	DocuSigned by: Jonathon Horta 856BB4B0BEC344F...	9/9/2020
7	**Todd Maxwell**	DocuSigned by: 7F4394438810459...	9/9/2020

The agreement signed is binding on each student until the end of the semester, and violating the agreement may require you to drop the course.

Note: All signatures must be obtained through DocuSign)

Note: Attach a copy of this status report sheet to your work (placed after the cover sheet) [2]

Note: Assignment for Outcome 5 in the syllabus

NOTES ON TEAM ROLES

Technical Team Roles may include but not limited to

1. **Organizer**

Leads in developing, maintaining task scheduling, and reviews progress on project schedule and refocuses efforts to meet deadlines in project schedule.

2. **Ideas Facilitator**

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Leads in generating, collecting and organizing ideas.

3. Graphics/Models Leader

Oversees developing of models, drawings, and simulations.

4. Design analysis leader

Oversees the various analysis needed for the design and ensures designated members present accurate design analysis and integrate analysis into the design report.

5. Manufacturing and Testing Leader

Oversees the fabrication, assembly, manufacture and testing of the system designed.

Non-Technical Roles may include but not limited to

1. Budgeter /Purchaser

Prepares detailed budget and coordinates purchasing of parts for the design

2. Presentation Manager

Leads in the organization, preparation and oversees presentation roles of team members.

3. Technical Writer

Leads in organizing, structuring and writing of the report using contributions from designated members.

4. Proof Reader

Responsible for ensuring the report has no grammatical or spelling errors and that the report is written using acceptable clear English language.

5. Recorder

Takes minutes and documents all meeting and design activities for the group. Short video clips can be used to catalog the group's activities.

Note: Group can add more roles if needed.

Grading Scheme for Group Agreement

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Project Group #_____

Item	Description	Maximum Points	Your Score
1	Development and description of group leader selection process Information provided on group leader	6 4	
2	Development and description of process for assigning roles Assignment of Proper Roles to team members	5 5	
3	Development and description of process for selecting meeting times Meeting times (days of the week, time) selected	3 4	
4	Total meeting hours/week (>=6 hours)	3	
5	Grouping meeting location specified	3	
6	Development and description of process for setting up meeting with project owner Meeting schedule with faculty project owner(s) fixed & Signed by advisor	2 3	
7	Properly legally phrased agreement that shows students did research to put in appropriate legal terms. *Included College statements in agreement and signed by each member*	6 4	
8	Homework cover page used and copy of assignment attached	2	

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	Total	50	

SENIOR DESIGN AND PREFESIONALISM I
FALL 2020

STATUS REPORT 3

TOPICS COVERED IN STATUS REPORT 3

Problem Formulation

COLLEGE OF ENGINEERING
SENIOR DESIGN & PROFESSIONALISM I
Fall 2020 SEMESTER
Status Report on Problem Formulation

Due: 09/10/2020

This status report covers the information on the Project Scope chapter of the project report. Consequently, it should be written in a detailed descriptive form as we discussed in class for the assignment #2. The report should be prepared using the chapter title.

" **1. PROJECT SCOPE**" . The subsections highlighted in blue fonts should be used in the status report
Provide an introductory statement for the chapter.

1.1 Problem Statement

Provide a detailed problem statement that clearly defines the project assigned to you. You may need to discuss the form of this project statement with the project advisor, not your instructor.

1.2 Client identification and recognition of need

(i) Identify the client for the project assigned to you.

*To identify the client, you need to assume you are designing this product for the market and identify who **all your potential customers** would be. You need to understand what you are designing, its usefulness, the segment of population or industries that can potentially use your design.*

Just listing the trivial (instructor, the department, Bell Aerospace, etc) will fetch you no credit for this section.

(ii) Identify the need to be fulfilled in your project.

The need should be stated as a current problem or dissatisfaction that needs to be addressed. *You need to be able to clearly state all of the problems that this design is going to address.*

No credit for just mentioning the project title or restating it in other forms

1.3 Project goals and objectives

1.3.1 Develop the Goal statement for your project

Once the need is identified, you need to have a general statement on how you are going to address this need. This will be your goal statement. The group needs to spend some time to formulate this goal statement.

You cannot just state the project title; in fact, the project title should be avoided.

1.3.2 From the goal statement, build an objective tree for your project using the steps below

(i) Prepare a list of design objectives

Objectives specify the characteristics of the system that are to be optimized in order to achieve the goals. They are the desired attributes of the design.

Design objectives depend on the specific design problem being addressed. The list of objectives in the PowerPoint notes were specifically for the problem mentioned in the notes which is completely different from your design problem. The group needs to produce original well-thought-out objectives for the specific design and not use the list provided in the notes because different design problems need different objectives. ***To identify the objectives for your design in this course you need to ask yourself what desirable characteristics or features can you build into your system so you can use these characteristics or features as the selling points for your product because these features make your product functional.***

(ii) Order the list of design objectives into sets of higher level and lower level Objectives. *(See example in the step 2 table in the PowerPoint notes)*

(iii) Draw the objective tree for your project
(See the example in the class lecture notes. See the diagram in step 3 in the PowerPoint notes)

(iv) Develop a Table showing how objectives will be measured and the units of measurement
(see example in class lecture shown in Table 2.1)

1.4 Initial Project constraints and Operating Environment

(i) Make a list of initial constraints for your project.
Note that constraints are limits that a design must meet to be acceptable. They establish permissible range of the design and performance parameters

They may be one of the three types below:

- yes/no constraints (such as must use 3/8”-24 UNF SAE grade 5 bolts)
- equality constraints (such as must be 18” high)
- inequality constraints (such as cannot weigh more than 50 lb, must hold at least 50 lbs of steam, must be between 12” and 15” long)

(ii) List the operating environment for your design.

Attach a copy of this assignment just after the cover page
Assignment for Outcome 5

Grading Scheme

Status Report on Problem Formulation

Project Group #_____Project Title_____

Item	Description	Maximum Points	Your Score
1	Problem statement clearly stated	5	
2	Properly defined Client: Local Client Potential Clients assuming design is to be marketed	5 5	
3	Need stated as a current problem or dissatisfaction that needs to be addressed. Stated all of the problems that this design is going to address	10 5	
4	Goal statement that encompasses the broad aims of the project	10	
5	Properly defined project objectives, Sub-objectives Developed logical objective tree	6 6 6	
6	Table of objectives, Measurement basis, Criteria for measurement Units of measurement	5 5 5 5	
7	Realistic constraints Yes/No or Equality, or Inequality constraints	10	
8	Operating environment for system	10	
9	Attached copy of assignment pages	2	
	Total	100	

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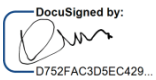
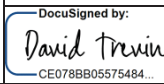
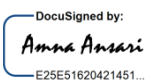
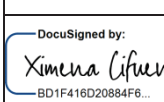
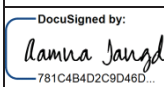
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1SENIOR DESIGN & PROFESSIONALISM I FALL 2020 PROJECT PROGRESS REPORT COVER SHEET

PROJECT TITLE: ~~Status Record III Assignment~~

GROUP NUMBER: 7

Progress Report Title: Problem Formulation
Due Date: 09/14/2020

No	Group Member Name Group Member signature	Brief Description of Work Assigned to Member	% Completed by Member*	Your Score
1	Daniel Akpan 	- Participated in identifying the scope of project, client, client need, goal, goal scope, objectives, and constraints. - Researched - Completed section 1.4 – Subsection 1.4(i) &1.4(ii)	100%	
2	David Trevino 	- Participated in identifying the scope of project, client, client need, goal, goal scope, objectives, and constraints. - Researched - Completed section 1 Subsections 1.1, 1.2(i) & 1.2 (ii)	100%	
3	Amna Ansari 	- Participated in identifying the scope of project, client, client need, goal, goal scope, objectives, and constraints. - Researched - Completed section 1.3 Subsections 1.3.1, 1.3.2(i), 1.3.2(ii), 1.3.2(iii), 1.3.2(iv)	100%	
4	Demetrious Sandford 	- Participated in identifying the scope of project, client, client need, goal, goal scope, objectives, and constraints. - Researched & proofread the report - Completed section 1 Subsections 1.1, 1.2(i) & 1.2 (ii)	100%	
5	Caleb Riggins 	- Participated in identifying the scope of project, client, client need, goal, goal scope, objectives, and constraints. - Researched & reviewed report technical writing/formatting - Completed section 1.4 – Subsection (i) &(ii)	100%	
6	Ximena Cifuentes 	- Participated in identifying the scope of project, client, client need, goal, goal scope, objectives, and constraints. - Researched - Completed sections 1.3 Subsections 1.3.1, 1.3.2(i), 1.3.2(ii), 1.3.2(iii), 1.3.2(iv)	100%	
7	Aamna Jangda 	- Participated in identifying the scope of project, client, client need, goal, goal scope, objectives, and constraints. - Researched - Completed section 1.3 Subsections 1.3.1, 1.3.2(i), 1.3.2(ii), 1.3.2(iii), 1.3.2(iv)	100%	

*100% means the member completed his/her assigned work

By signing this assignment cover sheet, I agree that the percentages stated in the % completed column reflect the contribution made by me and the other members of the group.

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COLLEGE OF ENGINEERING
SENIOR DESIGN & PROFESSIONALISM I
Fall 2020 SEMESTER
Status Report on Problem Formulation

Due: 09/10/2020

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(See the example in the class lecture notes. See the diagram

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in step 3 in the PowerPoint notes)

(iv) Develop a Table showing how objectives will be measured and the units of measurement *(see example in class lecture shown in Table 2.1)*

1.4 Initial Project constraints and Operating Environment

(i) Make a list of initial constraints for your project.

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- inequality constraints (such as cannot weigh more than 50 lb, must hold at least 50 lbs of steam, must be between 12" and 15" long)

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Attach a copy of this assignment just after the cover page
Assignment for Outcome 5

Grading Scheme

Status Report on Problem Formulation

Project Group #_____Project Title_____

Item	Description	Maximum Points	Your Score
1	Problem statement clearly stated	5	
2	Properly defined Client: Local Client Potential Clients assuming design is to be marketed	5 5	
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6	Table of objectives, Measurement basis, Criteria for measurement Units of measurement	5 5 5 5	
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8	Operating environment for system	10	
9	Attached copy of assignment pages	2	
	Total	100	

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1. PROJECT SCOPE

In this chapter, the problem at hand will be introduced in a greater detail including the potential clients, their need, project goals, objectives, and project restraints.

1.1 Problem Statement

Today, the main form of energy source comes from crude oil and other liquids produced from fossil fuels in which they are refined into petroleum. With the advancement of technology, we can extract oil from wells through offshore drilling. However, this mode of extraction can cause harm to the environment during oil spill incidents. With the increase of incidents every year, we need to combat this using improved designs for oil skimmers which are used to ultimately recover crude oil slicks. Oil skimmers are devices that are used to remove floating oil from the surface of a body of water. With the different and unpredictable changes in the world, the current oil recovering skimmers have a lot of room for optimization. When an oil spill occurs, the skimmers need to be able to combat the situation while maintaining the safety of the environment quickly and effectively. The skimmers need to be able to retain durability and functionality. Meaning, if a situation occurs where the skimmer takes sufficient damage, it should be able to protect the oil already stored without allowing another spill.

The purpose of this project is to design, fabricate and test a fully functional automated oil skimmer for companies to use during oil spill cleanups and containment. This will be accomplished by improving upon existing oil skimmer designs and overall increase the efficiency through various constraints and innovations.

1.2 Client Identification and Recognition of Need

In this section we identified the potential clients for the automated oil skimmer. While this technology is still in development, there are dozens of companies who have created oil skimmers. The main companies our design is intended for are oil companies that operate in coastal regions. In addition, the section discusses the clients' needs. The clients' needs will open the doors to the identification of the project goal.

(i) Identifying the project's client

- Bureau of Safety and Environmental Enforcement: This client was chosen due to its leading division in oil recovery. Within this organization, there is a division called Oil Spill Preparedness Division (OSPD) where specialized improving spill response countermeasures are taken to help develop decision making strategies for oil spill response. The organization has developed a scientific program that seeks to improve oil spill response and oil behavior understandings. In addition, the organization focuses on detecting effective methods by using alternative solutions.

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- Environmental Protection Agency: This client was chosen due to their mission in ensuring that all Americans have clean air and water. EPA is dedicated to reducing environmental risks by using the best scientific resources. One of EPA's top priorities is management of their (SPCC) Spill Prevention, Control, Countermeasure methods program.

- Marine Spill Response Corporation: This client was chosen as a potential contact due the recognition of the company. The Marine Spill Response Corporation is the largest oil response organization in the United States. In addition, if our product were to succeed, they have a robust network of qualified Spill Team Area Responders (STARs) in which we can apply and become a part of.

- Marine Preservation Association: This client was chosen due to its large influence in funding companies in the petroleum, energy, and related transportation industries. They are a leading organization in supporting the development and maintenance of effective spill response capability in the United States. They are the parent company of Marine Spill Response Corporation and include over 600 corporate members who utilize their technology in oil recovery.

- Occidental Petroleum Corporation: This client was chosen due to being an international energy company that operates in multiple regions such as the United States, Middle East, Africa, and Latin America. They are a leading producer of oil and gas and are looking into new innovations for oil skimmers to minimize damage to the environment and maximize oil recovery.

(ii) Identifying the client's need

A clear-cut problem for current Automated Oil skimmers is that their efficiency could be improved to where they can handle large amounts of oil spills. In addition, current automated skimmers are not able to collect large amounts of oil in a timely manner, which in turn negatively affects marine life and potentially becomes an environmental pollutant. The Use of innovative materials like Super absorbent materials paired with nanotechnology, incorporated into an existing automated skimmer by replacing a disc or a drum would significantly increase its efficiency. The overall goal for this project is to combat oil spill situations and effectively while maintaining the safety of the environment.

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1.3 **Project Goal and Objectives**

To break down the scope of the project, the team followed a series of steps. In this section, the goal statement is presented. In addition, the objectives were clearly defined and categorized to allow the team to experience the design thinking process. Finally, the purpose of this section is to ensure that the goal allowed room for different approaches to fulfill the clients' needs.

1.3.1 **Goal Statement**

The project goal is to design an improved oil skimmer system with a refined process by researching the current oil skimmers and addressing their current deficiencies/limitations. The scope of the team's goal is to design a system that is efficient enough to increase the recovery rate of slicks less than 1/2-inch thickness. During the developments of the design process, the team will prioritize the responder safety, portability of technology, simplicity of use, and reduction of waste during operation.

1.3.2 **Design Objectives**

In this subsection a variety of objectives were generated as the team collaborated about the different ways to access the clients' needs. In addition, the listed objectives were categorized between low-level and high-level objectives and their most relevant criteria category. Finally, the section demonstrates the hierarchical relationship between the objectives and their measurements units.

(i) List of objectives

- Cost effectiveness
- Product safety
- Can detect difference between water and oil
- Durability
- DC electric motor
- Capillary-disk design
- User friendly
- Low or no contamination of water
- Compact design
- Eco friendly
- Energy saver
- Reliable
- Efficient recovery rate
- Accessible cleaning
- Portability
- Extreme temperature resistance
- Improved external structure
- Waterproof
- Debris protection system
- Improved filtration

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- High pump capacity
- ~~Marketable~~
- ~~Universal usage~~
- Corrosion protection
- Automatic
- Alarm system
- Marine life friendly
- Low cost maintenance and repairs
- Low emissions
- Low pollution
- Low cost of fabrication
- Safety manual
- Meets safety regulations
- Meets environmental regulations
- Design should meet all federal and state regulations to prevent fines
- Detachable parts
- Oil containment capacity
- Easy assembly
- ~~Improved sensors~~
- More oil and water storage
- ~~Orientation~~
- Oil removal concentration
- Made from recyclable material
- Reuse collected oil for machine lubrication
- Water conservation friendly
- Design with simple and clear instructions of machinery
- Increase life cycle of filtering system

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(ii) Objectives in sets of higher and lower level

Table 1.1 Levels of objectives

High Level Objective	Low Level Objective
-Cost effectiveness	-Detachable parts
-Product safety	-Oil containment capacity
-Measure percent difference between water and oil	- Easy assembly
-Low maintenance and repairs	-Improved sensors
-Durability	-More oil and water storage
-User friendly	-Orientation
-Low or no contamination of water	-Made from recyclable material
-Compact design	-Reuse collected oil for recycling
-Eco friendly	-Water conservation friendly
-Energy saver	-Design with simple and clear instructions of machinery
- Reliable	-Increase life cycle of filtering system
- Efficient recovery rate	
-Accessible cleaning	
-Portability	
-Extreme temperature resistance	
-Improved external structure	
-Waterproof	
-Debris protection system	
-Improved filtration	
-High pump capacity	
-Marketable	
-Universal usage	
-Corrosion protection	

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- Automatic -Alarm system -Marine life friendly -Low emissions -Low pollution -Low cost of fabrication -Safety manual -Meets safety regulations -Meets environmental regulations -Design should meet all federal and state regulations to prevent fines. -Oil removal concentration	

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(iii) Categorizing objectives

Table 1.2 Categories of objectives

Safety	Quality	Environment	Economic	Workability	Convenient
Product safety Alarm system Safety manual Design with simple and clear instructions of machinery Meets safety regulations	Durability Compact design Accessible cleaning Portability Oil Containment capacity Improved external structure Debris protection system Waterproof High pump capacity Improved filtration Marketable Corrosion protection Orientation Oil removal concentration Detachable parts	Eco friendly Energy saver Marine life friendly Low emissions Low pollution Made from recyclable material Reuse collected oil for machine lubrication Water conservation friendly Meets environmental regulations	Cost effectiveness Low cost maintenance and repairs Low cost of fabrication Design should meet all federal and state regulations to prevent fines. Increase life cycle of filtering system	Measure percent difference between water and oil Low or no contamination of water Reliable Efficient recovery rate Extreme temperature resistance More oil and water storage Universal usage	User friendly Easy assembly Improved sensors Automatic

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(iv) Objective Tree

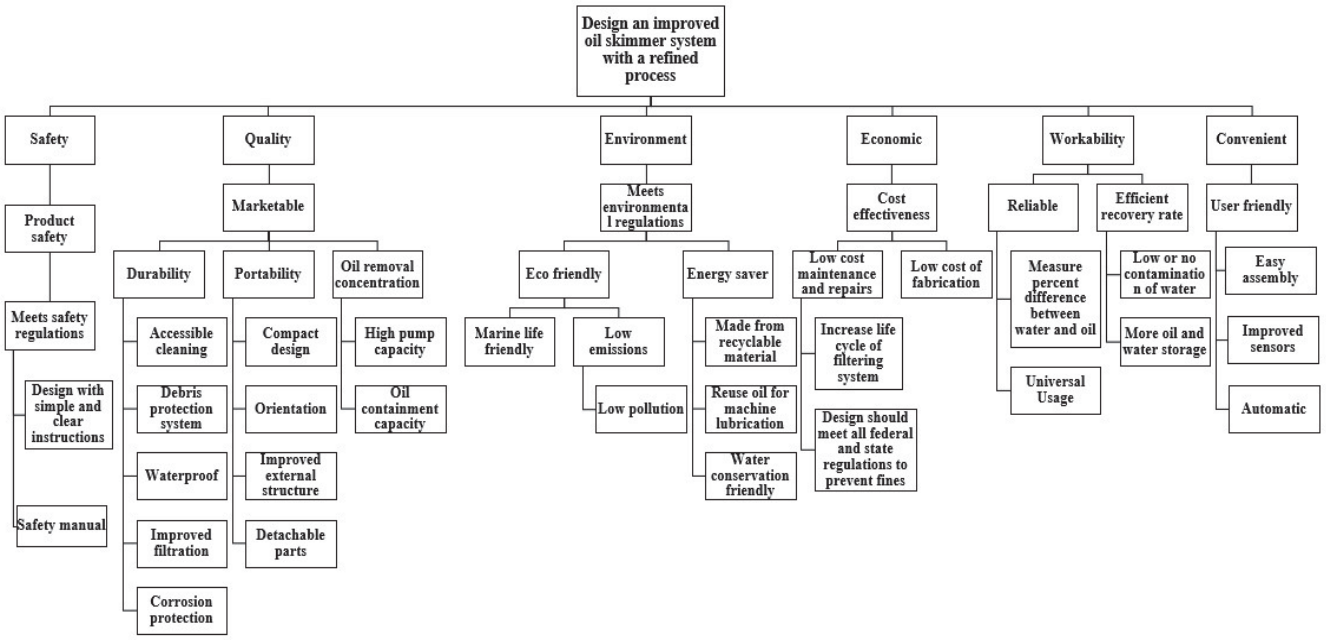


Figure 1.1 Objective tree

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(v) Table of measured objectives

Table 1.3 Measured objectives

Objective	Measurement Basis	Criteria	Units
Cost effectiveness	Fabrication cost to not exceed 5000	Economic	Currency
Product safety	Product to achieve lower incident rate of current oleophilic skimmers.	Safety	Incidents/Product life cycle
Measure percent difference between water and oil	95% accuracy	Workability	$lbf\ s\ ft^{-2}$
Durability	Toughness of design	Quality	$in \cdot lbf \cdot in^{-3}$
User friendly	Completion rate	Convenient	Time it takes to start machine/min
Low or no contamination of water	Water quality	Environment	pH
Compact design	To not exceed 5ft X 5ft	Quality	ft
Eco friendly	Energy efficiency	Environment	%
Energy saver	Energy efficiency	Environment	Watts
Reliable	To work 95% of the time	Workability	failures/min
Efficient recovery rate	Fast recover	Workability	recovery/min
Accessible cleaning	Clearance between parts or detachable parts	Quality	ft
Portability	Easy to transport	Quality	ft
Improved external structure	Can take high amounts of stress	Quality	lbf/ft^2

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Waterproof	150 fr	Quality	ft
Debris protection system	Efficiency of filtering system to reach 95%	Quality	%
Improved filtration	Design effective innovative filtering system	Quality	Micron
High pump capacity	High pump capacity	Quality	m3/h
Marketable	Sales performance	Quality	Number of sales
Universal usage	Product attractiveness	Workability	Number of sales
Corrosion protection	Less deformation to the product	Quality	Milli-inch per year
Automatic	Innovative technology, less manual labor required	Convenient	Technological l advancement
Alarm system	Alarm sound for warning signal and/or emergency	Safety	Decibel
Marine life friendly	Marine animals and plants saved	Environment	Conservation
Low cost maintenance and repairs	Less overall overtime	Economic	Currency
Low emissions	efficient discharge	Environment	lb/hr
Low pollution	Air quality	Environment	lb_m/ft^3
Low cost of fabrication	Profitability	Economic	Currency
Safety manual	Detailed manual that includes all the possible hazards.	Safety	Effectiveness %

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Meets safety regulations	More safety equals less possibility of legal issues by EPA/safer for employees working with machinery	Safety	Rating/companies satisfied by product
Meets environmental regulations	Environment acceptability	Environment	Environmental quality
Design should	Compliance measurement	Economic	User
meet all federal and state regulations to prevent fines	Compliance measurement	Economic	satisfaction rating/dollars
Detachable parts	Easy setup	Quality	Weight and quantity
Oil containment capacity	Increase in efficiency	Quality	Gallons
Easy assembly	Design attractiveness	Convenient	Rating/user satisfaction
Improved sensors	Improved accuracy	Convenient	Quality
More oil and water storage	Improves efficiency	Workability	gph
Orientation	Direction in which the skimmer going to remove oil	Quality	Degrees
Oil removal concentration	Quality of oil removed, not including other substances, pure oil.	Quality	Grams/Gallons
Made from recyclable material	Environmentally friendly/less development costs	Environment	Currency
Reuse collected oil for machine lubrication	Reuse of oil collected, post-skimming, for use in machine maintenance	Environment	Gallons

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Water conservation friendly	Reuse of fresh water saved by skimmer	Environment	Gallons
Design with simple and clear instructions of machinery	Easily operable means it will work for broader scope of people/company	Safety	Rating/companies satisfied by product
Increase life cycle of filtering system	Longer life cycles lead to less costs by lessening frequency of changing filtration.	Economic	Currency

1.4 **Initial Project constraints and Operating Environment**

All engineering designs require physical limitations to ensure that they are acceptable and functional. The design must be upheld to some initial constraints as well as be constructed within permissible parameters. The selection of these parameters and constraints were selected based on research as well as the mode of the operating environment. These selections are largely affected by the roles the design must perform within the given operating environment. This section will provide the generated lists of appropriate initial project constraints and the operating environment.

(i) Initial Project Constraints

-Must be buoyant.

-Must be autonomous.

-Needs to be an easily portable design.

-Must rely upon a custom computer algorithm for tracking and movement (PROJECT 1037) (BSEE).

-Cannot exceed an operating domain of 5 ft by 5 ft.

-Must operate in and be accustomed to thick layers of oil, up to 3 inches.

-Design requires an oil storage containment device.

-Skimmer must be adapted to recover different temperatures of oil.

-Skimmer design must be climate resistive or adaptable.

-Design needs a heat system to counteract ambient temperatures.

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-Skimmer must include an oil capacity sensor for measuring oil thickness (Development of an Oil Thickness Sensor, PROJECT 1072). (BSEE)

-Design must be Oleophilic (An affinity to oil rather than water/be able to distinguish the difference).

-Must have a velocity between 3-5 knots or 3.5- 6 mph (Recent research has led to boom systems that can be towed at speeds up to 3-5 knots and have automated inflation and deployment capabilities. (BSEE)

-Must at least operate at an efficiency of 25%-50% in 1-inch oil thickness.

-Must have an acceptable nameplate capacity number (number which defines skimmer efficiency). (BSEE)

-ASTM F2709 calls for testing stationary oil skimmers in either pure oil, or in a three-inch layer of oil on water. However, in an actual oil spill it is likely that a skimmer will be operating in a thinner range of oil thicknesses. BSEE is conducting testing on various skimming systems in varying slick thicknesses to better understand the relationship between Oil Recovery Rates (ORR) and Recovery efficiencies (RE) and decreasing oil slick. thicknesses.
(https://www.bsee.gov/research-record/evaluation-of-skimmer-performance-in-diminishing-oilslick-thicknesses) TESTED ON OLEOPHILIC SKIMMERS. (BSEE)

(ii) Operating environment

- Various water conditions including wavy and calm.
- Operational in different types of waters (Salt or freshwater).
- Houses in various types of marine life environments.

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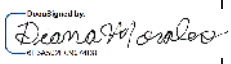
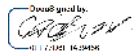
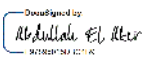
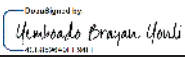
SENIOR DESIGN & PROFESSIONALISM I
FALL 2020
PROJECT PROGRESS REPORT COVER SHEET

PROJECT TITLE:_ Design of Experiment to Measure Heat Transfer Coefficient and Effective Thermal Conductivity in Nanofluids Under Different Boundary Conditions

GROUP NUMBER ___3__

Progress Report Title: Status Report on Problem Formulation

Due Date:___9/14/2020____

No	Group Member Name Group Member signature	Brief Description of Work Assigned to Member	% Completed by Member*	Your Score
1	Diana Morales 	Organized content to make sense w/ Fanta, worked on adding content to missing paragraphs, put together final layout details to be submitted.	100	
2	Fanta Kaba 	Thoroughly worked through the report with Diana. Researched material relating to the project for better understanding.	100	
3	Christian White 	Assigned to complete the client identification and recognition of need, worked with the group to discuss constraints. Submit document for group.	100	
4	Abdullah EL Aker 	Researched and contributed to the goal statement content. Initialized the DocuSign	100	
5	Yemboado Yonli 	Researched and found the constraints attached to the project. Helped in the problem statement formulation	100	
6	Marcelo Epam Ona 	Work on the problem scope and problem statement. Send the status report 3 to the project owner so that it can be reviewed and corrected.	100	

*100% means the member completed his/her assigned work

By signing this assignment cover sheet, I agree that the percentages stated in the % completed column reflect the contribution made by me and the other members of the group.

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COLLEGE OF ENGINEERING
SENIOR DESIGN & PROFESSIONALISM I
Fall 2020 SEMESTER
Status Report on Problem Formulation

Due:09/10/2020

1. PROJECT SCOPE

A proper measurement technique is selected amongst the current methods used in the industry to measure the convection transfer coefficient for nanofluids. The technique will measure the heat transfer coefficient and thermal conductivity of the nanofluid while accommodating for changes in boundary conditions and common constraints. Experimental testing will be performed for comparison in order to study the effects of heat transfer rates under different boundary conditions. To ensure functionality in the measurement technique selected, measurements of the convection coefficient for some nanofluids will be compared to the results of the published values given.

1.1. Problem Statement

Measurement of heat transfer coefficient and thermal conductivity of nanofluids do not accommodate different boundary conditions; therefore, an effective measurement technique will be selected to adapt to the change of properties of the nanofluids.

1.2. Client identification and recognition of need

(i) Identifying the client.

This project pertains to specific clients that have professional backgrounds in the study of heat transfer, thermal conductivity, and thermodynamics. This would include engineers, professors, scientists, and engineering firms who conduct research for industry use. An experiment will be conducted to measure thermal conductivity of nanofluids under different boundary conditions. Therefore, it is imperative that those who want to start or maintain a career in heat transfer have an effective system.

(ii) Identify the need to be fulfilled

The suspended nanoparticles of conventional fluids have been the subject of intense study worldwide for many years by pioneering researchers due to their anomalous thermal behavior. Over time, existing theories cannot seem to explain the behavior of these fluids with small-particle concentrations. We know that the current methods do not adequately predict the order of magnitude of thermal conductivity. This is due to a driven argument that nanofluids carry an enhanced thermal conductivity, relative to the base fluid. This in turn makes them superior agents for heat transfer in a variety of circumstances. As a result, finding the right ratio of nanoparticles to base fluid is needed to attain the most effective thermal conductivity in research. Along with obtaining the lowest possible effective viscosity from the fabricated nanofluid to ensure the application of heat transfer is met. A proper measurement technique will then help to form an educated hypothesis on understanding how to manipulate the nanofluid and the environment to gain accurate readings. Without a proper thermal conductivity measuring technique, researchers, engineers, professors, and scientists will ultimately find difficulty in understanding the true function of nanofluids. Including, how to effectively manipulate them to achieve the desired outcomes.

1.3 Project goals and objectives

1.3.1 Goal Statement:

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Designing or fabricating a setup with reliable and common results for convection heat transfer coefficient. The ~~selected~~ measurement technique establishes a system for data collection for the study of nanofluids under different boundary conditions.

1.3.2 ~~Objective Tree Breakdown.~~

(i) List of Objectives

Objectives List

- Measurement technique
- Method for measurements
- Experimental Set-up

(ii) High-Level & Low-Level Objectives

High Level Objectives

- Proper equipment and testing setup
- Efficient measurements for transferring heat
- Ability to measure heat transfer under constraints

Low Level Objectives

- Proper apparatus and experimental setup
- Effective measurement of convection heat transfer coefficient
- Ability to measure heat transfer coefficient of nanofluids with changing boundary conditions

(iii) Objective Tree

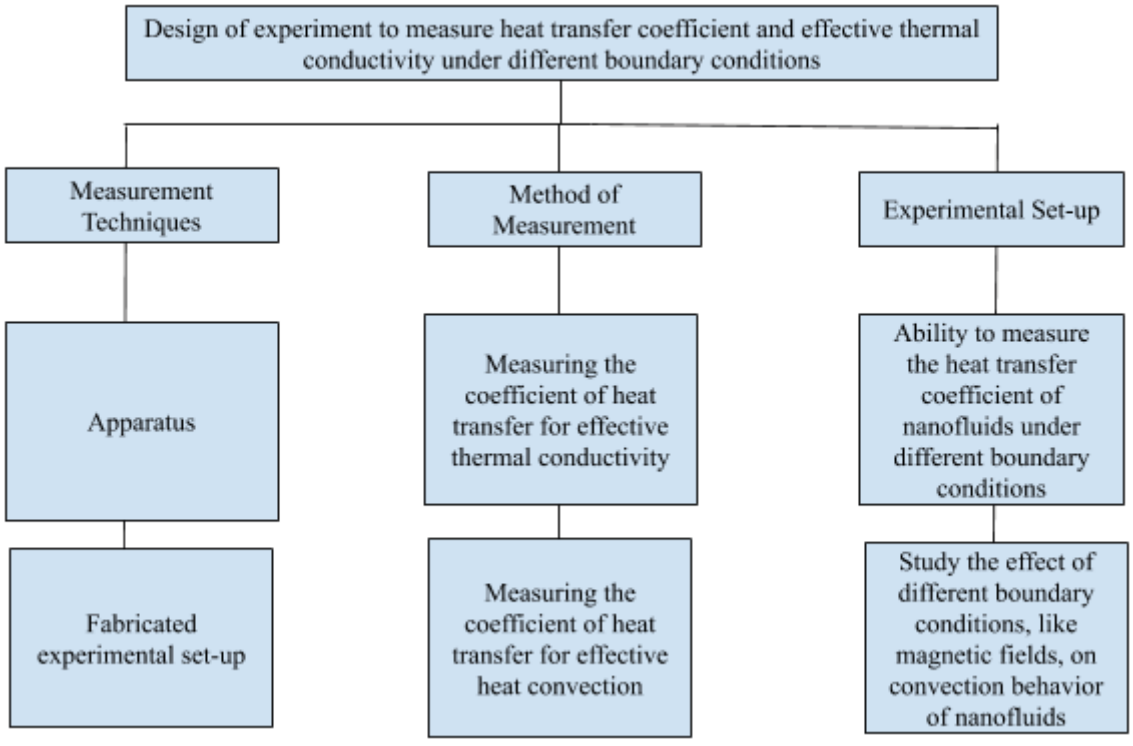


Figure 1.1 Objective Tree for the Measurement of Convection Heat Transfer

(iv) Breakdown of Objectives for Measurements and Units

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Table 1.1 Basis for, and Units of, Measuring Objective

Objective	Measurement Basis	Criteria	Units
Methods for Measurements	Appropriate for changing boundary conditions	Measurement	$W/(m^2K)$
Measurement techniques	Accuracy & Consistency	Measurement	$W/(m^2K)$
Experimental set-up	Measurement of the heat convection coefficient	Measurement	$W/(m^2K)$

1.4. Initial Project constraints and Operating Environment

(i) Initial Constraints

A few limits were identified in the design of the experiment. The very first constraint was the flexible boundary conditions in which the experiments are supposed to be performed. The apparatus and the experimental setup must be designed in order to be able to withstand different boundary conditions when performing experiments on nanofluids, such as adding or removing magnetic fields. This was identified as an inequality constraint, as the boundary conditions are not fixed to one condition but are varying. Another constraint in the design of the experiment is to choose the measurement technique applicable to nanofluids. ~~Therefore, to obtain reliable results, selecting the appropriate technique is necessary.~~ This could be put as a Yes or No constraint, as it would answer the question "can the technique be used to measure the heat transfer coefficient and thermal conductivity in nanofluids?" The material selection for the apparatus is also considered a constraint. Neutralism to the magnetic field and heat resistance is important to avoid any interference from the material set-up into the experimental results. The material must be able to withstand high pressures, while heating the fluid. It is worthy to note that an increase in liquid pressure can cause damage to the apparatus. This could also be identified as a yes or no constraint. The last identified constraint consists of results the experiments are to generate. The results in these experiments must be comparable to the published values. This can be identified as an equality constraint.

(ii) List of Operating Environment

Operating Environment

- High temperatures
- High pressures
- Magnetic fields

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Project Group #_____Project Title_____

Item	Description	Maximum Points	Your Score
1	Problem statement clearly stated	5	
2	Properly defined Client: Local Client Potential Clients assuming design is to be marketed	5 5	
3	Need stated as a current problem or dissatisfaction that needs to be addressed. Stated all of the problems that this design is going to address	10 5	
4	Goal statement that encompasses the broad aims of the project	10	
5	Properly defined project objectives, Sub-objectives Developed logical objective tree	6 6 6	
6	Table of objectives, Measurement basis, Criteria for measurement Units of measurement	5 5 5 5	
7	Realistic constraints Yes/No or Equality, or Inequality constraints	10	
8	Operating environment for system	10	
9	Attached copy of assignment pages	2	
	Total	100	

BELOW AVERAGE

COLLEGE OF ENGINEERING

SENIOR DESIGN & PROFESSIONALISM I
Fall 2020 SEMESTER
Status Report on Problem Formulation
Group 8

Due: 09/14/2020

This status report covers the information on the Project Scope chapter of the project report. Consequently, it should be written in a detailed descriptive form as we discussed in class for the assignment #2. The report should be prepared using the chapter title.

" 1. PROJECT SCOPE"

The goal of this project is to design and test a suspension for a unique chassis to withstand forces and loads of an off-road course. By the end of senior design 2, we should present a fabricated suspension mechanism for an off-road vehicle. The tasks involved in this project are doing literature reviews on how suspensions operate, designing a suspension that is compatible with a chassis that is already provided, formulate a test that will analyze the design with multiple forces acting on itself, fabricate and assemble the suspension after multiple iterations until suspension passes all tests and can withstand all forces for the chassis. The suspension mechanism should withstand all internal and external stresses on the off-road vehicle for a provided off-road course.

1.1 Problem Statement

Design, test, and fabricate a suspension and steering system for a unique chassis that takes on internal and external stresses as well as specified loads. Provide a detailed problem statement that clearly defines the project assigned to you. You may need to discuss the form of this project statement with the project advisor, not your instructor.

1.2 Client identification and recognition of need

(i) Identify the client for the project assigned to you.

PVAMU's Baja Club is the client for this project. This suspension will be designed and fabricated for an off-road vehicle. Once this suspension is fabricated and can withstand all forces and stresses, this suspension could be sold to other off-road vehicles with similar specs, such as weight and chassis design. Off-roads vehicles is a popular hobby for many and over $200 million dollars being spent on these vehicles each year and growing. When designing the suspension, our goal is to improve stability and increase range of motion for the vehicle which will improve desirability from other potential clients. To identify the client, you need to assume you are designing this product for the market and identify who ***all your potential customers*** *would be. You need to understand what you are designing, its usefulness, the segment of population or industries that can potentially use your design.*

Just listing the trivial (instructor, the department, Bell Aerospace, etc) will fetch you no credit for this section.

(ii) Identify the need to be fulfilled in your project.

A unique suspension and steering system for the concept vehicle must be created in order to withstand the off-road environment in which the vehicle will be operated. The system should be able to sync with the latest chassis design in order to function effectively in competition. Because this vehicle will be made for competitive events, the suspension system should not only be able to hold against the terrain but also increase the overall performance. The updated system should be able to increase the vehicle's range of motion and overall stability to help the driver maintain a certain level of safety as well as control and balance when operating on the given obstacle course. ***The need should be stated as a current problem or dissatisfaction that needs to be addressed.*** *You need to be able to clearly state all of the problems that this design is going to address.*

No credit for just mentioning the project title or restating it in other forms

1.3 Project goals and objectives

1.3.1 ~~Develop the Goal statement for your project~~

Present an affordable design of a suspension for the off-road vehicle. Meet design deadlines given by SAE Baja. Meet design constraints given by the organization for the suspension of the off-road vehicle. Consistently keep track of all progress made within meetings and share this information with the organization. Test the off-road vehicle suspension and make adjustments to the design if necessary. Successfully complete the off-road vehicle design before the competition date and present the final design to the organization. *Once the need is identified, you need to have a general statement on how you are going to address this need. This will be your goal statement. The group needs to spend some time to formulate this goal statement.*

You cannot just state the project title; in fact, the project title should be avoided.

1.3.2 ~~From the goal statement, build an objective tree for your project using the steps below~~

(i) ~~Prepare a list of design objectives~~

A. Safety
B. Durability
C. Economical
D. Safe for environment
E. Driver safety
F. Low Maintenance
G. Safety of bystanders
H. Affordable
I. Easy Repair
J. Range of motion
K. Withstand high speeds
L. Stability of vehicle
M. Sustainable
N. Handle all weather conditions
O. Interchangeable with other vehicles
P. Able to adjust to different terrains
Q. Fixed alignment
R. Able to support weight of vehicle but lightweight

Objectives specify the characteristics of the system that are to be optimized in order to achieve the goals. They are the desired attributes of the design.

Design objectives depend on the specific design problem being addressed. The list of objectives in the PowerPoint notes were specifically for the problem mentioned in the notes which is completely different from your design problem. The group needs to produce original well-thought-out objectives for the specific design and not use the list provided in the notes because different design problems need different objectives. ***To identify the objectives for your design in this course you need to ask yourself what desirable characteristics or features can you build into your system so you can use these characteristics or features as the selling points for your product because these features make your product functional.***

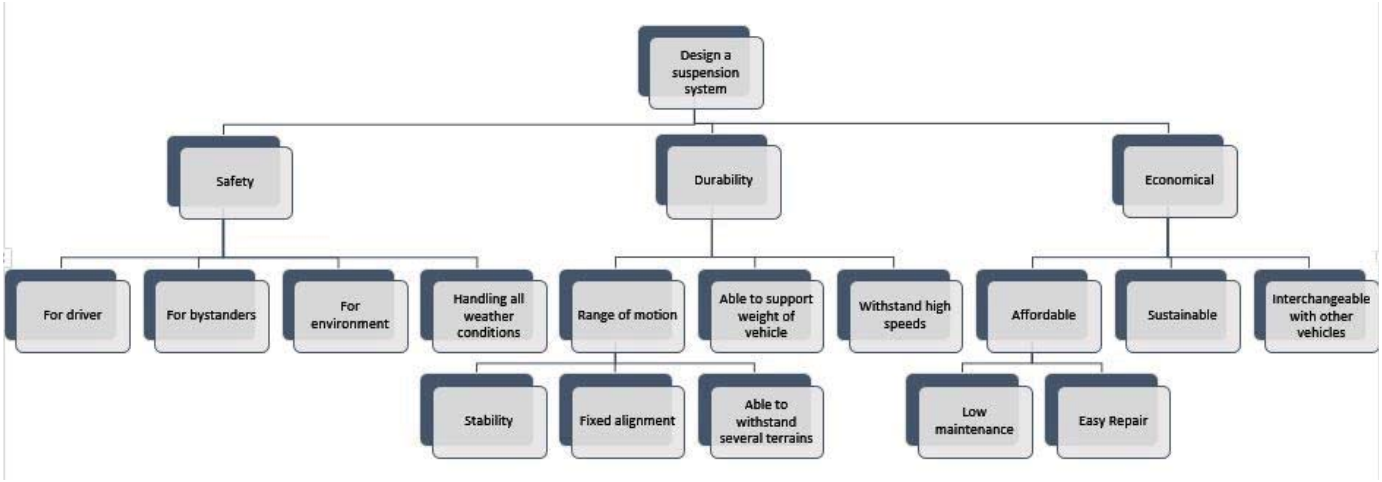
(ii) ~~Order the list of design objectives into sets of higher level and lower level Objectives~~.

Safety	Durability	Economical
Safety of driver	Able to withstand several terrains	Affordable
Safety of bystanders	Able to support weight of vehicle	Low maintenance
Safe for environment	Range of motion	Sustainable
Handling all weather conditions	Withstand high speeds	Easy repair
	Stability	Interchangeable with other vehicles
	Fixed alignment	

(See example in the step 2 table in the PowerPoint notes)

(iii) ~~Draw the objective tree for your project~~

(See the example in the class lecture notes. See the diagram



in step 3 in the PowerPoint notes)

(iv) ~~Develop a Table showing how objectives will be measured and the units of measurement~~
(see example in class lecture shown in Table 2.1)

Objective	**Measurement Basis**	**Criteria**	**Units**
Economical	Steel material machined and assembled as designed	cost	USD
Durability	Internal & external load acting on the suspension	Force	N/m^2 (si) or lb/in^2
Safety	Life expectancy of suspension	Factor of safety	Unitless
Range of motion	Motion	Movement	Degrees

1.4 Initial Project constraints and Operating Environment

(i) ~~Make a list of initial constraints for your project~~.
Note that constraints are limits that a design must meet to be acceptable. They establish permissible range of the design and performance parameters

- The suspension included with the off-road and tires cannot be wider than 64” as stated in the baja rule book
- The suspension must be conceived, designed, manufactured and fabricated by the team members without direct involvement from professional engineers, faculty or professionals
- Kit Vehicles Prohibited

They may be one of the three types below:

- yes/no constraints (such as must use 3/8”-24 UNF SAE grade 5 bolts)
- equality constraints (such as must be 18” high)
- inequality constraints (such as cannot weigh more than 50 lb, must hold at least 50 lbs of steam, must be between 12” and 15” long)

(ii) List the operating environment for your design.

- The vehicle must be capable of safe operation over rough land terrain including obstructions such as rocks, sand, logs, steep inclines, mud, and shallow water in any or all combinations and in any type of weather including rain, snow and ice.
- The vehicle must have adequate ground clearance and traction for the terrain type at the competition.

Attach a copy of this assignment just after the cover page
Assignment for Outcome 5

Grading Scheme

Status Report on Problem Formulation

Project Group #__8__Project Title_Design and Fabricate the Suspension and Steering for Off-Road Vehicle__

Item	Description	Maximum Points	Your Score
1	Problem statement clearly stated	5	
2	Properly defined Client: Local Client Potential Clients assuming design is to be marketed	5 5	
3	Need stated as a current problem or dissatisfaction that needs to be addressed. Stated all of the problems that this design is going to address	10 5	
4	Goal statement that encompasses the broad aims of the project	10	
5	Properly defined project objectives, Sub-objectives Developed logical objective tree	6 6 6	
6	Table of objectives, Measurement basis, Criteria for measurement Units of measurement	5 5 5 5	
7	Realistic constraints Yes/No or Equality, or Inequality constraints	10	
8	Operating environment for system	10	
9	Attached copy of assignment pages	2	
	Total	100	

SENIOR DESIGN AND PREFESIONALISM I
FALL 2020

STATUS REPORT 4

TOPICS COVERED IN STATUS REPORT 4

Project Planning

COLLEGE OF ENGINEERING
SENIOR DESIGN & PROFESSIONALISM I
FALL 2020 SEMESTER
Progress Report on Project Planning for Fall 2020 and for Spring 2021

Assigned: 09/09/2020 **Due: 09/17/2020**

This status report covers the information on the Project Planning and Task Identification chapter of the project report. Consequently, it should be written in a detailed descriptive form as we discussed in class for the assignment #2. The report should be prepared using the chapter title.

" 2. PROJECT PLANNING AND TASK DEFINITION". The subsections highlighted in blue fonts should be used in the status report.

In answering these five questions, copy the specific question followed by your response.

2.1 Task identification

1. Identify and make a **detailed** list of tasks (detailed activities that need to be performed) needed for the successful completion of your design this semester and continuation tasks for next semester. Provide more details on the tasks for this semester. As an introduction to this section, **provide a description of how the tasks were identified.**

2.2 Timeline

2. For each task state the objective(s) [defined as information to be refined or developed and communicated to others, not activities to be performed] and the specific deliverables [Noun things] needed to be provided to indicate the completion of the task, and indicate the responsible group member(s) , and estimate of time for the task. **Describe in greater detail, how this section was done as an introduction to this section.**

3. Arrange your tasks in the order that they need to be performed, and indicate the starting time, ending time, and the duration in hours for each task. **Describe in greater details how this section was done.**

NOTE: The description for items 1 through 3 should be provided and then Questions 1, 2, and 3 should be summarized in a Table format similar to the example provided in Table 1 below. This is a major part of this homework, and the table shows major tasks and how a major task should be broken into several logical subtasks. The objectives, deliverables, duration, and personnel should be provided for each subtask for a comprehensive project planning. Some of the major tasks (drawn from the design topics in the syllabus and the Project manual which you all should have consulted) have been included in Table 1 and you need to provide **additional tasks and detailed subtasks relative to your project** to complete this part of the assignment.

2.3 Gantt Chart

4. Using a project management software construct (i) a detailed Gantt chart for the tasks to be done this Fall 2020 semester and (ii) a detailed Gantt chart for the tasks to be done in the Spring 2020 semester**. Indicate all important milestones (**a milestone is simply a way to mark an important point in the project**) on each Gantt chart**. In addition to the milestones from your group, consult the syllabus and include important milestones listed in it.
Note: The Gantt chart should be done using Microsoft Projects Software or a similar project management software. In addition, the Gantt chart should be properly constructed and should be printed in sections showing only the details for that section after hiding the unwanted sections.

5. Indicate how you will use the Gantt chart to monitor the progress of the project, and indicate the current progress on the Gantt chart.

Note: Attach a copy of this assignment statement sheet to your homework (placed after the two cover sheets)

Assignment for Outcome 2

Recommended Reference for Assignment: **Successful Project Management by Gido & Clements, Chapter 4**

This is for you to know how this status report will be graded. We recommend grading yourself to ensure each part of the report has been done.

Grading Scheme for Project Planning Status Report

Project Group #_____

Item	Description	Maximum Points	Your Score
1	**2.1 Task Identification** Description of how the Tasks were identified is provided Identification and detailed listing of tasks Appropriateness of tasks listed in relation to project	 5 5 5	
2	**2.2 Timeline** Description of how this section in timeline was done provided Start & end date and responsible person for each task provided	 5 5	
3	Objective defined for each task **in the table** Deliverables (concrete things to be delivered to group) clearly stated for each task **in the table**	5 15	
4	Tasks arranged in logical order of execution **in the table**	5	
5	**3.3 Gantt Charts** Gant Chart for tasks and subtasks in Fall 2020 properly **formatted for printing and readable**. Legends provided and defined on Gantt Chart	 18 2	
6	Gant Chart for tasks and subtasks in Spring 2021 properly formatted for printing and readable. Legends provided and defined on Gantt Chart	9 1	
7	Important milestones indicated on Gantt charts	5	
8	Indicated how Gantt chart will be used to monitor progress and stated/showed current project status on Gantt chart	5	
9	Progress report properly formatted as a complete "Project Planning Chapter" with all three subsections.	10	
	Total	**100**	

This is a sample example of the proper way to summarize questions 1, 2 & 3 in a Table format (Except for the descriptions)

Table 1 Detailed Project Tasks, Objectives, Deliverables, Task Duration & Responsible Personnel

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
1. Problem Formulation	1.1 Identify customer	To find who will potentially use/buy product	A list of at least 4 potential customers & why they will need our product	5			Mr. Kind
	1.2 Identify needs	To determine why this product is needed	Complete description of unsatisfactory conditions that are being addressed by the design	5			Mr. Doe
	1.3 Formulate goal statement	To formulate a goal statement	A structured statement that defines the overall project goal	5			Ms. Dogood
	1.4 Define objectives	To define measurable performance characteristics of design	A list of all measurable performance characteristics with units	5			Mr. Eveready
	1.5 Develop objective tree	To arrange performance characteristics into higher-level & lower-level objectives in diagrammatic tree structure showing hierarchical relationships and interconnections	Well drawn and labelled objective tree showing hierarchical relationships and interconnections of the performance characteristics.	5			Mr. Noway
	1.6 Identify constraints and operating environments	To identify the permissible range of the design and performance parameters and the operating environment	A list of permissible range for the design parameters, description of the environment in which the design will operate.	5			Ms. Always
2. Project Planning	2.1 Task identification	To identify all the tasks that could be involved in the project	A list of all the tasks needed to be accomplished for project				Mr. Kind
	2.2 Develop objective for each task	Develop objectives (actions needed) for each task	List of things that need to be submitted for each objective to indicate completion of a task.				Mr. Doe
	2.3 Etc.						
3. Literature Review							
4. Functional Decomposition							
5. Concepts Generation							
6. Concept Evaluation							
7. Preliminary Design							
8. Detailed Design							
9. Detailed Parts Specifications							
10. Budget & Project Cost (Economic Analysis)							
11. Purchasing							
12. Fabrication & Testing							
13. Final Report & Presentation							



ABOVE AVERAGE

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SENIOR DESIGN & PROFESSIONALISM I
FALL 2020
PROJECT PROGRESS REPORT COVER SHEET

PROJECT TITLE: Project Planning

GROUP NUMBER: 7

Progress Report Title: Status report 4

Due Date: 09/23/2020

No	Group Member Name Group Member Signature	Brief Description of Work Assigned to Member	% Completed by Member	Your Score
1	**Daniel Akpan** DocuSigned by: D752FAC3D5EC429...	**Section work:** Section 2.1 & 2.2 **Topics:** Literature review, fabrication & testing **Attendance:** attend meetings. **Gantt chart:** added tasks, dates, and formatting (main responsible for chart) **Participation:** participate in meetings.	100%	
2	**David Trevino** DocuSigned by: David Trevino B6655ED6952348B...	**Introduction paragraphs:** 2.3 Gantt chart introduction and description statement **Section work:** Section 2.3 **Topics:** Screenshots of Gantt Chart **Gantt chart:** added tasks, dates, and formatting (main responsible for chart) **Attendance:** attend meetings. **Participation:** participate in meetings.	100 %	
3	**Amna Ansari** DocuSigned by: Amna Ansari E25E51620421451...	**Section work:** Section 2.1 & 2.2 **Topics:** Functional decomposition and purchasing **Gantt chart:** added tasks, dates, and formatting **Minutes:** Record meeting minutes for each meeting and record of attendance. **Attendance:** attend meetings. **Participation:** participate in meetings.	100 %	
4	**Demetrious Sandford** DocuSigned by: Demetrious Sandford C7D32FE84B0A419...	**Section work:** Section 2.1 & 2.2 **Topics:** Concepts generation, budget and project cost **Gantt chart:** added tasks, dates, and formatting **Proofreading:** Full report **Formatting:** indenting sections, font type and size consistency. **Meeting:** Organize meeting times. **Attendance:** attend meetings. **Participation:** participate in meetings.	100 %	
5	**Caleb Riggins** DocuSigned by: Caleb Riggins 41AFA23858EE4BC...	**Introduction paragraphs:** 2.2 descriptive paragraphs and table citing **Section work:** Section 2.1 & 2.2 **Topics:** Concept evaluation and preliminary design **Technical writing review:** Full report **Formatting:** indenting sections, font type and size consistency. **Attendance:** attend meetings. **Participation:** participate in meetings.	100 %	
6	**Ximena Cifuentes** DocuSigned by: Ximena Cifuentes BD1F416D20884F6...	**Introduction paragraphs:** Chapter introduction and S.2.1 introduction statement. **Section work:** Section 2.1 & 2.2 **Topics:** Problem Formulation, Project planning, and Final Report. **Formatting:** Cover page, empty report sheet, indenting sections, font consistency. **Communication:** Send report to Dr. Park for feedback, assign tasks. **Gantt chart:** added tasks, dates, and formatting. **Attendance:** attend meetings. **Participation:** participate in meetings.	100 %	
7	**Aamna Jangda** DocuSigned by: Amna 781C4B4D2C9D46D...	**Section work:** Section 2.1 & 2.2 **Topics:** Detailed design of parts and specifications **Formatting:** Font consistency within certain parts **Gantt chart:** Added Tasks to Part 8 and 9 **Attendance:** Attend meetings **Participation:** Participate in meetings	100 %	

*100% means the member completed his/her assigned work

By signing this assignment cover sheet, I agree that the percentages stated in the % completed column reflect the contribution made by me and the other members of the group.

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COLLEGE OF ENGINEERING SENIOR DESIGN & PROFESSIONALISM I
FALL 2020 SEMESTER
Progress Report on Project Planning for
Fall 2020 and for Spring 2021

Assigned: 09/09/2020 **Due: 09/17/2020**

This status report covers the information on the Project Planning and Task Identification chapter of the project report. Consequently, it should be written in a detailed descriptive form as we discussed in class for the assignment #2. The report should be prepared using the chapter title.

" 2. PROJECT PLANNING AND TASK DEFINITION". The subsections highlighted in blue fonts should be used in the status report.

In answering these five questions, copy the specific question followed by your response.

2.1 Task identification

1. Identify and make a **detailed** list of tasks (detailed activities that need to be performed) needed for the successful completion of your design this semester and continuation tasks for next semester. Provide more details on the tasks for this semester. As an introduction to this section, **provide a description of how the tasks were identified.**

2.2 Timeline

2. For each task state the objective(s) [defined as information to be refined or developed and communicated to others, not activities to be performed] and the specific deliverables [Noun things] needed to be provided to indicate the completion of the task, and indicate the responsible group member(s) , and estimate of time for the task. **Describe in greater detail, how this section was done as an introduction to this section.**

3. Arrange your tasks in the order that they need to be performed, and indicate the starting time, ending time, and the duration in hours for each task. **Describe in greater details how this section was done.**

NOTE: The description for items 1 through 3 should be provided and then Questions 1, 2, and 3 should be summarized in a Table format similar to the example provided in Table 1 below. This is a major part of this homework, and the table shows major tasks and how a major task should be broken into several logical subtasks. The objectives, deliverables, duration, and personnel should be provided for each subtask for comprehensive project planning. Some of the major tasks (drawn from the design topics in the syllabus and the Project manual which you all should have consulted) have been included in Table 1 and you need to provide **additional tasks and detailed subtasks relative to your project** to complete this part of the assignment**.**

2.3 Gantt Chart

4. Using a project management software construct (i) a detailed Gantt chart for the tasks to be done this Fall 2020 semester and (ii) a detailed Gantt chart for the tasks to be done in the Spring 2020 semester**. Indicate all important milestones (**a milestone is simply a way to mark an important point in the project**) on each Gantt chart**. In addition to the milestones from your group, consult the syllabus and include important milestones listed in it.

Note: The Gantt chart should be done using Microsoft Projects Software or a similar project management software. In addition, the Gantt chart should be properly constructed and should be printed in sections showing only the details for that section after hiding the unwanted sections.

5. Indicate how you will use the Gantt chart to monitor the progress of the project, and indicate the current progress on the Gantt chart.

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Note: Attach a copy of this assignment statement sheet to your homework (placed after the two cover sheets)

Assignment for Outcome 2

Recommended Reference for Assignment: **Successful Project Management by Gido & Clements, Chapter 4**

This is for you to know how this status report will be graded. We recommend grading yourself to ensure each part of the report has been done.

Grading Scheme for Project Planning Status Report Project Group #_____

Item	Description	Maximum Points	Your Score
1	**2.1 Task Identification** Description of how the Tasks were identified is provided Identification and detailed listing of tasks Appropriateness of tasks listed in relation to project	 5 5 5	
2	**2.2 Timeline** Description of how this section in timeline was done provided Start & end date and responsible person for each task provided	 5 5	
3	Objective defined for each task **in the table** Deliverables (concrete things to be delivered to group) clearly stated for each task **in the table**	5 15	
4	Tasks arranged in logical order of execution **in the table**	5	
5	**3.3 Gantt Charts** Gantt Chart for tasks and subtasks in Fall 2020 properly **formatted for printing and readable**. Legends provided and defined on Gantt Chart	 18 2	
6	Gantt Chart for tasks and subtasks in Spring 2021 properly formatted for printing and readable. Legends provided and defined on Gantt Chart	9 1	
7	Important milestones indicated on Gantt charts	5	
8	Indicated how Gantt chart will be used to monitor progress and stated/showed current project status on Gantt chart	5	
9	Progress report properly formatted as a complete "Project Planning Chapter" with all three subsections.	10	
	Total	**100**	

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This is a sample example of the proper way to summarize questions 1, 2 & 3 in a Table format (Except for the descriptions)

Table 1 Detailed Project Tasks, Objectives, Deliverables, Task Duration & Responsible Personnel

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
1. Problem Formulation	1.1 Identify customer	To find who will potentially use/buy product	A list of at least 4 potential customers & why they will need our product	5			Mr. Kind
	1.2 Identify needs	To determine why this product is needed	Complete description of unsatisfactory conditions that are being addressed by the design	5			Mr. Doe
	1.3 Formulate goal statement	To formulate a goal statement	A structured statement that defines the overall project goal	5			Ms. Dogood
	1.4 Define objectives	To define measurable performance characteristics of design	A list of all measurable performance characteristics with units	5			Mr. Eveready
	1.5 Develop objective tree	To arrange performance characteristics into higher-level & lower-level objectives in diagrammatic tree structure showing hierarchical relationships and interconnections	Well drawn and labelled objective tree showing hierarchical relationships and interconnections of the performance characteristics.	5			Mr. Noway
	1.6 Identify constraints and operating environments	To identify the permissible range of the design and performance parameters and the operating environment	A list of permissible range for the design parameters, description of the environment in which the design will operate.				Ms. Always
2. Project Planning	2.1 Task identification	To identify all the tasks that could be involved in the project	A list of all the tasks needed to be accomplished for project				Mr. Kind
	2.2 Develop objective for each task	Develop objectives (actions needed) for each task	List of things that need to be submitted for each objective to indicate completion of a task.				Mr. Doe
	2.3 Etc.						
3. Literature Review							
4. Function al Decomposition							

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5. **Concepts Generation**							
6. **Concept Evaluation**							
7. **Preliminary Design**							
8. **Detailed Design**							
9. **Detailed Parts Specifications**							
10. **Budget & Project Cost (Economic Analysis)**							
11. **Purchasing**							
12. **Fabrication & Testing**							
13. **Final Report & Presentation**							

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2. PROJECT PLANNING AND TASK DEFINITION

In this chapter, the planning of the Automated Skimmer Project will be discussed in detail. In addition, the chapter will reveal the key project tasks and subtasks that were vital to the execution of the project. The tasks will be delegated evenly depending on each individual's strengths. Finally, the chapter includes a visual representation of the fully developed project plan created by the team. The representation includes a timeline table and its interpretation in a Gantt chart form.

2.1 Task identification

1. Identify and make a **detailed** list of tasks (detailed activities that need to be performed) needed for the successful completion of your design this semester and continuation tasks for next semester. Provide more details on the tasks for this semester. As an introduction to this section, **provide a description of how the tasks were identified.**

In this section, the different project tasks are identified. In addition, each task is divided into subsections that detail the different stages required to successfully complete the tasks. In the subsection below, the tasks identified are listed with their respective sub-tasks. The combination of research and reference to the course syllabus, the team was able to successfully identify all the tasks needed to effectively complete the project.

- Problem Formulation
  - Identify project scope and problem statement
  - Define clients and recognition of need
  - Display project goals and objectives
    Point out initial project constraints

- Project Planning
  - Identify tasks to be completed
  - Generate a project timeline
  - Create a Gantt chart

- Literature Review
  - Identify relevant Information to project
  - Establish sources of relevant information
  - Research Oleophilic Skimmers
  - Analyze Non-Oleophilic Skimmers
  - Analyze Weir Skimmers
  - Make Inquiries into Operational Environment of skimmers

- Functional Decomposition
  - Define functional decomposition concept
  - Develop a strategy for the functions and subfunction
  - ~~Identify materials~~
  - Generate a morphology table

- Concepts Generation

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  - ~~Review Concepts~~
  - ~~Modify Concepts~~

- Concept Evaluation
  - Identify the Criteria
  - Organize the Criteria
  - Utilize the Go-no-go method
  - Create a decision matrix
  - Generate a Preliminary Design

- Preliminary Design
  - Rehabilitate existing designs
  - Identify options for flexibility
  - Approximate dimensions

- Detailed Design
  - Identify and plan for types of analysis needed for the design
  - Draw rough draft on paper
  - Produce real life blueprint of design in Fusion 360
  - Run simulation in Fusion 360

- Detailed Parts Specifications
  - Create specifications of each component
  - Identify constraints of design
  - Design Evaluation/Modifications

- Budget & Project Cost (Economic Analysis)
  - Organize a list of suppliers
  - Generate a Budget Generation
  - Evaluate the Approval of the Budget agreement

- Purchasing
  - Generate a technical report that identifies all the parts.
  - Purchase parts
- Fabrication & Testing
  - Devise plan for manufacturing and assembly of Automated Skimmer
  - Create a detailed schedule for monitoring machine shop work
  - Conduct final testing and inspection for the Automated Skimmer

- Final Report & Presentation
  - Finalize report
  - Prepare presentation

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2.2 Timeline

2. For each task state the objective(s) [defined as information to be refined or developed and communicated to others, not activities to be performed] and the specific deliverables [Noun things] needed to be provided to indicate the completion of the task, and indicate the responsible group member(s) , and estimate of time for the task. **Describe in greater detail, how this section was done as an introduction to this section.**

This section provides an overview of the active objectives' timeline for this project. The timeline serves to organize and present the objectives that will guide the accomplishment of deliverables through Fall 2020 and Spring 2021 in order for the construction of the automated oil skimmer to be completed. Selected tasks were created and communicated to be organized and arranged into an appropriate chronological sequence. Persons responsible for a given task were determined through examining previous experiences and expertise that correspond to the given tasks to know who was best fit. An assessment of workload and priority was taken to quantify the amount of time needed for each task to be completed.

- Problem Formulation: The objectives of the following task are
    - To formulate the current problem and identify the current need for product optimization
        - ~~Identify~~ current unsatisfactory conditions that will be approached by the proposed design
        - Person(s) Responsible: (David T.)
        - Estimated Time: 2 days
    - To find who will be a potential end user of the product and to determine the reason why the client needs the product
        - ~~Develop~~ a list of 5 potential clients and structured statement that defines the overall project goal and the scope of the goal
        - Person(s) Responsible: (Demetrious S.)
        - Estimated Time: 2 days
    - To develop a goal statement and define measurable performance characteristics of design
        - ~~Construct~~ a labelled objective tree showing hierarchical relationships between objectives based on their performance characteristics.
        - Person(s) Responsible:(Ximena C.)
        - Estimated Time: 4 days
    - To identify the different permissible ranges of the product design and recognizing the product working environment
        - ~~Build~~ a list of permissible range for the design parameters, description of the environment in which the design will operate
        - Person(s) Responsible: (Caleb R.)
        - Estimated Time: 2 days
- Project Planning: The objectives of the following task are

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- To identify the different tasks that will need to be completed during the project
  - ~~Define~~ a list of all the tasks that need to be completed for the project and their main subtasks
  - Person(s) Responsible: (Group work)
  - Estimated Time: 2 days

- To develop a detailed timeline for each one of the tasks listed in the task identification section
  - ~~Develop~~ an effective timeline table
  - Person(s) Responsible:(Group work)
  - Estimated Time: 4 days

- Effectively organize the tasks and subtasks in a Gantt chart for timely completion.
  - A Gantt chart that has multiple features for project tracking.
  - Person(s) Responsible: (David T.)
  - Estimated Time: 5 days

- Literature Review: The objectives of the following task are

  - To identify information relevant to project
    - ~~Create~~ a comprehensive list of relevant information
    - responsible group member (Group work)
    - Estimated Time: 1 day

  - To establish a list of credible sources for the Information provided
    - ~~Create~~ a list of credible cited sources
    - Person(s) Responsible: (Daniel)
    - Estimated Time: 1 day

  - To study relevant information on Oleophilic skimmers
    - ~~Type~~ a thorough research paper on oleophilic skimmers
    - Person(s) Responsible: (Caleb R)
    - Estimated Time: 1 day

  - To create a detailed research on Non-oleophilic skimmers
    - ~~Type~~ a thorough research paper on Non-oleophilic skimmers
    - Person(s) Responsible: (Ximena)
    - Estimated Time: 1 day

  - To Review information on Weir skimmers
    - ~~Type~~ a thorough research paper done on Weir Skimmers
    - Person(s) Responsible: (Amna)
    - Estimated Time: 2 days

  - To Inquire into operational environment of skimmers
    - List of inquiries made into operational environment of skimmers

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        - Person(s) Responsible: (Daniel)
        - Estimated Time: 2 days

- Functional Decomposition: The objectives for the following task are

    - To study functional decomposition and generate concepts
        - ~~Creat~~e an overall function statement
        - responsible group member (Group work)
        - Estimated time: 2 days

    - To establish a strategy that define functions and subfunctions
        - ~~Create~~ a list of overall functions, a level 1 subfunction, a level 2 subfunction, a level 3 subfunction
        - Responsible group member (Ximena C, Amna A, Amna J, Caleb R)
        - Estimated time: 3 days

    - ~~To recognize material input and output for the overall functions and subfunctions~~
        - ~~Generate material, energy, and information for overall function and~~
        - ~~Person(s) Responsible: (Amna J, David T)~~
        - ~~Estimated time: 2 days~~

    - To create a morphology table that identifies functional analysis
        - A morphology table for the functional decompositions, and a report that summarizes all the functions
        - Responsible group member (Demetrious S, Daniel A)
        - Estimated time: 2 days

- Concepts Generation: The objectives of the following task are

    - To review the concepts
        - Create a list of customer needs and specifications
        - Person(s) Responsible: (Demetrious S, David T, Daniel A)
        - Estimated time: 2 days

    - To modify the concepts
        - Evaluate the list of customer needs and specifications to generate a concept for all functions
        - Person(s) Responsible: (Demetrious S, David T, Daniel A)
        - Estimated time: 3 days

- Concept Evaluation: The objectives of the following task are

    - To develop a list of generated criteria to begin the design analysis
        - ~~Create~~ a list of criteria that will be used to determine the preliminary concept design
        - Person(s) Responsible: (Group)
        - Estimated Time: 3 days

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- Reorganize the created list into a manageable table
  - ~~Create~~ a Criteria Table
  - Person(s) Responsible: (Ximena, David)
  - Estimated time: 4 days

- Utilize the Go-no-go method and decision matrix to evaluate the list
  - ~~Determine~~ the final result of the Go-No-Go method of the given criteria
  - Person(s) Responsible: (Group)
  - Estimated time: 4 days

- Develop a final preliminary concept for the design
  - Final result of the decision matrix determined and the evaluation of the preliminary design
  - Person(s) Responsible: (Group)
  - Estimated time: 4 day

- Preliminary Design: The objectives of the following task are

  - To Explore the advantages and disadvantages of existing designs
    - ~~Determine~~ the most effective outcomes to improve the design process
    - Person(s) Responsible: (Group)
    - Estimated Time: 7 days

  - To Prepare for the design to be subject to change if applicable
    - ~~Plan~~ to allow the preliminary design construct to be flexible
    - Person(s) Responsible: (Amna J, Amna A)
    - Estimated Time: 7 days

  - To Meet the initial constraints requirements
    - Final preliminary design adheres to the constraint guidelines
    - Person(s) Responsible: (Group)
    - Estimated time: 7 days

- Detailed Design: The objectives of the following task are

  - To get a realistic idea of the type of functional skimmer to create
    - ~~Brainstorm~~ an idea for skimmer design
    - Person(s) Responsible: (Group)
    - Estimated Time: 3 days

  - To have a finalized image of skimmer design
    - ~~Create~~ a drawing on paper
    - Person(s) Responsible: (Aamna J)
    - Estimated Time: 6 days

  - To make design come to life virtually in Fusion 360 software
    - ~~Develop~~ blueprint of skimmer in Fusion 360
    - Person(s) Responsible: (Aamna J)
    - Estimated Time: 4-5 days

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- To run experimental testing of skimmer
  - ~~Run~~ simulations on design, record all data overtime
  - Person(s) Responsible: (Aamna J)
  - Estimated time: 6-7 days

- Detailed Parts Specifications: The objectives of the following task are

  - To apply standards and design constraints to generate realistic models.
    - ~~Creat~~e model with correct measurements of each component, and assuring all components are scaled properly
    - Person(s) Responsible: (Aamna J and Amna A)
    - Estimated time: 6 days

  - To identify the permissible range of the design and performance parameters
    - ~~Creating~~ a list of permissible ranges for the design parameters, and applying it to the model
    - Person(s) Responsible: (Aamna J)
    - Estimated Time: 4 days

  - To ensure all parts meet parameter criteria.
    - ~~Apply~~ drawing standards when generating drawings of the parts, making sure it's well labeled and has all components.
    - Person(s) Responsible: (Group)
    - Estimated Time: 4-5 days

  - To create design with all separate parts merged together for one finalized skimmer
    - Create finalized Fusion 360 drawing that is realistic, meets industry needs, and will function when fabricated.
    - Person(s) Responsible: (Group)
    - Estimated Time: 7 days

- Budget & Project Cost (Economic Analysis): The objectives of the following task are

  - ~~To review the concept~~s
    - ~~Create~~ a list of customer needs and specifications
    - Person(s) Responsible: (Demetrious S, David T, Daniel A)
    - Estimated time: 2 days
  - ~~To modify the concept~~s
    - ~~Evaluate~~ the list of customer needs and specifications to generate a concept for all functions
    - Person(s) Responsible: (Demetrious S, David T, Daniel A)
    - Estimated time: 3 days

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- Purchasing: The objectives of the following task are
    - Generate a report that identifies all the parts that need to be purchased
        - A detailed technical report that identifies all the necessary parts
        - Responsible person (Group work)
        - Estimated time: 4 days (2/05 - 2/09)
    - Purchase parts
        - A detailed technical report that identifies all the necessary parts
        - Responsible person (Group work)
        - Estimated time: 8 days (2/11 - 2/19)
- Fabrication & Testing: The objectives of the following task are
    - Construct a plan for manufacturing and assembly of Automated skimmer
        - A detailed plan on how to go about the production of the skimmer
        - Responsible Person(s): (Group Work)
        - Estimated Time: 1 day (2/26 - 02/27)
    - Create a detailed schedule for machine shop work rotation
        - A finalized schedule for workshop rotations
        - Responsible Person(s): (Group Work)
        - Estimated Time: 4 days (~~02/28 - 03/02~~)
    - Conduct final testing and inspections on the Automated skimmer
        - A fully functional Automated Skimmer
        - Responsible Person(s): (Group Work)
        - Estimated Time: ~~2 days (03/03 - 03/05)~~
- Final Report & Presentation: The objectives of the following task are
    - Construct a report that reveals the entire design process of the project
        - A compilation of revised reports
        - Person(s) Responsible: (Group work)
        - Estimated Time: 7 days
    - To present a well-prepared presentation of the project
        - Create a well-developed PowerPoint presentation
        - Person(s) Responsible: (Group work)
        - Estimated Time: 2 days

3. Arrange your tasks in the order that they need to be performed, and indicate the starting time, ending time, and the duration in hours for each task. **Describe in greater details how this section was done.**

NOTE: The description for items 1 through 3 should be provided and then Questions 1, 2, and 3 should be summarized in a Table format similar to the example provided in Table 1 below. This is a major part of this homework, and the table shows major tasks and how a major task should be broken into several logical subtasks. The objectives, deliverables, duration, and personnel should be provided for each subtask for comprehensive project planning. Some of the major

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tasks (drawn from the design topics in the syllabus and the Project manual which you all should have consulted) have been included in Table 1 and you need to provide **additional tasks and detailed subtasks relative to your project** to complete this part of the assignment.

The list below includes the estimated times for each one of the tasks to be performed during the course of the project. The estimated time for each task was determined based on the reflection of the current time spent on the previous reports. In addition, the list includes the approximated start and end dates for the task.

1. Problem Formulation
    - Identify project scope and problem statement
        - Start/End Dates: 9/3 to 9/5
        - Estimated Duration: 3 hrs
    - Define clients and recognition of need
        - Start/End Dates: 9/3 to 9/5
        - Estimated Duration: 2 hrs
    - Display project goals and objectives
        - Start/End Dates: 9/4 to 9/8
        - Estimated Duration: 6 hrs
    - Point out initial project constraints
        - Start/End Dates: 9/4 to 9/6
        - Estimated Duration: 2 hrs
2. Project Planning
    - Identify tasks to be completed
        - Start/End Dates: 9/10 to 9/12
        - Estimated Duration:2 hrs
    - Generate a project timeline
        - Start/End Dates: 9/11 to 9/15
        - Estimated Duration:4 hrs
    - Create a Gantt chart
        - Start/End Dates: 9/11 to 9/16
        - Estimated Duration:7 hrs
3. Literature Review
    - Identify relevant Information to project
        - Start/End Dates: 9/16 to 9/17
        - Estimated Duration: 2 hours
    - Establish sources of relevant information
        - Start/End Dates: 9/17 to 9/18
        - Estimated Duration: 4 hrs
    - Research Oleophilic Skimmers
        - Start/End Dates: 9/18 to 9/19
        - Estimated Duration: 4 hrs
    - Analyze Non-Oleophilic Skimmers
        - Start/End Dates: 9/20 to 9/21

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        - Estimated Duration: 4 hrs
    - Analyze Weir Skimmers
        - Start/End Dates: 9/20 to 9/22
        - Estimated Duration: 4 hrs
    - Make Inquiries into Operational Environment of skimmers
        - Start/End Dates: 9/22 to 9/24
        - Estimated Duration: 2 hrs

4. Functional Decomposition

    - Define functional decomposition concept
        - Start/End Dates: 9/23 to 9/25
        - Estimated Duration: 4hrs
    - Develop a strategy for the functions and subfunction
        - Start/End Dates: 9/23 to 9/26
        - Estimated Duration: 6hrs
    - Identify material
        - Start/End Dates: 9/26 to 9/28
        - Estimated Duration: 4hrs
    - Generate a morphology table
        - Start/End Dates: 9/28 to 9/30
        - Estimated Duration: 4hrs

5. Concepts Generation

    - To review the Concepts
        - Start/End Dates: 9/30 - 10/2
        - Estimated time: 8 hrs
    - To Modify the Concepts
        - Start/End Dates: 10/7 - 10/9
        - Estimated time: 4 hrs

6. Concept Evaluation

    - Identifying criteria
        - Start/End Dates: 10/14 to 10/17
        - Estimated Duration:4hrs
    - Organizing Criteria
        - Start/End Dates: 10/14 to 10/17
        - Estimated Duration: 4hrs
    - Go-no-go method
        - Start/End Dates: 10/16 to 10/20
        - Estimated Duration: 8hrs hrs
    - Decision matrix
        - Start/End Dates: 10/16 to 10/20
        - Estimated Duration: 8-10 hrs
    - Preliminary Design
        - Start/End Dates: 10/14 to 10/22
        - Estimated Duration: 8-10 hrs

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7. Preliminary Design

    - Rehabilitate existing design
        - Start/End Dates:10/22 to 10/28
        - Estimated Duration: 10-12hrs
    - Identify options for flexibility
        - Start/End Dates: 10/28 to 11/04
        - Estimated Duration: 10-12hrs
    - Approximate dimensions
        - Start/End Dates: 10/28 to 11/04
        - Estimated Duration: 4-6 hrs

8. Detailed Design

    - Identify and plan for types of analysis needed for the design
        - Start/End Dates: 11/04 to 11/07
        - Estimated Duration: 6 hrs
    - Draw rough draft on paper
        - Start/End Dates: 11/04 to 11/10
        - Estimated Duration: 4 hrs
    - Produce real life blueprint of design in Fusion 360
        - Start/End Dates: 11/10 to 11/14
        - Estimated Duration: 15-20 hrs
    - Run simulation in Fusion 360
        - Start/End Dates: 11/14 to 11/19
        - Estimated Duration: 10-15 hrs

9. Detailed Parts Specifications

    - Create specifications of each component
        - Start/End Dates: 11/04 to 11/08
        - Estimated Duration: 12 hrs
    - Identify constraints of design
        - Start/End Dates: 11/08 to 11/12
        - Estimated Duration: 4 hrs
    - Design Evaluations/Modifications
        - Start/End Dates: 11/13 to 11/19
        - Estimated Duration: 15-20 hrs

10. Budget & Project Cost (Economic Analysis)

    - List of suppliers
        - Start/End Dates: 1/15 to 1/20
        - Estimated Duration: 7 hrs
    - Budget Generation
        - Start/End Dates: 1/20 to 1/25
        - Estimated Duration: 2 hrs
    - Approval of Budget Agreement
        - Start/End Dates: 1/25 to 2/02

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        - Estimated Duration: 3 hrs

11. Purchasing

    - Technical report
        - Start/End Dates: 2/05 to 2/09
        - Estimated Duration: 6hrs
    - Purchases
        - Start/End Dates: 2/11 to 2/19
        - Estimated Duration: 8hrs

12. Fabrication & Testing

    - Manufacture and Assembly
        - Start/End Dates: 2/26 to 2/28
        - Estimated Duration: 12 hrs
    - Machine Shop Work
        - Start/End Dates: 2/28 to 3/02
        - Estimated Duration: 10-15 hrs
    - Product Testing
        - Start/End Dates: 3/03 to 3/05
        - Estimated Duration: 8-10 hrs

13. Final Report & Presentation

    - Finalize report
        - Start/End Dates: 4/22 to 4/29
        - Estimated Duration: 10 hrs
    - Prepare presentation
        - Start/End Dates: TBA
        - Estimated Duration: 3 hrs

The arrangement of the timeline was determined appropriately and accurately in order to effectively and efficiently complete the different tasks and objectives in a timely manner. To accomplish this, a step by step analysis was performed to prioritize which tasks needed to be completed before others. This allows for smooth transitions between tasks and provides certainties for objectives to be completed to reach deliverables. To regulate the time constraints for each task, the project manual and syllabus was observed in order to settle suitable time frames for every objective and piece of work needed to be achieved.

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Table 2.1 includes the arrangement of the developed project tasks, objectives, and deliverables for the automated oil skimmer. Task durations are presented through start and end dates that serve to create time constraints for effective production. Responsibility of personnel is also presented to establish accountability and work effectiveness.

Table 2.1 Detailed Project Tasks, Objectives, Deliverables, Task Duration & Responsible Personnel

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
Problem Formulation	1.1 Problem statement	To formulate the current problem and identify the current need for product optimization	Full description of the current unsatisfactory conditions that will be approached by the proposed design	2	9/3	9/5	David T.
	1.2 Client Identification and recognition of need	To find who will be a potential end user of the product and to determine the reason why the client needs the product	A list of 5 potential clients and structured statement that defines the overall project goal and the scope of the goal	2	9/3	9/5	Demetrious S.
	1.3 Project goals and objectives	To develop a goal statement and define measurable performance characteristics of design	A labelled objective tree showing hierarchical relationships between objectives based on their performance characteristics.	4	9/4	9/8	Ximena C.
	1.4 initial project constraints and operating environment	To identify the different permissible ranges of the product design and recognizing the product working environment	A list of permissible range for the design parameters, description of the environment in which the design will operate.	2	9/4	9/6	Caleb R.
Project Planning	2.1 Task identification	To identify the different tasks that will need to be completed during the project	A list of all the tasks that need to be completed for the project and their main subtasks	2	9/10	9/12	Group Work
	2.2 Timeline	To develop a detailed timeline for each one of the tasks listed in the task identification section	An effective timeline table	4	9/11	9/15	Group Work
	2.3 Gantt Chart	Effectively organize the tasks and subtasks in a gantt chart for timely completion.	A gantt chart that has multiple features for project tracking.	5	9/11	9/16	David T.

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Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
Literature Review	3.1 Identify relevant information to project	To identify information relevant to the project	A list of relevant Information for the project	1	9/16	9/17	Group Work
	3.2 Establish sources of relevant information	To establish a list of credible sources for the information provided	A list of credible cited sources	1	9/17	9/18	Caleb R.
	3.3 Research Oleophilic skimmers	To study relevant information on Oleophilic skimmers	A thorough research paper done on Oleophilic skimmers	1	9/18	9/19	DanielA.
	3.4 Analyze Non-Oleophilic skimmers	Detailed research on Non-oleophilic skimmers	A thorough research paper done on Non-oleophilic skimmers	1	9/19	9/20	Demetrious S.
	3.5 Analyze Weir Skimmers	Review information on weir skimmers	A thorough research paper done on Weir Skimmers	2	9/20	9/22	David T.
	3.6 Make Inquiries into operational environment of skimmers	Inquire into operational environment of skimmers	list of inquiries made into operations environment of skimmers	2	9/22	9/24	Group Work
Functional Decomposition	4.1. Define functional decomposition concept	To study functional decomposition and generate concepts	Create an overall function statement	2	9/23	9/25	Group work
			A list of overall functions	3	9/23	9/26	Ximena C.
	4.2 Develop a strategy for the functions and subfunctions.	To establish a strategy that define functions and subfunctions	A Level 1 subfunction,				Amna A.
			A Level 2 subfunction,				Caleb R.
			A Level 3 subfunction				
	4.3 Identify materials	To recognize material input and output for the overall function and subfunction	Generate material, energy, and information for overall function and subfunction	2	9/26	9/28	Amna J
			A report that summarizes all the functions				David T
	4.4 Generate a morphology table	To create a morphology table that identifies Functional analysis.	A morphology table for the functional decomposition	2	9/28	9/30	Demetrious S.
							Daniel A.

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Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
Concepts Generation	5.1 Review Concepts 5.2 Modify Concepts	Define and Generate concepts using well established concepts generation techniques for each of the functions. Consolidate individual concepts and sketches into team concepts for each function.	Create a list of customer needs and specifications to generate a concept for all functions Evaluate the list of customer needs and specifications to generate a concept for all functions	2 3	9/30 10/7	10/2 10/9	Demetrious S. Daniel A, David T
Concept Evaluation	6.1 Identifying Criteria 6.2 Organizing Criteria 6.3 Go-no-go method 6.4 Decision matrix 6.5 Preliminary Design	Develop a list of generated criteria to begin the design analysis Reorganize the create list into a manageable table Use the Go-No-Go and decision matrix to evaluate the list Use the Go-No-Go and decision matrix to evaluate the list Develop a final preliminary concept for the design	Create a list of criteria that will be used to determine the preliminary concept design Create a criteria table Determine the final result of the Go-No-Go method of the given criteria Determine the final result of the Go-No-Go method of the given criteria Final result of the decision matrix determined and the evaluation of the preliminary design	3 3 4 4 4	10/14 10/14 10/16 10/16 10/14	10/17 10/17 10/20 10/20 10/22	Group work Ximen C. David T. Group Work Group Work Group Work
Preliminary Design	7.1 Rehabilitate existing designs 7.2 Identify options for flexibility 7.3 Approximate Dimensions	Explore the advantages and disadvantages of existing designs Prepare for the design to have room for changes if needed Meet the initial constraints requirements	Determine the most effective ways to improve the design process Plan to allow the design construct to be flexible Final preliminary design should follow the constraint guidelines	7 7 7	10/22 10/28 10/28	10/28 11/04 11/04	Group Work Amna J, Amna A Group WOrk

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Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
Detailed Design	8.1 Identify and plan for types of analysis needed for the design	To get a realistic idea of the type of functional skimmer to create	A design idea created by working with all group members to produce ideas of skimmers that have never been on the market before.	4	11/04	11/07	Group Work
	8.2 Draw rough draft on paper		A drawing of rough draft on paper based on group ideas.	7	11/04	11/10	Amna A. Amna J.
	8.3 Produce real life blueprint of design in Fusion 360	To have a finalized image of skimmer design	A prototype in Fusion 360 software that has all aspects of design with correct parameters to resemble what the skimmer would look like once fabricated.	4	11/10	11/14	Group work Amna J.
	8.4 Run Simulation in Fusion 360	To make design come to life virtually in Fusion 360 software. To run experimental testing of skimmer.	A simulation run that replicates tests, i.e. stress analysis and skimmer capabilities before doing real time experimentation.	5	11/14	11/19	Amna A. Amna J.
Detailed Parts Specifications	9.1 Identify constraints of design	To apply standards and design constraints to generate realistic models.	A model in Fusion 360 that shows the correct measurements of each component, and assuring all components are scaled properly.	4	11/04	11/08	Group work Amna J
	9.2 Generate specifications of each component	To identify the permissible range of the design and performance parameters	A list of permissible ranges for the design parameters, and applying it to the model.	4	11/08	11/12	Group Work
	9.3 Design Evaluation/Modifications	To ensure all parts meet parameter criteria. To create design with all separate parts merged for one finalized skimmer	Apply drawing standards when generating drawings of the parts, making sure it is well labeled and has all components. A finalized Fusion 360 drawing that is realistic, meets industry needs, and will function when fabricated.	3 3	11/13 11/16	11/16 11/19	Group work Group Work

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Major Tasks Description	**Sub-Task Description**	**Objective(s) for Task**	**Deliverables to be Submitted**	**Duration (Days)**	**Start date**	**End Date**	**Primary Responsible Person**
10. Budget & Project Cost (Economic Analysis)	10.1 1 List of suppliers 10.2 Budget Generation 10.3 Approval of Budget Agreement	To Compare prices and quality with those from different suppliers To generate budgets for all the parts To get budget approval from the Mechanical Engineering Department To review the budget	Identify parts that are necessary for purchase Submit a budget that is reasonable Compare the cost	20	11/05	11/25	David Trevino
Purchasing	11.1 Technical report 11.2 purchases	Generate a report that identifies all the parts that need to be purchased. Purchase parts.	A detailed technical report that identifies all the necessary parts. finalize purchases Create a final report that identifies all the parts that have been purchased.	4 8	2/05 2/11	2/09 2/19	Group work Group work
Fabrication & Testing	12.1 Manufacture & Assembly 12.2 Machine shop work 12.3 Product Testing	To construct a plan for manufacturing and assembly of Automated Skimmer To create a detailed schedule for machine shop work rotation To conduct final testing and inspections for the automated skimmer	A detailed plan on how to go about the manufacturing of the skimmer Finalized schedule for workshop rotations Fully Functional Automated Skimmer	1	2/26 2/28 03/03	2/27 03/02 03/05	Group Work
Final Report & Presentation	13.1Finalize report 13.2 Prepare presentation	To construct a final report that reveals the entire design process of the project.	Compilation of revised reports and create table of contents and figure list	7	4/22	4/29	Group work

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		To present a well-prepared presentation of the project	A well-developed PowerPoint presentation	**2**	TBA	TBA	Group presentation

2.3 Gantt Chart

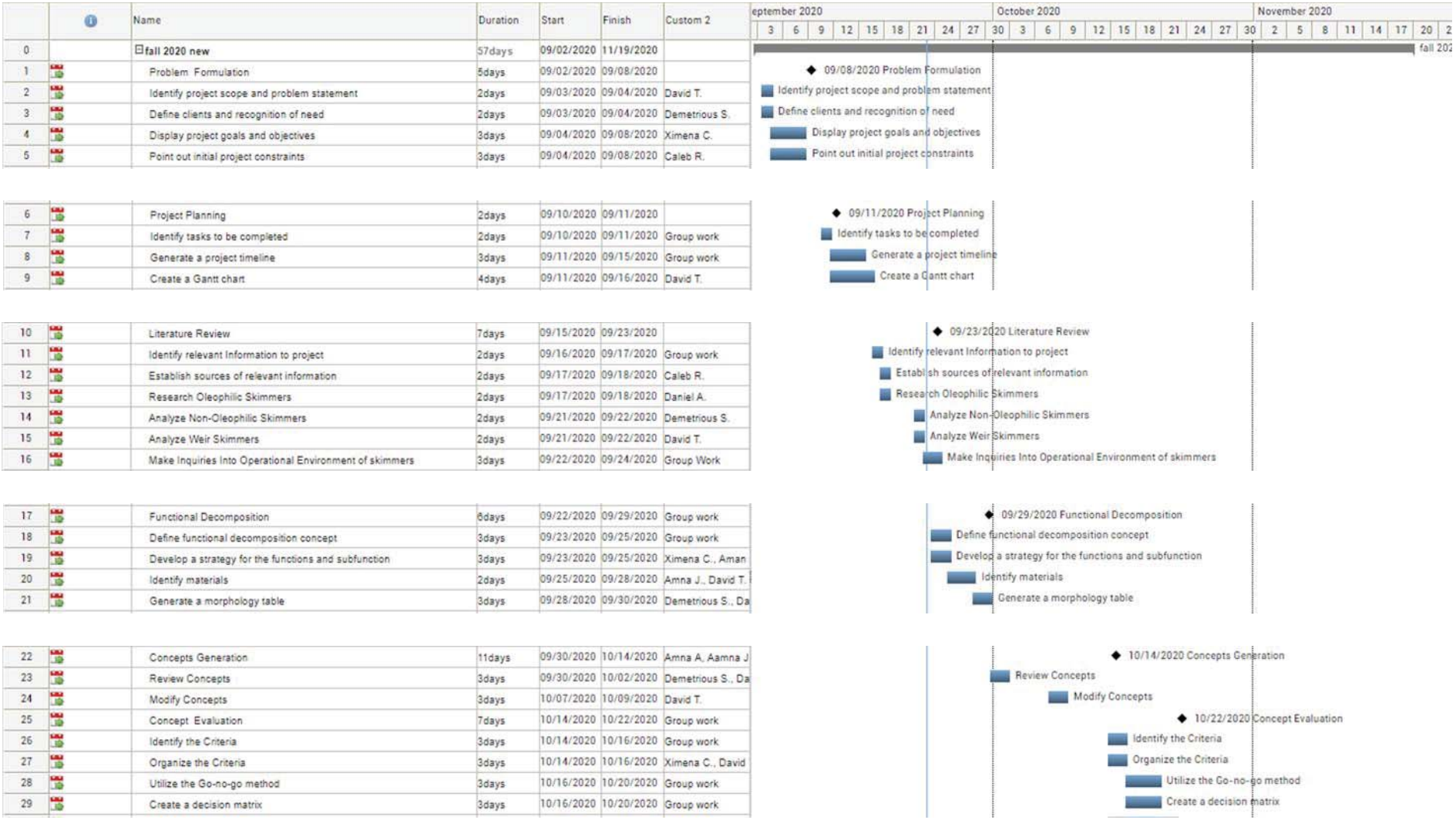
4. Using a project management software construct (i) a detailed Gantt chart for the tasks to be done this Fall 2020 semester and (ii) a detailed Gantt chart for the tasks to be done in the Spring 2020 semester**. Indicate all important milestones (**a milestone is simply a way to mark an important point in the project) **on each Gantt chart**. In addition to the milestones from your group, consult the syllabus and include important milestones listed in it.

Note: The Gantt chart should be done using Microsoft Projects Software or a similar project management software. In addition, the Gantt chart should be properly constructed and should be printed in sections showing only the details for that section after hiding the unwanted sections.

Gantt charts are a key tool for successful planning when executing a project. They are effective in projecting the duration of tasks and planning the order of milestone achievement. In this section, a Gantt chart was created to show a visual representation of the planning and scheduling of the tasks to be performed in Fall 2020 and Spring 2021. The program used to develop the planning of this project was Gantter Google.

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	Name	Duration	Start	Finish	Custom 2
0	fall 2020 new	57days	09/02/2020	11/19/2020	
1	Problem Formulation	5days	09/02/2020	09/08/2020	
2	Identify project scope and problem statement	2days	09/03/2020	09/04/2020	David T.
3	Define clients and recognition of need	2days	09/03/2020	09/04/2020	Demetrious S.
4	Display project goals and objectives	3days	09/04/2020	09/08/2020	Ximena C.
5	Point out initial project constraints	3days	09/04/2020	09/08/2020	Caleb R.
6	Project Planning	2days	09/10/2020	09/11/2020	
7	Identify tasks to be completed	2days	09/10/2020	09/11/2020	Group work
8	Generate a project timeline	3days	09/11/2020	09/15/2020	Group work
9	Create a Gantt chart	4days	09/11/2020	09/16/2020	David T.
10	Literature Review	7days	09/15/2020	09/23/2020	
11	Identify relevant Information to project	2days	09/16/2020	09/17/2020	Group work
12	Establish sources of relevant information	2days	09/17/2020	09/18/2020	Caleb R.
13	Research Oleophilic Skimmers	2days	09/17/2020	09/18/2020	Daniel A.
14	Analyze Non-Oleophilic Skimmers	2days	09/21/2020	09/22/2020	Demetrious S.
15	Analyze Weir Skimmers	2days	09/21/2020	09/22/2020	David T.
16	Make Inquiries Into Operational Environment of skimmers	3days	09/22/2020	09/24/2020	Group Work
17	Functional Decomposition	6days	09/22/2020	09/29/2020	Group work
18	Define functional decomposition concept	3days	09/23/2020	09/25/2020	Group work
19	Develop a strategy for the functions and subfunction	3days	09/23/2020	09/25/2020	Ximena C., Aman
20	Identify materials	2days	09/25/2020	09/28/2020	Amna J., David T.
21	Generate a morphology table	3days	09/28/2020	09/30/2020	Demetrious S., Da
22	Concepts Generation	11days	09/30/2020	10/14/2020	Amna A, Aamna J
23	Review Concepts	3days	09/30/2020	10/02/2020	Demetrious S., Da
24	Modify Concepts	3days	10/07/2020	10/09/2020	David T.
25	Concept Evaluation	7days	10/14/2020	10/22/2020	Group work
26	Identify the Criteria	3days	10/14/2020	10/16/2020	Group work
27	Organize the Criteria	3days	10/14/2020	10/16/2020	Ximena C., David
28	Utilize the Go-no-go method	3days	10/16/2020	10/20/2020	Group work
29	Create a decision matrix	3days	10/16/2020	10/20/2020	Group work

Figure 2.1 Gantt Chart Fall 2020

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31	Preliminary Design	10days	10/21/2020	11/03/2020	Amna A, Aamna J
32	Rehabilitate existing designs	5days	10/22/2020	10/28/2020	Group work
33	Identify options for flexibility	6days	10/28/2020	11/04/2020	Amna J, Amna A
34	Approximate dimensions	6days	10/28/2020	11/04/2020	Group work



35	Detailed Design	12days	11/03/2020	11/18/2020	Group work
36	Identify and plan for types of analysis needed for the design	5days	11/04/2020	11/10/2020	Group work
37	Draw rough draft on paper	4days	11/10/2020	11/13/2020	Amna A, Amna J
38	Produce real life blueprint of design in Fusion 360	4days	11/10/2020	11/13/2020	Group work, Amna
39	Run simulation in Fusion 360	2days	11/13/2020	11/16/2020	Group work, Amna
40	Detailed Parts Specifications	12days	11/03/2020	11/18/2020	Group,work
41	Create specifications of each component	4days	11/09/2020	11/12/2020	Group work
42	Identify constraints of design	2days	11/13/2020	11/16/2020	Amna J, Group wo
43	Design Evaluation/Modifications	4days	11/16/2020	11/19/2020	Group work

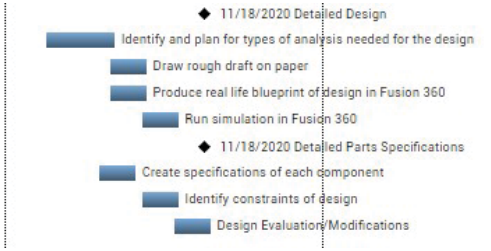
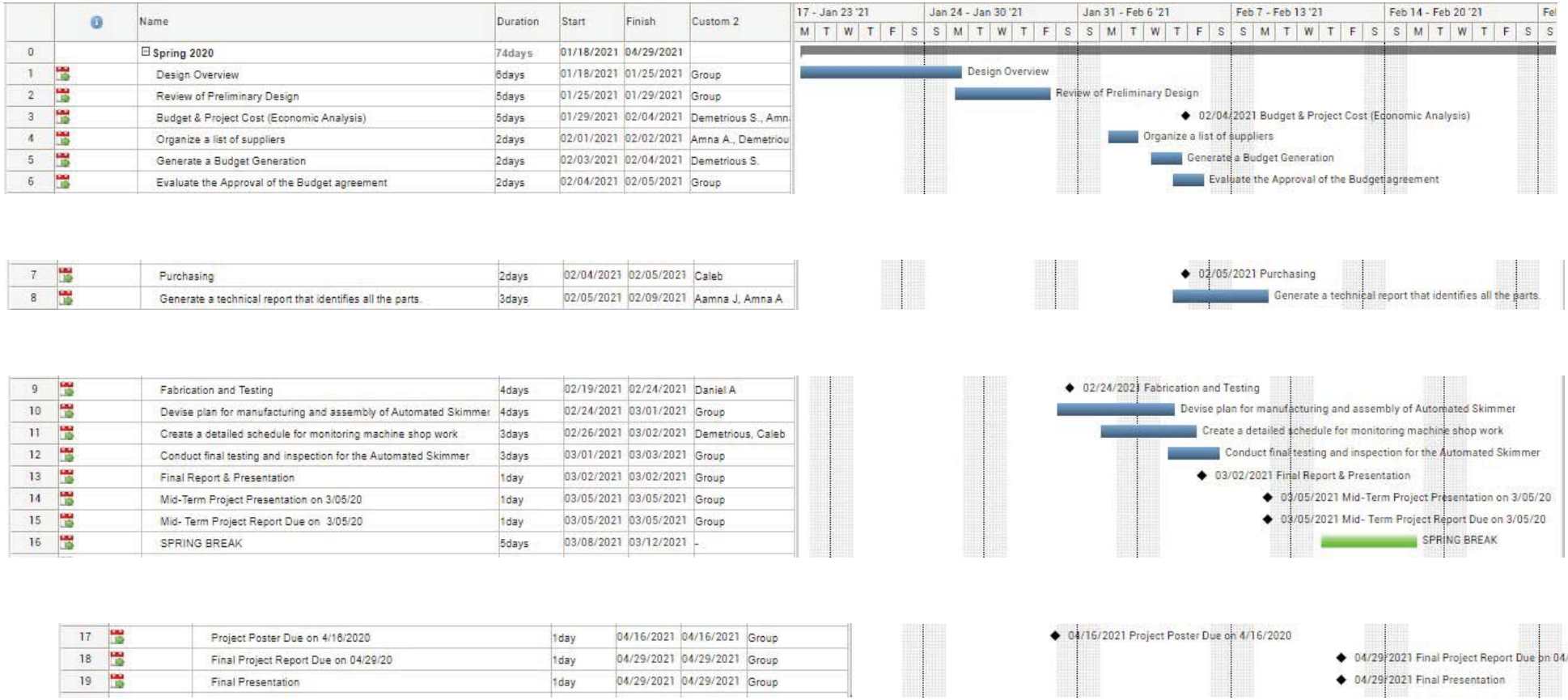


Figure 2.1 Gantt Chart Fall 2020 (Continued)

In the figure 2.1 a visual representation of the planning for the Fall 2020 semester is displayed.
In addition, the diamond shapes located above the bars indicate project milestones.

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	Name	Duration	Start	Finish	Custom 2
0	Spring 2020	74days	01/18/2021	04/29/2021	
1	Design Overview	6days	01/18/2021	01/25/2021	Group
2	Review of Preliminary Design	5days	01/25/2021	01/29/2021	Group
3	Budget & Project Cost (Economic Analysis)	5days	01/29/2021	02/04/2021	Demetrious S., Amn
4	Organize a list of suppliers	2days	02/01/2021	02/02/2021	Amna A., Demetriou
5	Generate a Budget Generation	2days	02/03/2021	02/04/2021	Demetrious S.
6	Evaluate the Approval of the Budget agreement	2days	02/04/2021	02/05/2021	Group
7	Purchasing	2days	02/04/2021	02/05/2021	Caleb
8	Generate a technical report that identifies all the parts.	3days	02/05/2021	02/09/2021	Aamna J, Amna A
9	Fabrication and Testing	4days	02/19/2021	02/24/2021	Daniel A
10	Devise plan for manufacturing and assembly of Automated Skimmer	4days	02/24/2021	03/01/2021	Group
11	Create a detailed schedule for monitoring machine shop work	3days	02/26/2021	03/02/2021	Demetrious, Caleb
12	Conduct final testing and inspection for the Automated Skimmer	3days	03/01/2021	03/03/2021	Group
13	Final Report & Presentation	1day	03/02/2021	03/02/2021	Group
14	Mid-Term Project Presentation on 3/05/20	1day	03/05/2021	03/05/2021	Group
15	Mid- Term Project Report Due on 3/05/20	1day	03/05/2021	03/05/2021	Group
16	SPRING BREAK	5days	03/08/2021	03/12/2021	-
17	Project Poster Due on 4/16/2020	1day	04/16/2021	04/16/2021	Group
18	Final Project Report Due on 04/29/20	1day	04/29/2021	04/29/2021	Group
19	Final Presentation	1day	04/29/2021	04/29/2021	Group

Figure 2.2 Gantt Chart Spring 2021

In the Figure 2.1 a visual representation of the planning for the Spring 2021 semester is displayed.
In addition, the green bar indicates the spring break week.

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5. Indicate how you will use the Gantt chart to monitor the progress of the project, and indicate the current progress on the Gantt chart.

The use of the Gantt chart consists in strictly tracking the completion of the milestones and following the plan during the course of the school year. Strict use of the gantt chart will ensure successful completion of the project. Currently, the team has reached the completion of the second milestone (Status Report on Project Planning) and are working on completing the third mile stone (Status Report on Literature Review) of the Fall 2020 Gantt chart.

Note: Attach a copy of this assignment statement sheet to your homework (placed after the two cover sheets)

Assignment for Outcome 2

Recommended Reference for Assignment: **Successful Project Management by Gido & Clements, Chapter 4**

This is for you to know how this status report will be graded. We recommend grading yourself to ensure each part of the report has been done.

AVERAGE

SENIOR DESIGN & PROFESSIONALISM I

FALL 2020

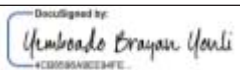
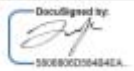
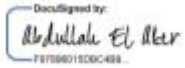
PROJECT PROGRESS REPORT COVER SHEET

PROJECT TITLE: Design of Experiment to Measure Heat Transfer Coefficient and Effective Thermal Conductivity in Nanofluids Under Different Boundary Conditions

GROUP NUMBER:3

Progress Report Title: **Project Planning**

Due Date:9/23/20

No	Group Member Name Group Member signature	Brief Description of Work Assigned to Member	% Completed by Member*	Your Score
1	Yemboado Yonli 	Created list of tasks Created list of subtasks for each task Created and filled table with tasks subtasks and deliverables Was able to generate a timeline for each task Reviewed and reorganized table	100	
2	Christian White 	Construct format for status report 4. Filled deliverables for identification of customers and recognition of need. Proofread the report for accuracy and precision.	100	
3	Fanta Kaba 	Filled in some of the deliverables assigned to me. Created the introduction for the major and subtask. Reviewed the report.	100	
4	Abdullah EL Aker 	Contributed to the table content in report 4. Created the Gantt chart. Worked on section 2.3 of the report. Contributed to the deliverables.	100	
5	Marcelo Epam Ona	Created and introductory paragraph for status report. Helped create the table for the tasks and subtasks. Created an introductory paragraph for explaining how the tasks were	100	

	DocuSigned by: Marcelo Epam Ona 32DFDFB1883D430...	arranged and the time it was going to take to complete it.		
6	Diana Morales DocuSigned by: Diana Morales BE3A502FC0874D8...	Wrote section 2.2 with paragraph and bullet points as requested by the first section of report. Assisted with introduction paragraph and table.	100	
7				
8				

*100% means the member completed his/her assigned work

By signing this assignment cover sheet, I agree that the percentages stated in the % completed column reflect the contribution made by me and the other members of the group

COLLEGE OF ENGINEERING
SENIOR DESIGN & PROFESSIONALISM I
FALL 2020 SEMESTER
Progress Report on Project Planning for Fall 2020 and for Spring 2021

Assigned: 09/09/2020 Due:09/17/2020

2. PROJECT PLANNING AND TASK DEFINITION

Every single project or design should be thought and planned out properly before starting. For example, it can be seen how architects first create and obtain the model of a particular building before getting into constructing such an establishment. In this chapter, the focus would be mainly on planning and having an schematic on how this senior design project is going to look like, taking into consideration the hours, days or months that it is going to take to carry out each major task. To do that, two main objectives were considered. First, project planning and task definition. This section was mainly focused on organizing and arranging the different tasks as well as understanding what those are and how to perform them. Since that is the only way groups can estimate the time might take to perform every single one of them. And second, the Gantt chart, which is where a series of horizontal lines shows the amount of work done or production completed in certain periods of time in relation to the amount planned for those periods.

2.1 Task identification

Identify and make a **detailed** list of tasks (detailed activities that need to be performed) needed for the successful completion of your design this semester and continuation tasks for next semester. Provide more details on the tasks for this semester. As an introduction to this section, **provide a description of how the tasks were identified.**

The task identification is in detail, to convey what will be done currently and in the future for the project. The detailed task list is the focal point for the manufacturing, conceptual design, ASME code & standards, and CAD modeling aspect of the project. The resources used to create the detailed list was the senior design manual and the syllabus. We specified the technical and non-technical aspects that will be presented in the final presentation. The non-technical component includes the research and study behind the project. The technical component includes the step by step process on how to design and develop the experiment for the project. Beneath are the identified tasks and subtasks in detail.

Senior 1

Problem Formulation (from 09/02/2020 to 09/09/2020)

- Identify and Recognize the Need.
- Define Goals.
- Define the objectives.
- Identify the Constraints and Operating Environment.

Project Planning (from 09/10/2020 to 09/16/2020)

- Identify the task.
- Develop objectives of each task.
- Set up the Timeline.
- Create a Gantt Chart.

Literature Review (from 09/16/2020 to 09/22/2020)

- Identify Potential Sources and Relevant Information
- Study convection of nanofluids
- Study convection of nanofluids under different boundary conditions.
- Study of Different measurement techniques for convection and their advantages
- Identify and collect comparable results
- Conclude the literature review.

Functional Decomposition (from 09/23/2020 to 09/29/2020)

- Use strategies to develop Level 1 Sub functions.
- Use strategies to develop Level 2 Sub functions.
- Use strategies to develop level 3 Sub functions.
- Develop the Morphology Table.

Concepts Generation (from 09/30/2020 to 10/05/2020)

- Generate techniques for the Concepts from Functions.
- Develop a Conceptual Designs of the experimental set up that would based on the properties of nanofluid and the boundary conditions that would be applied

Concepts Evaluation (10/14/2020 to 10/20/2020)

- Evaluate based on go-no-go.
- Evaluate based on decision matrix.

Preliminary Design (10/21/20 to 11/05/20)

- Make the design sizing and components Analysis.
- Develop Methods for presenting design analysis.
- Apply ASME codes & Standards
- Consider public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors in Design.

Detailed Design (11/06/21 to 11/21/20)

- To develop CAD models of project parts & components.
- Develop Engineering Drawings from part models.
- Develop sub-system assembly and system assembly.

Detailed Parts Specification (11/22/20 to 11/29/20)

- Specify of parts
- Identify the use of each part.

Budget and Project Cost (11/30/20 to 12/06/20)

- Identify the material needed for the parts
- Identify parts that can directly be bought
- Identify the manufacturing cost
- Summarize into a budget that can cover up for all costs.

Purchasing (01/25/21 to 02/06/21)

- Research Vendors able to manufacture the needed parts based on the Design.
- Obtain Quotes Generation by vendor
- Generate a cost/quality Analysis
- Choose the vendor best suited for Project Budget.
- Purchase from the vendor

Manufacturing and Testing (02/07/21 to 04/16/21)
- Manufacture the parts based on the design.
- Assemble of the part
- Testing of the experiment and testing of the equipment

Final senior Design Presentation (04/17/21 to05/12/21)
- To come with a detailed Project Presentation of the Problem.
- To come with Detailed explanation on the project planning.
- To come with Detailed Presentation on the Literature Review.
- To come with Detailed Presentation of functional decomposition.
- To come with Detailed presentation on the concept generation.
- To come with Detailed presentation on the design analysis.
- Etiquette and laws applied to the project**.**

2.2 Timeline

2.2.1.For each task state the objective(s) [defined as information to be refined or developed and communicated to others, not activities to be performed] and the specific deliverables [Noun things] needed to be provided to indicate the completion of the task, and indicate the responsible group member(s) , and estimate of time for the task. **Describe in greater detail, how this section was done as an introduction to this section.**

To successfully undertake the design of this experiment in its entirety, it was important that the framework for this project was clearly outlined and defined. This was done by initially defining the major tasks. These tasks represent the basic building blocks of what it takes to complete this design experiment from start to finish. From this point, each task is followed by its objectives. These objectives give clear understanding to the purpose of the task associated with it. Once the objectives are clear, there is a specific deliverable for each objective. The deliverables define exactly what needs to be done to fulfill the assigned objective. These are awfully specific jobs that needed to be carried out for the task to be considered complete. Every deliverable was allotted a time frame that was estimated for its completion. This time frame was estimated depending on the difficulty and ease of the deliverable. More days were given to more difficult deliverables and fewer days to those that were considered less time consuming. Once the process was broken down to clear and precise deliverable associated with the task, it was assigned a specific person to carry out the deliverable. Each team member's knowledge and personal strengths were taken into consideration with this step. Some deliverables were given more than one person to accommodate time restrictions, a person’s knowledge/strengths or for the importance of collaboration needed. A list of tasks, objectives, deliverables, responsible members, and time frame is shown below in the following format.

1. Problem Formulation

1.1 Identify clients and recognize need.

-Objective: Identify the consumer.

-Deliverable: Specify at least 3 clients.

-Members: Marcelo Epam Ona/Christian White

-Timeline: 3 days

1.2 Define goals.

-Objective: Clear understanding of need.

-Deliverable: Define 3 specific needs.

-Members: Christian White

-Timeline: 3 days

1.3 Define objectives.

-Objective: Clarify objectives.

-Deliverable: List objectives for each task.

-Members: Yemboado Yonli

-Timeline: 2 days

1.4 Identify the constraints and operating environment.

-Objective: Understand limitations of design.

-Deliverable: List all constraints.

-Members: Marcelo Epam Ona/Abdullah El Aker

-Timeline: 5 days

2. Project Planning

2.1 Identify the tasks.

-Objective: Clear understanding of task.

-Deliverable: List of tasks.

-Members: Diana Morales

-Timeline: 2 days

2.2 Develop objectives for each task.

-Objective: Develop objectives.

-Deliverable: Specify all requirements to complete task.

-Members: Fanta Kaba

-Timeline: 2 days

2.3 Set up a timeline.

-Objective: Estimate timeline for completion.

-Deliverable: Estimate dates for tasks.

-Members: Fanta Kaba

-Timeline: 3 days

2.4 Create a Gantt chart.

-Objective: Visual representation of timeline.

-Deliverable: Create a Gantt Chart.

-Members: Abdullah El Aker

-Timeline: 2 days

3. Literature Review

3.1 Identify potential sources and relevant information.

-Objective: Understand the background of the project.

-Deliverable: List of research previously found on convection of nanofluids.

-Members: Marcelo Epam Ona/Christian White

-Timeline: 2 days

3.2 Study convection of nanofluids.

-Objective: Understand the mechanism.

-Deliverable: List of research on heat convection under different boundary conditions.

-Members: Diana Morales/Fanta Kaba

-Timeline: 2 days

3.3 Study convection of nanofluid under different boundary conditions.

-Objective: Understand change of boundary condition.

-Deliverable: List boundary conditions.

-Members: Yemboado Yonli

-Timeline: 2 days

3.4 Study measurement techniques of convection and their advantages.

-Objective: Identify different measurement technique for convection.

-Deliverable: List 3 techniques.

-Members: Yemboado Yonli/Christian White

-Timeline: 2 days

3.5 Identify and collect of comparable results.

-Objective: Obtain a range of results that satisfy results.

-Deliverable: List comparable results.

-Members: Marcelo Epam Ona/Abdullah El Aker

-Timeline: 2 days

3.6 Conclude the literature review.

-Objective: To summarize research.

-Deliverable: Write paragraph on summary of research.

-Members: Christian White

-Timeline: 1 day

4. Functional Decomposition

4.1 Use strategies used to develop Level 1 Sub Functions.

-Objective: Define the general function of experiment.

-Deliverable: Give definition of the major ~~task~~ based on the project statement.

-Members: Christian White/Marcelo Epam Ona/Abdullah El Aker

-Timeline: 1 day

4.2 Use strategies used to develop Level 2 Sub Functions.

-Objective: To define the main functions of what is to be accomplished.

-Deliverable: To break each second level function into sub function.

-Members: ~~Yemboado Yonli~~

-Timeline: 3 days

4.3 Develop the Morphology Table.

-Objective: To break each second level function into sub function

-Deliverable: An assignment for each member to build up in order to complete the project.

-Members: ~~Yemboado Yonli/ Marcelo Epam Ona/Fanta Kaba~~

-Timeline: 2 days

5. Concept Generation

5.1 Generate techniques for concept.

-Objective: To Generate concepts using concept generation techniques.

-Deliverable: ~~Brainstorm and generate concept for techniques.~~

-Members: Christian/Fanta/Bryan/Marcelo/Diana/Abdullah

-Timeline: 2 days

5.2 Develop a conceptual design of the experimental.

-Objective: To consolidate individual concepts and sketches.

-Deliverable: Combine concepts/sketches and ~~choose best concept.~~

-Members: Christian/Fanta/Bryan/Marcelo/Diana/Abdullah

-Timeline: 3 days

6. Concept Evaluation

6.1 Evaluate based on Go-No-Go.

-Objective: Select and acquire relevant information.

-Deliverable: Select 4 merits that may meet the needs of the customer.

-Members: Diana Morales/Cristian White/Abdullah El Aker

-Timeline: 6 days

6.2 Evaluate based on decision matrix.

-Objective: Decisions made based on a descriptive matrix evaluation method.

-Deliverable: Select the best choice from the matrix with an explanation on its selection

-Members: Yemboado Yonli/ Marcelo Epam Ona/Fanta Kaba

-Timeline: 1 day

7. Preliminary Design

7.1 Make the Design Sizing & Components Analysis.

-Objective: Analyze project and design from basic science.

-Deliverable: Select the proper tools needed for the experiment.

-Members: Diana Morales/Cristian White/Abdullah El Aker

-Timeline: 5 days

7.2 Develop methods for design analysis.

-Objective: Choose different methods used.

-Deliverable: Proper method is chosen for each respective part.

-Members: Yemboado Yonli/ Marcelo Epam Ona/Fanta Kaba

-Timeline: 4 days

7.3 Apply ASME Codes & Standard to experiment.

-Objective: Rules and ethics applied to obtain best results.

-Deliverable: Defining 5 rules that are necessary for this experiment to function with the most accurate results.

-Members: Diana Morales/Cristian White/Abdullah El Aker

-Timeline: 4 days

7.4 Consider public health, safety, and welfare factors into design.

-Objective: Assure experiment is safe.

-Deliverable: List at least 10 rules that would make this experiment safe for consumers and environment.

-Members: Yemboado Yonli/ Marcelo Epam Ona/Fanta Kaba

-Timeline: 4 days

8. Detailed Design

8.1 Design CAD models of project parts & components.

-Objective: Generating a design of the different parts needed with precise measurements.

-Deliverable: ~~Generate~~ designed parts with precise measurement.

-Members: White/Marcelo Epam Ona/Abdullah El Aker

-Timeline: 7 days

8.2 Develop Engineering Drawings from part models.

-Objective: Have perspective and schematic of project.

-Deliverable: ~~Produce~~ schematic of design experiment.

-Members: Yemboado Yonli/ Marcelo Epam Ona/Fanta Kaba

-Timeline: 7 days

8.3 Develop sub-system assembly and system assembly.

-Objective: Creating a simpler system.

-Deliverable: ~~Assure~~ that each part fits perfectly for a simple design.

-Members: Diana Morales/Cristian White/Abdullah El Aker

-Timeline: 5 days

9. Detailed Parts Specifications

9.1 Specify the parts.

-Objective: To be able to identify each part.

-Deliverable: ~~Identify each part used~~.

-Members: White/Marcelo Epam Ona/Abdullah El Aker

-Timeline: 7 days

9.2 Identify the use of each part.

-Objective: To identify the utility of each part.

-Deliverable: ~~Determine~~ the utility of part and build each one.

-Members: Diana Morales/Cristian White/Abdullah El Aker

-Timeline: 5 days

10. Budget and Project Cost

10.1 Identify the material needed for the parts.

-Objective: Know what should be purchased.

-Deliverable: ~~Determine~~ the material needed and where it can be found.

-Members: Christian White.

-Timeline: 3 days

10.2 Identify parts that can directly be purchased.

-Objective: Identify what can be directly acquired.

-Deliverable: ~~Identify~~ every part that can be directly purchased.

-Members: Fanta kaba/Diana Morales

-Timeline: 2 days

10.3 Identify manufacturing cost.

-Objective: Know how much it would cost to manufacturing the part.

-Deliverable: ~~Identify~~ the cost of the part that can be directly acquired.

-Members: Yemboado Yonli

-Timeline: 2 days

10.4 Summarize budget plan to that cover all costs.

-Objective: Make sure that every dollar is properly spent.

-Deliverable: ~~Add~~ the estimated cost and ~~set up~~ final budget.

-Members: Marcelo Epam Ona/ Abdullah El Aker

-Timeline: 4 days

11. Purchasing

11.1 Research vendors that can provide manufactured parts.

-Objective: Know the companies or manufacturers that can build necessary parts.

-Deliverable: Prepare a list of the parts specifications to be purchased and manufactured.

-Members: Yemboado Yonli

-Timeline: 13 days

11.2 Have the vendors generate quotes.

-Objective: To list the possible vendors or providers for the different parts needed.

-Deliverable: Prepare detailed drawings and prototypes of desired parts.

-Members: Marcelo Epam Ona

-Timeline: 13 days

11.3 Generate a cost quality analysis.

-Objective: Understand and prepare a budget.

-Deliverable: List 3 or more quotes of parts worth more than $50.

-Members: Fanta Kaba

-Timeline: 13days

11.4 Choose the vendor that best suits Project Budget.

-Objective: Pick the parts to satisfy experiment needs at low cost and highest quality available.

-Deliverable: Purchase parts and test part on assembly.

-Members: Abdullah El Aker/Christian White

-Timeline: 13 days

12. Fabricating and Testing

12.1 Manufacture parts based of the design.

-Objective: Have tangible parts.

-Deliverable: Establish a detailed plan for manufacturing and assembly.

-Members: Yemboado Yonli/Marcelo Epam Ona

-Timeline: 20 days

12.2 Assembly of the parts.

-Objective: Verify the functionality of the designed product.

-Deliverable: Assemble the parts to meet the project requirements.

-Members: Abdullah El Aker

-Timeline: 10 days

13. Final Report and Presentation

13.1 Presenting the problem in detail.

-Objective: Assure audience understands the task at hand.

-Deliverable: Utilizing Microsoft PowerPoint, provide a slide defining the problem.

-Members: Yemboado Yonli

-Timeline: 7 days

13.2 Detailed explanation on the project planning.

-Objective: Show how the project has been divided into multiple steps that allow for full development.

-Deliverable: Create a list of steps taken to create our physical system.

-Members: Marcelo Epam Ona

-Timeline: 7 days

13.3 Detailed presentation on the literature review.

-Objective: A brief overview of the information helps the concept generations.

-Deliverable: Show the helpful documents used through individual research and result.

-Members: Fanta Kaba

-Timeline: 7 days

13.4 Detailed Presentation of functional decomposition.

-Objective: Help the audience understand the material, energy and information inputs and outputs for the overall subfunctions.

-Deliverable: Show various components of the system and explain why they have been chosen.

-Members: Diana Morales

-Timeline: 7 days

13.5 Detailed presentation on the concept generation

-Objective: Present to the audience chosen concept for full understanding.

-Deliverable: Explain why this concept was the most acceptable for this project.

-Members: Abdullah El Aker

-Timeline: 7 days

13.6 Detailed presentation on the design analysis.

-Objective: Present to the audience how the design was generated.

-Deliverable: Create bullets points on the major concepts behind the experiment.

-Members: Christian White

-Timeline: 7 days

13.7 The etiquette and laws of the project.

-Objective: Show rules and laws of the engineering were respected.

-Deliverable: Make a list of rules that were abided by.

-Members: Diana Morales

-Timeline: 7 days

2.2.2.Arrange your tasks in the order that they need to be performed, and indicate the starting time, ending time, and the duration in hours for each task. **Describe in greater details how this section was done.**

The section above describes the list of tasks that need to be performed to fulfill the goals and objectives of this project. It was mainly done or created by following the Prairie View A&M Department of Engineering Senior Design Project manual, which helps mechanical engineers build a list of actions that need to be completed in the process of designing or building a product. The dates were set up by identifying and recognizing the importance of each task, which led this to come out with an estimated date that such task might take to be completed. Based on how much or little work each task seemed to have once identified, a certain amount of days and hours were given to complete it. For example, when it comes to the Literature review, it is understood that this is actually one of the tasks that will definitely take some time to complete because it mostly focuses on objectives like Identifying most of the potential sources and relevant information related to Measurement of heat transfer coefficient and thermal conductivity of nanofluids that do not accommodate different boundary conditions. As it can be seen, there will be a lot of research and work to do on this objective alone, which also means a lot of time invested into identifying these potential sources. Furthermore, the hours were set up by putting into this project at least 6 hours a week which translate into for every two weeks a total of 12 hours were invested into accomplishing every single objective.

Senior 1

- Problem Formulation (From 09/02/2020 to 09/08/2020) 6 hours are to be invested.
- Project Planning (From 09/10/2020 to 09/15/2020) 6 hours are to be invested.
- Literature Review (From 09/16/2020 to 09/22/2020) 6 hours are to be invested.
- Functional Decomposition (From 09/23/2020 to 09/29/2020) 6 hours are to be invested.
- Concepts Generation (From 09/30/2020 to 10/03/2020) 6 hours are to be invested.
- Concepts Evaluation (From 10/14/2020 to 10/21/2020) 6 hours are to be invested.
- Preliminary Design (From 10/02/2020 to 11/05/2020) 24 hours are to be invested.
- Detailed Design analysis (From 11/06/2020 to 11/21/2020) 12 hour are to be invested.
- Detailed parts specifications (From 11/22/2020 to 11/29/2020) 6 hours are to be invested.
- Budget & Project Cost (From 11/02/2020 to 12/06/2020) 24 hours are to be invested.
- Purchasing (From 01/25/2021 to 02/06/2021) 12 hours are to be invested.
- Fabrication & Testing. (From 02/07/2120 to 04/16/2120) 6 hours are to be invested.
- Final Presentation for Senior 1(From 04/17/2120 to 05/12/2120) 6 hours are to be invested.

Table 1 is an organized representation of each task, subtasks and deliverables the group judged important to be performed for the goals and objectives of the project to be reached. The timeline has also been divided in a way that each deliverable would have a specific time during which it has to be completed which is breaking the whole project into smaller and more achievable goals. The group will work in the most diligent way to make good use of its time.

Table 1 Detailed Project Tasks, Objectives, Deliverables, Task Duration & Responsible Personnel

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
1. Problem Formulation	1.1 Identify clients and Recognize need 1.2 Define goals 1.3 Define objectives. 1.4 Identify the constraints and operating environment.	To identify the consumer that may need the product and understand the reason why the product needs to be built To have a clear understanding of the output that is needed To have clear cut objectives while designing the product To understand the limitation of the design and the product	A list of at least 4 potential customers & why they will need our product . A list of objectives such as how the design of this heat transfer measuring system will expel any confusion about how nanofluids interact with different boundary conditions. zoom meeting setup, a list of 4 different constraints, formulation of the problem statement. A list of all measurable performance characteristics with units. A well-drawn and labelled objective tree showing hierarchical relationships and interconnections of the performance characteristics. A list of permissible range for the design parameters, description of the environment in which the design will operate and specifying why different constraints will hinder successful experiments.	3 3 2 5	9/2 9/2 9/3 9/4	9/4 9/4 9/4 9/8	Marcelo Epam Ona/Christian White Christian White Yemboado YONLI Marcelo Epam Ona/Abdullah El Aker
Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
2. Project Planning	2.1 Identify the tasks 2.2 Develop objectives for each task 2.3 Set up a timeline 2.4 Create a Gantt chart.	To have a schematic and a clear idea about what the project and its different tasks will look like. To develop objectives (actions needed) for each task. To set up estimate dates in which each task might be completed. To give a visual representation of the timeline	A list of all the tasks needed to be accomplished for the project. Detailed list of specific requirements to assure completion of each individual task. Various dates of meetings that involve discussion and time spent applying what has been discussed into the project. Physical Gantt Chart to give a detailed description of time spent in a 24 hour day.	2 2 3 2	9/10 9/10 9/12 9/14	9/11 9/11 9/14 9/15	Diana Morales Fanta Kaba Fanta Kaba Abdullah El Aker

3. Literature Review	3.1 Identify potential sources and relevant information.	To understand the background of the project and I have a clear idea of what it is needed for each task to be completed.	A list of research previously found about convection of nanofluid	2	09/16	09/18	Marcelo Epam Ona/Christian White
	3.2 Study convection of nanofluids.	To understand the mechanism behind convection heat transfer for nanofluids	A list of papers about heat convection of nanofluids under different boundary conditions.	2	09/16	09/18	Diana Morales/Fanta Kaba
	3.3 Study convection of nanofluid under different boundary conditions	To understand how a change of boundary condition like magnetic field will affect the properties of the nanofluid	A thorough documentation on measurement techniques for convection and their advantages	2	09/17	09/19	Yemboado YONLI
	3.4 Study measurement techniques of convection and their advantages	to identify different measurement technique for convection and sort them out to to get the one that will work best for that project	A choice of the most advantageous measurement technique	2	09/18	09/20	Yemboado Yonli/Christian White
	3.5 Identify and collect of comparable results	To obtain a range of results that will help make sure that experiment is generating satisfying results	A good understanding on the instrumentations used for the experiment	2	09/18	09/20	Marcelo Epam Ona/Abdullah El Aker
	3.6 Conclude the literature review	To summarize all the information obtained and organize them in a way that will be beneficial for the project	A list of comparable results	2	09/20	09/21	Christian White
			Conclusion of literature review	1	09/21	09/22	
Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person

4. Functional Decomposition	4.1 Use strategies used to develop Level 1 Sub functions. 4.2 Use strategies used to develop Level 2 Sub functions. 4.3 Develop the Morphology Table.	To define the general function and what is to be accomplished by the system To define the main functions of what is to be accomplished To break each second level function into sub function until the point of basic functionality	A definition of the major task based on the project statement A List of all ask the major task can be divide in to have more attainable goals a breakdown of the second level function into subfunctions An assignment to each group member of a task to build up in order to complete the project.	1 2 3 2	09/23 09/24 09/25 09/27	09/24 09/26 09/28 09/29	Christian White/Marcelo Epam Ona/Abdullah El Aker Yemboado YONLI/Fanta Kaba Diana Morales/Cristian White/Abdullah El Aker Yemboado Yonli/ Marcelo Epam Ona/Fanta Kaba
5. Concept Generation	5.1 Generate techniques for generating concepts from functions. 5.2 Develop a conceptual design of the experimental set up that would be based on the properties of nanofluid and the boundary conditions that would be applied	To Generate concepts using concept generation techniques To Consolidate individual concepts and sketches into team concepts for each function.	Techniques to generate a concept would be brainstorming, developing, and communicating abstract ideas. Combining individual concepts and sketches by communicating collectively on the concept each person has come up with. Then choosing the best concepts that are aligned with the scope of the project.	2 3	09/30 10/3	10/2 10/05	Christian/ Fanta/Bryan/Marcelo/Diana/Abdullah Christian/ Fanta/Bryan/Marcelo/Diana/Abdullah
Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person

6. Concept evaluation	6.1 Evaluate based on Go-No-Go 6.2 Evaluate based on decision matrix	To select and acquire relevant information based on how it might relate to the project. Decisions will be made based on a descriptive matrix evaluation method.	Select 4 merits that may meet the needs of the customer. Select the best choice from the matrix with an explanation on why it was selected.	6 1	10/14 10/19	10/19 10/20	Diana Morales/Cristian White/Abdullah El Aker Yemboado Yonli/ Marcelo Epam Ona/Fanta Kaba
7. Preliminary Design	7.1 Make the design Sizing & Components Analysis 7.2 Develop methods for design analysis 7.3 Apply ASME Codes & Standards 7.4 Consider public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors in Design.	Where the project must be designed and analyzed, it is essentially a decision-making process in which analytical tools are derived from basic sciences. Where the different methods used have to be chosen and accommodated to its respective part of the project. Where the different rules and ethics must be applied in order to obtain the best of the product. Where it must be made sure that the product is safe for consumers and that it will be used in its designated environment	Select the proper tools needed for the experiment to give the desired results. A proper method is chosen for each respective part so that the experiments give needed results as expected. Defining 5 rules that are necessary for this experiment to function with the most accurate results. List at least 10 rules that would make this experiment safe for consumers and environment.	5 4 4 4	10/21 10/26 10/29 11/02	10/28 10/30 11/03 11/05	Diana Morales/ Cristian White/Abdullah El Aker Yemboado Yonli/ Marcelo Epam Ona/Fanta Kaba Diana Morales/ Cristian White/Abdullah El Aker Yemboado Yonli/ Marcelo Epam Ona/Fanta Kaba
Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person

8. Detailed design	8.1 Design CAD models of project parts & components 8.2 Develop Engineering Drawings from part models 8.3. Develop sub-system assembly and system assembly	Generating a design of the different parts needed with the precise measurements. Having access to different apps and software that can give a perspective or schematic of how the project will look like. Creating a simpler system that can be used to assemble all the different parts of the experiment. Making sure that each part fits perfectly and functions accordingly.	The designed parts needed are generated with precise measurement. A schematic of the design is obtained through the different mechanical software, which could be NX or AutoCAD. A simpler system is created to assemble all the different parts of the experiment. It is made sure that each part fits and works for the purposes it was made for. Every part of the design fulfills its task.	7 7 5	11/06 11/12 11/16	11/13 11/19 11/21	White/Marcelo Epam Ona/Abdullah El Aker Yemboado YONLI/Fanta Kaba Diana Morales/ Cristian White/Abdullah El Aker
9. Detailed part Specification	9.1 specify of parts 9.2 Identify the use of each part	To be able to identify each part To identify the utility of each part	Identify each part Determine the utility of each part build each part	3 3 2	11/22 11/24 11/27	11/25 1/27 11/29	White/Marcelo Epam Ona/Abdullah El Aker Yemboado YONLI/Fanta Kaba Diana Morales/Cristian White
10. Budget and Project cost	10.1 Identify the material needed for the parts 10.2 Identify parts that can directly be bought 10.3 Identify manufacturing cost 10.4 Summarize into a budget that can cover all costs	to know what should be bought To identify what does not need to be bought but can be directly acquired To know how much it would cost on average for manufacturing the part To create a sound budget and make sure that every dollar is properly spent.	Determine the material needed and where it can be found identify every part that can be directly bought identify the cost of the part that can be directly acquired add the supposed cost together set up a final budget	3 2 2 2 2	11/30/20 12/01/20 12/02/20 12/03/20 12/04/20	12/02/20 12/03/20 12/04/20 12/05/202 12/06/20	Christian White. Fanta kaba/Diana Morales. Yemboado Yonli Marcelo Epam Ona Abdullah El Aker

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
11. Purchasing	11.1 Research Vendors able to manufacture the needed parts based on the Design	To list the companies or manufacturers that can build the parts needed to develop the product.	Prepare a list of the parts specifications to be purchased and manufactured.	13	01/25	02/06	Yemboado Yonli
			Prepare Detailed drawing and prototypes of desired parts.				Marcelo Epam Ona
	11.2. Have the Vendors Generate quotes.	To list the possible vendors or providers of the different parts needed for the project, contact them to get an estimate on the prices and delivery dates.	List 3 or more quotes of parts more than $50	13	01/25	02/06	
	11.3 Generate a cost quality analysis		List the parts with prices and quotes for the product.	13	01/25	02/06	Fanta Kaba
		To come out with a budget of what they need and what they might not for the desirable project.	Purchase the parts and start manufacturing.				
			Test and inspect the parts to proceed to assembly of the product.				Diana Morales
	11.4 Choose the vendor that best suits Project Budget	To pick the parts to satisfy their needs at lower cost possible and at the highest quality available.		13	01/25	02/06	
							Abdullah El Aker
							Christian White
12. **Manufacturing and Assembly of the Product**	12.1 **Manufacture part based of the design**	To have tangible parts	Prepare detailed codes and standards used in the project.	20	02/07/21	02/27/20	Yemboado Yonli/Marcelo Epam Ona
	12.1 Assemble **of the part**	To assemble the parts and verify the functionality of the designed product					
			Establish a detailed plan for manufacturing and assembly of the product.	20	02/27/21	03/11/21	Fanta Kaba
			Risk assessment and identifications of critical issues for in depth analysis.	14	03/11/21	0\3/25/21	Diana Morales
			Assemble the parts to meet the project requirements.	10	03/25/21	04/05/21	Abdullah El Aker
			Test the product and collect measurements and data	10	04/06/21	04/16/21	Christian White

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
13. **Final senior Design Presentation**	13.1 Detailed Project Presentation of the Problem	To make the audience understand the task at hand.	Utilizing Microsoft PowerPoint, a specific slide will be incorporated defining the problem.	7	04/17/21	04/24/21	Yemboado Yonli
	13.2. Detailed Explanation on the Project Planning	Show how the project has been divided into multiple steps that allow its good development.	Reference the timeline and Gantt chart created earlier in the project. Create a list of steps taken to create our physical system.	7	04/19/21	04/23/21	Marcelo Epam Ona
	13.3. Detailed Presentation on the literature Review	A brief overview of the information that has been found on previous projects of that same kind and how it helped the concept generations.	Show our helpful documents conducted through individual research within the group pertaining to specific functions of the project.	7	04/23/21	04/30/21	Fanta Kaba
	13.4. Detailed Presentation of functional decomposition	Make the audience understand the material, energy and information inputs and outputs for the overall and the subfunctions.	Show various components of the system and explain why they have been chosen.	7	04/24/21	05/01/21	Diana Morales
	13.5. Detailed presentation on the concept generation	To present to the audience the concept chosen and the reason why this concept was the most acceptable for this project	Show personal meeting notes with the project advisor and professors who have insight on this specific project. Show feedback given by professors who grade weekly assignments.	7	04/27/21	05/03/21	Abdullah El Aker
	13.6. Detailed presentation on the design analysis	Present to the audience how the design must be generated based on the concept that was brought up and how the design will be created.	Create bullets points on the concept behind the experiment and its functionality and why it works on PowerPoint slides.	7	05/01/21	05/08/21	Christian White
	13.7. The etiquette and laws of the project	To show to the that the rules and laws of the engineering world were respected	Make a list of rules that were abided by that show rules were followed.	7	05/05/21	05/12/21	Diana Morales

2.3 Gantt Chart

Using a project management software construct (i) a detailed Gantt chart for the tasks to be done this Fall 2020 semester and (ii) a detailed Gantt chart for the tasks to be done in the Spring 2020 semester**. Indicate all important milestones (**a milestone is simply a way to mark an important point in the project) **on each Gantt chart**. In addition to the milestones from your group, consult the syllabus and include important milestones listed in it.

Note: The Gantt chart should be done using Microsoft Projects Software or a similar project management software. In addition, the Gantt chart should be properly constructed and should be printed in sections showing only the details for that section after hiding the unwanted sections.

Indicate how you will use the Gantt chart to monitor the progress of the project and indicate the current progress on the Gantt chart.

ID	Task Name	Duration	Start	Finish
1	1. Problem formulation	5 days	Wed 9/2/20	Tue 9/8/20
2	1.1 Identify the consumer that may need the product and understand the reason why the product needs to be	3 days	Wed 9/2/20	Fri 9/4/20
3	1.2 Have a clear understanding of the output that is needed	3 days	Wed 9/2/20	Fri 9/4/20
4	1.3 Have clear cut objectives while designing the product	2 days	Thu 9/3/20	Fri 9/4/20
5	1.4 Understand the limitation of the design and the	3 days	Fri 9/4/20	Tue 9/8/20

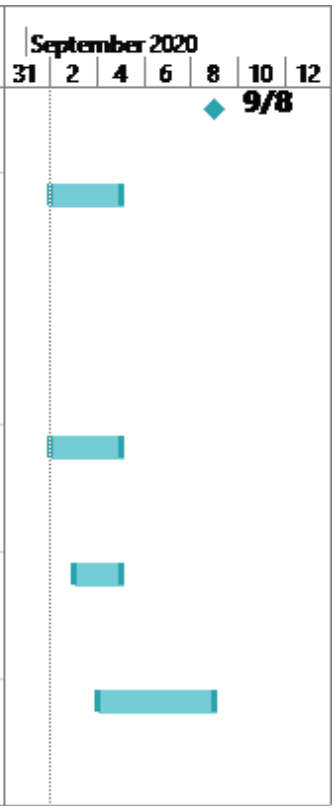


Figure 2.1 shows the Gantt chart of the Major task and its corresponding sub-tasks to complete the milestone for that task

ID	Task Name	Duration	Start	Finish
8	2.1 Have a schematic and a clear idea about what the project and its different tasks will	2 days	Thu 9/10/20	Fri 9/11/20
9	2.2 Develop objectives (actions needed) for each	2 days	Fri 9/11/20	Sat 9/12/20
10	2.3 Set up estimate dates in which each task might be completed.	2 days	Sat 9/12/20	Mon 9/14/20
11	2.4 Give a visual representaation of the timelime	2 days	Mon 9/14/20	Tue 9/15/20

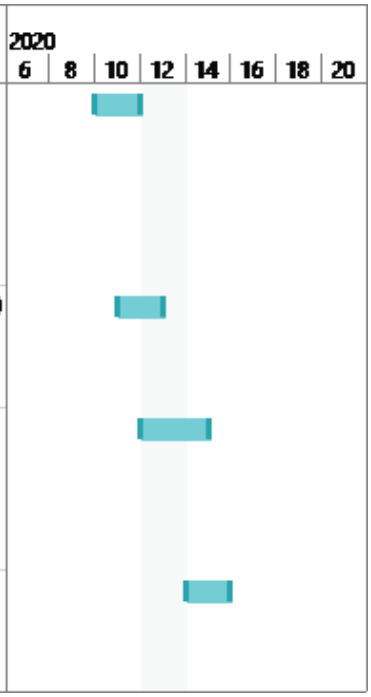


Figure 2.2 shows the Gantt chart of the Major task and its corresponding sub-tasks to complete the milestone for that task

ID	Task Name	Duration	Start	Finish
12	3 Literature Review	4 days	Wed 9/16/20	Mon 9/21/20
13	3.1 Understand the background of the project and I have a clear idea of what it is needed for each task to be completed.	3 days	Wed 9/16/20	Fri 9/18/20
14	3.2 Understand the mechanism behind convection heat transfer for	3 days	Wed 9/16/20	Fri 9/18/20
15	3.3 Understand how a change of boundary condition like magnetic field will affect the properties of the	3 days	Thu 9/17/20	Sat 9/19/20
16	3.4 Identify different measurement technique for convection and sort them out to to get the one that will work best for that	2 days	Fri 9/18/20	Sun 9/20/20
17	3.5 Obtain a range of results that will help make sure that experiment is generating satisfying results	2 days	Sun 9/20/20	Mon 9/21/20
18	3.6 Conclusion of the literature review	2 days	Mon 9/21/20	Tue 9/22/20

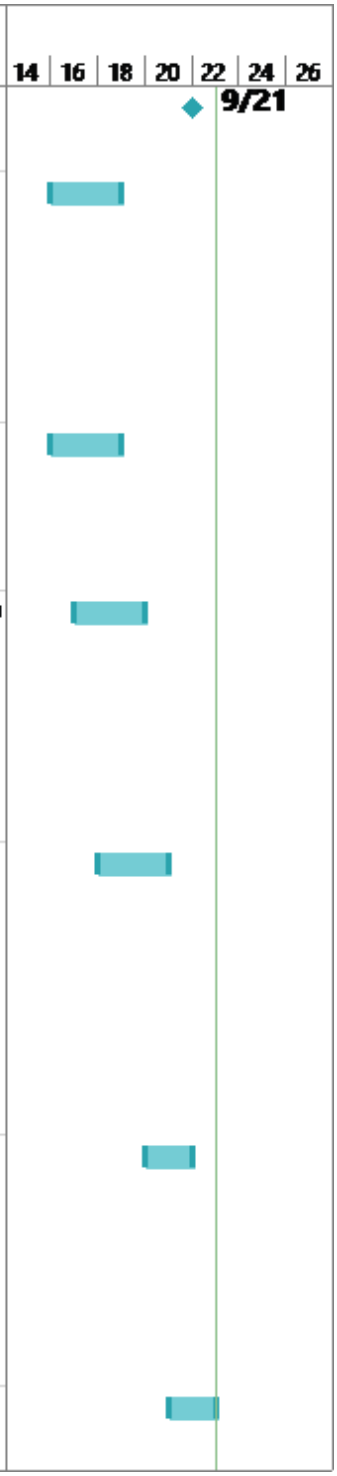


Figure 2.3 shows the Gantt chart of the Major task and its corresponding sub-tasks to complete the milestone for that task

ID	Task Name	Duration	Start	Finish
19	4. Functional Decomposition	5 days	Wed 9/23/20	Tue 9/29/20
20	4.1 Define the general function and what is to be accomplished by the	2 days	Wed 9/23/20	Thu 9/24/20
21	4.2 Define the main functions aof what is to be accomplished	3 days	Thu 9/24/20	Mon 9/28/20
22	4.3 Break each second level function into sub function until the point of	3 days	Sun 9/27/20	Tue 9/29/20

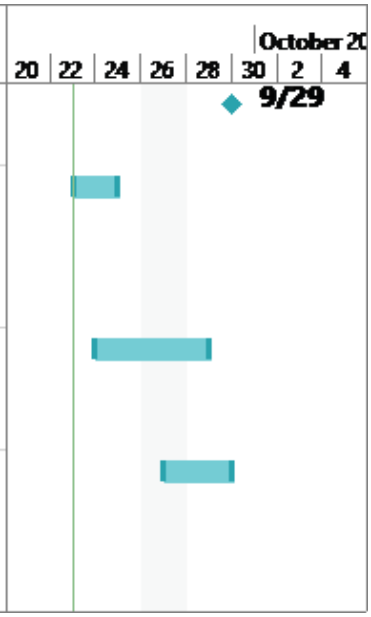


Figure 2.4 shows the Gantt chart of the Major task and its corresponding sub-tasks to complete the milestone for that task

ID	Task Name	Duration	Start	Finish
23	5. Concept Generation	4 days	Wed 9/30/20	Mon 10/5/20
24	5.1 Generating concepts using concept generation	3 days	Wed 9/30/20	Fri 10/2/20
25	5.2 Consolidating individual concepts and sketches into team concepts for each function.	2 days	Sat 10/3/20	Mon 10/5/20

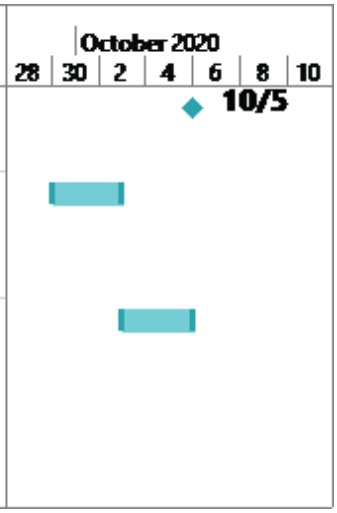


Figure 2.5 shows the Gantt chart of the Major task and its corresponding sub-tasks to complete the milestone for that task

ID	Task Name	Duration	Start	Finish
26	6. Concept evaluation stage	5 days	Wed 10/14/20	Tue 10/20/20
27	6.1 Select and acquire relevant information based on how it might relate	4 days	Wed 10/14/20	Mon 10/19/20
28	6.2 Decisions will be made based on a descriptive matrix evaluation method.	2 days	Mon 10/19/20	Tue 10/20/20

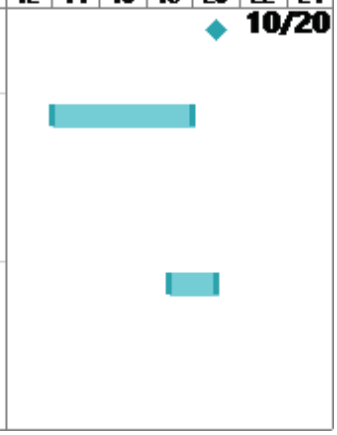


Figure 2.6 shows the Gantt chart of the Major task and its corresponding sub-tasks to complete the milestone for that task

ID	Task Name	Duration	Start	Finish
29	7. Preliminary Design	12 days	Wed 10/21/20	Thu 11/5/20
30	7.1 Select the proper tools needed for the experiment in order to give the desired results.	6 days	Wed 10/21/20	Wed 10/28/20
31	7.2 A proper method is chosen for each respective part so that the experiments give needed results as expected.	5 days	Mon 10/26/20	Fri 10/30/20
32	7.3 Defining 5 rules that are necessary for this experiment to function with the most accurate	3 days	Thu 10/29/20	Mon 11/2/20
33	7.4 List at least 10 rules that would make this experiment safe for consumers and environment.	4 days	Mon 11/2/20	Thu 11/5/20

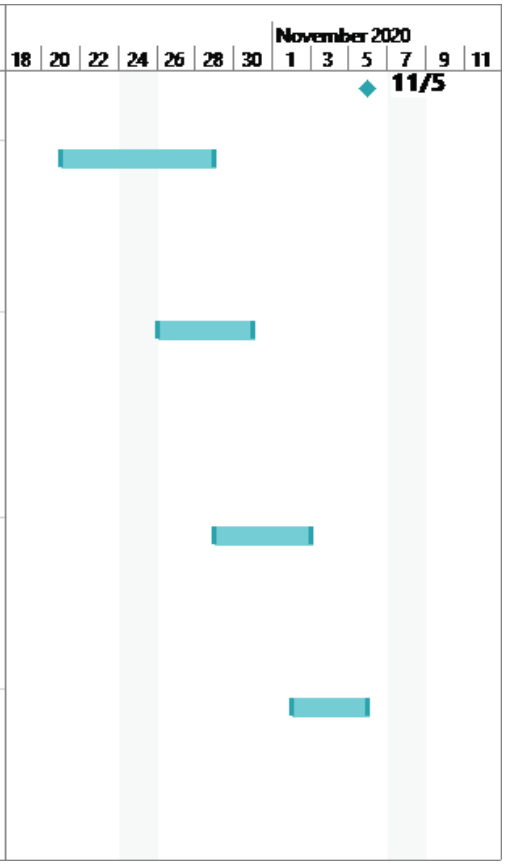


Figure 2.7 shows the Gantt chart of the Major task and its corresponding sub-tasks to complete the milestone for that task

ID	Task Name	Duration	Start	Finish
34	8. Detailed Design Analysis	12 days	Fri 11/6/20	Sat 11/21/20
35	8.1 Where the project has to be designed and analysed, it is essentially a decision-making process in which analytical tools are derived from basic	6 days	Fri 11/6/20	Fri 11/13/20
36	8.2 Where the different methods used have to be chosen and accommodated to its respective part of the	6 days	Fri 11/6/20	Fri 11/13/20
37	8.3 Where the different rules and ethics have to be applied in order to obtain the best of the product.	6 days	Thu 11/12/20	Thu 11/19/20
38	8.4 Where it must be made sure that the product is safe for consumers and that it will be used in its designated environment	6 days	Mon 11/16/20	Sat 11/21/20

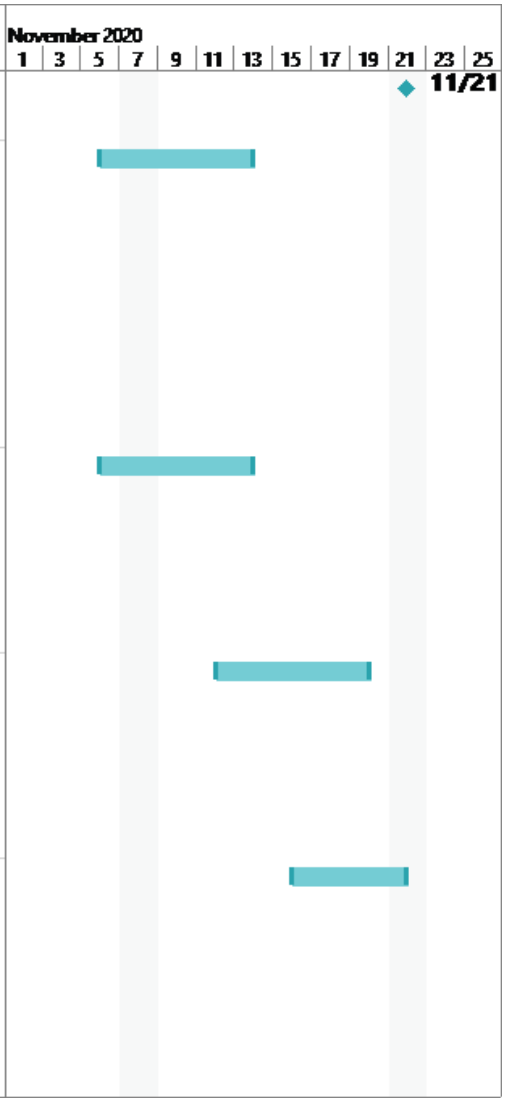


Figure 2.8 shows the Gantt chart of the Major task and its corresponding sub-tasks to complete the milestone for that task

ID	Task Name	Duration	Start	Finish
39	9. Detailed part Specification	14 days	Wed 11/11/20	Mon 11/30/20
40	9.1 Identify each part	14 days	Wed 11/11/20	Mon 11/30/20
41	9.2 Determine the utility of each part	7 days	Thu 11/12/20	Fri 11/20/20
42	9.3 Build each part	14 days	Wed 11/11/20	Mon 11/30/20

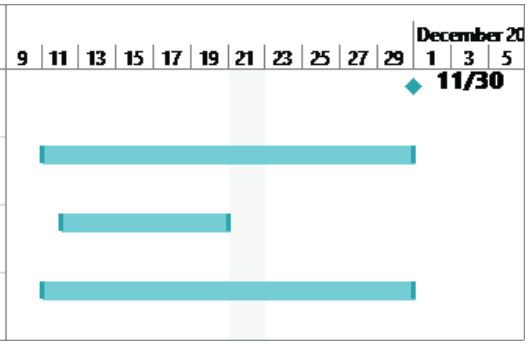


Figure 2.9 shows the Gantt chart of the Major task and its corresponding sub-tasks to complete the milestone for that task

ID	Task Name	Duration	Start	Finish	December 2020 1 3 5 7 9
43	10. Budget and Project cost	2 days	Wed 12/2/20	Thu 12/3/20	12/3
44	10.1 Determine the material needed and where it can be	2 days	Wed 12/2/20	Thu 12/3/20	
45	10.2 Identify every part that can be directly bought	1 day	Wed 12/2/20	Wed 12/2/20	
46	10.3 Identify the cost of the part that can be directly	1 day	Wed 12/2/20	Wed 12/2/20	
47	10.4 Add the supposed cost	1 day	Wed 12/2/20	Wed 12/2/20	
48	10.5 Set up a final budget	1 day	Wed 12/2/20	Wed 12/2/20	

Figure 2.10 shows the Gantt chart of the Major task and its corresponding sub-tasks to complete the milestone for that task

ID	Task Name	Duration	Start	Finish
49	11. Purchasing	11 days	Mon 1/25/21	Sat 2/6/21
50	11.1 list the companies or manufacturers that are able to build the parts needed to develop the product.	11 days	Mon 1/25/21	Sat 2/6/21
51	11.2 List the possible vendors or providers of the different parts needed for the project, contact them to get an estimate on the prices and	11 days	Mon 1/25/21	Sat 2/6/21
52	11.3 Come out with a budget of what they need and what they might not for the desirable project.	11 days	Mon 1/25/21	Sat 2/6/21
53	11.4 Pick the parts to satisfy their needs at lower cost possible and at the highest quality available.	11 days	Mon 1/25/21	Sat 2/6/21

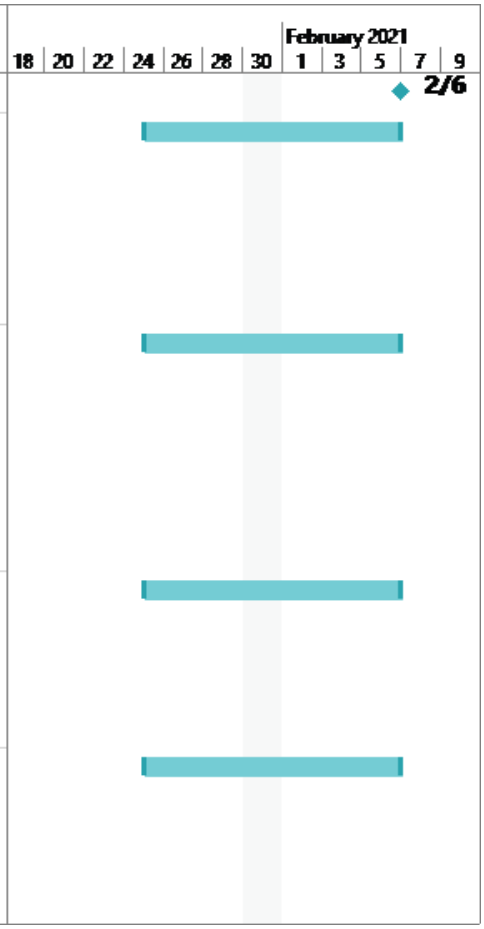


Figure 2.11 shows the Gantt chart of the Major task and its corresponding sub-tasks to complete the milestone for that task

ID	Task Name	Duration	Start	Finish
54	12. Manufacturing and Assembly of the Product	51 days	Sun 2/7/21	Fri 4/16/21
55	12.1 Prepare detailed codes and standards used in the project.	17 days	Sun 2/7/21	Sat 2/27/21
56	12.2 Establish a detailed plan for manufacturing and assembly of the product.	25 days	Sun 2/7/21	Thu 3/11/21
57	12.3 Risk assessment and identifications of critical issues for in depth analysis.	11 days	Thu 3/11/21	Thu 3/25/21
58	12.4 Assemble the parts to meet the project requirements.	8 days	Thu 3/25/21	Mon 4/5/21
59	12.5 Test the product and collect measurements and data	9 days	Tue 4/6/21	Fri 4/16/21

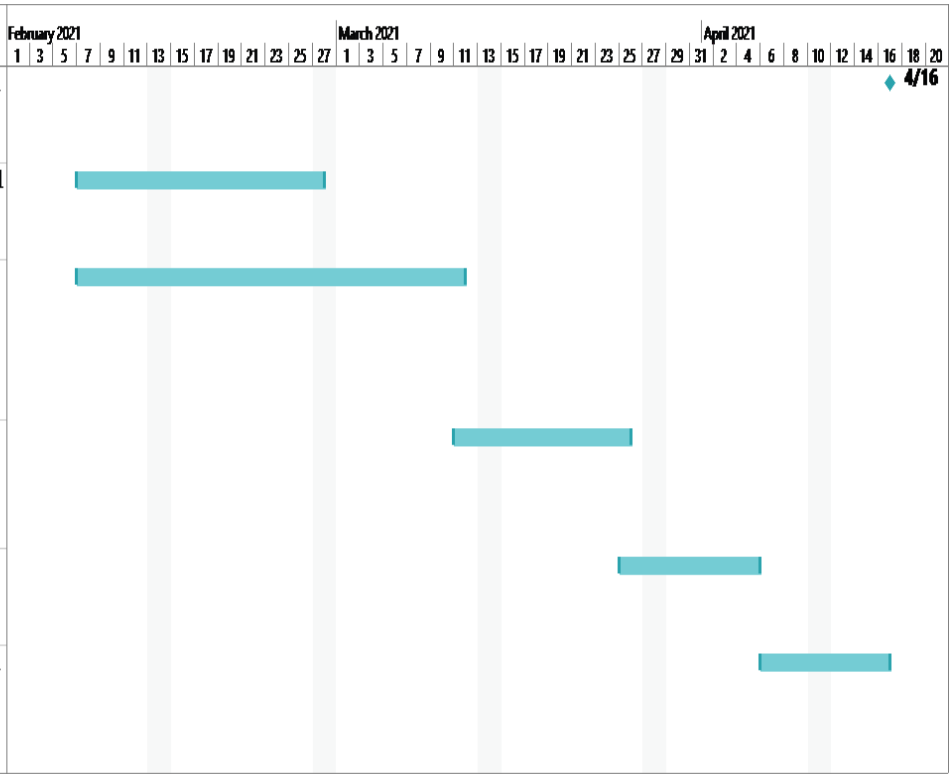


Figure 2.12 shows the Gantt chart of the Major task and its corresponding sub-tasks to complete the milestone for that task

ID	Task Name	Duration	Start	Finish
60	13. Final senior Design Presentation	19 days	Sat 4/17/21	Wed 5/12/21
61	13.1 Utilizing Microsoft Powerpoint, a specific slide will be incorporated defining	7 days	Sat 4/17/21	Sat 4/24/21
62	13.2 Reference the timeline and Gantt chart created earlier in the project. Create a list of steps taken to create our physical system.	5 days	Mon 4/19/21	Fri 4/23/21
63	13.3 Show our helpful documents conducted through individual research within the group pertaining to specific functions of the	6 days	Fri 4/23/21	Fri 4/30/21
64	13.4 Show various components of the system and explain why they have been chosen.	7 days	Sat 4/24/21	Sat 5/1/21
65	13.5 Show personal meeting notes with the project advisor and professors who have insight on this specific project. Show feedback given by professors who grade weekly	5 days	Tue 4/27/21	Mon 5/3/21
66	13.6 Create bullets points on the concept behind the experiment and its functionality and why it works on	7 days	Sat 5/1/21	Sat 5/8/21
67	13.7 Make a list of rules that were abided by that show rules were followed.	6 days	Wed 5/5/21	Wed 5/12/21

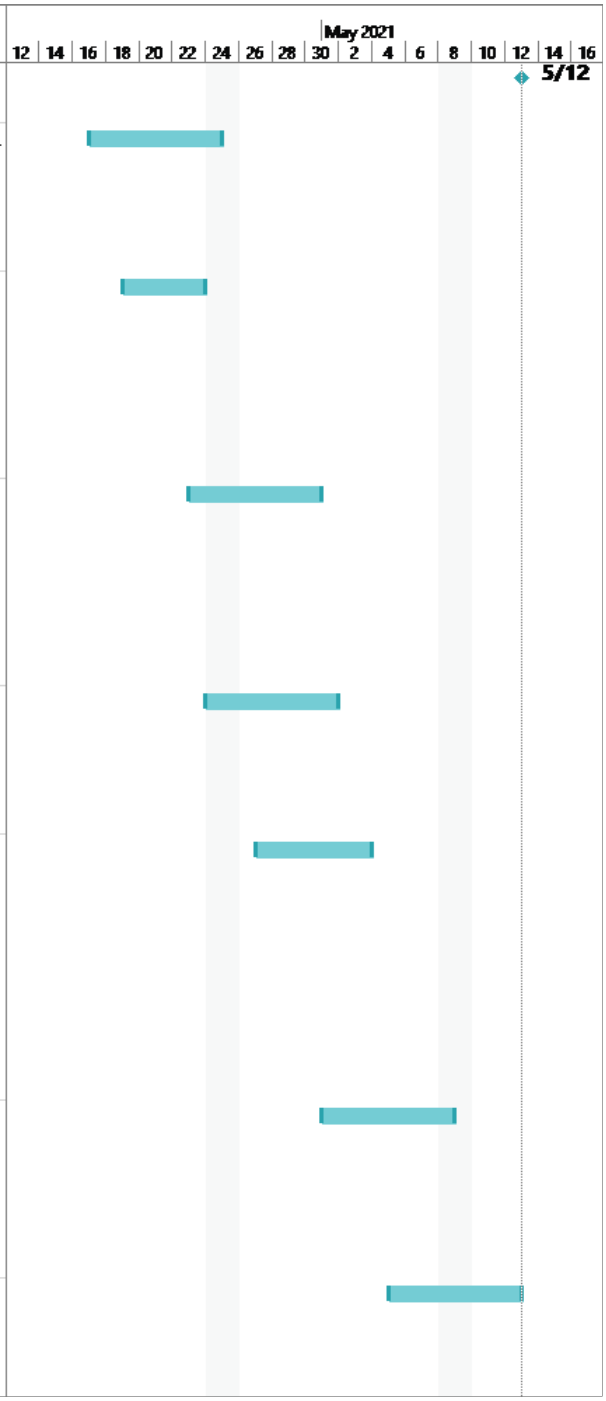


Figure 2.13 shows the Gantt chart of the Major task and its corresponding sub-tasks to complete the milestone for that task

Using the Gantt chart will help the group member to stay on top of the project and its tasks, we can easily access the Gantt chart to look at the day and what we are supposed to do and accomplish, this way is more efficient than looking for each major task and subtask individually. We were able to identify each task and what needs to be done to complete the milestone. Currently we completed the first 3 major tasks of the report as shown in Figure 2.1, 2.2, 2.3. At the moment we are completing the 4th major task as shown in Figure 2.4 and by looking at figure 2.5 we can tell by next week we have to start the work on the major task 5 and finish before October 5th, 2020 to be able to stick with the deliverables and the milestone of that task.

Note: Attach a copy of this assignment statement sheet to your homework (placed after the two cover sheets)

Assignment for Outcome 2

Recommended Reference for Assignment: **Successful Project Management by Gido & Clements, Chapter 4**

This is for you to know how this status report will be graded. We recommend grading yourself to ensure each part of the report has been done.

Grading Scheme for Project Planning Status Report

Project Group #3

Item	Description	Maximum Points	Your Score
1	**2.1 Task Identification** Description of how the Tasks were identified is provided Identification and detailed listing of tasks Appropriateness of tasks listed in relation to project	 5 5 5	
2	**2.2 Timeline** Description of how this section in timeline was done provided Start & end date and responsible person for each task provided	 5 5	
3	Objective defined for each task **in the table** Deliverables (concrete things to be delivered to group) clearly stated for each task **in the table**	5 15	
4	Tasks arranged in logical order of execution **in the table**	5	
5	**3.3 Gantt Charts** Gantt Chart for tasks and subtasks in Fall 2020 properly **formatted for printing and readable**. Legends provided and defined on Gantt Chart	 18 2	
6	Gantt Chart for tasks and subtasks in Spring 2021 properly formatted for printing and readable. Legends provided and defined on Gantt Chart	9 1	
7	Important milestones indicated on Gantt charts	5	
8	Indicated how Gantt chart will be used to monitor progress and stated/showed current project status on Gantt chart	5	
9	Progress report properly formatted as a complete "Project Planning Chapter" with all three subsections.	10	
	Total	**100**	

BELOW AVERAGE

SENIOR DESIGN & PROFESSIONALISM I

PROJECT PROGRESS REPORT COVER SHEET

Design and Fabricate the Suspension and Steering for Off-Road Vehicle (Dr. Jiang)

GROUP NUMBER: 8

Progress Report Title: Status Report 4 Project Planning

Due Date: 9/23/20

No	Group Member Name Group Member signature	Brief Description of Work Assigned to Member	% Completed by Member*	Your Score
1	Robert Barbee Robert Barbee	Responsible for creating the subtasks with objectives, deliverables and assigning roles	~~14.3~~	
2	Jonathan Horta Jonathon Horta	Responsible for assisting with tasks, deliverables, and interpretation of gantt chart on a table	~~14.~~3	
3	Todd Maxwell Todd Maxwell	Responsible for the detailed task that needed to be done, accurate time and duration of objectives. Also a detailed table summarizing project planning.	~~14.~~3	
4	Michael Samuel Michael Samuel	Responsible for creating the Gantt Chart & formulate the status report	~~14.~~3	
5	Aramis King Aramis King	Responsible for task identification and table analyzation	~~14.3~~	
6	Daniel Ward Daniel C. Ward	Responsible for task identification and detailed analysis of project tasks, subtasks and details	~~14.3~~	
7	Titus Woodard Titus Woodard	Responsible for detailed timeline information involving objectives, deliverables and completion of task.	~~14.3~~	

COLLEGE OF ENGINEERING
SENIOR DESIGN & PROFESSIONALISM I
FALL 2020 SEMESTER
Progress Report on Project Planning for Fall 2020 and for Spring 2021

Assigned: 09/09/2020 **Due: 09/23/2020**

This status report covers the information on the Project Planning and Task Identification chapter of the project report. Consequently, it should be written in a detailed descriptive form as we discussed in class for the assignment #2. The report should be prepared using the chapter title.

" 2. PROJECT PLANNING AND TASK DEFINITION". The subsections highlighted in blue fonts should be used in the status report.

In answering these five questions, copy the specific question followed by your response.

2.1 Task identification

1. Identify and make a **detailed** list of tasks (detailed activities that need to be performed) needed for the successful completion of your design this semester and continuation tasks for next semester. Provide more details on the tasks for this semester. As an introduction to this section, **provide a description of how the tasks were identified.**

2.2 Timeline

2. For each task state the objective(s) [defined as information to be refined or developed and communicated to others, not activities to be performed] and the specific deliverables [Noun things] needed to be provided to indicate the completion of the task, and indicate the responsible group member(s) , and estimate of time for the task. **Describe in greater detail, how this section was done as an introduction to this section.**

3. Arrange your tasks in the order that they need to be performed, and indicate the starting time, ending time, and the duration in hours for each task. **Describe in greater details how this section was done.**

NOTE: The description for items 1 through 3 should be provided and then Questions 1, 2, and 3 should be summarized in a Table format similar to the example provided in Table 1 below. This is a major part of this homework, and the table shows major tasks and how a major task should be broken into several logical subtasks. The objectives, deliverables, duration, and personnel should be provided for each subtask for a comprehensive project planning. Some of the major tasks (drawn from the design topics in the syllabus and the Project manual which you all should have consulted) have been included in Table 1 and you need to provide **additional tasks and detailed subtasks relative to your project** to complete this part of the assignment**.**

2.3 Gantt Chart

4. Using a project management software construct (i) a detailed Gantt chart for the tasks to be done this Fall 2020 semester and (ii) a detailed Gantt chart for the tasks to be done in the Spring 2020 semester**. Indicate all important milestones (**a milestone is simply a way to mark an important point in the project**) on each Gantt chart**. In addition to the milestones from your group, consult the syllabus and include important milestones listed in it.

Note: The Gantt chart should be done using Microsoft Projects Software or a similar project management software. In addition, the Gantt chart should be properly constructed and should be printed in sections showing only the details for that section after hiding the unwanted sections.

5. Indicate how you will use the Gantt chart to monitor the progress of the project, and indicate the current progress on the Gantt chart.

Note: Attach a copy of this assignment statement sheet to your homework (placed after the two cover sheets)

Assignment for Outcome 2

Recommended Reference for Assignment: **Successful Project Management by Gido & Clements, Chapter 4**

This is for you to know how this status report will be graded. We recommend grading yourself to ensure each part of the report has been done.

Grading Scheme for Project Planning Status Report

Project Group #___8___

Item	Description	Maximum Points	Your Score
1	**2.1 Task Identification** Description of how the Tasks were identified is provided Identification and detailed listing of tasks Appropriateness of tasks listed in relation to project	 5 5 5	
2	**2.2 Timeline** Description of how this section in timeline was done provided Start & end date and responsible person for each task provided	 5 5	
3	Objective defined for each task **in the table** Deliverables (concrete things to be delivered to group) clearly stated for each task **in the table**	5 15	
4	Tasks arranged in logical order of execution **in the table**	5	
5	**3.3 Gantt Charts** Gant Chart for tasks and subtasks in Fall 2020 properly **formatted for printing and readable**. Legends provided and defined on Gantt Chart	 18 2	
6	Gant Chart for tasks and subtasks in Spring 2021 properly formatted for printing and readable. Legends provided and defined on Gantt Chart	9 1	
7	Important milestones indicated on Gantt charts	5	
8	Indicated how Gantt chart will be used to monitor progress and stated/showed current project status on Gantt chart	5	
9	Progress report properly formatted as a complete "Project Planning Chapter" with all three subsections.	10	
	Total	**100**	

PROJECT PLANNING AND TASK DEFINITION

This chapter is about how ~~we~~ are going to go through the tasks in greater detail. This chapter will also contain how ~~we~~ came up with the tasks and subtasks and how ~~we~~ came up with the order of those tasks with deadlines.

2.1 Task identification

Identify and make a **detailed** list of tasks (detailed activities that need to be performed) needed for the successful completion of your design this semester and continuation tasks for next semester. Provide more details on the tasks for this semester. As an introduction to this section, **provide a description of how the tasks were identified.**

During the semester there are tasks that need to be completed during set time windows to ensure that we meet deadlines set by project owner's and advisors. With each of these tasks there are a set of activities which need to be performed to ensure completion. These specified tasks were identified by collaborating on the weekly team zoom call along with the Baja Project president and board members and were distributed accordingly. Each individual within the group was assigned a specific task based on the previously constructed Gantt Chart. The first task is to complete the project scope. The activities that are involved with this task is to define the objective and create the project formulation which goes in detail regarding the formulation of the project scope, problem statement and other various deliverables, including the identification of the client, needs, constraints, goals and objectives. The second task is project planning in which the Gantt Chart and objective tree will be constructed with emphasis on the identification of the team's tasks and overall project timeline. The third task is to complete the literature review, and this will be conducted finding the details needed and identify the sources to ensure our literature review is accurate and organized with coherent facts and information needed. The next tasks will be the functional decomposition as well as the generation and evaluation of concepts. The final tasks that will need to be completed is the preliminary and detailed design. These tasks will be the most time consuming and have the highest number of activities that need to be completed. These activities consist of reviewing codes and standards that must be met, analysis of equations and specified parameters; taking in consideration other underlying factors regarding safety and welfare, CAD design for prototype model, and complete an analysis on the prototype. The project tasks, subtasks and activities associated with each task are listed below.

~~2.1.1 Project Tasks, Subtasks and Details~~

- Problem Formulation
  - ~~Project scope~~ - primary focus and expected results
  - ~~Problem statement~~ - determination of problem and applied tasks
  - Identify the client - who does this project serve

    - Identify the needs - determine measurable performance characteristics of design
    - ~~Project goals and objectives~~ - arrange characteristics into higher/lower level objectives; utilizing tree structures to determine hierarchy and interconnections
    - Identify the constraints and operating environments - permissible range and parameters
- Project Planning
    - Task identification - identification of major tasks and needs
    - ~~Timeline~~ - length of tasks
    - ~~Gantt chart~~ - organization of timeline based on specified tasks
    - Detailed Project Tasks, Objectives, Deliverables, Task Duration & Responsible Personnel - detailed table of actions that should be taken by each individual
- Literature Review
    - Identify information needed - important project information and details
    - Identify sources - necessary source location
    - ~~Composing the literature review~~ - full review of relevant information found
- Functional Decomposition
    - Identify functions and subfunctions - list of all functions
    - ~~Functional decomposition diagram~~ - graph of related functions
- Concept Generation
    - Individual concept generation - each team member develops their own concept of design functions
    - Group concept generation - combined ideas of group developed by individual functions
- ~~Concept Evaluation~~
    - Using multiple evaluation techniques - concepts developed by stated methods
    - Using techniques to arrive at overall design - mentioned techniques and methods to produce the design
- Preliminary Design
    - Review codes and standards - relevant codes and specifications that must be followed
    - Identify analysis equations - list of critical equations needed for design specifications
    - Perform engineering detailed analysis needed to size and specify parameters for selecting parts and components - Sketches based on calculations
    - Consider public health, safety, welfare and other factors in the design - design must meet needs and provide a safe environment for personnel
- ~~Detailed Design~~
    - NX and CAD models - 3D modeling of parts and components

2.2 Timeline

For each task state the objective(s) [defined as information to be refined or developed and communicated to others, not activities to be performed] and the specific deliverables [Noun things] needed to be provided to indicate the completion of the task, and indicate the responsible group member(s) , and estimate of time for the task. **Describe in greater detail, how this section was done as an introduction to this section.**

Arrange your tasks in the order that they need to be performed, and indicate the starting time, ending time, and the duration in hours for each task. **Describe in greater details how this section was done.**

Tasks that are assigned are collaborated and agreed upon by each group member. Reading over the syllabus during our first meeting really helped us organize assigned tasks and deliverables throughout both semesters. We also took upon ourselves to individually find resources such as articles, videos and previous reports so that we get different perspectives on how to attack each objective. This will help us gradually complete every topic on time. During our meetings with Dr. Jiang and Dr. Peng we asked the necessary questions to keep our reports as detailed and efficient as possible. Their experience and feedback really helped make sure our divided roles, assignments and objectives were not disorganized. Lastly, meeting with The Baja Club regularly really helps complete all goals including putting in extra hours, understanding the total design and most importantly having every group member participate and be hands on. The gantt chart and table 1 are our exact goals and deadlines needed to be successful in this design.

Below is a brief description and synopsis of timeline, that includes the duration period for the different objectives given along with the duration it takes to complete this task and which team member participated. We have prepared for the duration of the Steering and Suspension of an Off-road motor vehicle, breaking the sections down throughout the different group members, some objectives have been assigned due to the strong area of expertise that individuals have. As well as some areas are assigned through collaboration of team members to better understand given tasks.

1.1 Project Scope

- **To identify the client with what is set out to be completed**
- **Duration: 7 days 9/3/20-9/10/20 Robert Barbee**

1.2 Problem statement

- **To determine the problem and the task that will be taken to solve the problem**
- **Duration: 7 days 9/3/20-9/10/20 Jonathon Horta**

` 1.3 Identify the client

- **To identify the client what is the purpose behind the project**
- **Duration: 7 days 9/3/20-9/10/20 Michael Samuel**

1.4 Identify the needs

- **To define measurable performance characteristics of design**
- **Duration: 7 days 9/3/20-9/10/20 Aramis King**

1.5 Project goals and objectives

- **To arrange performance characteristics into higher-level & lower-level objectives in diagrammatic tree structure showing hierarchical relationships and interconnections**
- **Duration: 7 days 9/3/20-9/10/20 Titus Woodard/ Daniel Ward**

1.6 Identify constraints and operating environments

- **To identify the permissible range of the design and performance parameters and the operating environment**
- **Duration: 7 days 9/3/20-9/10/20 Todd Maxwell**

2.1 Task identification

- **To identify the major tasks that need be completed for the project**
- **Duration: 14 days 9/10/20-9/24/20 Aramis King/ Daniel Ward**

2.2 Timeline

- **Develop a timeline for the length of how long each task should take**
- **Duration: 14 days 9/10/20-9/24/20 Todd Maxwell /Titus Woodard**

2.3 Gantt Chart

- **Create a Gantt Chart based off the timeline developed**
- **Duration: 14 days 9/10/20-9/24/20 Michael Samuel**

2.4 Detailed Project Tasks, Objectives, Deliverables, Task Duration & Responsible Personnel

- **Create a detailed table based off the Gantt chart and actions taken for the project**
- **Duration: 14 days 9/10/20-9/24/20 Jonathon Horta/ Robert Barbee**

3.1 Identify information needed

- **To identify important information needed for the project**
- **Duration: 12 days 9/17/20-9/29/20 Robert Barbee/ Jonathon Horta/Michael Samuel**

3.2 Identify sources

- **To identify where the important project information will be coming from**
- **Duration: 12 days 9/17/20-9/29/20 Jonathon Horta/Robert Barbee/ Daniel Ward**

3.3 Composing the literature review

- **Create a full literature review with all relevant information found**
- **Duration: 12 days 9/17/20-9/29/20 Todd Maxwell/ Titus Woodard/ Aramis King**

4.1 Identify functions and subfunctions

- **To create a list that contains all functions**
- **Duration: 7 day 9/23/20-9/30/20 Jonathon Horta/ Robert Barbee/ Daniel Ward**

4.2 Functional decomposition diagram

- **Compose a graph showing how all functions are related to each other**
- **Duration: 7 day 9/23/20-9/30/20 Michael Samuel/Todd Maxwell**

5.1 Individual Concept Generation

- **Each member creates their own concept of functions for a design**
- **Duration: 7 days 9/30/20-10/07/20 Everyone**

5.2 Group Concept Generation

- **The group combining their ideas to come up with all functions**
- **Duration: 14 days 9/30/20-10/14/20 Everyone**

6.1 Using multiple Evaluation techniques

- **Evaluate concepts using multiple methods including feasibility study, go-no-go, and decision matrix**
- **Duration: 7 days 10/14/20-10/20/20 Robert Barbee/ Michael Samuel**

6.2 Using techniques to arrive at the overall design

- **Apply concept evaluation techniques for each function to get to an overall design**

- **Duration: 3 days 10/20/20-10/23/20 Jonathon Horta/ Todd Maxwell**

7.1 Review codes and standards

- **Pull up relevant codes and standards that should be followed throughout the project**
- **Duration: 1 days 10/21/20-10/22/20 Jonathon Horta**

7.2 Identify analysis equation

- **Find list of equations critical to project that is needed to come up with the design**
- **Duration: 3 days 10/22/20-10/25/20 Robert Barbee/ Daniel Ward**

7.3 Perform engineering detailed analysis needed to size and specify parameters for selecting parts and components

- **Sketch the idea of the design based of calculations**
- **Duration: 8days 10/24/20-11/1/20 Robert Barbee/ Daniel Ward**

7.4 Consider public health, safety, welfare, and other factors in the design

- **Make sure design is not harmful to the environment or the public**
- **Duration: 5 days 10/30/20-11/4/20 Titus Woodard/ Aramis King**

8.1 Use NX or CAD to model parts and components

- **Create a NX model for all the parts of the system**
- **Duration: 8 days 11/4/20-11/12/20 Michael Samuel**

8.2 Assemble all parts and components

- **Assemble all parts of the system to show our design**
- **Duration: 3 days 11/10/20-11/13/20 Robert Barbee**

8.3 Use analysis software to test individual/whole assembly

- **Use Ansys to run stress tests to see how the system relates to our calculations**
- **Duration: 5 days 11/12/20-11/17/20**

8.4 Making changes to design

- **Make changes in design based on the analysis tests to make a suitable and passing system**
- **Duration: 2 days 11/17/20-11/19/20**

9.1 Use NX or CAD software to create detailed drawings

- **Use Nx software to come up with detailed drawings of all parts and assemblies**
- **Duration: 10 days 11/4/20-11/14/20 Jonathon Horta**

9.2 Apply drawing standards to drawings

- **Make sure drawings are up to standards**
- **Duration: 6 days 11/14/20-11/20/20**

10.1 Project cost analysis

- **Determine the price of all parts in the system**
- **Duration: 7 days 10/21/20-11/4/20 Jonathon Horta**

10.2 Part specifications needed

- **Determine the parts needed to be ordered**
- **Duration: 7 days 10/21/20-11/4/20 Aramis King/ Daniel Ward**

10.3 Receiving vendor quotes

- **Research companies that can make the parts needed for the system**
- **Duration: 7 days 10/21/20-11/4/20 Robert Barbee/ Michael Samuel**

11.1 Prepare detailed drawings to meet prototype requirements

- **Gather all information that will be sent to companies to produce our parts/materials**
- **Duration: 7 days 2/19/21-2/26/21 Titus Woodard**

11.2 Discussion of timelines for equipment on order

- **Discuss when we need to order each part to fit our timeline to begin fabricating our system**
- **Duration: 7 days 2/19/21-2/26/21 Robert Barbee**

11.3 Selection of vendors for components

- **Choose which companies we will be outsourcing from**
- **Duration: 7 days 2/19/21-2/26/21**

12.1 Detailed plans on manufacturing and assembly of system

- **Create a detailed plan stating the order of how we are going to assemble the parts**
- **Duration: 34 days 2/26/26-4/1/21 Robert Barbee**

12.2 Conduct testing in the lab

- **Find real world testing techniques to run on the system**
- **Duration: 34 days 2/26/21-4/1/21**

12.3 Test system on Chassis

- **Weld system to chassis to see performance of our design**
- **Duration: 34 days 2/26/21-4/1/21 Daniel Ward/ Aramis King**

13.1 Complete each part of the report along the way

- **To complete each section of the report as we are finishing each assignment**
- **Duration: 28 days 04/1/21-04/29/21 Everyone**

13.2 Create a project poster for visual representation

- **Create a project poster and PowerPoint for presentation**
- **Duration: 28 days 04/1/21-04/29/21 Michael Samuel**

13.3 Prepare for presentation

- **Prepare how we are going to present the information from the overall experience of this project**
- **Duration: 28 days 04/1/21-04/29/21 Everyone**

2.3 Gantt Chart

1. Using a project management software construct (i) a detailed Gantt chart for the tasks to be done this Fall 2020 semester and (ii) a detailed Gantt chart for the tasks to be done in the Spring 2020 semester**. Indicate all important milestones (**a milestone is simply a way to mark an important point in the project**) on each Gantt chart**. In addition to the milestones from your group, consult the syllabus and include important milestones listed in it.
2. Indicate how you will use the Gantt chart to monitor the progress of the project, and indicate the current progress on the Gantt chart.

(i) This figure is to show how long each of the tasks/subtasks should take for the semester.



Figure 2.1: ~~This Figure shows the the gantt chart for major tasks 1-6~~

(ii) This figure is a rough estimate for next semester of the major tasks/subtasks in chronological order.

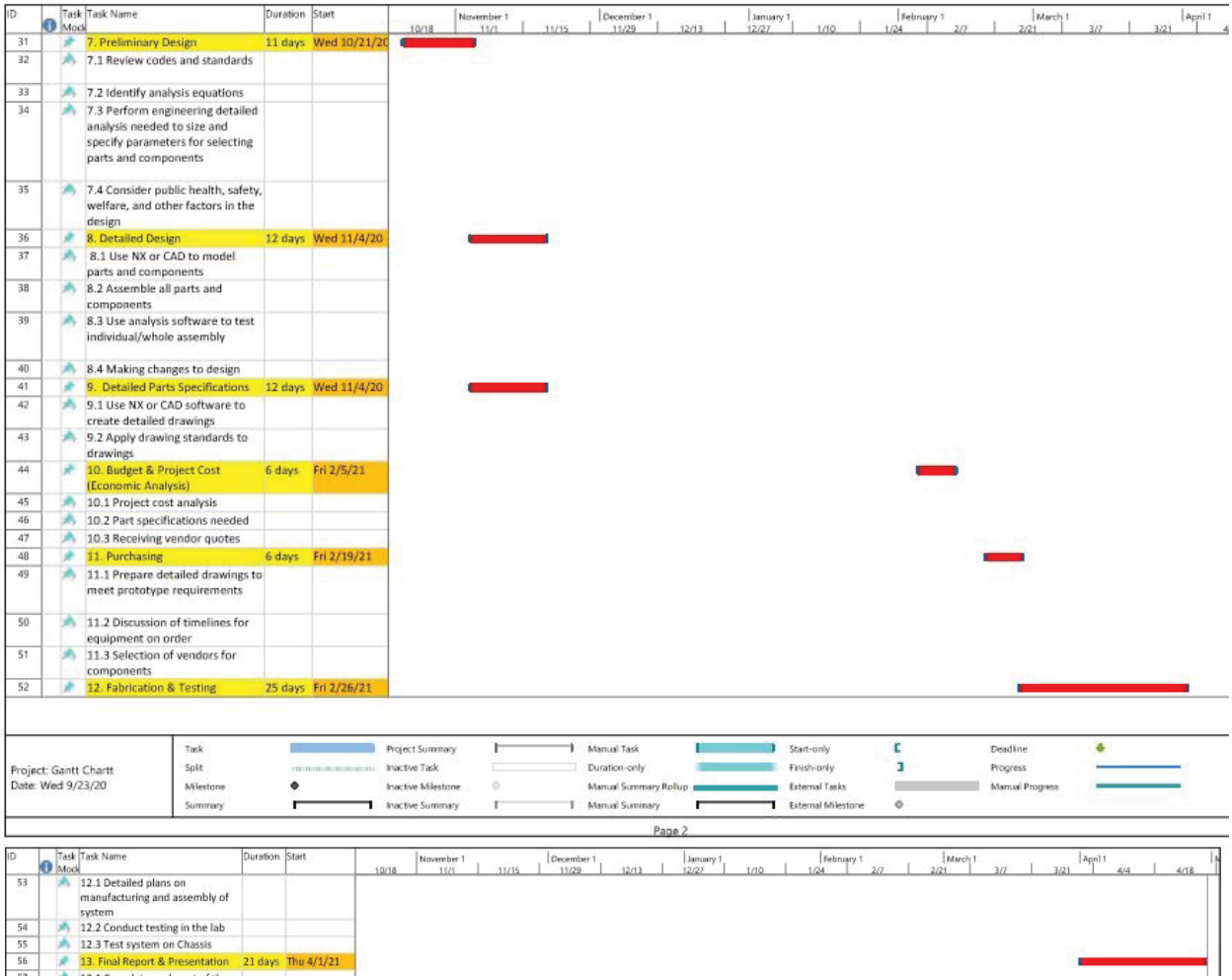


Figure 2.2: ~~This Figure shows the the gantt chart for major tasks 7-13~~

We will use the gantt chart to make sure we are completing tasks on time. Also, to document all of the start and end date of each task. With roles assigned to each member, it is easy for each member to know when they need to start the task and the deadline for that task. The member assigned the role will be able to wrap up each task or know when to ask for help if the deadline is approaching. This gantt chart will allow us to stay focused on the project and show everyone what is in progress and what is next to start.

(iii) This is a detailed table of each major task with its subtasks. It also includes the objectives, deliverables, the duration of the task, start/ end date, and the person it was assigned to.

~~Table 1~~ Detailed table for Tasks, Objectives, and Deliverables

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
1. Problem Formulation	1.1 Project Scope	To identify the client with what is set out to be completed	A description of what major points should be focussed on throughout the project and what are the expected results	7	9/3/20	9/10/20	Robert Barbee
	1.2 Problem statement	To determine the problem and the task that will be taken to solve the problem	Complete description of the problem behind this project and how it will be solved	7	9/3/20	9/10/20	Jonathon Horta
	1.3 Identify the client	To identify the client what is the purpose behind the project	A structured statement that defines the overall project goal	7	9/3/20	9/10/20	Michael Samuel
	1.4 Identify the needs	To define measurable performance characteristics of design	A list of all measurable performance characteristics with units	7	9/3/20	9/10/20	Aramis King
	1.5 Project goals and objectives	To arrange performance characteristics into higher-level & lower-level objectives in diagrammatic tree structure showing hierarchical relationships and interconnections	Well drawn and labelled objective tree showing hierarchical relationships and interconnections of the performance characteristics.	7	9/3/20	9/10/20	Titus Woodard/ Daniel Ward
	1.6 Identify constraints and operating environments	To identify the permissible range of the design and performance parameters and the operating environment	A list of permissible range for the design parameters, description of the environment in which the design will operate.	7			Todd Maxwell

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
2. Project Planning	2.1 Task identification	To identify the major tasks that need be completed for the project	Complete a list including the project's major tasks	14	9/10/20	9/24/20	Aramis King/ Daniel Ward
	2.2 Timeline	Develop a timeline for the length of how long each task should take	List of tasks with the estimated time to complete to be transferred to a Gnatt chart	14	9/10/20	9/24/20	Titus Woodard/Todd Maxwell
				14	9/10/20	9/24/20	Michael Samuel
	2.3 Gantt Chart	Create a Gantt Chart based off the timeline developed	Gantt Chart With actual time to complete tasks as well as estimated time to complete the tasks	14	9/10/20	9/24/20	Jonathon Horta/ Robert Barbee
	2.4 Detailed Project Tasks, Objectives, Deliverables, Task Duration & Responsible Personnel	Create a detailed table based off the Gantt chart and actions taken for the project	Complete a table including specific information for all portions of the project				
3. Literature Review	3.1 Identify information needed	To identify important information needed for the project	Complete a description of important information needed for project	13	9/17/20	9/29/20	Robert Barbee/ Jonathon Horta/ Michael Samuel
	3.2 Identify sources	To identify where the important project information will be coming from	Create a list of sources used	13	9/17/20	9/29/20	Jonathon Horta/Robert Barbee/ Daniel Ward
	3.3 Composing the literature review	Create a full literature review with all relevant information found	A Finalized literature review	3	9/27/20	9/30/20	Todd Maxwell/ Titus
4. Functional Decomposition	4.1 Identify functions and subfunctions	To create a list that contains all functions	A detailed listed of all functions	4	9/23/20	9/27/20	Jonathon Horta/ Robert Barbee/ Daniel Ward
	4.2 Functional decomposition diagram	Compose a graph showing how all functions are related to each other	Create a diagram that shows functions and their sub-functions and how they relate to each other	4	9/27/20	10/1/20	Michael Samuel/Todd Maxwell

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
5. Concepts Generation	5.1 Individual Concept Generation	Each member creates their own concept of functions for a design	A concept list of functions for a design	8	9/30/20	10/7/20	Everyone
	5.2 Group Concept Generation	The group combining their ideas to come up with all functions	Collaborating all concepts with each member to form a full function list for consideration of a design	15	9/30/20	10/14/20	Everyone
6. Concept Evaluation	6.1 Using multiple Evaluation techniques	Evaluate concepts using multiple methods including feasibility study, go-no-go, and decision matrix	Positive evaluation results which push our project to its design stage	6	10/14/20	10/20/20	Robert Barbee/ Michael Samuel
	6.2 Using techniques to arrive at the overall design	Apply concept evaluation techniques for each function to get to an overall design	A list of functions tested to make sure all functions were considered and the design stage may now begin	3	10/20/20	10/23/20	Jonathon Horta/ Todd Maxwell

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
7. Preliminary Design	7.1 Review codes and standards	Pull up relevant codes and standards that should be followed throughout the project	Provide a list of standards that were followed to approve our design	1	10/21/20	10/22/20	Jonathon Horta
	7.2 Identify analysis equations	Find list of equations critical to project that is needed to come up with the design	Provide a list of equations that we used to come up with our design	3	10/22/20	10/25/20	Robert Barbee/ Daniel Ward
	7.3 Perform engineering detailed analysis needed to size and specify parameters for selecting parts and components	Sketch the idea of the design based of calculations	A beginning sketch of our design based on the calculation and standards for the system	8	10/24/20	11/1/20	Robert Barbee/ Daniel Ward
	7.4 Consider public health, safety, welfare, and other factors in the design	Make sure design is not harmful to the environment or the public	Considerations that were made to the design for the safety of everyone	5	10/30/20	11/4/20	Titus Woodard/ Aramis King

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
8. Detailed Design	8.1 Use NX or CAD to model parts and components	Create a NX model for all the parts of the system	A NX or CAD model of all the individual parts	8	11/4/20	11/12/20	Micheal Samuel
	8.2 Assemble all parts and components	Assemble all parts of the system to show our design	An assembly of all of the parts	3	11/10/20	11/13/20	Robert Barbee
	8.3 Use analysis software to test individual/whole assembly	Use Ansys to run stress tests to see how the system relates to our calculations	Stress analysis test results which determine if we need to make changes to our design	5	11/12/20	11/17/20	Aramis King
	8.4 Making changes to design	Make changes in design based on the analysis tests to make a suitable and passing system	Updated design with passing stress tests	2	11/17/20	11/19/20	Todd Maxwell
9. Detailed Parts Specifications	9.1 Use NX or CAD software to create detailed drawings	Use Nx software to come up with detailed drawings of all parts and assemblies	Detailed drawings of all parts and assemblies	10	11/4/20	11/14/20	Daniel Ward
	9.2 Apply drawing standards to drawings	Make sure drawings are up to standards	Drawings that will be used to send to vendors for quotes	6	11/14/20	11/19/20	Jonathon Horta
10. Budget & Project Cost (Economic Analysis)	10.1 Project cost analysis	Determine the price of all parts in the system	A table showing total cost of the project and the cost of all individual parts	3	2/05/21	2/8/21	Jonathon Horta
	10.2 Part specifications needed	Determine the parts needed to be ordered	A list of all the parts needed to be ordered and their detailed drawings	3	2/5/21	2/8/21	Aramis King/ Daniel Ward
	10.3 Receiving vendor quotes	Research companies that can make the parts needed for the system	A List of at Least 3 companies we will send our drawings to	4	2/8/21	2/12/21	Robert Barbee/ Michael Samuel

Major Tasks Description	Sub-Task Description	Objective(s) for Task	Deliverables to be Submitted	Duration (Days)	Start date	End Date	Primary Responsible Person
11. Purchasing	11.1 Prepare detailed drawings to meet prototype requirements	Gather all information that will be sent to companies to produce our parts/materials	A list that was sent to the company for the fabrication of our parts	7	2/19/21	2/26/21	Titus Woodard
	11.2 Discussion of timelines for equipment on order	Discuss when we need to order each part to fit our timeline to begin fabricating our system	A table of when all of the parts that will be needed to order from third party companies	7	2/19/21	2/26/21	Robert Barbee
	11.3 Selection of vendors for components	Choose which companies we will be outsourcing from	A list of companies that we ordered from	7	2/19/21	2/26/21	Michael Samuel
12. Fabrication & Testing	12.1 Detailed plans on manufacturing and assembly of system	Create a detailed plan stating the order of how we are going to assemble the parts	A Timeline of how we are going to assemble the system	34	2/26/21	4/1/21	Robert Barbee
	12.2 Conduct testing in the lab	Find real world testing techniques to run on the system	Results from our system with found techniques that are used in automobile industries	34	2/26/21	4/1/21	Todd Maxwell Daniel Ward/ Aramis King
	12.3 Test system on Chassis	Weld system to chassis to see performance of our design	The success of our system ran on homemade obstacle course	34	2/26/21	4/1/21	
13. Final Report & Presentation	13.1 Complete each part of the report along the way	To complete each section of the report as we are finishing each assignment	A final report of all the work done to successfully finish our system	28	4/1/21	4/29/21	Everyone
	13.2 Create a project poster for visual representation	Create a project poster and PowerPoint for presentation	A poster and PowerPoint to visualize our system and how we achieved it	28	4/1/21	4/29/21	Michael Samuel
	13.3 Prepare for presentation	Prepare how we are going to present the information from the overall experience of this project	Presented our project with the desirables of the panel	28	4/1/21	4/29/2021	Everyone