

**PRAIRIE VIEW A&M UNIVERSITY
ROY G. PERRY COLLEGE OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING
MCEG 4316- ST Fundamental and Applications of Renewable Energy
Spring 2022**

- 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
- II. TESTS**
Summary of Topics covered by Test
Original Test Questions & Master Solution/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)
- III. LABORATORY REPORTS**
Summary of Topics covered by lab
Laboratory Handout/Instructions and Grading Scheme
Above Average (Graded original work)
Average (Graded original work)
Below Average (Graded original work)
- IV. PROJECT**
Summary of Topics Covered by Project
Project Problem Statement and Grading Scheme
Above Average (Graded original work)
Average (Graded original work)
Below Average (Graded original work)

[Include any other evaluation used and omit any method above method (Test, Quizzes, Homework, Laboratory and Project reports) that was not used]

(Note: All Pages shown in Yellow should be printed on YELLOW PAPER)

Course Description in ABET Format

MECHANICAL ENGINEERING DEPARTMENT

MCEG 4316 ST Fund. And Appl. Of Renewable Energy

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

1.	Course number and name:	ST Fund. And Appl. Of Renewable Energy – MCEG 4316 – P19
2.	Credits and contact hours:	3 credit hours; 3 contact hours
3.	Instructor's or course coordinator's name:	Dr. Shahin Shafiee
4.	Text book: Title:	M. Kanoglu, Y. Cengel , J. Cimbala, Fundamentals and Applications of Renewable Energy, McGrawHill, ISBN 978-1-260-45530-4
	Author:	
	Publisher, Year & Edition:	
	a. Other Supplemental material	Experimental Methods for Engineers by J. P. Holman, 7 th Edition, McGraw Hill, 2001. ISBN-13: 9780073660554
5.	Specific course information	
	a. Brief description of the content of the course (catalog description)	MCEG 4316. Special topic on Fundamentals and Applications of Renewable Energy (0-3) Credit 3 semester hour. This course includes introduction to several renewable energy resources including solar, wind, geothermal, hydropower, hydrogen and fuel cells, and biomass
	b. Prerequisites or Co-requisites	MCEG 3302 Thermodynamics 2 MCEG 3306 Fluid mechanics MCEG 3301 Heat transfer
	c. *Indicate whether a required, elective, or selected elective (as per definition provided) course in the program	Selected elective
6.	Specific goals for the course	Students will be able to :
	a. Specific outcomes of instruction (e.g. the student will be able to explain the significance of current research about a particular topic.)	Have a working knowledge of fundamentals of renewable energy resources Be able to compute basic renewable sourced power for various loads and component energy consumption using fundamental heat and mass balances on system components Be familiar with industry standard methodologies for calculating renewable sourced power generation for different applications
	b. Explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are addressed by the course.	This course addresses: Outcome 1 1.1: Identify & Formulate CEP (i-vi) based on E, S, M 1.2: Solve CEP (i-vi) based on E, S, M

7	Brief list of topics to be covered	An introduction to renewable energy (3 hours) A review of the course pre-requisites (6 hours) Fundamentals and applications of solar energy (6 hours) Wind energy (3 hours) Hydropower (3 hour) Geothermal (3 hours) Biomass energy (3 hours) Ocean energy (3 hours) Hydrogen and fuel cells (3 hours)
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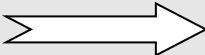
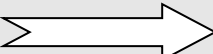
***Required** courses are required of all students in the program, **elective** courses (often referred to as open or free electives) are optional for students, and **selected elective** courses are those for which students must take one or more courses from a specified group

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

Assessment Summary of Class Semester Averages for Outcomes (Should be provided for Fall 2019 through Spring 2022 Assessment Period)

Semester	Analysis Type	Number of Students	Outcome 1 (Previously Outcome a) Identify & Formulate CEP (i-vi) based on E, S, M (Outcome 1.1), Solve CEP (i-vi) based on E, S, M (Outcome 1.2)			
			Expected Class Average/	Expected Percent of students at or above average	Class Average	% Students meeting Expected Average
Spring 2022	Direct	9	70	70	69	56
Implementation Summary	Items implemented from previous report or after meeting previous instructor		- Detailed Class notes were prepared from the Text book and made available to students - Review sheets for differential and integral calculus were handed out. - Different problems with various levels of difficulty practiced with students in class.			
Perceived Problems			Students were kept informed of their standing after each quiz and test. The major problems were: - Students are not good in course pre-requisites including thermodynamics and heat transfer - Lack of desire to study to improve even when counseled to do so repeatedly. - Students do not normally reach out if they need any part of the course to be explained further although repeatedly encourage to contact instructor with any questions.			
Recommendations for Addressing Problems			The following is recommended for implementation: - Department should have a pool of questions in algebra and calculus (basic Mathematics for Fluid mechanics) to be admitted in the beginning of the semester and students who do not pass be required to take a required remedial Basic Mathematics course/Tutorial and be requested to retake the Basic Mathematics for Fluid Mechanics exam and pass before mid-term or be asked to drop the course. - Students need to be motivated to study - College/Department should set admission requirements at a level to allow quality students into the College of Engineering/ME department because a large percentage of the students do not have the necessary background and motivation to succeed in engineering.			
Were Expectations Met?			YES			

*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 Reports Spring 2022 and Last Three Assessment Periods.

Each 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. **Realistic problems should be identified throughout the semester and summarized in this section of the report.**

4. New Plans for Addressing Problems

- Instructor's plans for addressing the perceived problems the next time the class is taught. **These should be specific enough for another instructor to implement. Most of these should be things that, you, the instructor can implement to help students to improve. Be creative.**

5. Overall Trend over last three assessment periods

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

5. Were Expectations Met?

- Answer **YES** if the **class average was above the expected average** and the **stated percentage of students** scored at or above the expected average, else answer NO.

**Special topic – Fundamentals and Applications of Renewable
Energy
Spring 2022**

Title of Assignment: Final project

TOPICS COVERED IN final project

1. Research on operational principles, advantages, disadvantages, and comparison of
Different topics related to renewable energy

**Repeated this section for each Quiz and Similarly for all the other
assignments in the course binder**

ABOVE AVERAGE



PRAIRIE VIEW A&M UNIVERSITY



**MCEG 4316 FUNDAMENTALS AND
APPLICATION OF RENEWABLE ENERGY**

Spring 2022 Section P19

LABORATORY REPORT ON

Biomass Production Methods

Submitted by

Malaika Lee & Prince Riley

On

May 1, 2022

To

Dr. Shafiee

Fluid Mechanics lab Instructor

ABSTRACT

Biomass production, a renewable energy source, has potential in becoming a large-scale use of energy in areas such as biofuel, bioplastics, pharmaceuticals, and feedstock. However, there are many limitations that have contributed to the challenges of biomass production growth as a renewable energy source. There has been continuing research conducted on implementing various methods to contribute to a more feasible cost-efficiency and an efficient way of bypassing these challenges to eventually produce biomass on a larger scale. In the report, it dives into a few of the various forms of biomass production with a brief overview of biomass as a source of renewable energy. These methods of biomass production discussed through this report include microalgal cultivation, biomass production methods, and animal waste production methods. To conclude a well-thought out list of advantages and disadvantages of the different methods of biomass production is used followed by a discussion of the final results concluding the report.

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CHAPTER 1

BIOMASS PRODUCTION

1. Introduction

1.1 Biomass

Biomass can be used for fuels, power production, and products that would otherwise be made from fossil fuels. Biomass production and processing have the potential to give us a uniquely sustainable source of organic chemicals, organic materials (such as biopolymers) and liquid transportation fuels. Biomass can also help us sustainably produce electricity, although there are several other sustainable sources of electricity. Biomass is also uniquely a source of human food and animal feed.

1.2 Theory

Biomass, a renewable energy source, is biological material from living, or recently living organisms, such as trees, crops, animals and plants, but also agricultural, urban and industrial wastes. Biomass is stored sun energy in the form of carbohydrates.

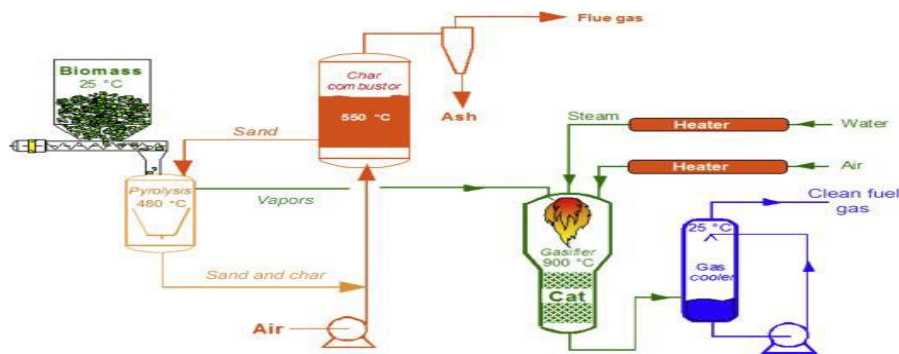
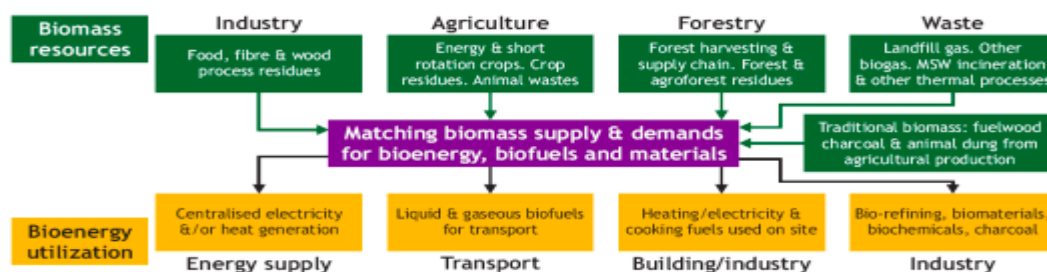


Figure 1.1

A biomass system typically comprises the following components:

- external or outdoor area (fuel delivery)
- fuel storage (for example, in the form of a bunker or a containerised store)
- mechanical transport (such as augers or ‘walking floors’) to move the fuel to the boiler
- boiler house (incorporating the boiler, chimney, controls etc)
- boiler (fired with biofuel)
- heat exchanger (to convert to hot water or steam)
- chimney (including fans)
- system control



CHAPTER 2

DIFFERENT FORMS OF BIOMASS PRODUCTION METHODS

2.1 Microalgal Biomass in Renewable Energy

Microalgal Biomass is a source of renewable energy that contains cells with a significant amount of protein. This protein, combined with accessory pigments and other factors within the cell, has the potential of not only becoming the main product in the biofuel production industry but can also increase the profitability.

Microalgal Biomass main factor in production is microalgae. Microalgae can be defined as “unicellular photosynthetic micro-organisms, living in saline or freshwater environments, that convert sunlight, water and carbon dioxide to algal biomass” (Vale, 2020). They are classified as eukaryotic micro-organisms and prokaryotic cyanobacteria. Eukaryotic micro-organisms are organisms whose cells contain a nucleus and other membrane-bound organelles. Cyanobacteria, also known as blue-green algae, are defined as a heterogeneous group of prokaryotes and are principally photosynthetic organisms. These micro-organisms are known for performing photosynthesis which is an essential natural mechanism in reducing the atmospheric CO₂ concentration (Vale, 2020).

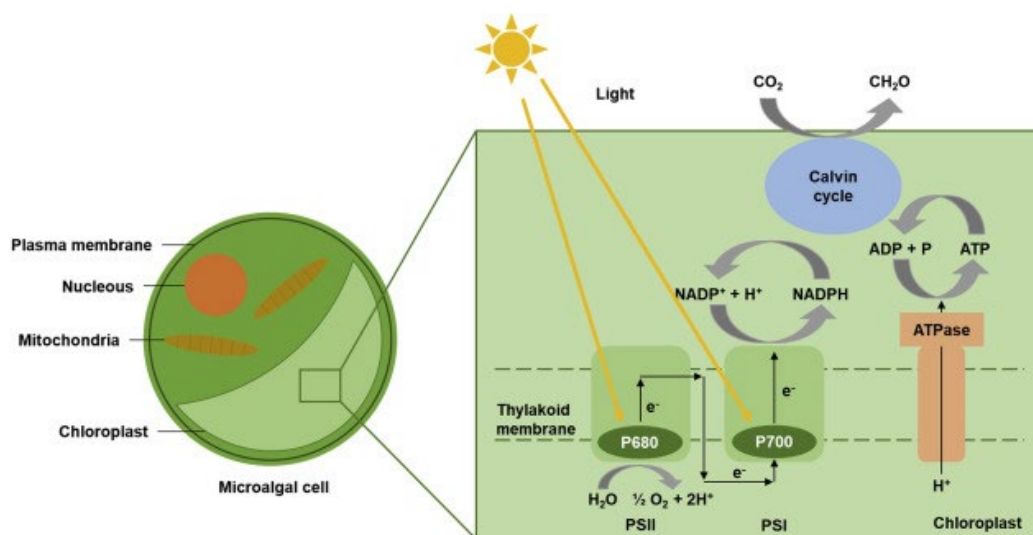


Figure 2.1

Microalgal biomass can be used in various applications ranging from bioenergy to pharmaceuticals production. Microalgae can accumulate high amounts of lipids that could be used for biodiesel production. After microalgae undergoes extraction of fatty acids, the biomass residue can be used for the production of bio-oil, bio-crude, ethanol, and methane. Due to high contents of carbohydrates, proteins, vitamins, and essential minerals, microalgal biomass can be a significant resource for human food and animal feed (Vale, 2020).

2.2 Microalgal Cultivation Method

Microalgal cultivation isn't a complex method of biomass production. It does not require harmful chemicals, fertile land, and a massive amount of water compared to other land-based crops. This method could potentially accelerate

the rising sustainable application through biomass production used in biofuels, bioplastics, pharmaceuticals, and feedstock. It can also reduce atmospheric CO₂ and in result control environmental pollution(Vale, 2020).

Microalgal cultivation requires a high level of nutrients such as nitrogen, carbon, potassium, sulfur, iron, and phosphorus for a sustainable biomass production. Coincidentally, the unrestricted amounts of nutrients found in the waste and polluted water could potentially become the ideal medium for microalgal cultivation that relates to the efficient removal of nitrogen, phosphorus, and heavy metals. By utilizing nutrient recycling, wastewater, and synthetic nutrient resources is a significant factor in reducing nutrient supplies which would potentially become cost-effective(Vale, 2020).

However, there are many disadvantages that coincide with microalgae cultivation, one being biological contamination. Biological contamination has constantly remained a significant challenge for outdoor mass production of microalgae. This will lead to the reduction of product synthesis by blooming effects. To help prevent biological contamination novel potent evolutionary methodologies and metabolic engineering is utilized.

Cultivation of microalgae is an important step in the production of biomass. The ease of harvesting is economically feasible. The cultivation essentially affects the growth pattern and metabolism of these micro-organisms resulting in a regulation of the quantity and quality of bioproducts. On the other hand, harvesting from a large scale, microalgal cultivation systems require high-energy input for the production of commercial products.

2.3 Bioreactors for Microalgal Cultivation

Microalgal cultivation on a large-scale was done by using natural locations such as open raceway pond systems and a closed production system to produce biomass. Photosynthetic bioreactors (PBR), a bioreactor that utilizes a light source to cultivate phototrophic micro-organism, requires an abundance of growth which can result in high productivity with least operational costs. There has been extensive research conducted to cultivate diverse cyanobacteria through different cultivation methods ranging from controlled laboratories methods to uncontrollable outdoor tanks. However, most industries prefer the natural way of cultivation to avoid high infrastructural expenses(Veerabadhran et al.).

Advantages of photosynthetic bioreactors are precisely controlled environment, water loss prevention usually caused by evaporation, lower contamination, and high photosynthetic efficiency. The highest air-to-volume ratio is favorable for high photosynthetic activity and mixing patterns. The cultivation of microalgal in the tubular bioreactor is the most beneficial to cultivate unicellular forms. The major disadvantage of this specific type of bioreactor is that heating sterilization is impossible and in outdoor cultivation photo limitations occur often. The figure below depicts different forms of bioreactors and their design. It also shows their feasibility in production and application settings(Veerabadhran et al.).

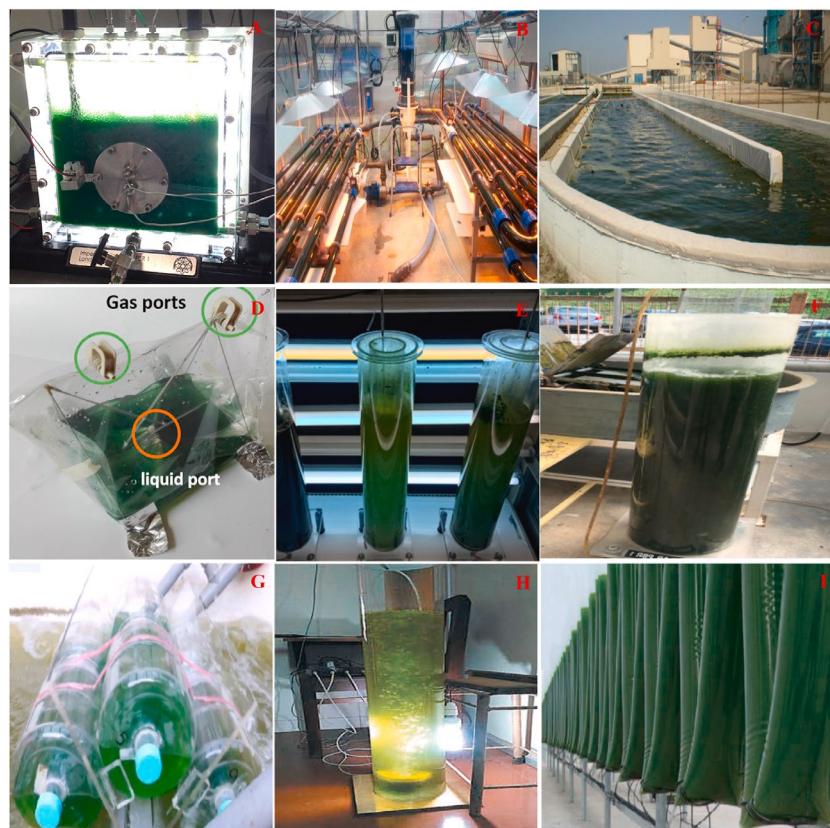


Figure 2.2

2.4 Lignocellulosic Biomass Pretreatment Treatment Method

Lignocellulosic Biomass, defined as plant dry matter residue, is considered one of the most abundantly accessible raw materials on earth in regards to the production of biofuels. Lignocellulosic is composed of carbohydrate polymers, cellulose and hemicellulose, and lignin an aromatic-rich polymer. In the form of agricultural deposits such as corn and sugarcane, lignocellulosic biomass can be used as ethanol production. It has been estimated that this form of biomass annual consumption is around 5-8 % of the total annual consumption of fossil fuels (Ziaei-Rad et al.).

Low-cost Ionic Liquid, also known as “IL”, is potentially the most effective method for the lignocellulosic biomass pretreatment in regards to the production of bioethanol. However, this method holds significant disadvantages. One of the most major challenges of applying the biomass production method of IL on a larger scale is the high cost. The estimated production of [emim][OAc], defined as ionic liquids, cost between \$20 to \$101 per kg. This factor will also result in low thermal stability and moisture tolerance. IL also undergoes the challenge of not maintaining low water content in biomass treatment, due to the high fresh biomass moisture content that is up to 50% and hygroscopicity of IL. These disadvantages combined is the primary reason why imidazolium-based ILS are limited to the laboratory- scale production of biofuels and research studies (Ziaei-Rad et al.).

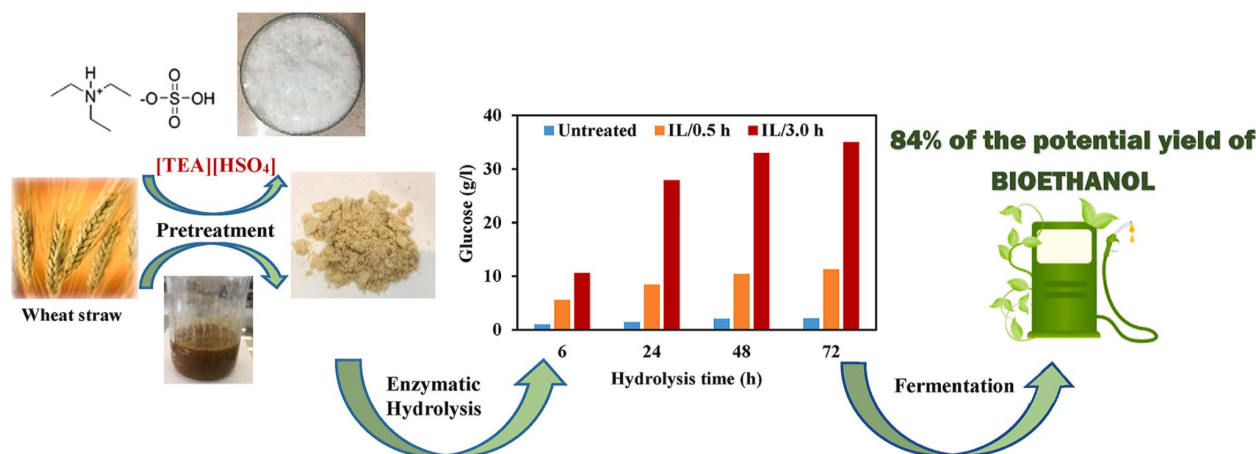


Figure 2.3

2.5 Nematode Biomass Production

Nematodes are defined as predators that are naturally found in sludge. Sludge generated in urban wastewater treatment plants has become a huge environmental and economic challenge of sustainability. Sludge recovery is a requirement for wastewater treatment plants and is an environmental necessity. Predators, such as nematodes, have been proposed as a potential biological solution and simultaneously obtaining by-products of interest (López-Viso et al.).

This form of biomass production holds significant advantages, one being inexpensive technology. This advantage will effectively decrease the cost of production. Nematode Biomass production has the possibility to generate new added-value products which will essentially help in achieving circular economy. The only major disadvantage is that this form of production is not easy to control; therefore skilled labours would be needed (López-Viso et al.).

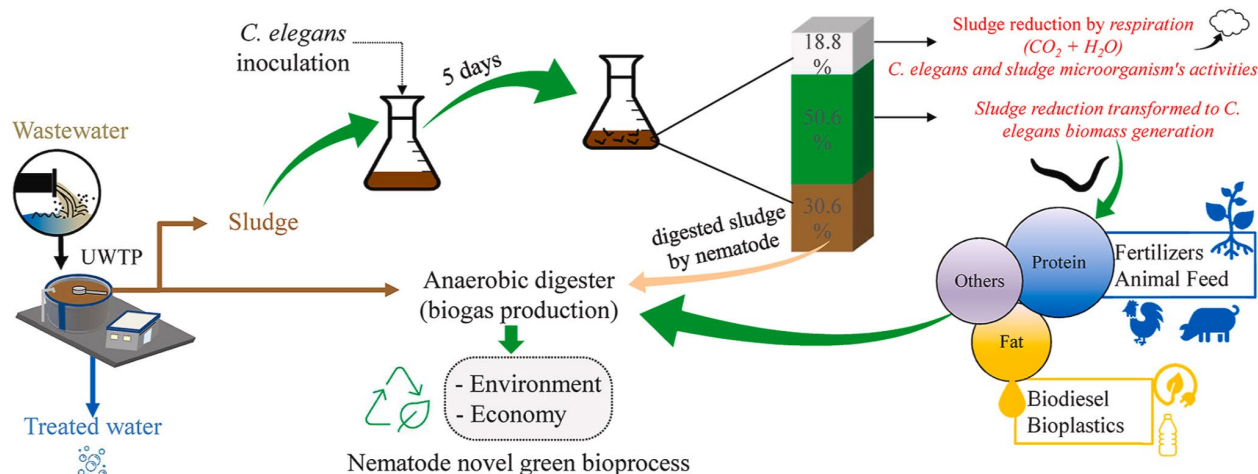


Figure 2.4

2.6 Methods in Production of Wood Biomass

Wood biomass is defined as the by-product of management, restoration, and hazardous fuel reduction treatments, as well as the product of natural disasters, including trees and woody plants (limbs, tops, needles, leaves, and other

woody parts, grown in a forest, woodland, or rangeland environment). Industry accounts for the majority of wood and wood-waste fuel consumption in the United States. The largest industrial users are wood products and paper manufacturers. They use lumber mill and paper mill waste to produce steam and electricity, which saves money because it reduces the amount of other fuels and electricity they purchase to operate their facilities.

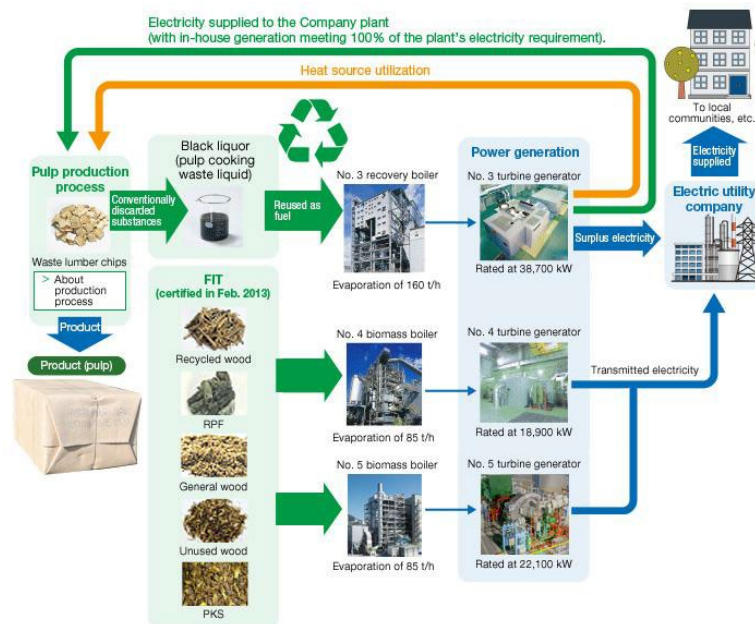


figure 2.5

The benefits of using, as opposed to disposing, woody biomass produced by hazardous fuels treatments, forest and range management, urban and disaster cleanup, and other activities are numerous, but have not been comprehensively identified or economically quantified such as,

- Improves air quality, visibility, and public health by reducing the smoke created by burning woody biomass.
- Provides renewable fuel for clean energy while saving landfill space, reducing waste, and mitigating the need for additional landfill construction. biomass provides enhanced energy independence, security and reliability, rural economic development, and a reduction in greenhouse gasses and other pollutants associated with fossil fuels.
- Creates economic opportunities in the community.

2.7 Methods in Production of Animal Waste Biomass

Biomass is a form of renewable energy, which is gaining the attention of energy providers as a low-maintenance and economically efficient alternative to fossil fuels. Take these two examples:

- Vegetation, such as trees, are gathered and burned in a factory to heat water.
- Animal droppings are collected and disposed of in a digester tank. Bacteria eat manure, and methane gas is created. This gas is used to heat water.

Animal wastes can be used as sources of biomass-based conversion processes, especially in bio-energy and bio-fertilizer production. The most common sources include dairy shed effluent (containing urine, dung, wash water, residual milk, and waste feed), dairy manure, poultry litter (a mix of manure, water, spilled feed, feathers, and bedding material), renderings, and other wastes from livestock finishing operations. Besides recovery of substantial energy, these technologies can lead to a substantial reduction in the overall waste quantities requiring final disposal, which can be better managed for safe disposal in a controlled manner while meeting the pollution control standards. Biomass waste-to-energy conversion reduces greenhouse gas emissions in two ways. Heat and electrical energy is generated which reduces the dependence on power plants based on fossil fuels. The greenhouse gas emissions are significantly reduced by preventing methane emissions from landfills. Moreover, waste-to-energy plants are highly efficient in harnessing the untapped sources of energy from wastes.

CHAPTER 3

CONCLUSION

3.1 Advantages and Disadvantages of Biomass Production

Questions that are raised during biomass production would be This raises the question of why biomass energy hasn't been adopted on a wider scale. Here is a list of advantages and disadvantages.

<u>Advantages of Biomass Energy</u>	<u>Disadvantages of Biomass Energy</u>
It is Renewable	It's Not Completely Clean
Carbon Neutrality	High Costs In Comparison To Other Alternatives
Less Dependency On Fossil Fuels	Possible Deforestation
It Is Versatile	Space
Availability	It Requires Water
Low Cost In Comparison To Fossil Fuels	It Has Inefficiencies
It Reduces Waste	It's Under Development

Figure 3.1

3.2 Comparison of Biomass Production Methods

There are various biomass production methods that can contribute to the growth of biomass as a renewable energy source. Microalgal Cultivation, Lignocellulosic Biomass Pretreatment Treatment, Nematode Biomass, Wood Biomass, and Animal Waste Biomass are all significant methods of biomass production. These methods, as stated

throughout the report, have similar significant advantages such as being cost-efficient, increasing profit, and assisting in a decrease in environmental pollution. However, with these advantages comes disadvantages as well. Based on the information found it can be determined that microalgal cultivation, in the form of bioreactors, would be the most affordable and efficient biomass production method compared to the other five methods previously stated.

3.3 Conclusions

Biomass is renewable organic material that comes from plants and animals. Biomass was the largest source of total annual US energy consumption. Biomass continues to be an important fuel in many countries, especially for cooking and heating in developing countries. The use of biomass fuels for transportation and for electricity generation is increasing in many developed countries as a means of avoiding carbon dioxide emissions from fossil fuel use. biomass sources for energy include:

- Wood and wood processing wastes—firewood, wood pellets, and wood chips, lumber and furniture mill sawdust and waste, and black liquor from pulp and paper mills
- Agricultural crops and waste materials—corn, soybeans, sugar cane, switchgrass, woody plants, and algae, and crop and food processing residues
- Biogenic materials in municipal solid waste —paper, cotton, and wool products, and food, yard, and wood wastes
- Animal manure and human sewage

The utilization of biomass as an energy source changes the dynamics of everyday use of fuels in everyday living.

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AVERAGE



MCEG 4316 FUNDAMENTALS AND APPLICATION OF RENEWABLE ENERGY

SPRING 2022 Section P19

EXPERIMENT REPORT ON

“Comparisons of Water Desalination Technologies and their Operational Principles”

Presented on
May 2, 2022

Submitted by
Taylor Aaron and Kierra Brossette
On
May 1, 2022

To
Dr. Shahin Shafiee
Special Topics Instructor

Letter of Transmittal

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May 1, 2022
Dear Dr.Shafiee:

The following pages are a detailed report for the final project of MCEG 4316 Fundamentals and Application of Renewable Energy, “Comparison of Water Desalination Technologies and their Operational Principles”. In this report the concept of water desalination is being discussed as well as the issues that arise with water scarcity in underdeveloped areas of the planet. Therefore, in this report is an analysis of the various classifications of desalination technologies, and comparisons between each system and their operational principles. This report is being submitted on May 1, 2022 and being presented on May 2, 2022.

If you have any questions or concerns, please call, or email me at any time.

Sincerely,

Taylor
Aaron
Kierra
Brossette

Enclosure: Lab Report

Abstract

Safe drinking water is not easily accessible within various parts of the planet. Here in the United States, we have large numbers of people who do not have access to safe clean drinking water. The purpose of this study is to identify various classifications of water desalination technologies and examine the comparisons between their operational principles. The most abundant source of water is saturated with salt and not drinkable. Seawater desalination is regarded as one of the most effective solutions to address water scarcity. Water desalination technologies consist of a desalination process that separates saline water into two parts, one that has a low concentration of salt which is treated water or product water and the other with a much higher concentration than the original feed water, usually referred to as brine concentrate or simply as concentrate, which is one of the concerns when it comes to water desalination. Within this report the primary focus will be water desalination technologies and articles to support the analysis of those technologies being utilized, the procedures, and materials used to conduct the experiment with the devices that will be mentioned. Within this

report the devices will be classified based upon their main energy input. Therefore, the first technology to be discussed is Solar Still Distillation which falls under thermal energy. The second is reverse osmosis, classified as a mechanical energy. The last two will fall under electrical energy, Electrodialysis and Desalination batteries.

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Introduction

71% of our planet's surface is covered in water. 332.5 million cubic miles of it. 366 billion billion gallons. That's over 48 billion gallons of water for every person on earth. But today 1 out of 3 people do not have access to safe drinking water. 96.5 % of that water is found in our oceans, it's saturated with salt and undrinkable. Most of the earth's freshwater is locked away in glaciers or deep underground; less than 1% of it is available to us. Desalination broadly is the process of removing salts from water. It is a natural process that occurs when the sun heats the surface of the ocean and fresh water evaporates off and it falls again as rainfall. An example of this process, if examined closely, is when salt has dissolved in water. The water is breaking salt apart into charged particles that chemically interact with the water. Therefore, salt water is a chemically new solution, not exactly water with some salt grains floating around in it. There are two main classifications of desalination technologies, thermal desalination, and membrane, with thermal being the oldest form of desalination. It is the boiling of water and the capturing of steam, resulting in freshwater. Thermal technology is the technology of producing,

storing, controlling, transmitting, and getting work from heat energy. Whenever the amount of energy in one place or form diminishes, the amount in other places or forms increases by the same amount. Future types of desalination technologies would be electrochemical. Desalination technologies are separated into three classifications being evaporation and condensation, filtration and crystallization. Another way the technologies are classified is also by their main energy input, which is thermal, chemical, mechanical and electrical.

Methods & Materials

I. Solar Still

Within this section the methods and materials of each desalination technology will be presented. The methods and materials will involve the explanation of how the work was conducted within the article utilized to present the experimental design of the technology. The first classification that will be mentioned is thermal energy, featuring an article by Zhenyuan Xu called, “Ultrahigh-efficiency desalination via a thermally-localized multistage solar still” discussing the limited current commercial approaches such as multistage flash and reverse osmosis exist at large-scales, they are not suited for developing regions due to the requirement of well-established infrastructure, centralized installation and significant energy consumption. In the last decade, commercial large scale desalination facilities including the newly built reverse osmosis plants and legacy installations with multi-stage flash evaporation and multi-effect distillation have partly relieved the water shortage stress. However, these technologies require well-developed

infrastructure and centralized installations, which are not available in many developing regions. Passive solar desalination systems with simple configuration and off grid operation are attractive for several developing regions with abundant solar energy and seawater, but the high cost of water production and large area requirements from low conversion efficiency have limited their adoption thus far. Solar stills are the simplest devices that are used to obtain freshwater using solar energy as the sole energy supply.

A thermally localized multistage solar still (TMSS) prototype was fabricated based upon a conceptual schematic of the TMSS device architecture, which exhibited the key components necessary for the first stage of the TMSS. The first stage consisted of a solar transparent monolithic silica aerogel thermal insulator, a solar absorber, a capillary wick, and a condenser. With the use of low-cost materials, a ten-stage device prototype was composed of eleven identical nylon frames using a 3D printer, one solar absorber covered by a silica aerogel monolith, ten Teflon AF-coated aluminum condensers, and ten cellulose fiber (paper towel) evaporators.

The TMSS architecture enables high performance desalination, due to three key attributes that optimize heat and mass transport. Vaporization enthalpy recycling is realized by the multistage configuration, where the latent heat released from the previous stage is harnessed by the next stage to induce evaporation. The vertically aligned layers with tunable tilt angles can significantly reduce the parasitic heat loss due to the negligible area of contact between the thin film evaporator and bulk brine and enable operation for different sun positions due to geographical and seasonal variations.

A solar simulator was used to provide uniform solar illumination. The TMSS device was supported by an acrylic box with an opening on the top for the capillary wicks to access the water reservoir. A balance was used to measure the mass loss of the reservoir continuously. A

1.27 cm thick thermal insulation was installed on the side wall to reduce the heat loss. In order to perform a detailed thermal characterization, twelve thermocouples were used to measure the

real-time temperature response where the first ten thermocouples monitored the evaporator/condenser temperature of each stage, while the remaining two thermocouples recorded the condenser temperature of the last stage and the ambient temperature. The temperature and mass loss data were collected by data acquisition equipment and processed by a computer. The experiment started at 11:10 am (local time) and ended around 4:00 pm (local time). The temperature of each stage rose rapidly during the first one hour where the temperature of solar absorber reached more than 30 degrees Celsius higher than the ambient temperature.

Water began to flow out from the first stage after 20 minutes. The solar flux varied significantly from 200 to 800 W m² due to the scattered clouds leading to fluctuations of the solar absorber temperature. Each spike in the measured solar flux due to the clouds corresponds to a temperature drop and recovery. The temperature decreased rapidly with the decrease of solar flux and took a longer time (10 minutes) to

recover the peak temperature due to thermal inertia. Since the weather became cloudier in the afternoon, the corresponding solar absorber temperature was more unstable. The temperature fluctuation in each stage led to variation in water collection rate, which was extracted from the water level in the graduated cylinder, 72 ml of water in total for 4.5 hours, which corresponds to an average productivity of $2.6 \text{ L kW}^{-1} \text{ h}^{-1}$. Although the cloudy weather and solar flux fluctuation can significantly degrade the overall performance, this ten-stage TMSS prototype still demonstrates a record-high outdoor productivity compared with current state-of-the-art technologies. To meet the average daily water intake for one adult. TMSS devices can be placed into a 10×10 array, filling a 1 m^2 area, which would provide approximately 10–20 L of clean water every day depending on the weather condition.

The operational principle of this technology is that Solar energy is converted into heat and transferred from the absorber to the thin capillary wick. Evaporation occurs on the capillary wick due to interfacial heating. Brine is pumped from the reservoir due to capillary pressure to compensate for

the loss of liquid in the capillary wick. The generated vapor travels across the air gap and condenses at the condenser. Vaporization enthalpy recycling enabled by the TMSS architecture. Thermal energy released from condensation is transferred to the capillary wick, attached to the condenser of the previous stage, which drives evaporation in the next stage. The condenser of the last stage is inserted into the bulk brine to maintain a temperature close to ambient.

The experimental results were that salt accumulation was observed after two hours on the farthest corners to the reservoir, which had the largest diffusion resistance. After the solar simulator was turned off, the accumulated salt diffused back to the reservoir gradually. The evaporator exhibited high salt rejection capability throughout the test. Salt accumulation was only observed at the two upper corners which had the largest diffusion resistance since they were the farthest distance from the bulk brine. Salt crystals did not appear during the first two hours due to the high solubility of NaCl in water and the relatively high diffusive transport of salt in the evaporator. After two hours, salt began to crystallize and accumulate at the corner. After 3.5-

hour operation, the crystallized salt covered approximately 45% of the 4 x 4 cm² area at the corner. Almost all the salt on the evaporator diffused back to the bulk brine after 15 hours, indicating adequate salt-rejection performance.

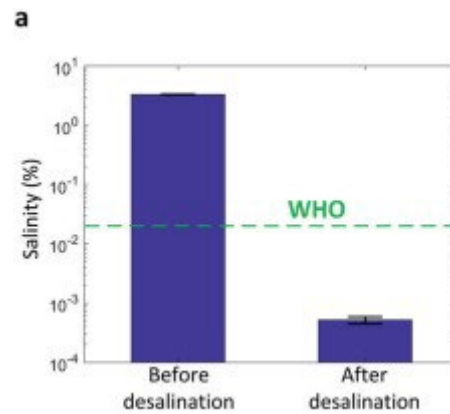


Figure 1:

Salinity of the simulated seawater before and after desalination. The salinity of the water produced by the TMSS prototype was two orders of magnitude lower than the drinking water standard provided by green dashed line.

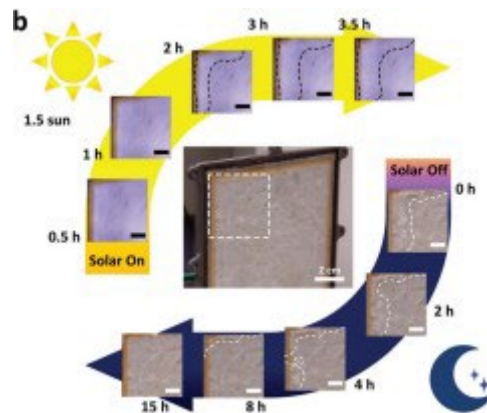


Figure 2:

Salt rejection performance during a daytime salt accumulation period and a nighttime salt diffusion cycle. 1500 W m² solar illumination was supplied to the TMSS prototype over 3.5 hours to simulate total

daily solar irradiation. The largest image at the center shows the evaporator before the experiment started without the accumulation of salt. Salt accumulation was observed after two hours. The white-dashed box shows the area where most of the salt accumulated during the test. The black and white dashed lines serve as a visual guide and show the exact area covered by salt and its evolution with time. The scale bars represent one centimeter.

II. Desalination Batteries

An electrochemical technology that will be mentioned within this report is desalination batteries. Rather than generating electricity from salinity differences, as in mixing entropy

batteries, desalination batteries use an electrical energy input to extract sodium and chloride ions from seawater and to generate fresh water. Within this section an article by Do-Hwan Nam and Margaret Lumley called, “A Desalination Battery Combining $\text{Cu}_3[\text{Fe}(\text{CN})_6]_2$ as a Na-Storage Electrode and Bi as a Cl-storage Electrode Enabling Membrane-Free Desalination”, where it is discussed how a desalination battery is an attractive approach to seawater desalination because it couples ion removal with energy storage. $\text{Cu}_3[\text{Fe}(\text{CN})_6]_2 \cdot n\text{H}_2\text{O}$ as the Na-storage electrode with Bi as the Cl-storage electrode to construct a novel desalination battery that enables membrane-free desalination. Most current desalination technologies, except for thermal distillation, rely on the use of membranes. Eliminating the need for a membrane can significantly simplify the construction and maintenance of desalination systems. In this study an investigation was conducted to examine the performance and stability of $\text{Cu}_3[\text{Fe}(\text{CN})_6]_2 \cdot n\text{H}_2\text{O}$ as a Na- storage electrode in both neutral and acidic solutions with the intention to construct a membrane- free Bi-based desalination battery.

Within the article preparation of $\text{Cu}_3[\text{Fe}(\text{CN})_6]_2 \cdot n\text{H}_2\text{O}$ Electrodes had to take place first. It was synthesized by a coprecipitation method following a procedure reported in another study. Next was the preparation of the Bi electrodes, which were prepared by electro deposition also following a procedure reported in a previous study. An undivided three-electrode cell was used with a Ti sheet as the working electrode, a Pt sheet as the counter electrode, and a saturated calomel electrode (SCE) as the reference electrode. The Ti sheet was masked to expose an area of 1 cm^2 . The materials for this experiment consisted of NaCl, BiCl_3 , polyethylene glycol (PEG), HCl, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, $\text{K}_3\text{Fe}(\text{CN})_6$, polytetrafluoroethylene, Super P Li, and colloidal graphite were used without further purification. Deionized water was used to prepare all the solutions.

Therefore, when it comes to the bigger picture of the work, an investigation of the compatibility of $\text{Cu}_3[\text{Fe}(\text{CN})_6]_2 \cdot n\text{H}_2\text{O}$ with a neutral concentrated NaCl solution mimicking the composition of seawater. In addition, it was necessary to confirm that the presence of Cl^- would not affect the desodiation properties in acidic media. In addition,

an examination of the sodiation/desodiation properties and cyclability of $\text{Cu} [\text{Fe} (\text{CN})] \cdot n\text{H}_2\text{O}$ in both an acidic and neutral NaCl solutions. Then, constructed a membrane-free $\text{Cu}_3[\text{Fe}(\text{CN})_6]_2 \cdot n\text{H}_2\text{O}/\text{Bi}$ desalination battery and evaluated its performance for seawater desalination.

The operational principle was based upon the calculation of the cell potential (E_{cell}) of the CuHCF/Bi cell, by subtracting the anode potential (E_{anode}) from the cathode potential (E_{cathode}) using the equation $E_{\text{cell}} = E_{\text{cathode}} - E_{\text{anode}}$. Because E_{cathode} is more positive than E_{anode} during the desalination reaction, E_{cell} is positive. This means that for the CuHCF/Bi cell desalination is a spontaneous process equivalent to discharging, which generates electrical energy.

The results were exhibited when the salination, the reduction of BiOCl and the oxidation of CuHCF occurred, and electrons flowed from the CuHCF electrode (anode) to the BiOCl electrode (cathode).

As the reaction proceeded, the potential of the BiOCl electrode decreased from its open circuit potential and plateaued at around -1.15 V vs Ag/AgCl while the potential

of the CuHCF electrode increased from 0.58 to 0.67 V vs Ag/AgCl. Because the anode reaction (desodiation of CuHCF) occurs at a more positive potential than the cathode reaction (dechlorination of BiOCl), E_{cell} is negative. This means that salination performed by the CuHCF/Bi cell is a non-spontaneous process equivalent to charging and requires an energy input.

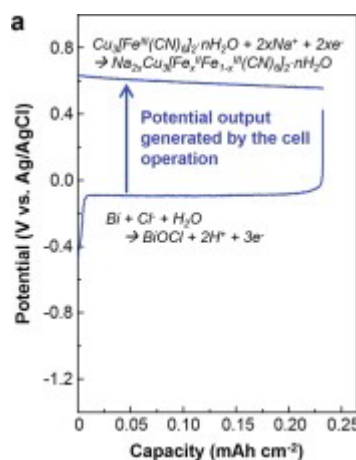


Figure 3:

The desalination performance of the CuHCF/Bi cell was first examined in a neutral NaCl solution with a constant current density. During the desalination process, Fe (III) in CuHCF was reduced to Fe (II) to store Na^+ (cathode) while Bi was oxidized to BiOCl to store Cl^- (anode).

Therefore, electrons flowed from the Bi electrode to the CuHCF electrode. As the reaction proceeded, the potential of Bi rapidly increased from its open

circuit potential and the potential of the CuHCF electrode gradually decreased.

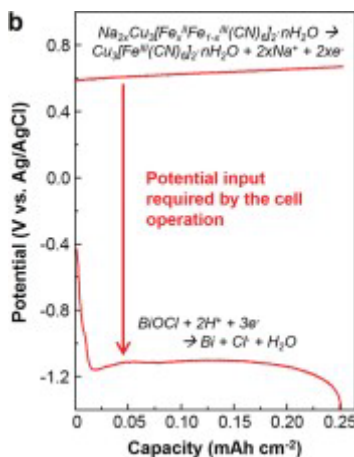


Figure 4:

The figure above shows the potential profiles of the sodiated CuHCF and chlorinated Bi electrodes measured against the reference electrode during the salination process in neutral NaCl solution. During salination, the reduction of BiOCl and the oxidation of CuHCF occurred, and electrons flowed from the CuHCF electrode (anode) to the BiOCl electrode (cathode). As the

reaction proceeded, the potential of the BiOCl electrode decreased from its open circuit potential while the potential of the CuHCF electrode increased.. Because the anode reaction occurs at a more positive potential than the cathode reaction, Ecell is negative. This means that salination performed by the CuHCF/Bi cell is a nonspontaneous process equivalent to charging and requires an energy input

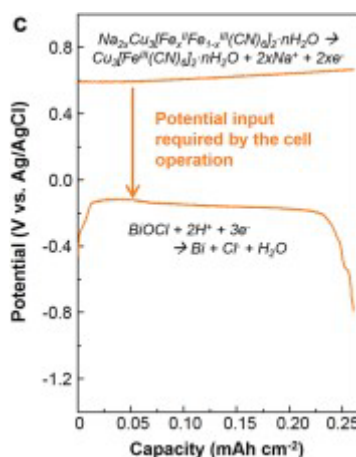


Figure 5:

Above it is observed that when the charging process was performed in an acidic solution (pH 1.2), the average potential required for dechlorination of BiOCl was reduced. Most of the decrease in cell potential observed in this study is due to a decrease in kinetic overpotential required for the conversion of BiOCl to Bi.

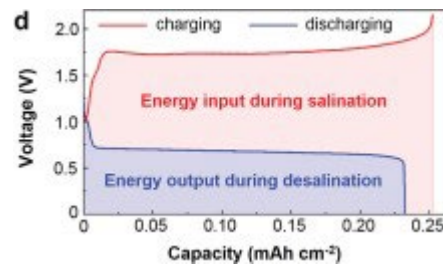


Figure 6:

Above is the comparison of cell potential charge plots obtained when the desalination and salination processes were both performed in neutral NaCl solutions. The area below the desalination plot provides the energy output generated during discharging, and the area below the salination plot provides the energy input required during charging. The difference between the energy generated during desalination (0.158 mWh) and energy input required during salination (0.442 mWh) was calculated to be 0.284 mWh, which is the energy consumption required for a complete desalination/salination cycle. This means that 35.7% of the energy consumed during salination is recovered during desalination.

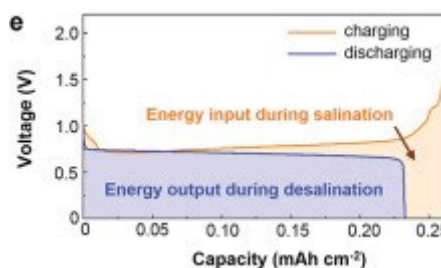


Figure 7:

However, unlike Figure 6 when salination was performed in 65 mM HCl (pH 1.2), the energy input required for salination was reduced from 0.442 to 0.209 mWh, resulting in a decrease in the overall energy consumption required for a desalination/salination cycle from 0.284 to 0.051 mWh (Figure 6e). In this case, 75.6% of the energy consumed during salination is recovered during desalination.

III. Reverse Osmosis

Reverse osmosis is a desalination technology based on semipermeable membranes, which are specific layers allowing the passage only to selected molecules. When two solutions with different concentrations of solutes are separated by a semipermeable membrane, the solvent flows spontaneously from the more diluted solution to the more concentrated one, to balance the energy potential of both solutions. A high pressure is applied to a solution with a high salt concentration.

The solution is being pushed through a semipermeable membrane. The freshwater will flow in the reverse direction of the membrane and leave behind the sodium and chloride. This concentration is called hypersaline brine.

RO systems are made up of 3-5 stages of filtration. Depending on the position of the filters in reference to the semipermeable membrane, they are either considered prefiltration or post filtration. The value of pressure that must be applied for the brackish water to be filtered through the semipermeable membrane is Osmotic Pressure, Δp_{osm} .

RO semipermeable membranes are classified as either isotropic or anisotropic. The only difference between the two being uniformity. Most RO membranes are made of a synthetic organic polymer. Typically, these membranes are either cellular acetate or polysulfone coated with aromatic polyamides. As the brackish water goes through the RO process, there are several different filtration stages. Often, the two main types used are carbon filters and sediment filters. Sediment filters get rid of the dirt, dust, and rocks in the solution. The carbon filters get rid of unwanted chemicals in the solution.

The brackish water, or saltwater is poured into the RO tube. The tube allows the solutions to go through a filter, which often is in a sediment filter.

This is the prefiltration stage of RO. Next, a pressure is applied to the solution and pushes it towards the semipermeable membrane. Once a high enough pressure is applied, on the opposite side of the membrane there will be freshwater. On the other side, there will be the hypersaline brine. Finally, the hypersaline is drained from the tube and the freshwater is stored in a safe space. This is to ensure that the freshwater and hypersaline brine don't mix.

For the operational principles this process can be used to effectively remove many types of dissolved and suspended chemical particles as well as biological entities (like bacteria) from the water. This technique has a wide application in treating liquid waste or discharge. Bacteria, viruses and pyrogen materials are rejected by the intact membrane. In this respect RO water approaches distilled water in quality.

The results for Reverse osmosis (RO) are a water purification process that removes ions, unwanted molecules and larger particles from drinking water using a partially permeable membrane. As a result, the solute is kept on the membrane's pressurized side and the pure solvent is allowed to pass to the other side.

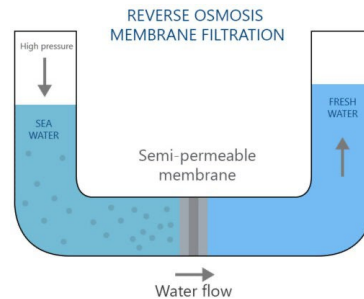


Figure 8

IV. Electrodialysis

Electrodialysis (ED) is used to transport salt ions from one solution through ion-exchange membranes to another solution under the influence of an applied electric potential difference. This is done in a configuration called an electrodialysis cell. The cell consists of a feed (dilute) compartment and a concentrate (brine) compartment formed by an anion exchange membrane and a cation exchange membrane placed between two electrodes. In almost all practical electrodialysis processes, multiple electrodialysis cells are arranged into a configuration called an electrodialysis stack, with alternating anion and cation-exchange membranes forming the multiple electrodialysis cells. Electrodialysis is usually applied to deionization of aqueous solutions. However, desalting of sparingly conductive aqueous organic and organic solutions is also possible.

The ED stack is composed of the dilute feed stream, concentrate stream and the electrode stream.

Two types of membranes are used: one which is preferentially permeable to the transport of anions (anion-selective), and one which is preferentially permeable to cations (cation-selective). Membranes are arranged alternately between the electrodes, forming individual compartments (or cells). The solution to be desalinated is held in one compartment and during current flow, anions move through the anion exchange membrane in the direction of the anode into adjacent compartment while cations move in the opposite direction into an adjacent compartment on the other side. Thus, overall, the solution becomes depleted in ions in one compartment and solutions in adjacent compartments become enriched in ions.

In an electrodialysis stack, the dilute (D) feed stream, brine or concentrate (C) stream, and electrode (E) stream are allowed to flow through the appropriate cell compartments formed by the ion-exchange membranes. Under the influence of an electrical potential difference, the negatively charged ions (e.g., chloride) in the dilute stream

migrate toward the positively charged anode. These ions pass through the positively charged anion-exchange membrane but are prevented from further migration toward the anode by the negatively charged cation-exchange membrane and therefore stay in the C stream, which becomes concentrated with the anions. The positively charged species (e.g., sodium) in the D stream migrate toward the negatively charged cathode and pass through the negatively charged cation-exchange membrane. These cations also stay in the C stream, preventing further migration toward the cathode by the positively charged

anion-exchange membrane. As a result of the anion and cation migration, electric current flows between the cathode and anode. Only an equal number of anion and cation charge equivalents are transferred from the D stream into the C stream and so the charge balance is maintained in each stream. The overall result of the electrodialysis process is an ion concentration increase in the concentrate stream with a depletion of ions in the dilute solution feed stream

For the operational principle, the following takes place when the DC potential is applied across the electrode's cations are attracted to the cathode, or negative electrode. The Anions are attracted to the anode, or positive electrode Pairs of water molecules break down at the cathode to produce two hydroxyl ions plus hydrogen gas Pairs of water molecules dissociate at the anode to produce four hydrogen ions, one molecule of oxygen, and four electrons.

The results concerning Electrodialysis is an electrochemical separation process that uses DC power to move ions through selective ion exchange

membranes in order to remove salt from a feed stream into a concentrate stream, leaving a product behind with increased value.

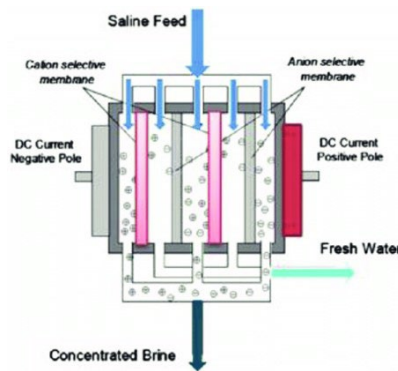


Figure 9

Discussions/Comparison

Electrodialysis processes are different from distillation techniques and other membrane-based processes (such as reverse osmosis (RO)) in that dissolved species are moved away from the feed stream rather than the reverse. Because the quantity of dissolved species in the feed stream is far less than that of the fluid, electrodialysis offers the practical advantage of much higher feed recovery in many applications. An advantage of ED is that, unlike RO, the osmotic pressure is not a factor in ED system, so the pressure can be used for concentrating salt solutions to 20% or higher.

The benefits of RO have made it a popular choice among consumers for filtering the water in their homes. Additionally, many restaurants are using reverse osmosis to improve the safety and taste of their food by using the best quality water. A major advantage of RO is that it is a safe alternative to bottled water. However, there is a significant amount of water wasted while using reverse osmosis.

Conclusion

In this report the issue of water scarcity was discussed. Water desalination is an ideal approach toward the issue of water scarcity around the world, however there are concerns about the brine which is a byproduct of water desalination plants. The classifications of water desalination technologies were identified. Also, articles were presented to examine the functionalities and operational principles of various water desalination Technologies that are currently available commercially. The two technological classifications were mentioned, based upon their energy input which was electrochemical and thermal. Electrochemistry is a new technological approach that is still being developed.

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BELOW AVERAGE

**MECHANICAL ENGINEERING DEPARTMENT
PRAIRIE VIEW A&M UNIVERSITY**



**MCEG 4316 Renewable Energy
Spring 2022 Section P19**

REPORT ON

“Classification of Carbon Capture Technologies, their Operating Principles and Comparison”

**Conducted throughout:
March 31, 2022 – May 1, 2022**

**Submitted by
Kiron Buie and Aniya Facion**

**On
May 1, 2022**

To

**Dr. Shahin Shafiee
ABSTRACT**

The purpose of this project is to evaluate and examine a specific type of renewable energy technologies, Carbon Capture Storage, a process that allows you to capture already existing carbon from within the atmosphere and store it for use in a way that does not allow it to re-enter the atmosphere. This report is a detailed description of the process of capturing CO₂, as well as the details necessary for understanding; with additional information such as costs and methods of storage of the carbon.

To find the necessary information on carbon capture technologies for the beginning of this topic, over the course of a few weeks, multiple articles and research reports were investigated. They are then assembled in this report to give a better clarification over the process Carbon Capture Storage and its environmental impact.

The biggest conclusion drawn from this project were the various methods in which a CCS facility can benefit other aspects of life and that main goal of carbon negation

Chapter 1: Introduction

Carbon Dioxide, for many years, was not a particularly huge concern for the people here on Earth. It would help trap heat in the atmosphere to keep life on Earth from practically freezing. However, in recent years or even decades there has been a fear of too much Carbon dioxide emitting into the atmosphere causing the global temperature to rise. This rise in temperature may sound like a small deal, but this is starting to disrupt the other properties of Earth. For this reason, scientists and engineers have found what they believe is a good solution to the problem called Carbon Capture and Storage.

Carbon Capture and storage is the process of capturing carbon dioxide (CO₂) formed during power generation and industrial processes and storing it so that it is not emitted into the atmosphere. With the main goal to carbon negate (to not add to the overall concentration already existing in the atmosphere) most CCS technologies have the same process in common: Carbon Dioxide is concentrated into a liquid form, transported to a suitable site for storage and then, in some cases, the concentration is pumped underground or, as detailed in this report, another method of renewable energy is aided with the concentration created.

Chapter 2: Methods and Materials

There are multiple innovations & methods relating to the capture of carbon from the atmosphere. These technologies are able to capture up to 90% of carbon dioxide out of the atmosphere from industrial processes..

One method of carbon capture is post-combustion, post-combustion technology removes carbon dioxide from the flue gasses that result from burning fossil fuels. Pre-combustion is another method used which involves converting the fuel into a hydrogen and carbon dioxide mixture. Here in the United States there are about 10 operational facilities participating in carbon capturing, while rapidly growing and building more as the plan is to eliminate as much carbon as possible. Direct air capture (DAC) is used to pull carbon dioxide out of the air by using a chemical that only carbon dioxide is going to attract.

Climeworks is currently finishing the largest DAC, which is estimated to capture 4,000 tons of carbon dioxide. To further explain, using a solvent in this process and a sorbent that is constantly routed between an absorber that binds to the carbon dioxide. The solvent of the process is then heated to a specific temperature to release the carbon dioxide to the desorber. Gambhir's paper calculates keeping pace with current global CO₂ emissions 36 gigatonnes per year would mean building an estimate of 30,000 large-scale DAC plants. Each plant would cost up to \$500 million to build, coming to a grand total cost of up to \$15 trillion. To help mitigate the costs of the facilities, different methods of utilizing the converted carbon have been studied as well as their productions by 2050. The following paragraphs discuss those methods as well as the products they produce.



2.1 Example of Direct Air Capture

Chapter 3: Results

Carbon capture facilities need more fuel than a facility without one to generate the energy to extract, pump and compress the CO₂. If the CO₂ is not pumped in an underground storage facility then the costs of the CCS facility varies from what the necessary and reusable material the carbon is converted into. To help mitigate the costs of the facilities, different methods of utilizing the converted carbon have been studied as well as their productions by 2050. The following paragraph discusses those methods as well as the products they produce.

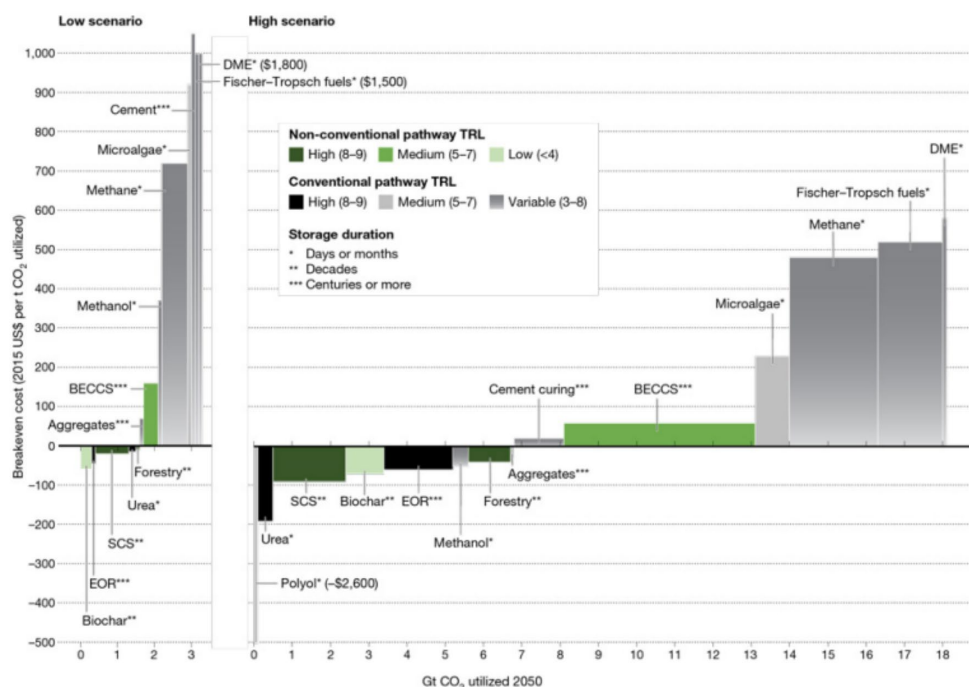


Table 3.1: Costs and utilization of Carbon Dioxide

Reducing the CO₂ to its specific components and using chemical reactions to produce methanol, urea (to use as fertilizer) or polymers is one of the most common versions of carbon conversion. This process could process 0.3 to 0.6 Gt of carbon dioxide a year with costs between -\$80 to \$300 per tonne (by 2050).

One cost effective (by 2050) but environmentally concerning method with cost was the process of using CO₂ to “cure” cement. With this, carbon dioxide is stored for longevity and displaces emission-intensive conventional cement. With capturing 0.1 to 1.4 Gt of carbon dioxide (by 2050) the costs are between -\$30 and \$70 per tonne of CO₂

With thought towards the commercialized transportation’s unending need for fuel. CCS is useful by combining carbon dioxide with hydrogen producing hydrocarbon fuels such as methanol synfuels and syngas. The process of converting carbon into fuel is not an inexpensive one; though ranges of 1 to 4.2 Gt of CO₂ a year, the costs for this upwards towards \$670 per ton of carbon dioxide (by 2050).

One alternative that is also very costly but is being researched thoroughly is microalgae. This can be effective in creating fuels and high-value chemicals by fixing the CO₂ at high efficiencies and then processing the biomass. However, with complicated production costs, and the utilization of 0.2 to 0.9 Gt of carbon dioxide, rates go between \$230 and \$920 per tonne (by 2050).

Use in even agricultural use was researched, CO₂ can be stored and utilized in the enhancement of agricultural yields. This is estimated to have an increased output as much as 0.9 to 1.9 Gt of carbon dioxide per year, with costs between -\$90 to -\$20 per tonne.

Various other methods of Carbon conversion such as forestry, biochar, electricity and enhanced weathering have differing research teams producing results. These topics are being seriously researched however do not have enough information for the common statistic of 2050.

Chapter 4: Discussion

With so many differing applications of carbon capture storage and costs, there is so much to look into and analyze. However, we will look into a CCS technique that is slowly making changes through a process that requires a look not too far outside the box.

Concrete production is a field that has use in everyday life, most structures and landmarks, it requires the use of a binder to form the bone for many buildings and facilities. What happens? Well, concrete is made with cement through a carefully observed and measured process involving calcium, aluminum, silicon, iron and oftentimes limestone. Once the mixture is made, a natural process of CCS occurs as carbon is absorbed by (typically) a cement (or concrete) block. Cement, itself, is responsible for 80-90% of carbon missions even though it can only encompass 10-15% of the total mass of the concrete block.

Researchers noticed that carbon absorption process and thought to utilize it to, not only decrease the time needed for the cement to cure completely but also address the atmospheric issue of greenhouse gasses. A Montreal based company is completing this task with immaculate results, to the point that maybe, concrete will become a carbon sink.

Carbocrete is a company that focuses its developments on cement-free, carbon-negative concrete. To achieve this goal, they require the need of slag from steel factories, this by-product replaces the cement as the necessary binding agent. Once the concrete is formed, CO₂ is permanently encased within the concrete through injection, providing the concrete with increased compressive strength of 30% and an increased resistance to weathering. With every masonry unit, approximately 2kg of carbon dioxide is cut from every concrete masonry due to removing the need of fossil fuels.

This process has its own setback, as the amount of steel slag necessary for a worldwide production of concrete is unattainable. However, this does not stop Carbocrete and other companies from innovating themselves into finding new ways that increase quality of life on and throughout the world.

Chapter 5: Conclusion

To conclude, CCS is a reasonable and cost manageable solution for decreasing global warming to our planet. It is seen that CCS can capture up to 90% of the carbon that is transmitted from modern and such sources. Scientists from one side of the globe to the next acknowledge that global warming is a continuously developing issue that ought to be tended to as fast as time allows. With advancing countries like the USA, India, UK, it will in general be settled that CCS can be practiced around the world to give individuals later on a cleaner future where global warming wouldn't be an issue.

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Acknowledgements:

Dr. Shahin Shafiee - for always listening intently and guiding us. For allowing the ideas to flow and opportunities for new interests and intrigue to spark from discussion. Thank you for increasing my courage.

**Special topic – Fundamentals and Applications of Renewable Energy
Spring 2022**

Title of Assignment: Quiz 2

TOPICS COVERED IN Quiz 2

1. Fundamentals of Geothermal energy, Biomass energy, Ocean energy,
Hydrogen and fuel cells

**Repeated this section for each Quiz and Similarly for all the other assignments in the
course binder**

Prairie View A&M University
Department of Mechanical Engineering
MCEG 4316 Fundamentals and Applications of Renewable Energy, Section P19
Spring 22 – Quiz 2

Name:

ID:

Show all your work precisely. Label all the steps of your solution. Follow the problem solving procedure as mentioned in class.

1. For an indoor temperature of $22\text{ }^{\circ}\text{C}$, the design heating load of a residential building in Charlotte, North Carolina, is determined to be 28 kW . The house is to be heated by geothermal energy, which costs $\$13/10^6\text{ kJ}$. The efficiency of geothermal heating can be taken as 100 percent. Determine (a) the heat loss coefficient of the building, in $\text{kW}/^{\circ}\text{C}$, and (b) the annual energy usage for heating and its cost. (40 points)
2. A synthesis gas consists of 50 percent CO and 50 percent H_2 by volume. This gas is burned with stoichiometric amount of air. Write the balanced chemical reaction and determine the air-fuel ratio. (30 points)
3. The average wave height of an ocean area is 2.5-m-high and each wave lasts for an average period of 7 s. Determine (a) the energy and power of the waves per unit area and (b) the work and average power output of a wave power plant on this site with a plant efficiency of 35 percent and a total ocean wave area of 1 km^2 . Take the density of seawater to be 1025 kg/m^3 . (30 points)

ABOVE AVERAGE

Prairie View A&M University
Department of Mechanical Engineering
MCEG 4316 Fundamentals and Applications of Renewable Energy, Section P19
Spring 22 – Quiz 2

Name: shumirai Jaja

ID: 21660165

87/100

Show all your work precisely. Label all the steps of your solution. Follow the problem solving procedure as mentioned in class.

- Q1 40/40
1. For an indoor temperature of 22°C , the design heating load of a residential building in Charlotte, North Carolina, is determined to be 28 kW . The house is to be heated by geothermal energy, which costs $\$13/10^6\text{ kJ}$. The efficiency of geothermal heating can be taken as 100 percent. Determine (a) the heat loss coefficient of the building, in $\text{kW}/^{\circ}\text{C}$, and (b) the annual energy usage for heating and its cost. (40 points)
 - 25/30 2. A synthesis gas consists of 50 percent CO and 50 percent H_2 by volume. This gas is burned with stoichiometric amount of air. Write the balanced chemical reaction and determine the air-fuel ratio. (30 points)
 - 22/30 3. The average wave height of an ocean area is 2.5-m -high and each wave lasts for an average period of 7 s . Determine (a) the energy and power of the waves per unit area and (b) the work and average power output of a wave power plant on this site with a plant efficiency of 35 percent and a total ocean wave area of 1 km^2 . Take the density of seawater to be 1025 kg/m^3 . (30 points)
- $1.532 \times 10^8\text{ kJ/year}$
 $1.532 \times 10^8\text{ kJ/year}$
 $1.532 \times 10^8\text{ kJ/year}$

Given: $T_i = 22^\circ\text{C}$

Heating load = 28 kW

Cost = $\$13/10^6\text{ kJ}$

efficiency = 100%

Find: Heat loss coefficient
Annual energy usage

Solve:

$$A) Q = UA \Delta T = UA (T_s - T_o) = k_{overall}$$

$$k_{overall} = \frac{Q}{(T - T_i)} = \frac{28000}{(22 - (-6))} = 1000\text{ W/}^\circ\text{C} = \boxed{1\text{ kW/}^\circ\text{C}}$$

$$B) \frac{k_{overall}}{1_{Heating}} D = \frac{1\text{ kW} \cdot 5^\circ\text{C}}{1} (1775^\circ\text{C}) \left(\frac{24(3600\text{ s})}{1\text{ day}} \right)$$

$$= 1.532 \times 10^8\text{ kJ}$$

$$(1.532 \times 10^8\text{ kJ/year}) (\$13/10^6\text{ kJ})$$

$$= \boxed{\$1992\text{ Year}}$$

ben : 50% CO
50% H₂

Find : Balanced Chemical Reaction / Air Fuel Ratio
Solve :

Molar mass C → 12

H → 1

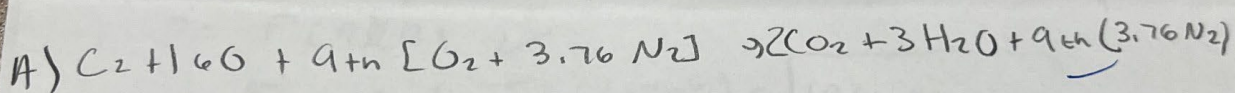
O → 16 ✓

1 mol of Air
↓ ↓
O₂ N₂ ✓

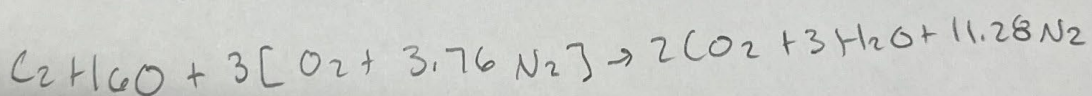
LHV → 17430 kJ/kg

HHV → 18880 kJ/kg

$$AF = \frac{m_{air}}{m_{fuel}} = \frac{12 \times 1 + 16 \times 1 + 1 \times 2}{1} \quad \checkmark$$



B) $0.5 + a_{th} = 2 + 1.5 \rightarrow a_{th} = 3$



$$AF = \frac{(3 \times 4.76 \times 29)}{(12 \times 1 + 16 \times 1 + 1 \times 2)} = \underline{\underline{13.8}} \quad \checkmark$$

2.5 m high efficiency = 35%
Time = 7s area = 1 km²

find: energy / Power of waves

work / average power output of wave power

Solve:

$$A) E = \frac{1}{10} \rho g H^2 \rightarrow \frac{1}{10} \times 1025 \text{ kg/m}^3 \times 9.81 \text{ m/s}^2 \times (2.5 \text{ m})^2 \checkmark$$

$$= 3927.83 \text{ J/m}^2 \times 10^{-2}$$
$$P = \frac{E}{T} = \frac{3927.83}{7} = \boxed{561.12 \text{ W/m}^2} \times 10^{-2}$$

$$B) W = E(T)(A) \checkmark$$
$$= 3927.83 (.35) (1 \times 10^6 \text{ m}^2) = 1374174 \text{ J} \times 10^{-2}$$

$$P = P(T)(A) \checkmark$$
$$561.12 (.35) (1 \times 10^6) = \boxed{196.39 \text{ MW}} \times 10^{-2}$$

AVERAGE

Prairie View A&M University
Department of Mechanical Engineering
MCEG 4316 Fundamentals and Applications of Renewable Energy, Section P19
Spring 22 – Quiz 2

Name: MALAIKA LEE

ID: PA1648286

55/100

Show all your work precisely. Label all the steps of your solution. Follow the problem solving procedure as mentioned in class.

- 40/40
1. For an indoor temperature of 22°C , the design heating load of a residential building in Charlotte, North Carolina, is determined to be 28 kW . The house is to be heated by geothermal energy, which costs $\$13/10^6\text{ kJ}$. The efficiency of geothermal heating can be taken as 100 percent. Determine (a) the heat loss coefficient of the building, in $\text{kW}/^{\circ}\text{C}$, and (b) the annual energy usage for heating and its cost. (40 points)
- $\Rightarrow \text{CH7}$
Geothermal
- 0/30
CH8 $\leftarrow$
Biomass
2. A synthesis gas consists of 50 percent CO and 50 percent H_2 by volume. This gas is burned with stoichiometric amount of air. Write the balanced chemical reaction and determine the air-fuel ratio. (30 points)
- $\text{Energy cost} = \text{Energy consumption} \times \text{unit price of energy}$
- 15/30
3. The average wave height of an ocean area is 2.5-m-high and each wave lasts for an average period of 7 s. Determine (a) the energy and power of the waves per unit area and (b) the work and average power output of a wave power plant on this site with a plant efficiency of 35 percent and a total ocean wave area of 1 km^2 . Take the density of seawater to be 1025 kg/m^3 . (30 points)
- $\Rightarrow \text{CH9}$

PROBLEM #1

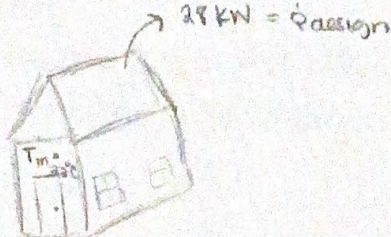
Q1/ 40/40

KNOWN: $\dot{Q}_{\text{design}} = 28 \text{ kW}$; $A = 100 \text{ m}^2 = 1$; $T_{\text{indoor}} = 22^\circ\text{C}$; unit cost of energy = $13/10^6 \text{ ¢/kWh}$

FIND: a.) $k_{\text{overall}} = ?$

b.) Annual energy consumption = ? ; Annual heating cost = ?

SCHEMATIC:



ASSUMPTIONS / PROPERTIES:

- From table 7-1 $\Rightarrow$ Charlotte, North Carolina: 3191°F days $\xrightarrow{\text{Yearly Total}} 3191/1.8 = 177.27^\circ\text{C}$
- Winter design temp $\Rightarrow -6^\circ\text{C}$
- $\text{DD}_{\text{heating}} = (177.27^\circ\text{C-days}) (24(3600\text{s})/\text{day})$ ✓

SOLUTION PLAN:

a.) $\dot{Q}_{\text{design}} = UA \Delta T_{\text{design}} = UA (T_i - T_o)_{\text{design}} = k_{\text{overall}} (T_i - T_o)_{\text{design}} \xrightarrow{\text{equation (7-12)}}$

$$\Rightarrow k_{\text{overall}} = \dot{Q}_{\text{design}} / (T_i - T_o)_{\text{design}}$$

b.) Annual energy consumption = $k_{\text{overall}} / \eta_{\text{heating}} (\text{DD}_{\text{heating}}) \xrightarrow{\text{equation (7-8)}}$

Annual heating cost = Annual energy consumption (unit cost of energy) ✓

SOLUTION:

a.) $k_{\text{overall}} = \frac{28 \text{ kW}}{(22 - (-6))^\circ\text{C}} = 1 \text{ kW}/^\circ\text{C}$ ✓

b.) Annual energy consumption = $1 \text{ kW}/^\circ\text{C} / 1 \left((177.27^\circ\text{C-days}) (24(3600\text{s})/\text{day}) \right)$
 $= 1.532 \times 10^8 \text{ kWh}$ ✓

Annual heating cost = $1.532 \times 10^8 (13/10^6)$
 $[\text{kWh/yr}] [\text{kWh}]$

$= \$1992/\text{year}$ ✓

PROBLEM #2

Oxygen
↓
Nitrogen

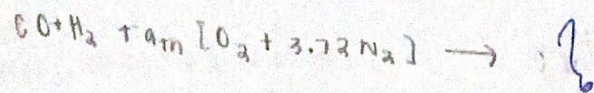
KNOWN: $\text{CO} \Rightarrow \text{vol.} = .5 \xrightarrow{\text{by volume}} \text{H}_2 = \text{vol.} = .5$

FIND: Balanced chemical reaction?; AFR = ?

ASSUMPTIONS / PROPERTIES:

- molar mass of C = 12 kg/kmol; molar mass of H_2 = 2 kg/kmol; molar mass of O = 16 kg/kmol
- HHV = 18,880 kJ/kg; LHV = 17,430 kJ/kg

SOLUTION PLAN:



SOLUTION:

2

PROBLEM #3

KNOWN: wave height = 2.5 m ; $\rho = 1025 \text{ kg/m}^3$; $\rho_{\text{plant}} = 35\% = 0.35$; $T = 7\text{s}$ ^{period}

FIND: $e_{\text{wave}} = ?$; $w_{\text{available}} = ?$

SCHEMATIC:

ASSUMPTIONS / PROPERTIES:

$$\cdot \lambda_a = 2.5 \text{ m} \Rightarrow \text{amplitude} = 1.25 \text{ m}$$

$$\cdot L = 1.56 T^2 \Rightarrow 1.56 (7\text{s})^2 = 76.44 \text{ m}$$

SOLUTION PLAN:

$$P_e = \frac{1}{4} \rho a^2 g \quad \checkmark$$

$$P_k = \frac{1}{4} \rho a^2 g$$

$$e_{\text{wave}} = P_e + P_k \Rightarrow \frac{1}{2} \rho a^2 g$$

$$w_{\text{available}} = \frac{1}{2} \rho a^2 g$$

SOLUTION:

$$e_{\text{wave}} = \frac{1}{2} (1025) (1.25)^2 (9.81) \cdot \left(\frac{1\text{N}}{1\text{kg} \cdot \text{m/s}^2} \right) \left(\frac{1\text{N}}{1\text{N} \cdot \text{m}} \right) = 7855.66 \text{ J/m}^2$$

$$w_{\text{available}} = \frac{1}{2} (1) (1025) (1.25)^2 (9.81) \left(\frac{1\text{N}}{1\text{kg} \cdot \text{m/s}^2} \right) \left(\frac{1\text{N}}{1\text{N} \cdot \text{m}} \right) \left(\frac{1\text{N}}{1\text{J/s}} \right)$$

$$= 1122.23 \text{ W/m}^2$$

BELOW AVERAGE

Prairie View A&M University
Department of Mechanical Engineering
MCEG 4316 Fundamentals and Applications of Renewable Energy, Section P19
Spring 22 – Quiz 2

Name: Prince Rfley

35/100

ID: P21321624

Show all your work precisely. Label all the steps of your solution. Follow the problem solving procedure as mentioned in class.

10/40 1. For an indoor temperature of 22°C , the design heating load of a residential building in Charlotte, North Carolina, is determined to be 28 kW . The house is to be heated by geothermal energy, which costs $\$13/10^6\text{ kJ}$. The efficiency of geothermal heating can be taken as 100 percent. Determine (a) the heat loss coefficient of the building, in $\text{kW}/^{\circ}\text{C}$, and (b) the annual energy usage for heating and its cost. (40 points)

5/30 2. A synthesis gas consists of 50 percent CO and 50 percent H_2 by volume. This gas is burned with stoichiometric amount of air. Write the balanced chemical reaction and determine the air-fuel ratio. (30 points)

20/30 3. The average wave height of an ocean area is 2.5-m -high and each wave lasts for an average period of 7 s . Determine (a) the energy and power of the waves per unit area and (b) the work and average power output of a wave power plant on this site with a plant efficiency of 35 percent and a total ocean wave area of 1 km^2 . Take the density of seawater to be 1025 kg/m^3 . (30 points)

$$Q_{\text{design}} = UA \Delta T_{\text{design}} = UA (T_i - T_o)_{\text{design}} = k_{\text{overall}} (T_i - T_o)_{\text{design}}$$

$$k_{\text{overall}} = \frac{Q_{\text{design}}}{(T_i - T_o)_{\text{design}}}$$

$$Q_1 = 10/40$$

Solution: $k_{\text{overall}} = \frac{28_{1000}}{22 - (-6)} = 1 \checkmark$

$$-10 \times \text{Stoichiometric} = 0.5 + 4 \times 1 = 21.5$$

Air = 1 Mol of air

$$\text{Air-Fuel ratio} = AF = \frac{m_{\text{air}}}{m_{\text{fuel}}}$$

$$\checkmark \frac{W_{\text{air}}}{W_{\text{gas}}} = \frac{LHV_{\text{air}}}{LHV_{\text{gas}}} \times \frac{AF_{\text{air}}}{AF_{\text{gas}}}$$

$$LHV = 17,430$$

$$HHV = 18,880$$

$$\text{Solution: } (50 \text{ kmol}) (28 \text{ kg/kmol}) = 1400 \text{ kg} = \text{CO} \times -10$$

$$(50 \text{ kmol}) (2 \text{ kg/kmol}) = 100 \text{ kg} = \text{H}_2 \times$$

$$\text{total mass} = 1500 \text{ kg} \times -5$$

average Wave height = 2.5 m

average period = 7 sec

Plant eff = 35%

total wave area = 1 km

Density = 1025 kg/m³

$$E_{\text{wave}} = P_e + P_k = \frac{1}{2} \rho a^2 g$$

$$2a = 2.5 = a = 1.25$$

$$\frac{1}{2} \rho a^2 g$$

$$\text{Solution: } \frac{1}{2} (1025) (1.25)^2 (9.81) = \boxed{7855.16 \text{ J/m}^2} \quad \begin{matrix} 10 \\ \checkmark \end{matrix}$$

$$\frac{1}{2(7)} (1025) (1.25)^2 (9.81) = \boxed{1122.24 \text{ W/m}^2} \quad \begin{matrix} 5 \\ \checkmark \end{matrix}$$

$$W = ? \quad -10$$

**Special topic – Fundamentals and Applications of Renewable Energy
Spring 2022**

Title of Assignment: Midterm Exam

TOPICS COVERED IN midterm exam

1. Review of thermal sciences, solar energy, wind energy, hydropower

Repeated this section for each Quiz and Similarly for all the other assignments in the course binder

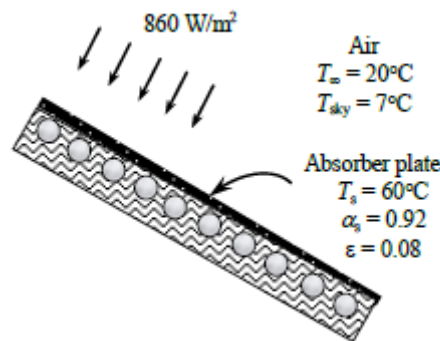
Prairie View A&M University
Department of Mechanical Engineering
MCEG 4316 Fundamentals and Applications of Renewable Energy, Section P19
Spring 22 – Midterm Exam

Name:

ID:

Show all your work precisely. Label all the steps of your solution. Follow the problem solving procedure as mentioned in class.

1. The absorber surface of a solar collector is made of aluminum coated with black nickel oxide ($\alpha_s = 0.92$ and $\varepsilon = 0.08$). Solar radiation is incident on the surface at a rate of 860 W/m^2 . The air and the effective sky temperature are 20 and 7°C , respectively, and the convection heat transfer coefficient is $15 \text{ W/m}^2\cdot\text{K}$. For an absorber surface temperature of 60°C , determine the net rate of solar energy delivered by the absorber plate to the water circulating behind it.



2. Solar radiation is incident on a flat-plate collector at a rate of $260 \text{ Btu/h} \cdot \text{ft}^2$. The product of the transmissivity of glazing and the absorptivity of absorber plate is $t_a = 0.85$ for this single glazing collector. The heat loss coefficient of the collector is $0.5 \text{ Btu/h} \cdot \text{ft}^2 \cdot ^\circ\text{F}$. The collector is at an average temperature of 120°F and the ambient air temperature is 67°F . (a) Determine the efficiency of this collector. (b) Determine the efficiency of a double-glazing collector whose t_a value is 0.80 and the heat loss coefficient is $0.3 \text{ Btu/h} \cdot \text{ft}^2 \cdot ^\circ\text{F}$. Use the same collector and ambient air temperatures.
3. The measurements over an entire week period indicates that a wind turbine with a blade diameter of 40 m has produced $11,000 \text{ kWh}$ of electricity. If the overall efficiency of the wind turbine is estimated to be 28 percent, determine the average wind velocity during this period. Take the density of air to be 1.16 kg/m^3 .
4. The water in a large dam is to be used to generate electricity by the installation of a hydraulic turbine. The elevation difference between the free surfaces upstream and downstream of the dam is 480 ft . Water is to be supplied to the turbine at a rate of 1075 gal/s . The turbine efficiency is 89 percent based on the net head, and the generator efficiency is 98 percent. The total irreversible head loss (major losses + minor losses) in the piping system including the penstock is estimated to be 13 ft . Determine (a) the overall efficiency of this hydroelectric plant, (b) the electric power produced, and (c) the turbine shaft power.

ABOVE AVERAGE

65

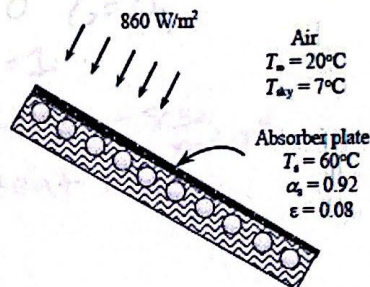
Prairie View A&M University
Department of Mechanical Engineering
MCEG 4316 Fundamentals and Applications of Renewable Energy, Section P19
Spring 22 – Midterm Exam

Name: Kierra Brossette

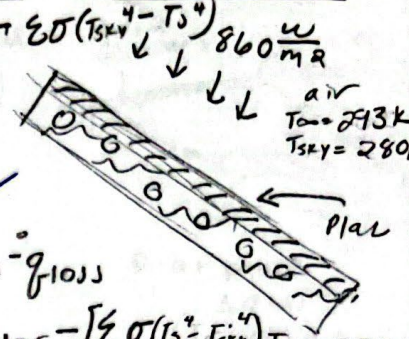
ID: P21447624

Show all your work precisely. Label all the steps of your solution. Follow the problem solving procedure as mentioned in class.

- ✓ 1. The absorber surface of a solar collector is made of aluminum coated with black nickel oxide ($\alpha_s = 0.92$ and $\epsilon = 0.08$). Solar radiation is incident on the surface at a rate of 860 W/m^2 . The air and the effective sky temperature are 20 and 7°C , respectively, and the convection heat transfer coefficient is $15 \text{ W/m}^2\cdot\text{K}$. For an absorber surface temperature of 60°C , determine the net rate of solar energy delivered by the absorber plate to the water circulating behind it.



2. Solar radiation is incident on a flat-plate collector at a rate of $260 \text{ Btu/h} \cdot \text{ft}^2$. The product of the transmissivity of glazing and the absorptivity of absorber plate is $t_a = 0.85$ for this single glazing collector. The heat loss coefficient of the collector is $0.5 \text{ Btu/h} \cdot \text{ft}^2 \cdot ^\circ\text{F}$. The collector is at an average temperature of 120°F and the ambient air temperature is 67°F . (a) Determine the efficiency of this collector. (b) Determine the efficiency of a double-glazing collector whose t_a value is 0.80 and the heat loss coefficient is $0.3 \text{ Btu/h} \cdot \text{ft}^2 \cdot ^\circ\text{F}$. Use the same collector and ambient air temperatures.
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Analysis	Assumptions	Physical Laws	Schematic
$\alpha_s = .92$ $\epsilon = .08$ $G = 860 \frac{W}{m^2}$ $T_{\infty} = 20^\circ C + 273$ $T_{sky} = 7^\circ C + 273$ $\eta = 15 \frac{W}{m^2 \cdot K}$ $T_s = 60^\circ C + 273$ determine the net rate of the solar energy ✓	air incompressible $p = ?$ water circulating no black body nickel oxide absorptivity $0 < \alpha < 1$ $p = 0$ $z = 0$ $\alpha = 1$ $\sigma = 5.67E-8 \frac{W}{m^2 \cdot K^4}$ incident	$\dot{q}_{net, rad} = \alpha_s G_{solar} - \epsilon \sigma (T_{sky}^4 - T_s^4)$ $\epsilon(T) = \alpha(T)$ $\alpha = \frac{G_{abs}}{G}$ ✓ $\dot{q}_{net} = \dot{q}_{gain} - \dot{q}_{loss}$ $\dot{q}_{net} = \alpha_s G_{solar} - [\epsilon \sigma (T_s^4 - T_{sky}^4) + h(T_s - T_{air})]$ ✓	

Calculation

$$\dot{q}_{net} = (0.92) \left(860 \frac{W}{m^2} \right) - \left[.08 \left(5.67E-8 \frac{W}{m^2 \cdot K^4} \right) \left[(60 + 273)^4 - (7 + 273)^4 \right] - \left(15 \frac{W}{m^2 \cdot K} \right) (60 - 20^\circ C) \right]$$

$$\boxed{\dot{q}_{net} = 163.30 \frac{W}{m^2}} \quad \checkmark$$

25

Analysis

$$G = 260 \frac{\text{Btu}}{\text{h ft}^2}$$

$$\tau = \alpha = 0.85$$

$$U = 0.5 \frac{\text{Btu}}{\text{h ft}^2 \text{ } ^\circ\text{F}}$$

$$120^\circ\text{F}$$

$$67^\circ\text{F}$$

$$a) \eta_{\text{collector}}?$$

$$b) \eta_{\text{double glazing}}$$

$$\tau = \alpha = 0.80$$

$$U = 0.3 \frac{\text{Btu}}{\text{h ft}^2 \text{ } ^\circ\text{F}}$$

Assumptions

Solar radiation incident

Flat plate horizontal

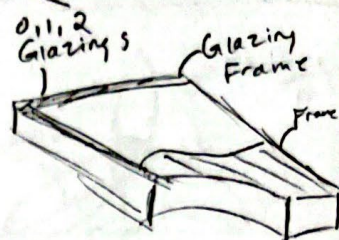
glazing

absorptivity

single

Physical Laws

$$\eta_c = F_R K_{\tau\alpha} \tau \alpha - F_R U \left(\frac{T_{w,in} - T_a}{G} \right)$$

Schematic

Flat plate solar collector

Calculations

single glazing

$$\eta_c = F_R K_{\tau\alpha} \tau \alpha - F_R U \left(\frac{T_{w,in} - T_a}{G} \right) \times$$

$$\eta_c = (0.85)(1)(0.85)(0.85) - (0.85)(0.5) \left(\frac{120^\circ\text{F} - 67^\circ\text{F}}{260} \right)$$

$$\boxed{\eta_c = 0.527} \quad a) \quad \boxed{52.7\%}$$

$$b) \eta_c = F_R K_{\tau\alpha} \tau \alpha - F_R U \left(\frac{T_{w,in} - T_a}{G} \right) \times$$

$$= (0.80)(1)(0.80)(0.80) - (0.80)(0.3) \left(\frac{120 - 67}{260} \right)$$

$$\eta_c = 0.46307$$

$$b) \quad \boxed{\eta_c = 46.30\%}$$

5

Analysis

$$D = 40\text{m}$$

$$\dot{W}_{\text{available}} = 11,000\text{kWh}$$

$$\eta = 28\%$$

average
wind
velocity?

$$\rho = 1.16 \frac{\text{kg}}{\text{m}^3}$$

Assumptions

Entire week
period

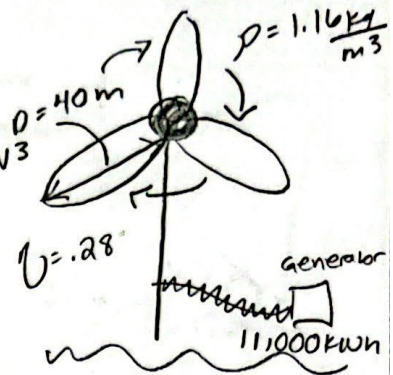
air
incompressible

$$(24\text{hrs})(7\text{day})$$
$$[=168]$$

Physical Laws

$$A = \frac{\pi D^2}{4}$$

$$\dot{W}_{\text{shaft}} = \frac{1}{2} \eta \rho A V^3$$



Calculations

$$A = \frac{\pi (40\text{m})^2}{4}$$

$$[A = 1256.63\text{m}^2]$$

$$\frac{11,000\text{kWh}}{168}$$

$$65.47\text{ kW}$$

$$\dot{W}_{\text{shaft}} = 65.47\text{ kW}$$

$$65.47\text{ kW} = \frac{1}{2} (0.28) (1.16 \frac{\text{kg}}{\text{m}^3}) (1256.63\text{m}^2) V^3 \left(\frac{1 \frac{\text{kg}}{\text{m}^3}}{1000 \frac{\text{m}^2}{\text{s}^2}} \right)$$

$$65.47 = 0.204076 V^3$$

$$0.204076 \cdot 0.204076$$

$$V^3 = \sqrt[3]{320.8118544}$$

$$V = 6.845 \frac{\text{m}}{\text{s}}$$

average
wind
velocity

What equations did you use?

You must show all your
solution details.

25

Analysis

Assumptions

Physical laws

Schematic

$$H_{gross} = 480 \text{ ft}$$

$$\dot{V} = 1075 \frac{\text{gal}}{\text{s}}$$

$$\eta_{\text{turbine}} = 89\%$$

$$\eta_{\text{generator}} = 98\%$$

$$h = 13 \text{ ft}$$

a) overall efficiency

b) Electric power produced

c) Turbine shaft power

large dam

water

Electricity

- work

no irreversible losses

$$\rho = 1000 \text{ kg/m}^3$$

$$\rho = 62.4 \frac{\text{lbm}}{\text{ft}^3}$$

$$g = 32.2 \frac{\text{ft}}{\text{s}^2}$$

$$g = 32.2 \frac{\text{ft}}{\text{s}^2}$$

$$\eta_{\text{turbine-generator}} = \eta_{\text{turbine}} \times \eta_{\text{generator}}$$

$$\dot{W}_{\text{max}} = \dot{m}gh$$

$$\dot{W}_{\text{max}} = \rho g \dot{V} H_{\text{gross}}$$

$$\dot{V} = \frac{\dot{W}_{\text{max}}}{\rho (u_{\text{max}})}$$

$$\dot{W}_{\text{max}} = \rho g \dot{V} H_{\text{gross}}$$

$$\dot{E}_{\text{mean, low piping}} = \rho \dot{V} g h_L \times$$

$$\dot{W}_{\text{max}} = \left(62.4 \frac{\text{lbm}}{\text{ft}^3} \right) \left(32.2 \frac{\text{ft}}{\text{s}^2} \right) \left(1075 \frac{\text{gal}}{\text{s}} \right) (480 \text{ ft}) \times \left(\frac{1 \text{ ft}^3}{7.4804 \text{ gal}} \right)$$

$$\dot{W}_{\text{max}} = 138600.67 \text{ kW}$$

Calculations

overall efficiency

$$\eta_{\text{turbine-generator}} = (0.89)(0.98) \eta_{\text{piping}} ?$$

$$\eta_{\text{turbine-generator}} = 0.8722 \times$$

$$\dot{E}_{\text{mean, low piping}} = \left(62.4 \frac{\text{lbm}}{\text{ft}^3} \right) \left(1075 \frac{\text{gal}}{\text{s}} \right) \left(32.2 \frac{\text{ft}}{\text{s}^2} \right) (13 \text{ ft}) \times \left(\frac{1 \text{ ft}^3}{7.4804 \text{ gal}} \right)$$

$$\dot{E}_{\text{mean, low piping}} = 3753.76 \text{ kW}$$

(10)

$$\eta_{\text{turbine-generator}} = 87.22\%$$

$$\dot{W}_{\text{shaft}} = \eta_{\text{turbine}} (\dot{W}_{\text{max}} - \dot{E}_{\text{mean, low piping}})$$

$$= (0.89) (138600.67 \text{ kW} - 3753.76 \text{ kW})$$

$$\dot{W}_{\text{shaft}} = 119.9$$

$$\dot{W}_{\text{shaft}} = 120 \text{ kW}$$

$$\dot{m} = \rho \dot{V} = \left(62.4 \frac{\text{lbm}}{\text{ft}^3} \right) \left(1075 \frac{\text{gal}}{\text{s}} \right) \left(\frac{1 \text{ ft}^3}{7.4804 \text{ gal}} \right)$$

$$\dot{m} = 8967.43 \frac{\text{lbm}}{\text{s}}$$

AVERAGE

60

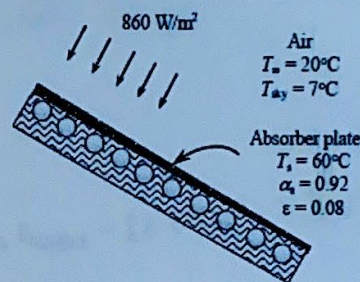
Prairie View A&M University
Department of Mechanical Engineering
MCEG 4316 Fundamentals and Applications of Renewable Energy, Section P19
Spring 22 – Midterm Exam

Name: MALAIKA LEE

ID: P21048280

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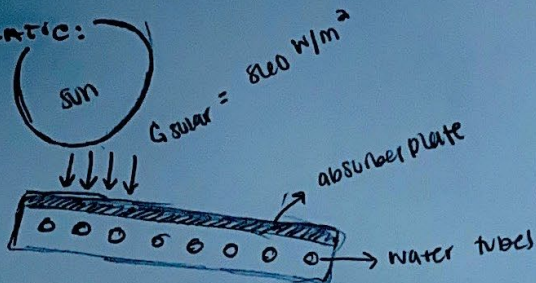
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Qsm #1

KNOWN: $T_{air} = 20^\circ\text{C}$; $T_{sky} = 7^\circ\text{C}$ } air $\Rightarrow$ Absorber plate $\begin{cases} T_s = 60^\circ\text{C} \\ \alpha_s = .92 \\ \epsilon = .08 \end{cases}$; $G_{solar} = 800 \text{ W/m}^2$; $h = 15 \text{ W/m}^2\text{K}$

FIND: $\dot{q}_{net} = ?$

SCHEMATIC:



ASSUMPTIONS / PROPERTIES:

$$\sigma = 5.67 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4$$

$$T_s = 60 + 273 \text{ K} = 333 \text{ K}$$

$$T_{sky} = 7 + 273 \text{ K} = 280 \text{ K}$$

SOLUTION PLAN:

$$\dot{q}_{net} = \dot{q}_{gain} - \dot{q}_{loss}$$

$$\Rightarrow - \alpha_s G_{solar} - [\epsilon \sigma (T_s^4 - T_{sky}^4) + h(T_s - T_{air})]$$

SOLUTION:

$$\dot{q}_{net} = .92 (800) - [.08 (5.67 \times 10^{-8}) ((333)^4 - (280)^4) + (15)(60 - 20)]$$

$\frac{[\text{W/m}^2]}{[\text{W/m}^2 \cdot \text{K}^4] \quad [\text{K}] \quad [\text{K}] \quad \frac{[\text{W/m}^2 \cdot \text{K}]}{[^\circ\text{C}]} [^\circ\text{C}]}$

$$\dot{q}_{net} = 163.30 \text{ W/m}^2$$

RENEWABLE RESOURCES - MIDTERM

Problem #2
Given:

$$G_{\text{solar}} = 200 \text{ BTU/h} \cdot \text{ft}^2 \quad ; \quad T_a = .85 \quad ; \quad U = .5 \text{ BTU/h} \cdot \text{ft}^2 \cdot ^\circ\text{F} \quad ; \quad T_a = 67^\circ\text{F} \quad ; \quad T_{\text{avg}} = 120^\circ\text{F}$$

Find: I. $\eta = ?$ II. $\eta \rightarrow$ double glazing collector

$$\rightarrow T_a = .80 \quad ; \quad .3 \text{ BTU/h} \cdot \text{ft}^3 \cdot ^\circ\text{F}$$

SCHEMATIC:

ASSUMPTIONS / PROPERTIES:

- Single glazing $\Rightarrow U = .5 \text{ BTU/h} \cdot \text{ft}^2 \cdot ^\circ\text{F}$ & $U = 2.8 \text{ W/m}^2 \cdot ^\circ\text{C}$
- Same ambient temp & air temp for both collectors.

SOLUTION PLAN:

I. $\eta_c =$

α

SOLUTION:

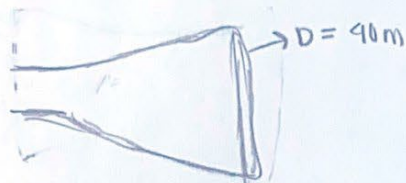
5

Problem #3

KNOWN: $\rho_{air} = 1.16 \text{ kg/m}^3$; $d = 40 \text{ m}$; $\dot{W}_{electric} = 11,000 \text{ kWh}$

FIND: $(V?)$

SCHEMATIC:



ASSUMPTIONS / PROPERTIES

$$A = \pi D^2 / 4 = \pi (40)^2 / 4 = 1256.63 \text{ m}^2$$

SOLUTION PLAN:

$$\eta_{overall} = \dot{W}_{electric} / \frac{1}{2} \rho A V^3 \quad \checkmark$$

SOLUTION:

$$.28 = \frac{11000}{\frac{1}{2} (1.16) (1256.63) (V^3)} \Rightarrow .28 = \frac{11000}{728.84 (V^3)} \quad (\cancel{728.84} (V^3))$$

$$\Rightarrow \frac{.28 (728.84) (V^3)}{.28 (728.84)} = \frac{11000}{.28 (728.84)}$$

$$\sqrt[3]{V^3} = \sqrt[3]{4.900} \Rightarrow \underline{V = 1.698 \text{ m/s}} \quad \times$$

15

RENEWABLE ENERGY - MIDTERM

PROBLEM #4
 KNOWN: $\dot{V} = 1075 \text{ gal/s}$; $\eta_{\text{gen}} = 75\%$; $\eta_{\text{turb}} = 89\%$
 FIND: I. $\eta_{\text{overall}} = ?$; II. $\dot{W}_{\text{electric}} = ?$; III. $\dot{W}_{\text{shaft}} = ?$

SCHEMATIC:

ASSUMPTIONS:

SOLUTION PLAN:

- $\eta_{\text{overall}} = \eta_{\text{generator}} (\eta_{\text{turbine}})$
- $\eta_{\text{overall}} = \dot{W}_{\text{electric}} / \dot{W}_{\text{max}} \Rightarrow \dot{W}_{\text{electric}} = \dot{W}_{\text{max}} \cdot \eta_{\text{overall}}$

$\eta_{\text{piping}} ?$

SOLUTION:

- $\eta_{\text{overall}} = .98 (.89) = .8722 = 87.22\% = \eta_{\text{overall}}$

- I. $\dot{W}_{\text{max}} = \rho \dot{V} g H_{\text{gross}} = 1000 (1075) (9.81) (980 \text{ ft})$
 $= 5061960 \text{ kW}$

$\dot{W}_{\text{electric}} = 5061960 \text{ kW} (.87)$

$= 4403905 \text{ kW}$

- II. $\dot{W}_{\text{shaft}} = \eta_{\text{turb}} (\dot{W}_{\text{max}} -$

15

BELOW AVERAGE

(40)

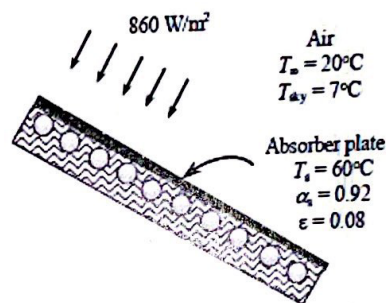
Prairie View A&M University
Department of Mechanical Engineering
MCEG 4316 Fundamentals and Applications of Renewable Energy, Section P19
Spring 22 – Midterm Exam

Name: DASHAWN HOUSTON

ID: 21774944

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Dr. Smawen Houston

① GIVEN:

$$\alpha_s = 0.92 \quad T_s = 60^\circ\text{C} \quad \left. \begin{array}{l} \text{Absorber} \\ \text{Plate} \end{array} \right\}$$

$$\varepsilon = 0.08$$

$$G = 860 \text{ W/m}^2$$

$$T = 20^\circ\text{C} = 293\text{K}$$

$$T_{\text{avg}} = 7^\circ\text{C} = 280\text{K}$$

$$h_a = 15 \text{ W/m}^2\cdot\text{K}$$

SOL'N:

$$T_p = \frac{20 + 7}{2} = 13.5^\circ\text{C} \quad \times \quad \therefore \sigma = 5.67 \times 10^{-8} \text{ W/m}^2\cdot\text{K}$$

$$\dot{q} = 0.92 \cdot 860 - q_{\text{con}} - q_{\text{rad}} \quad \times$$

$$q_{\text{con}} = 15(293 - 280)$$

$$q_{\text{rad}} = 0.08 \times \sigma (293^4 - 280^4)$$

$$\dot{q} = 0.92 \cdot 860 - 15(293 - 280) - 0.08 \cdot 5.67 \times 10^{-8} (293^4 - 280^4)$$

$$\boxed{\dot{q} = 590.65 \text{ W/m}^2} \quad \times$$

5

Small Houston

Given:

$$I = 260 \text{ Btu/h} \cdot \text{ft}^2$$

$$t_a = 0.85$$

$$= 0.5 \text{ Btu/h} \cdot \text{ft}^2 \cdot \text{F}^\circ$$

$$T_{\text{coll}} = 120^\circ \text{F}$$

$$T_{\text{air}} = 67^\circ \text{F}$$

Find:

$$\textcircled{a} \mu_{\text{coll}}$$

$$\textcircled{b} \mu_{\text{dg.coll}} ; t_a = 0.80, A_{\text{loss}} = 0.3 \text{ Btu/h} \cdot \text{ft}^2 \cdot \text{F}^\circ$$

Sol'n:

$$\textcircled{a} \mu_{\text{sg.coll}} = \frac{T_{\text{coll}} - T_{\text{air}}}{I \times t_a} \Rightarrow \frac{120 - 67}{260 \times 0.85} = 0.239 \approx \boxed{23.9\% = \mu_{\text{sg}}} \quad \times$$

$$\textcircled{b} \mu_{\text{dg.coll}} = \frac{T_{\text{coll}} - T_{\text{air}}}{I \times t_a} \Rightarrow \frac{120 - 67}{260 \times 0.80} = 0.255 \approx \boxed{25.5\% = \mu_{\text{dg}}} \quad \times$$

$$\text{Ratio} = \frac{\mu_{\text{dg}} - \mu_{\text{sg}}}{\mu_{\text{sg}}} \Rightarrow \frac{(0.255) - (0.239)}{(0.239)} = \boxed{0.0669 \approx 6.7\%} \quad \times$$

marginally more
5% more loss
loss would be small so
control no. below 5%

5

① DaShawel Houston

③

Given:

$$d = 40\text{m}$$

$$W = 11,000 \text{ kWh}$$

$$\eta_{\text{ave}} = 28\%$$

$$\rho = 1.16 \text{ kg/m}^3$$

Find:

$$V_{\text{avg}} = ?$$

Sol'n:

$$P_n = \frac{1}{2} \rho A V^2 = \text{Input}$$

$$\eta_{\text{ave}} = \frac{\text{Output (Electric)}}{\text{Input (Wind)}}$$

$$\text{Output} = \frac{11000}{7 \times 24} = 65.48 \text{ kW} \checkmark$$

$\therefore$

$$0.28 = \frac{65.48 \times 10^3}{\frac{1}{2} (1.16) \left(\frac{\pi}{4} (40)^2\right) V^3}$$

$$V^3 = \frac{65.48 \times 10^3}{\frac{1}{2} (1.16) \left(\frac{\pi}{4} (40)^2\right) (0.28)}$$

$$V = 6.85 \text{ m/s}$$

which equation
did you use?

You have to show all
your solution details.

25

Summit Houston

④ Given:

$$\Delta h = 480 \text{ ft}$$

$$= 1075 \text{ gal/s}$$

$$\eta = 89\%$$

$$\eta_{\text{gen}} = 98\% \quad \checkmark$$

$$\text{head}_{\text{loss}} = 13 \text{ ft}$$

Find:

① η

② P_{elec}

③ P_{out}

Sol'n:

Solution ?

⑤

**Special topic – Fundamentals and Applications of Renewable Energy
Spring 2022**

Title of Assignment: Homework 2

TOPICS COVERED IN homework 2

1. Review of thermal sciences (thermodynamics, heat transfer, and fluid mechanics)

Repeated this section for each Quiz and Similarly for all the other assignments in the course binder

Prairie View A&M University
Department of Mechanical Engineering
MCEG 4316 Fundamentals and Applications of Renewable Energy, Section P19
Spring 22 – HW 2

Name:

ID:

Show all your work precisely. Label all the steps of your solution. Follow the problem solving procedure as mentioned in class.

1. A 12-cm diameter spherical ball whose surface is maintained at a temperature of 110 °C is suspended in the middle of a room at 20 °C. If the convection heat transfer coefficient is 15 W/m²°C and the emissivity of the surface is 0.6, determine the total rate of heat transfer from the ball.

2-69 The heat transfer surface area is

$$A = \pi D^2 = \pi (0.12 \text{ m})^2 = 0.04524 \text{ m}^2$$

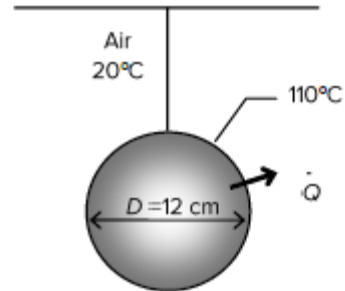
Under steady conditions, the rates of convection and radiation heat transfer are

$$\dot{Q}_{\text{conv}} = hA\Delta T = (15 \text{ W/m}^2 \cdot ^\circ\text{C})(0.04524 \text{ m}^2)(110 - 20)^\circ\text{C} = 61.1 \text{ W}$$

$$\begin{aligned}\dot{Q}_{\text{rad}} &= \epsilon \sigma A (T_s^4 - T_o^4) \\ &= 0.6(0.04524 \text{ m}^2)(5.67 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4)[(383 \text{ K})^4 - (293 \text{ K})^4] \\ &= 21.8 \text{ W}\end{aligned}$$

Therefore,

$$\dot{Q}_{\text{total}} = \dot{Q}_{\text{conv}} + \dot{Q}_{\text{rad}} = 61.1 + 21.8 = \mathbf{82.9 \text{ W}}$$



2. A 900-MW steam power plant, which is cooled by nearby river, has a thermal efficiency of 40 percent. Determine the rate of heat transfer to the river water. Also, determine the maximum thermal efficiency this power plant if the temperature of the furnace and river are 1000 and 20 °C, respectively.

2-139 The rate of heat supply to the power plant is determined from the thermal efficiency relation,

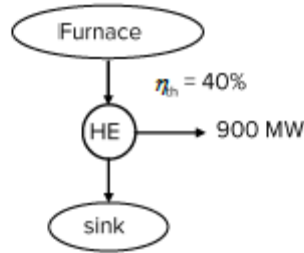
$$\dot{Q}_H = \frac{\dot{W}_{\text{net,out}}}{\eta_{\text{th}}} = \frac{900 \text{ MW}}{0.4} = 2250 \text{ MW}$$

The rate of heat transfer to the river water is determined from the first law relation for a heat engine,

$$\dot{Q}_L = \dot{Q}_H - \dot{W}_{\text{net,out}} = 2250 - 900 = \mathbf{1350 \text{ MW}}$$

The maximum thermal efficiency of the plant can be determined from the Carnot heat engine efficiency relation:

$$\eta_{\text{th}} = 1 - \frac{T_L}{T_H} = 1 - \frac{(20 + 273) \text{ K}}{(1000 + 273) \text{ K}} = 0.770 = \mathbf{77.0\%}$$



3. A horizontal opaque plate is well insulated on the edges and the lower surface. The top surface has an area of 8 m^2 , and it experiences uniform irradiation at a rate of 6000 W by convection. If the plate maintains a uniform temperature of 350 K , determine the absorptivity, reflectivity, and emissivity of the plate.

3-35 The irradiation on the plate is

$$G = \frac{6000 \text{ W}}{8 \text{ m}^2} = 750 \text{ W/m}^2$$

The irradiation absorbed by the plate is

$$G_{\text{abs}} = \frac{5000 \text{ W}}{8 \text{ m}^2} = 625 \text{ W/m}^2$$

The convection heat flux is

$$\dot{q}_{\text{conv}} = \frac{750 \text{ W}}{8 \text{ m}^2} = 93.8 \text{ W/m}^2$$

Applying energy balance on the surface, the emissive power is

$$E = G_{\text{abs}} - \dot{q}_{\text{conv}} = 625 \text{ W/m}^2 - 93.8 \text{ W/m}^2 = 531.3 \text{ W/m}^2$$

Hence, the absorptivity of the plate is

$$\alpha = \frac{G_{\text{abs}}}{G} = \frac{625 \text{ W/m}^2}{750 \text{ W/m}^2} = \mathbf{0.833}$$

Then, the reflectivity of the plate is determined using

$$\alpha + \rho + \tau = 1 \quad \rightarrow \quad \rho = 1 - \alpha \quad (\text{for opaque surface, } \tau = 0)$$

$$\rho = 1 - 0.833 = \mathbf{0.167}$$

Finally, the emissivity of the plate is

$$\epsilon = \frac{E}{E_b} = \frac{E}{\sigma T_s^4} = \frac{531.3 \text{ W/m}^2}{(5.67 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4)(350 \text{ K})^4} = \mathbf{0.624}$$

Since the plate is opaque, that means it is reflecting $G_{\text{ref}} = G - G_{\text{abs}} = 125 \text{ W/m}^2$ of the irradiation.

ABOVE AVERAGE

MCEG 4316 HW 2

1. Known:

$$D = 12 \text{ cm}$$

$$T_1 = 110^\circ \text{C}$$

$$T_2 = 20^\circ \text{C}$$

$$hA = 15 \text{ W/m}^2 \cdot ^\circ \text{C}$$

$$\Delta = 0.04524$$

$$\epsilon = 0.6$$

$$\sigma = 0.04524 \text{ W/m}^2 \cdot \text{K}^4$$

$$A = 5.67 \times 10^{-8}$$

Formula:

$$A = \pi D^2$$

$$Q_{\text{conv}} = hA\Delta T$$

$$Q_{\text{rad}} = \epsilon \sigma A (T_s^4 - T_o^4)$$

$$Q_{\text{total}} = Q_{\text{conv}} + Q_{\text{rad}}$$

Solution:

$$A = \pi (0.12)^2 = 0.04524$$

$$Q_{\text{conv}} = (15 \text{ W/m}^2) (0.04524) (110 - 20) = 61.1 \text{ W}$$

$$Q_{\text{conv}} = 61.1 \text{ W}$$

$$Q_{\text{rad}} = 0.6 (0.04524) (5.67 \times 10^{-8}) (383)^4 - (293)^4$$

$$Q_{\text{rad}} = 21.8 \text{ W}$$

$$Q_{\text{total}} = Q_{\text{conv}} + Q_{\text{rad}} = 61.1 + 21.8 = 82.9 \text{ W}$$

2. Known:

$$W_{\text{net, out}} = 900 \text{ MW}$$

$$\eta_{\text{th}} = 40\% \text{ or } .4$$

$$T_1 = 1000^\circ\text{C}$$

$$T_2 = 20^\circ\text{C}$$

Formulas:

$$Q_H = \frac{W_{\text{net, out}}}{\eta_{\text{th}}} = \frac{900 \text{ MW}}{.4} = 2250 \text{ MW}$$

$$Q_L = Q_H - W_{\text{net, out}}$$

$$\eta_{\text{th}} = 1 - \frac{T_2}{T_1} = 1 - \frac{20}{1000}$$

Solution:

$$Q_H = \frac{W_{\text{net, out}}}{\eta_{\text{th}}} = \frac{900 \text{ MW}}{.4} = 2250 \text{ MW}$$

$$Q_L = Q_H - W_{\text{net, out}} = 2250 - 900 = 1350 \text{ MW}$$

$$\eta_{\text{th}} = 1 - \frac{T_2}{T_1} = 1 - \frac{(20 + 273) \text{ K}}{(1000 + 273) \text{ K}} = .770 \text{ or } 77\%$$

3. Known:

$$A = 8 \text{ m}^2$$

$$\text{Uniform rate} = 6000 \text{ W}$$

$$T = 350 \text{ K}$$

Formulas:

$$\alpha = \frac{G_{\text{abs}}}{G}$$

$$Q_{\text{conv}} = \frac{G}{A}$$

$$\alpha + \rho + \tau = 1$$

$$\rho = \frac{G_{\text{ref}}}{G}$$

$$E = G_{\text{abs}} - Q_{\text{conv}}$$

$$\epsilon = \frac{E}{E_b} = \frac{E}{\sigma T_s^4}$$

$$\tau = \frac{G_{\text{tr}}}{G}$$

$$a = \frac{G_{\text{abs}}}{G}$$

Solution:

$$G = \frac{6000 \text{ W}}{8 \text{ m}^2} = 750 \text{ W/m}^2$$

$$G_{\text{abs}} = \frac{5000 \text{ W}}{8 \text{ m}^2} = 625 \text{ W/m}^2$$

$$\alpha = \frac{G_{\text{abs}}}{G} = \frac{625}{750} = 0.833$$

$$Q_{\text{conv}} = \frac{750 \text{ W}}{8 \text{ m}^2} = 93.8 \text{ W/m}^2$$

$$E = 625 \text{ W/m}^2 - 93.8 \text{ W/m}^2 = 531.3 \text{ W/m}^2$$

$$\rho = 1 - 0.833 = 0.167$$

$$G_{\text{ref}} = G - G_{\text{abs}} = 125 \text{ W/m}^2$$

$$\epsilon = \frac{531.3 \text{ W/m}^2}{(5.67 \times 10^{-8}) (350)^4} = 0.624$$

AVERAGE

Kiron Sam

Homework 2

Problem: 12 cm diameter spherical ball has a temp of 110°C , suspended in the middle of the room at 20°C . If the convection heat transfer coefficient is $15 \text{ W/m}^2\text{C}$ and the emissivity of the surface is 0.6, determine total heat transfer

Known: $d = 12 \text{ cm}$ $T_s = 110^{\circ}\text{C}$ $T_{\text{room}} = 20^{\circ}\text{C}$
 $h = 15 \text{ W/m}^2\text{C}$ $\epsilon = 0.6$

Find: Total rate of heat transfer from ball

Analysis: $A = 4\pi R^2 = 3.14 (.12)^2 = .045 \text{ m}^2$

$$\dot{Q}_{\text{conv}} = hA\Delta T = 15(.045) \times (110 - 20) = 60.75 \text{ W}$$

$$\begin{aligned}\dot{Q}_{\text{rad}} &= \epsilon \sigma A (T_s^4 - T_{\text{room}}^4) \\ &= 0.6(.045) \times 5.67 \times 10^{-8} \left[(110 + 273)^4 - (20 + 273)^4 \right] \\ &= 21.66 \text{ W}\end{aligned}$$

$$\dot{Q}_{\text{total}} = \dot{Q}_{\text{conv}} + \dot{Q}_{\text{rad}} = 60.75 + 21.66 = \boxed{82.41 \text{ W}}$$

A 900-mW steam power plant, cooled by a river, has a 40% thermal efficiency. Determine rate of heat transfer to the river water. Also determine the max thermal efficiency of the power plant if the temp. of the furnace & river are 1000 and 30°C.

Known: Thermal efficiency = 40%, $\dot{W} = 900 \text{ mW}$

Find: rate of heat transfer, max thermal efficiency

Analysis:

$$\eta = \frac{|\dot{W}|}{|\dot{Q}_H|} \quad |\dot{Q}_H| = \frac{|\dot{W}|}{\eta} = 900 \text{ mW} / 0.4 = 2250 \text{ mW}$$

$$|\dot{Q}_H| = |\dot{Q}_L| + |\dot{W}|$$

$$= 2250 - 900 = 1350$$

$$|\dot{Q}_L| = 1350 \text{ mW}$$

$$\eta = 1 - (T_L / T_H) = 1 - (30 / 1000) = 1 - 0.03 = 0.97$$

$$\eta = 97\%$$

A horizontal opaque plate is well insulated on the edges and the lower surface. The top surface has an area of 8 m^2 and it experiences uniform irradiation at a rate of 6000 W by convection. If the plate maintains a uniform temp. of 350 K determine absorptivity, reflectivity and emissivity of the plate.

Known: $T = 350 \text{ K}$ $G = 6000 \text{ W}$ $A = 8 \text{ m}^2$

Find: absorptivity, reflectivity, emissivity

Analysis: $F = G_{\text{abs}}/G$

no absorbed heat???

BELOW AVERAGE

Prairie View A&M University
Department of Mechanical Engineering
MCEG 4316 Fundamentals and Applications of Renewable Energy, Section P19
Spring 22 – HW 2

Name: Taylor Aaren

ID: P211699001

Show all your work precisely. Label all the steps of your solution. Follow the problem solving procedure as mentioned in class.

1. A 12-cm diameter spherical ball whose surface is maintained at a temperature of 110 °C is suspended in the middle of a room at 20 °C. If the convection heat transfer coefficient is 15 W/m²°C and the emissivity of the surface is 0.6, determine the total rate of heat transfer from the ball.

Given:

$$D = 12 \text{ cm or } 0.12 \text{ m}$$

$$T_s = 110^\circ\text{C}$$

$$T_{\text{room}} = 20^\circ\text{C}$$

$$h = 15 \text{ W/m}^2\cdot^\circ\text{C}$$

$$\epsilon = 0.6$$

Schematic:

no sketch

Assumptions:

no assumptions

properties:

all need properties are known

Find:

$$\dot{Q}_{\text{total}}$$

Analysis:

Solution plan:

$$A = 4\pi R^2$$

$$A = \pi D^2$$

$$= 3.14 (0.12)^2$$

$$= 0.045216 \text{ m}^2$$

$$\dot{Q}_{\text{conv}} = h A \Delta T$$

$$= (15)(0.0452)(110 - 20)$$

$$= 61.02 \text{ W}$$

$$\dot{Q}_{\text{rad}} = \epsilon \sigma A (T_s^4 - T_{\text{room}}^4)$$

$$= 0.6 (0.0452) (5.67 \times 10^{-8}) [(110 + 273)^4 - (20 + 273)^4]$$

$$= 21.75 \text{ W}$$

$$\dot{Q}_{\text{total}} = \dot{Q}_{\text{conv}} + \dot{Q}_{\text{rad}}$$

$$= 61.02 + 21.75$$

$$\boxed{= 82.77 \text{ W}}$$

2. A 900-MW steam power plant, which is cooled by nearby river, has a thermal efficiency of 40 percent. Determine the rate of heat transfer to the river water. Also, determine the maximum thermal efficiency this power plant if the temperature of the furnace and river are 1000 and 20 °C, respectively.

Given:

$$P = 900 \text{ MW}$$

$$\text{thermal efficiency} = 40\%$$

$$T_{\text{furn}} = 1000^\circ\text{C}$$

$$T_{\text{river}} = 20^\circ\text{C}$$

Find:

rate of heat transfer to river
max thermal efficiency

Schematic:

no sketch

Assumptions:

no assumptions

Properties:

all needed properties
are known

3. A horizontal opaque plate is well insulated on the edges and the lower surface. The top surface has an area of 8 m^2 , and it experiences uniform irradiation at a rate of 6000 W by convection. If the plate maintains a uniform temperature of 350 K , determine the absorptivity, reflectivity, and emissivity of the plate.

Given:

area = 8 m^2
 irradiation = 6000 W
 $T = 350 \text{ K}$

Schematic:

no sketch

Properties:

all needed properties are known

Find:

absorptivity
 reflectivity
 emissivity

Assumptions:

because it is an opaque flat plate
 τ (transmissivity) = 0

Analysis:

solution plan:

$$\text{absorptivity} = \frac{\text{absorption}}{\text{irradiation}}$$

$$= \frac{0}{6000} = 0$$

$$\text{absorptivity} + \text{reflectivity} + \text{transmissivity} = 1$$

$$\boxed{\text{reflectivity} = 1}$$

$$E = \epsilon \sigma T^4$$

$$0 = \epsilon \times 5.67 \times 10^{-8} \times 350^4 \times 8$$

$$\boxed{E = 0}$$