



Production Of Urea Using Natural Gas

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▪ **Forsurea Co**

Outline

Project scope

Background

Product Overview

Process Selection

Process Flow Diagram

Material & Energy Balance

Aspen

Economics

Process Safety

PID Control

HAZOP



Project Scope and Deliverables

Scope

- Design a plant that produces $\geq 98\%$ pure prills Urea.
- Develop production transportation and storage of Urea.

Deliverables

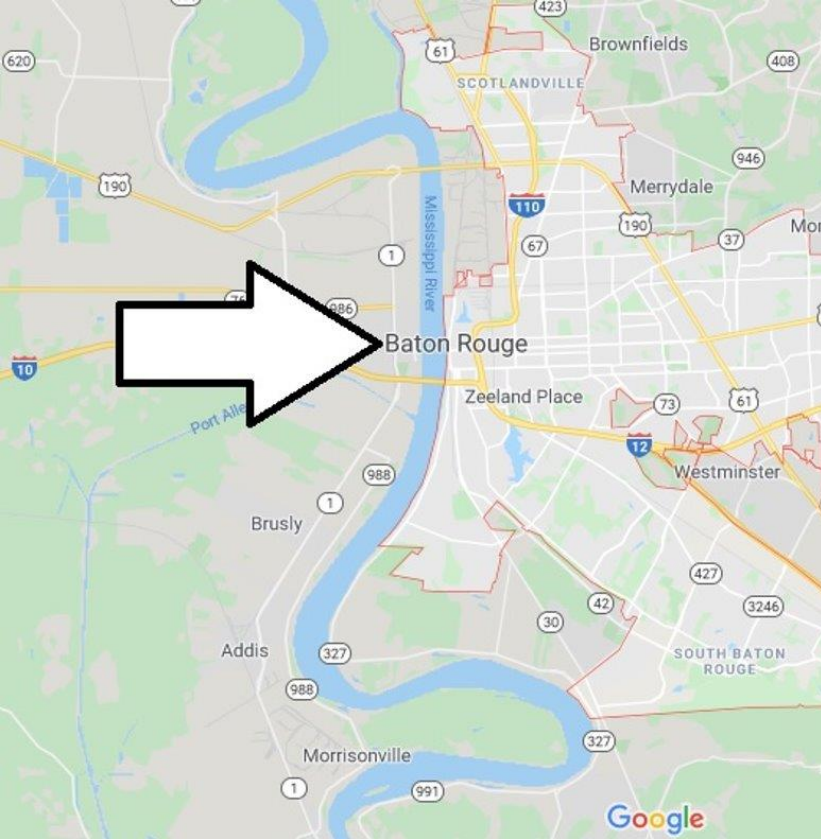
- Proved Material and Energy balance
- Complete Process Flow Diagram
- ASPEN simulation
- HAZOP & PID of Reactor
- Economics



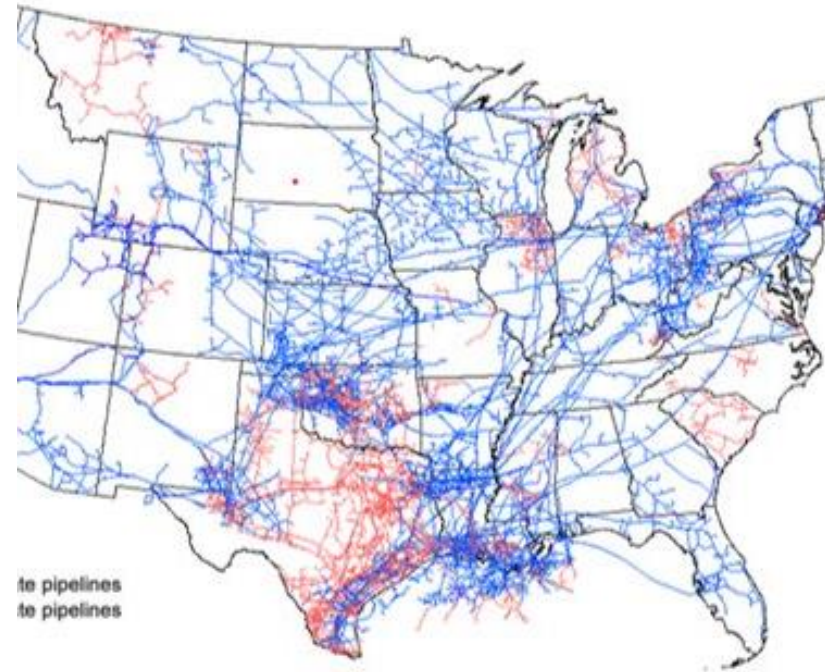
Urea Prill Specification



Component	Concentration
Nitrogen	46% Minimum by Weight
Biuret	1% Maximum by Weight
Moisture Content	0.3 Maximum by Weight
Sizing	90% 2-4 mm by Weight



Interstate and intrastate natural gas pipelines



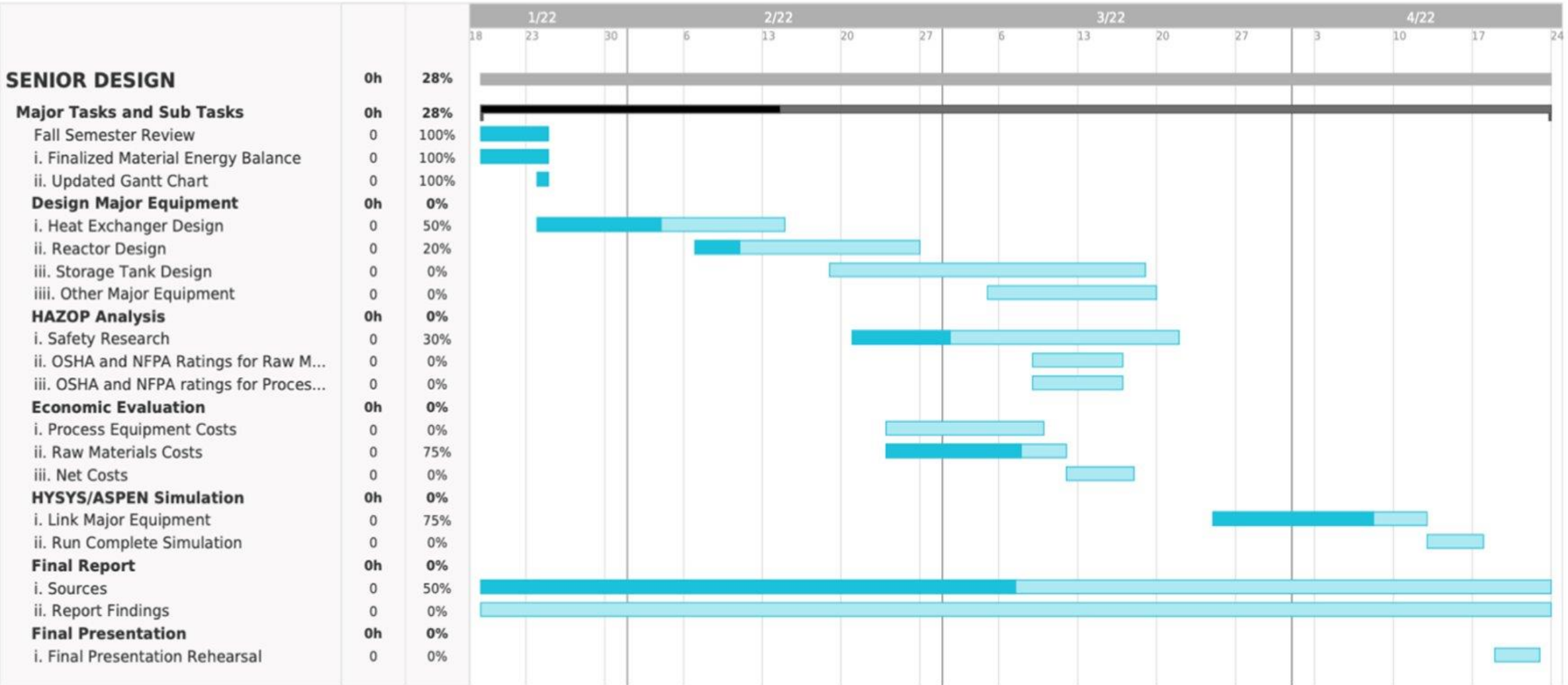
Interstate pipelines
Intrastate pipelines

Energy Information Administration, About U.S. Natural Gas Pipelines



Plant Location

- **Louisiana, Gulf of Mexico**
 - **Abundance of Natural Gas Pipelines**
 - **Abundance of fresh water for production process**



Gantt Chart

Design Basis

Plant Capacity	100,000 tons/yr
Operating Days	350 days
Raw Materials	
Natural Gas	152,000 lb/day
Water	171,000 lb/day
Air	337,000 lb/day
Desired Product	
Urea	571,000 lb/day
Product Purity	>98%

Process Chemistry

Ammonia Synthesis

Methane converted to Hydrogen:



Carbon Monoxide converted to carbon dioxide:



Ammonia Formation:



Urea Synthesis

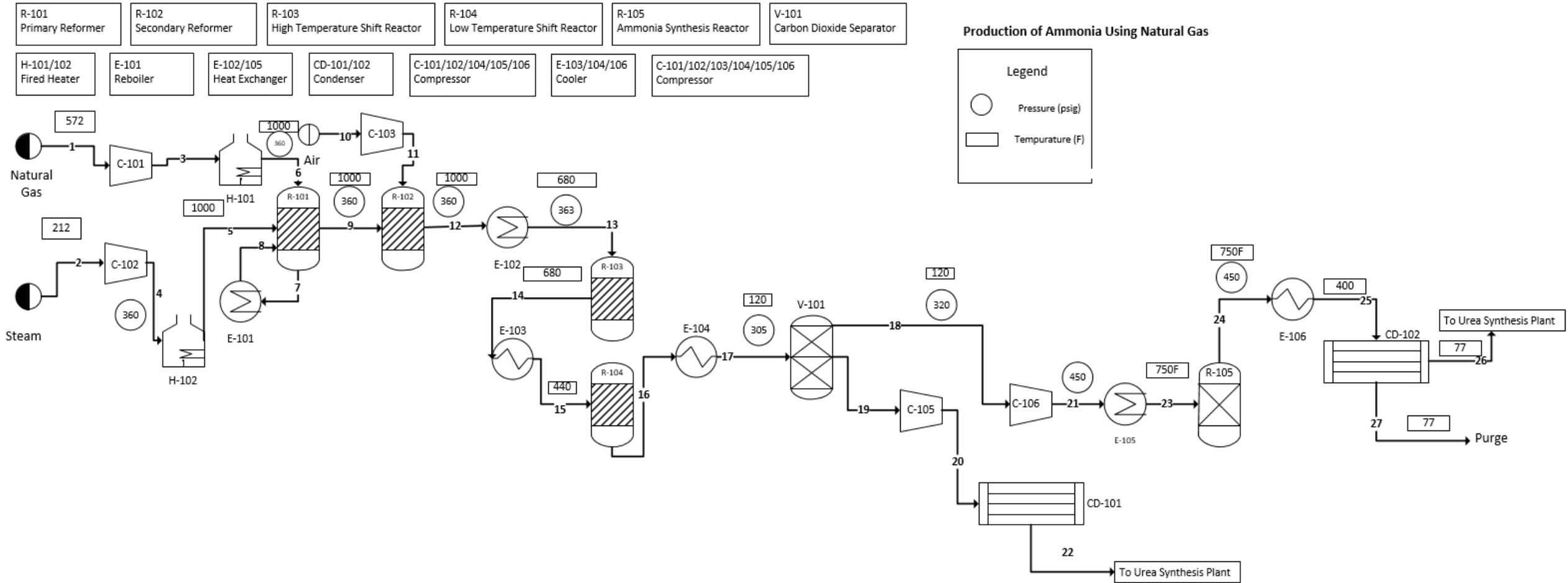
Ammonia and carbon dioxide reacted to create ammonium carbamate:



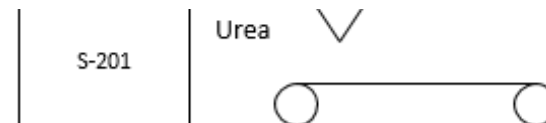
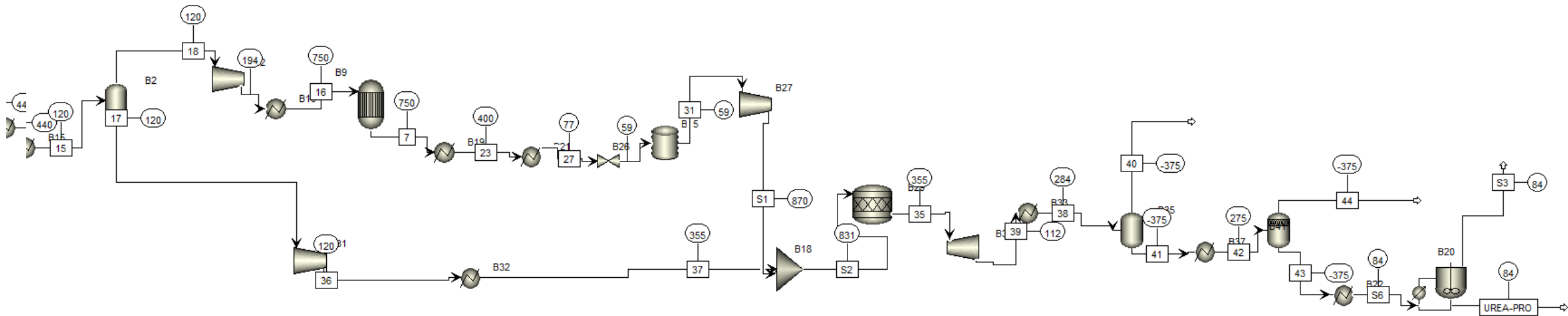
Urea formed in second step of 2 step process:



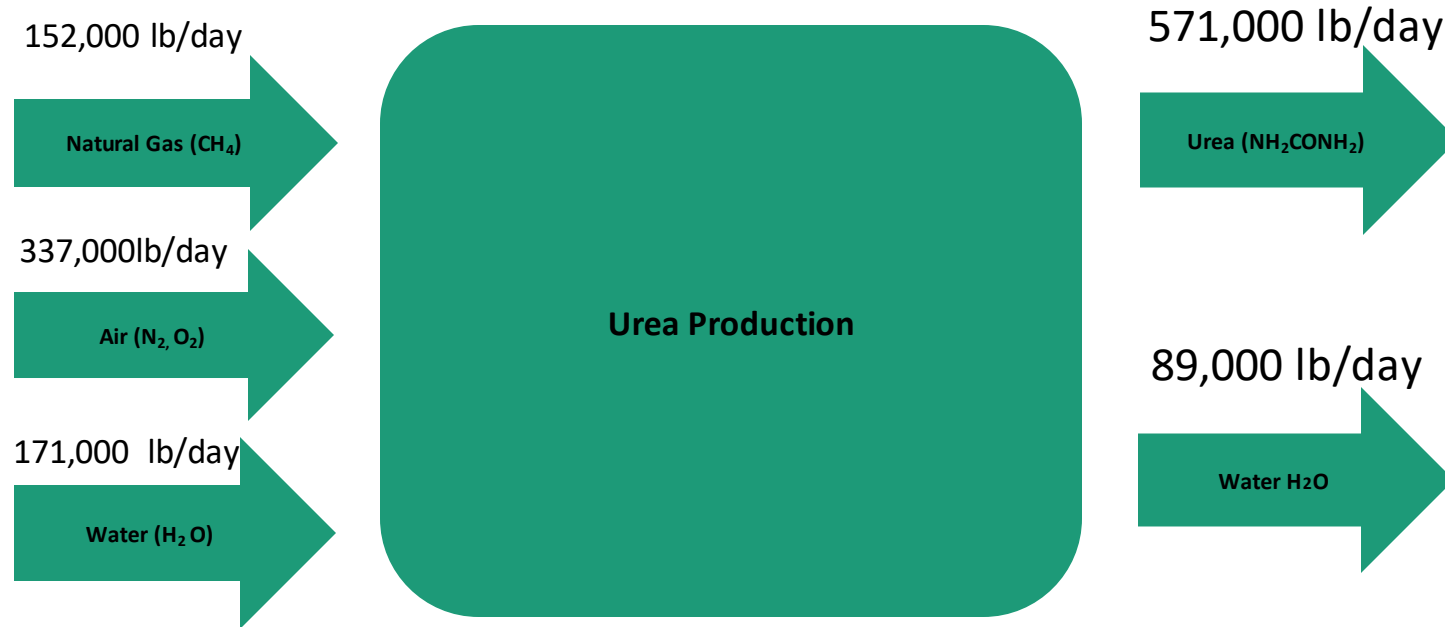
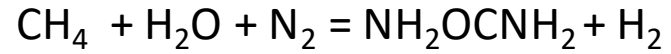
PFD Process Flow



V-201 Ammonia Receiver Tank	R-201 Urea Synthesis Reactor	E-201/203 Heat Exchanger	E-202 Ammonia Preheater	V-203 Molten Urea Tank	P-201/202/203 Pumps
V-201 Flash Drum Evaporator	V-202 Vacuum Evaporator	S-201 Urea Storage Tank	PR-201 Prilling Tower	CP-201/202/203/204/205 Compressor	Legend



Overall Material Balance



Summary of Energy Balance For Primary Reformer

Catalyst: Copper Oxide and Iron Oxide

Enthalpy: 1.95×10^5 BTU/day

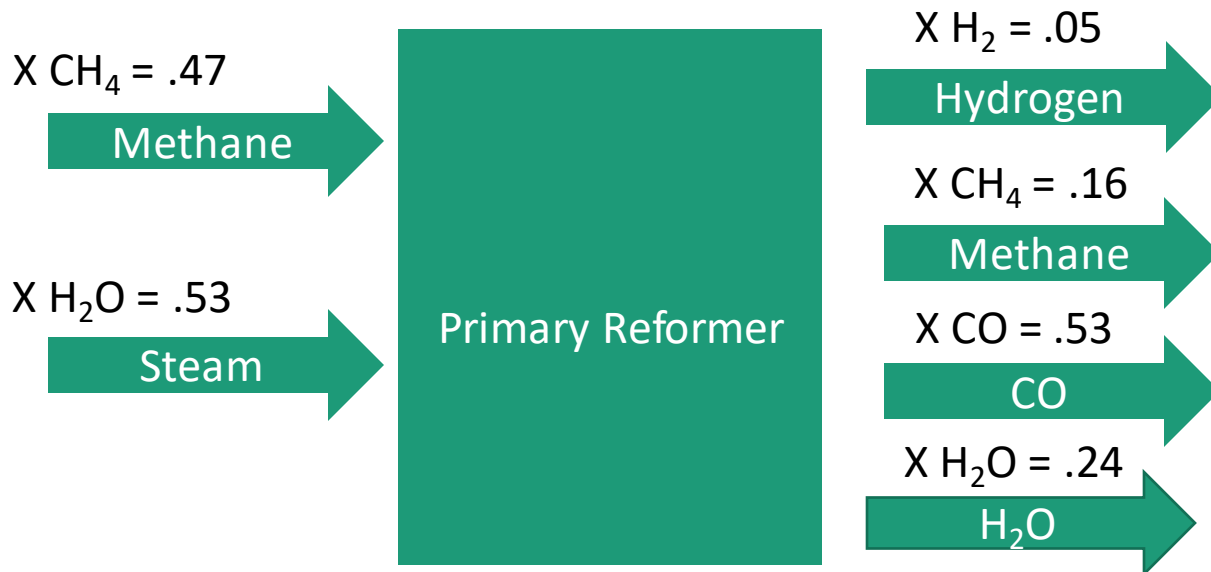
Inlet: CH_4 8.62×10^4 BTU/hr

H_2O 1.08×10^4 BTU/hr

Outlet: CH_4 3.81×10^4 BTU/hr

H_2O 1.78×10^5 BTU/hr

Feed Composition



Catalyst Parameters	Dimensions
Pellet Diameter	1.14×10^{-2} ft
Density	68 lb ft ⁻³
Specific Heat	3.7 BTU/lb ⁻¹ F ⁻¹
Thermal Conductivity	2.8 BTU/lb ⁻⁷ F ⁻¹

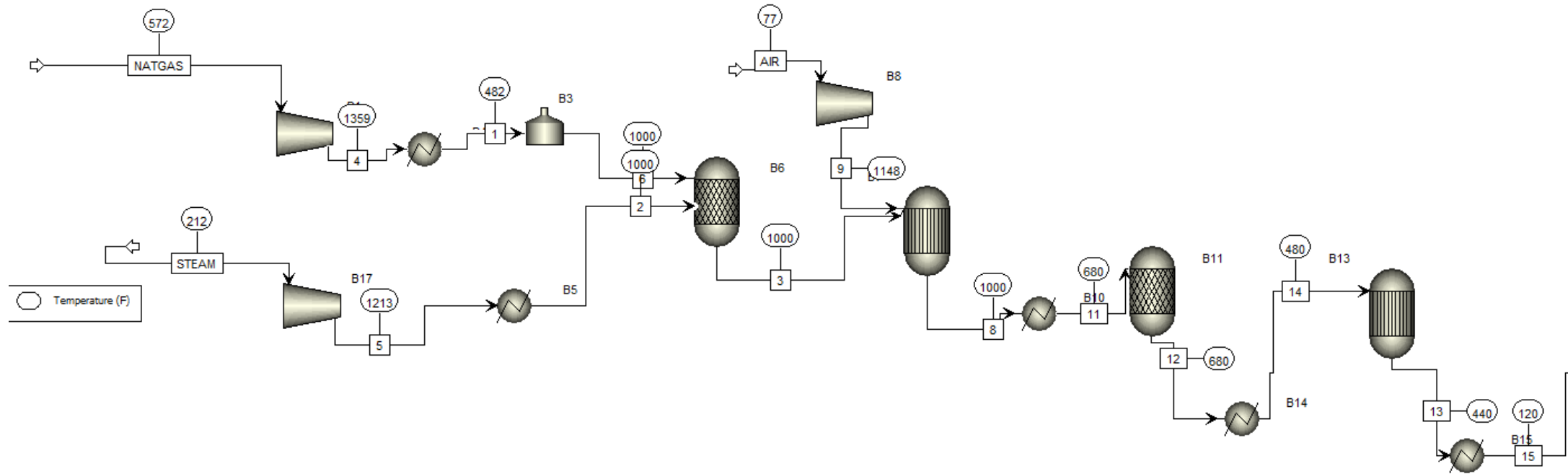
Tube side	
Feed Temperature	1,000 F
Feed Pressure	435 Psi

Material Balance

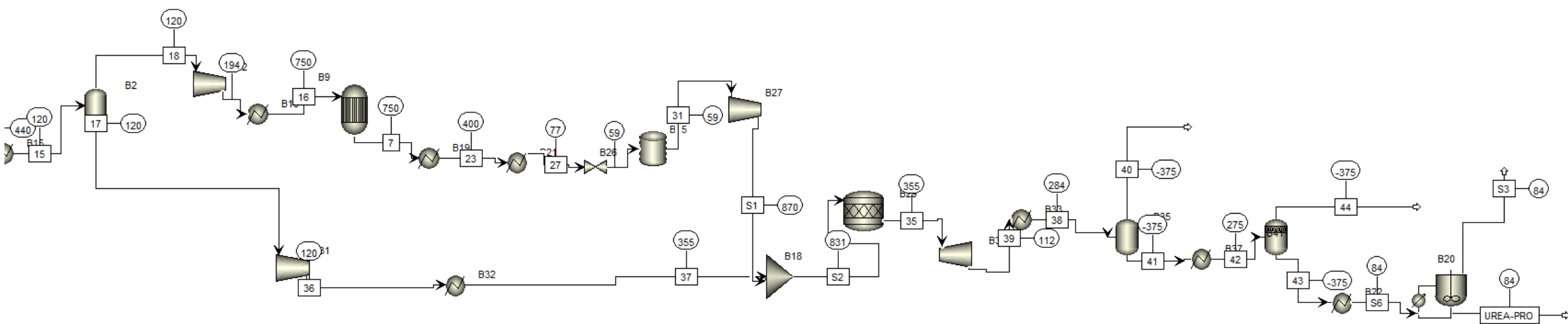
Stream Number	PR (IN)	SR (IN)	HTS (IN)	LTS(IN)	CO2(IN)	AMMONIA (IN)	UREA (IN)	FLASH (IN)
Temperature (°F)	1000	999	764	414	527	750	355	275
Pressure (psia)	370	360	360	360	305	305	2000	44
Total Mass Flow (lb/day)	323486	660701	660700	660700		329606	775386	1537164
Component Mass Flow(lb/day)								
Methane	152228	53280						
Water	171257	78492	166843	10344	6804	6804	6804	
Carbon Monoxide	-	121659	121659	3649	321700			
Nitrogen	-	266400	266400	266400	266400	265630		
Hydrogen	-	18552	36762	62145	65686	57173		
Oxygen	-	70815	69035	0				
Carbon Dioxide	-			318160	321700		461920	236522
Ammonia	-						306662	6133
Ammonia Carbamate								525926

Stream Number	VE(OUT)	Priller (Out)
Temperature (°F)	210	210
Pressure (psia)	14.7	14.7
Total Mass Flow (lb/day)	1537165	1296935
Component Mass Flow (lb/day)		
Water	768582	
Carbon Monoxide		
Nitrogen		
Hydrogen		
Oxygen		
Carbon Dioxide	236	
Ammonia	61	
Ammonia Carbonate	525926	
Urea		525926
Biuret		297

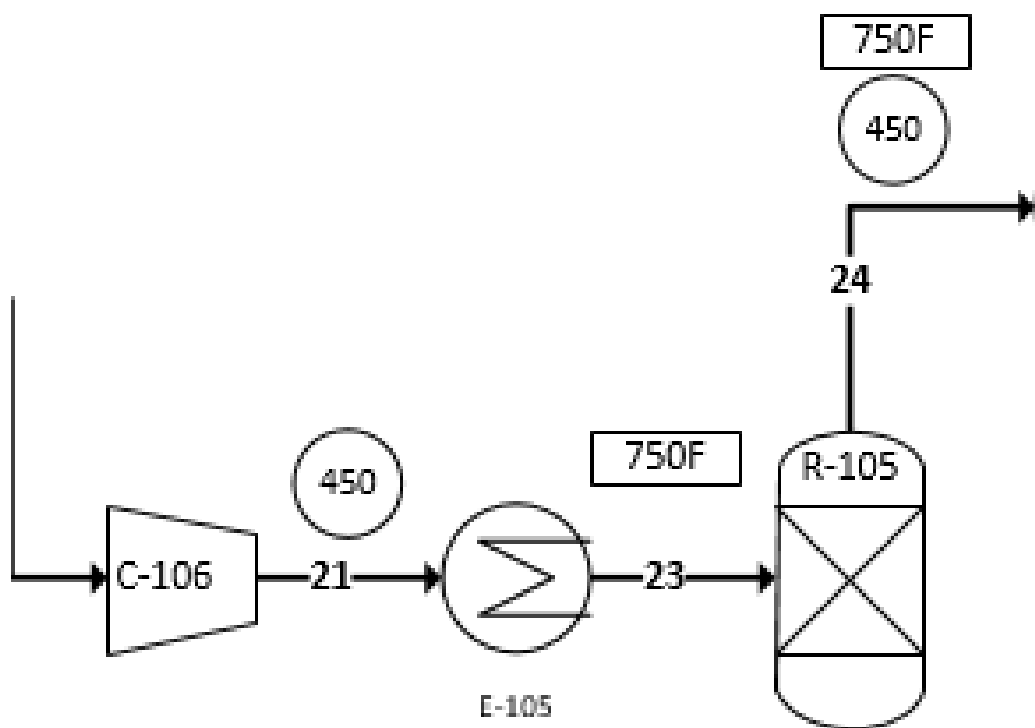
ASPEN



ASPEN



Specification Sheet



Ammonia Reactor

Identification:	Item:	<i>Packed-Bed Reactor</i>		
	Item No:	<i>R-105</i>	Date:	<i>4/17/2022</i>
	No. Required:	<i>1</i>	By:	<i>Forsurea Co</i>
	CPE (\$)	<i>\$ 54,200</i>	CBM (\$):	<i>\$217,000</i>

Function: To react with nitrogen and hydrogen to produce ammonia for urea production.

Operation: Continuous

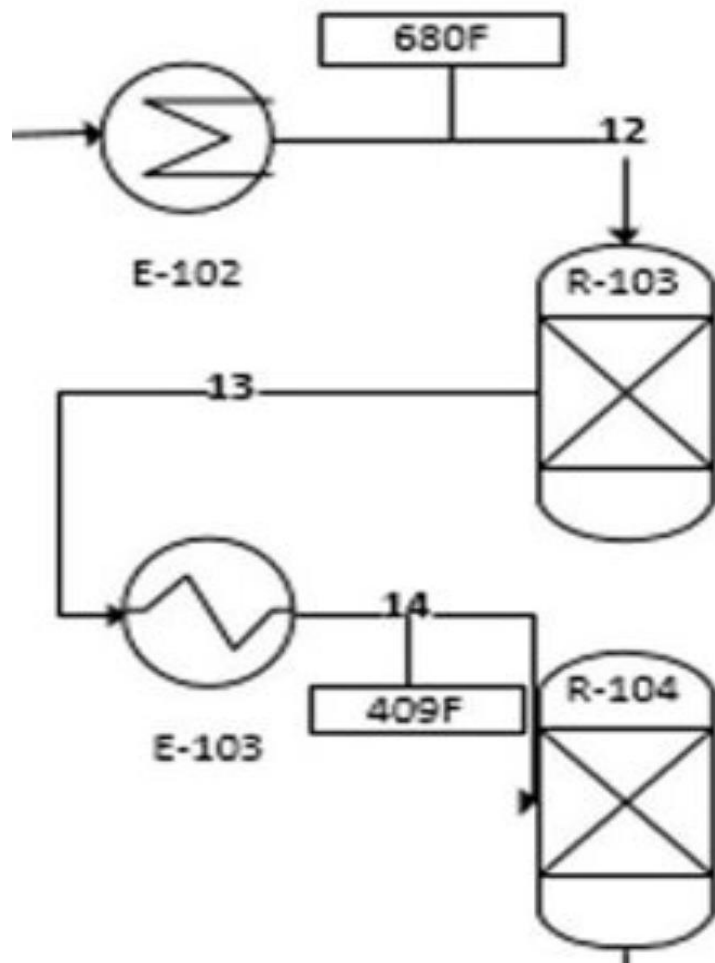
	In	Out
Materials Handled:		
Volumetric Flow (ft ³ /min)	341.681	
Component Flows (lb/day):		
Nitrogen	266000	13300
Hydrogen	57200	2900
Ammonia	0	307000
Temperature (°F):	1000	
Pressure (psia):	725	

Vessel				
Height (ft)	31			
Diameter (ft)	9			
Weight of the Column(lb)				
Wall Thickness	0.065			
Pressure Drop (psi)				
Material	Stainless Steel			
Volume (ft ³)	112			

Vessel Internals				
Bed Height (ft)	18			
Bed Diameter (ft)	7			
Catalyst Weight (lb)	577			
Bed Voidage	0.4			
Catalyst Bed Volume (ft ³)	20			
Catalyst` Life (yrs)	4			

Comments				
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Specification Sheet



High Temperature Shift

Identification:	Item:	Pack-Bed Reactor		
	Item No:	R-103	Date:	4/17/2022
	No. Required:	1	By:	<i>Forsurea</i> Co
	C _{PE} (\$)	\$ 54,200	C _{BM} (\$):	\$217,000

Function: To produce more hydrogen and convert CO to CO₂.

Operation: Continuous

	In	Out		
Materials Handled:				
Component Flows (lb/day):				
Nitrogen	266400	266400		
Carbon Monoxide	173200	121600		
Water	78500	167000		
Hydrogen	18600	36800		
Methane	53300	0		
Oxygen	70800	69000		
Temperature (°F):	1000			
Pressure (psia):	440			
Vessel				
Height (ft)	5.44			
Diameter (ft)	2.03			
Weight of the Column(lb.)				
Pressure Drop (psi)				
Material	Stainless Steel			
Volume (ft ³)	145.28			
Vessel Internals				
Bed Height (ft)	2.54			
Bed Diameter (ft)	1.01			
Catalyst Weight (lb)	909.23			
Catalyst Bed Volume(ft ³)	1.62			

Economics: Capital & Operation Expenses

- Total Capital Investment - \$67 Million
- Operation Expense (Annual) - \$29 million

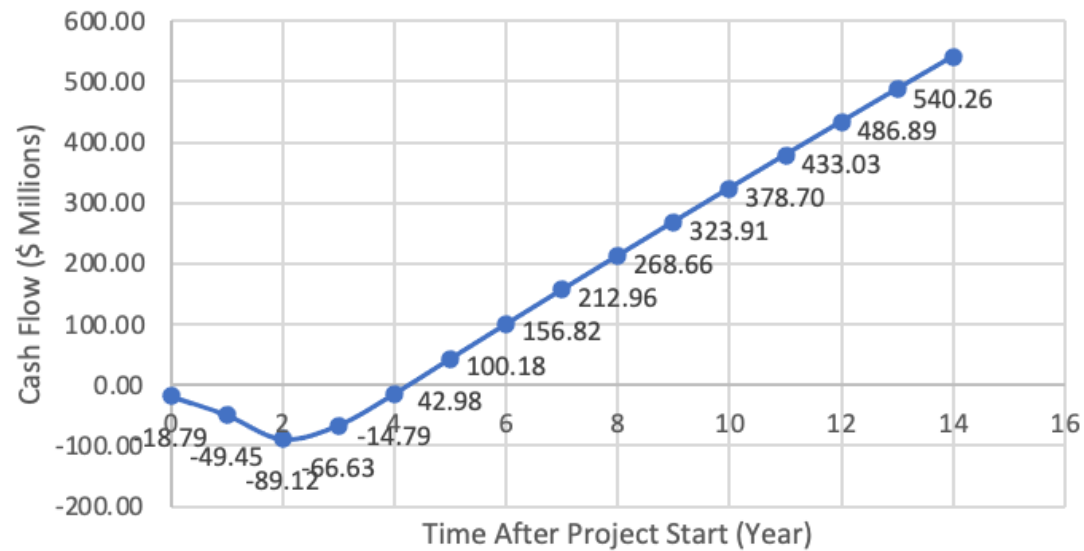
ESTIMATION OF CAPITAL INVESTMENT BY PERCENTAGE OF DELIVERED EQUIPMENT METHOD					
(See Table 6-9)					
The fractions in the cells below are approximations applicable to typical chemical processing plants. These values may differ depending on many factors such as location, process type, etc.					
Required user input	Default		Subtotal		Result
Required, from a linked sheet or entered manually				Notes & comments	
Project Identifier: Illustration 101	Fraction of delivered equipment		User: copy from values at left or insert	Calculated values, million \$	
	Solid-processing plant	Solid-fluid processing plant	Fluid processing plant		
Direct Costs					
Purchased equipment, E'					10.200
Delivery, fraction of E'	0.10	0.10	0.10	0.10	1.020
Subtotal: delivered equipment					11.220
Purchased equipment installation	0.45	0.39	0.47	0.47	5.273
Instrumentation & Controls (installed)	0.18	0.26	0.36	0.36	4.039
Piping (installed)	0.16	0.31	0.68	0.68	7.630
Electrical systems (installed)	0.10	0.10	0.11	0.11	1.234
Buildings (including services)	0.25	0.29	0.18	0.18	2.020
Yard improvements	0.15	0.12	0.10	0.10	1.122
Service facilities (installed)	0.40	0.55	0.70	0.70	7.854
Total direct costs	1.69	2.02	2.60	2.60	40.392
Indirect Costs					
Engineering and supervision	0.33	0.32	0.33	0.33	3.703
Construction expenses	0.39	0.34	0.41	0.41	4.600
Legal expenses	0.04	0.04	0.04	0.04	0.449
Contractor's fee	0.17	0.19	0.22	0.22	2.468
Contingency	0.35	0.37	0.44	0.44	4.937
Total indirect costs	1.28	1.26	1.44	1.44	16.157
Fixed capital investment (FCI)					56.549
Working capital (WC)					9.986
Total capital investment (TCI)					66.535

ANNUAL TOTAL PRODUCT COST AT 100% CAPACITY				
See Figure 6-7 and 6-8				
Default, may be changed		Subtotal		Notes & comments
User input		RESULT		
Required, may be calculated here, in linked worksheet, or entered manually.				
Project identifier: Illustration 101				
Capacity	91	10 ⁶ kg per year		
Fixed Capital Investment, FCI	58.087	million \$		
Item	Default factor, user may change	Basis	Basis cost, million \$/y	Cost, million \$/y
Raw materials				9.250
Operating labor				0.885
Operating supervision	0.15	of operating labor	0.885	0.133
Utilities				1.869
Maintenance and repairs	0.06	of FCI	58.087	3.485
Operating supplies	0.15	of maintenance & repairs	3.485	0.523
Laboratory charges	0.15	of operating labor	0.885	0.133
Royalties (if not on lump-sum basis)	0.01	of c_o	28.830	0.288
Catalysts and solvents	0.15	--	1.200	0.180
Variable cost =				16.746
Taxes (property)	0.02	of FCI	58.087	1.162
Financing (interest)	0	of FCI	58.087	0.000
Insurance	0.01	of FCI	58.087	0.581
Rent	0	of FCI	58.087	0.000
Depreciation	Calculated separately			
Fixed Charges =				1.743
Plant overhead, general	0.6	of labor, supervision	4.503	2.702
Plant Overhead =				2.702
Manufacturing cost =				21.190
Administration	0.2	of labor, supervision	4.503	0.901
Distribution & selling	0.05	of c_o	28.830	1.441
Research & Development	0.04	of c_o	28.830	1.153
General Expense =				3.495
TOTAL PRODUCT COST WITHOUT DEPRECIATION = c_o =				28.830

Economics: Cumulative Cash Flow Diagrams

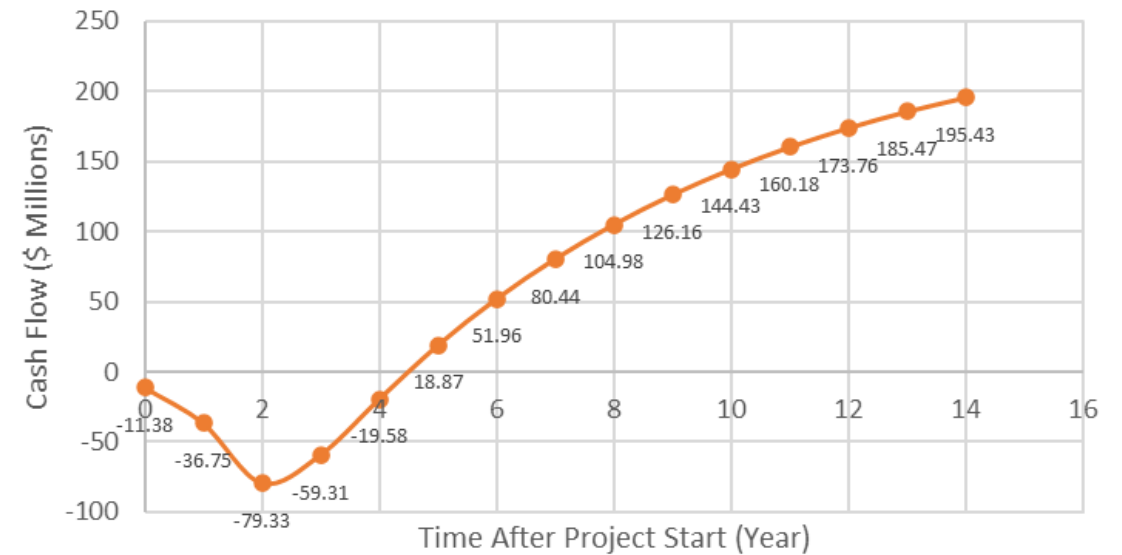
- Discount Rate – 15%
- Income Tax – 39% (4% LA Income Tax)*

Nondiscounted Cumulative Cash Flow Diagram



ROR – 79.9%

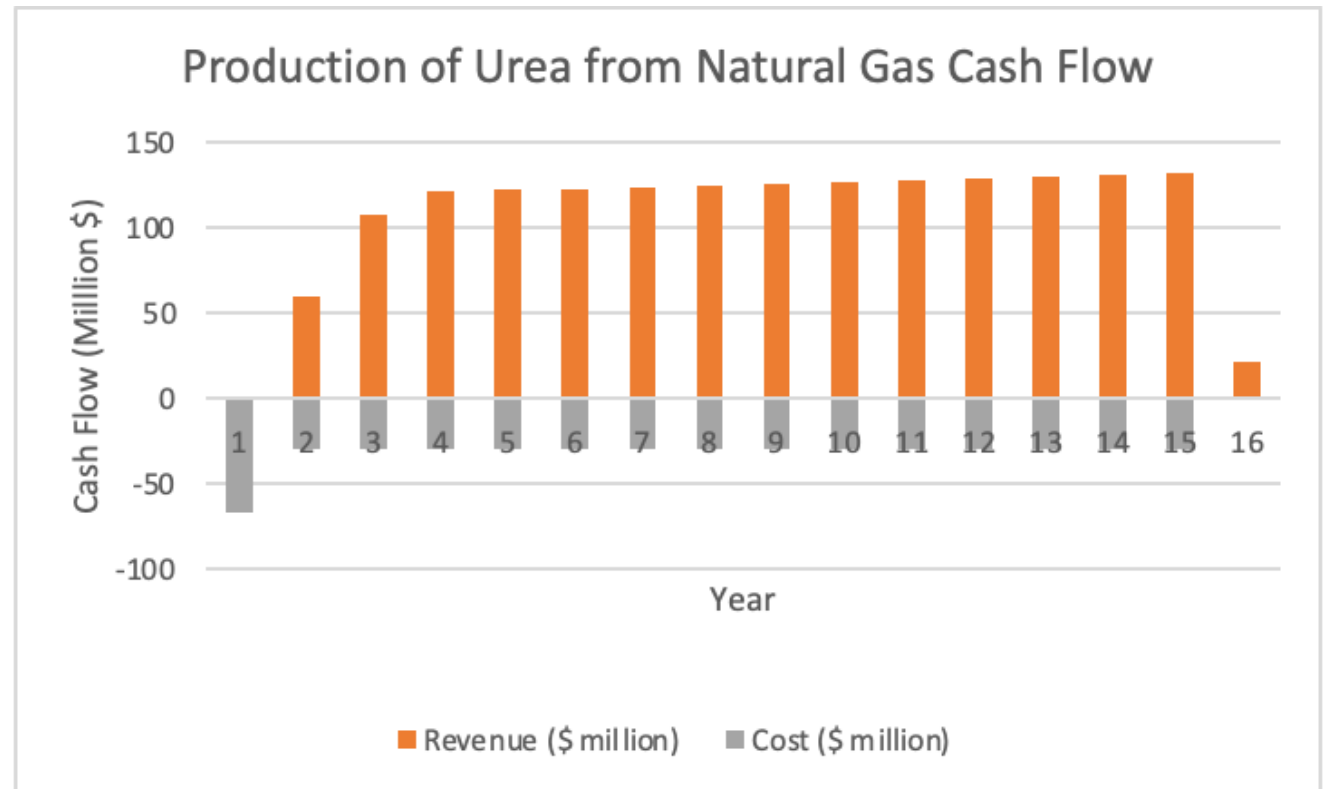
Discounted Cumulative Cash Flow Diagram



DCFRROR – 38.9%

Economics: Investment Appeal

- High Demand:
 - All – Time High Prices
 - 960 \$/ton (Late March)
 - 790 \$/ton (Current)
- Revenue – 118 MM\$/year (100%)
- NPV - \$182 Million
- IRR – 47.6%
- Payback Period – 1 year

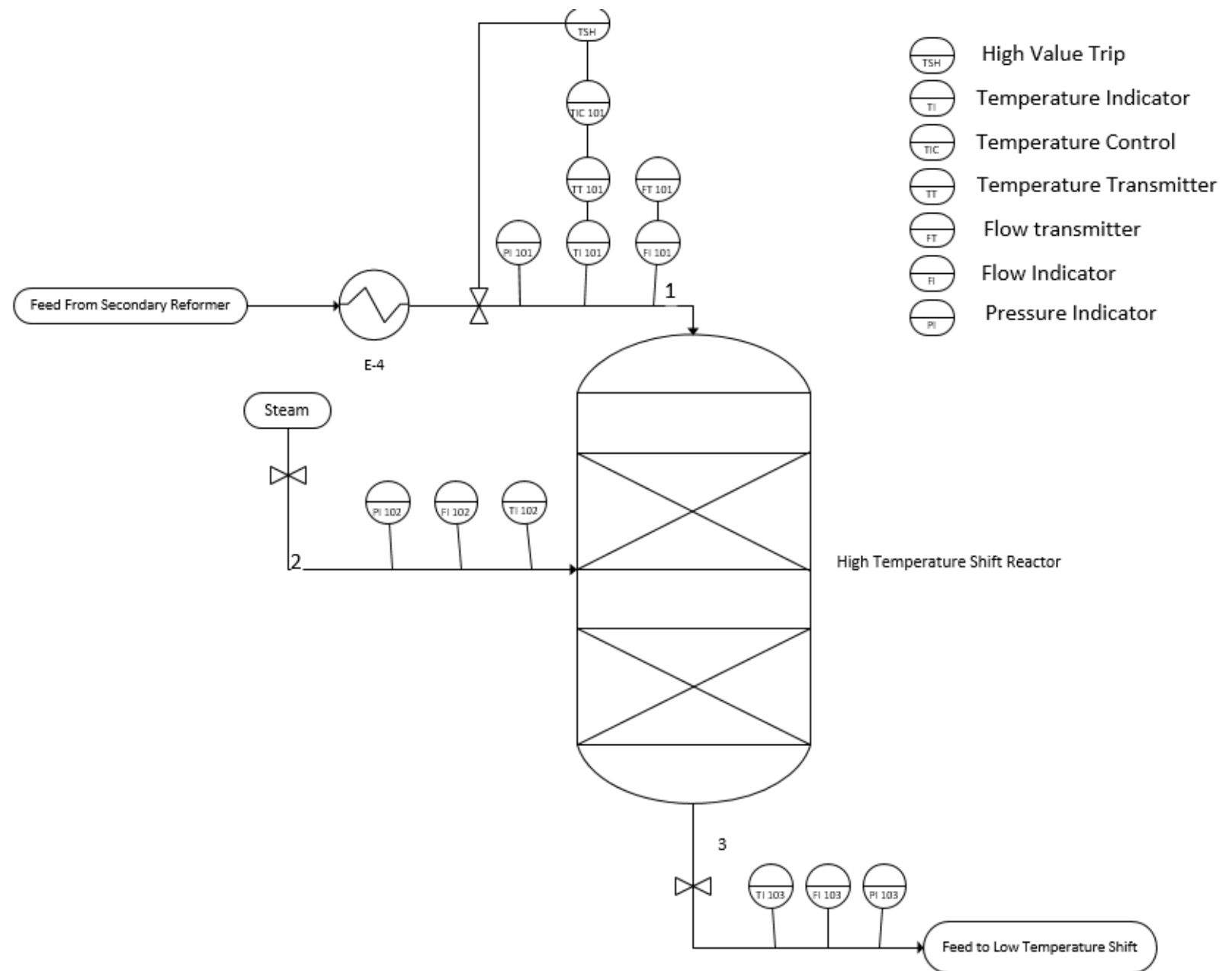


Hazard Analysis

Parameter	Deviation	Causes	Consequences	Action Required
Flow of Gas	No / Less	Low feed flow rate at node 1	Loss of catalytic activity and selectivity	Maintain/check valves and pipelines
	More	More feed	The potential energy in HTS may exceed the scope of the safety standards.	Ensure the controller for the expander is functioning properly.
Temperature	High	The increased steam temperature at node 2	Hot Spots	Temperature alarms at node 2
		High syngas temperature at node 1	Decrease permeance and selectivity	Fast temperature control before nodes 1 and 2 (installed in heat exchanger for syngas cooling and steam heating)
	Low	The low steam temperature at node 2	Decreased CO conversion and H ₂ recovery	Flow temperature alarm on node 2
		Low syngas temperature at node 1	Defects /cracks on the membrane surface and decreased selectivity	Fast temperature control before nodes 1 and 2

Parameter	Deviation	Causes	Consequences	Action Required
Pressure	High	If failure of pressure relief valve	The integrity of the HTS packed bed is compromised explosive.	Ensure the safety valve and pressure relief valve are functioning properly.
	Low	Possible Hydrogen leak from line to vessel.	Possibly hazardous work environment	The pressure relief valve may be malfunctioning.
Temperature	High	The steam stream inlet is too high and possibly lacks sufficient cooling.	Possible damage to the HTS packed-bed reactor.	Ensure the flow control loop to the steam stream inlet functions properly. Ensure flow control lops of cooling fluids are functioning properly.
	Low	Possible error from controller valve.	Impact on the conversion of the HTS in the packed bed reactor.	Ensure valves from cooling sources work properly.

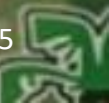
P&ID High Temperature Converter



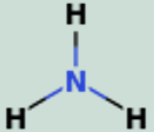
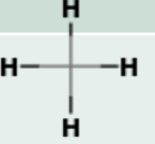
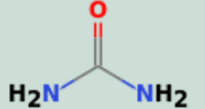


Environmental Safety

- All wastewater effluent sent to a holding pond where it is treated.
- Composition of wastewater is checked before and after discharge
- Carbon emissions are regulated and maintained in correspondence to EPA guidelines



Safety and Handling

	Storage	Safety Hazards	Controls	Chemical Structure
Ammonia	Non-Corrosive(steel) Stored in container at -91°F at 1psi	- Ammonia gas can decompose at high temperatures forming very flammable hydrogen and toxic nitrogen dioxide. - Installation a leak detection system	Use non-sparking ventilation systems; approved explosion proved equipment	
Methane	Stored in tightly closed containers in well ventilated area (125°F)	- Suffocation - Uncontrolled combustion	Keep in well ventilated area	
Urea	Closed or sealed bags on pallets		Store in dry, cool and well-ventilated place	

Conclusion

Current Work

- Perform material and energy balance for overall process & around individual units
- Sized Major Equipment
- Created HAZOP on a Reactor showing an PID
- Create a process flow diagram (PFD) of our plant
- Evaluate our market value and safety of our plant.
- Estimate Operating Cost, Major Equipment Capital Cost, Net Present Value, Investor Rate Of Return

Thank you!

