CH4250: PROCESS ENGINEERING

Project Deliverable - 2

Group: 7

Problem Statement

Chemical	Propylene
Capacity	17,000 TPA
Location	Chennai, Tamil Nadu

Group Members

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Olefin Conversion Technology

Problem Statement: Design a plant, for production of 17,000 TPA of Propylene plant in Chennai, Tamil Nadu, which will be profitable, safe, & environmentally benign

Propylene, also called **propene**, a colourless, flammable, gaseous hydrocarbon, C_3H_6, obtained from petroleum. Large quantities of propylene are used in the manufacture of resins, fibres, and elastomers, and numerous other chemical products

Some of the major production processes of propylene are:

1. Olefin conversion technology
2. OLEFLEX Process
3. Fluid catalytic cracking
4. CATOFIN Technology
5. LURGI MTP

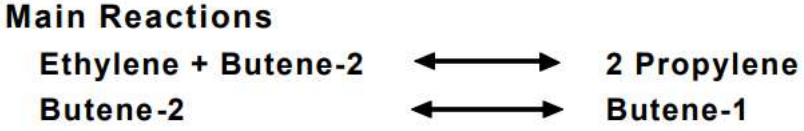
As per the preliminary economic analysis and research on the above technologies (from deliverable 1) we have decided to go ahead with the **Olefin Conversion Technology** for production of propylene.

Olefin Conversion Technology [1]

Olefins Conversion Technology (OCT) process is the only commercial on-purpose metathesis technology for propylene production. For the production of propylene from ethylene plus butene's and pentenes, simultaneous isomerization, and metathesis reactions take place in the OCT reactor.

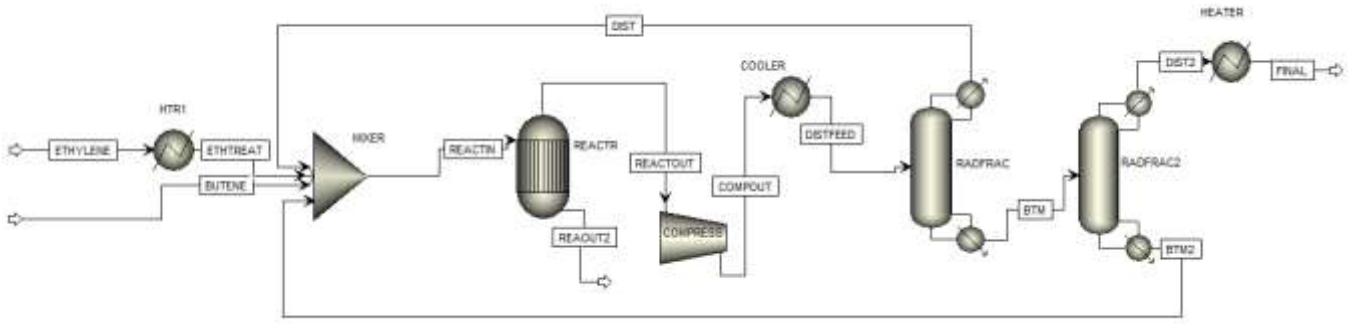
The main equilibrium reactions involving in OCT technology are:

- **Metathesis** - Propylene is formed by the metathesis of ethylene and butene-2.
- **Isomerization** – The butene-2 consumed in the metathesis reaction is formed by isomerization of butene -1.



Process Flow Sheet(Using Aspen):

Design 1:



The process flowsheet consists of the following equipment:

- **Feed and Recycle Streams**
- **Mixer**
- **Reactor**
- **Compressor**
- **Heater, Cooler**
- **Distillation Columns**

Overall Material Balance

6.25 ktonne/year of ethylene is reacted with **12** ktonne/year of butylene to produce **17** ktonne/year (17,000 TPA) of propylene of **92.5%** purity

	Units	ETHYLENE	BUTENE	FINAL
Description				
From				HEATER
To		HTR1	MIXER	
Stream Class		CONVEN	CONVEN	CONVEN
Maximum Relative Error				
Cost Flow	$/hr			
– MIXED Substream				
Phase		Vapor Phase	Vapor Phase	Vapor Phase
Temperature	C	-103.2	150	52
Pressure	bar	0.0557288	1.01325	1.01325

	Units	ETHYLENE	BUTENE	FINAL
Molar Enthalpy	cal/mol	11386.7	2867.29	5492.58
Mass Enthalpy	cal/gm	405.89	51.1035	131.419
Molar Entropy	cal/mol-K	-12.0104	-48.509	-31.5848
Mass Entropy	cal/gm-K	-0.42812	-0.864572	-0.755718
Molar Density	mol/cc	3.94395e-06	2.88002e-05	3.74805e-05
Mass Density	gm/cc	0.000110642	0.00161591	0.00156648
Enthalpy Flow	cal/sec	80386.7	19432.5	76000.2
Average MW		28.0538	56.1075	41.7944
+ Mole Flows	**kmol/hr**	**25.4148**	**24.3983**	**49.8128**
+ Mole Fractions				
− Mass Flows	ktonne/year	**6.25**	**12**	**18.2499**
ETHYL-01	ktonne/year	6.25	0	0.582604
1-BUT-01	ktonne/year	0	12	0.664444
CIS-2-01	ktonne/year	0	0	0.00087286
PROPY-01	ktonne/year	0	0	17.002

	Units	ETHYLENE	BUTENE	FINAL
− Mole Fractions				
ETHYL-01		1	0	0.0475598
1-BUT-01		0	1	0.0271203
CIS-2-01		0	0	3.56271e-05
PROPY-01		0	0	0.925284

Feed Streams:

Assumptions:

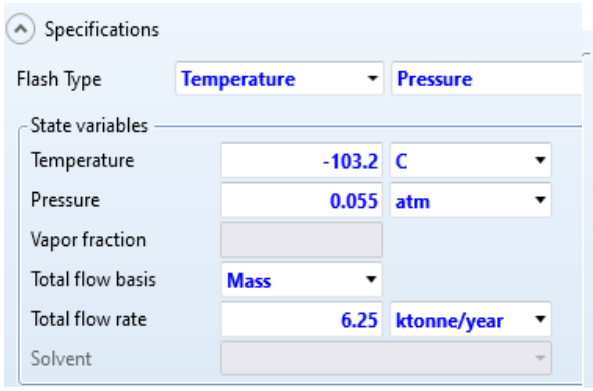
- In OCT industrial process the feed streams of ethylene and butene contains impurities such as metals, water, oxygenates, and sulphur compounds. The ethylene feed stream can vary from dilute ethylene (typical from an FCC) to polymer-grade ethylene
- We assumed both the feeds are pure

Storage Conditions of ethylene

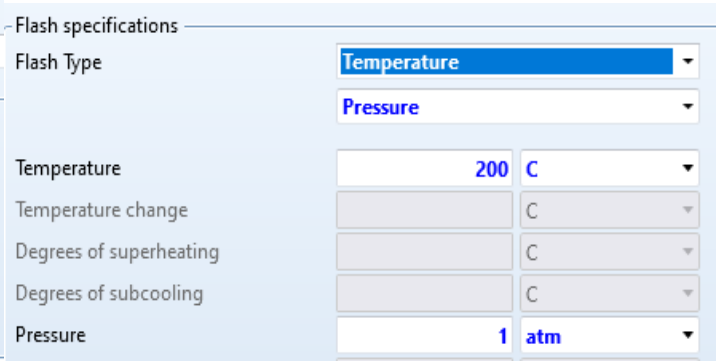
- Temperature: -103.2 C
- Pressure: 0.055 atm [2]

Utilised heater to bring ethylene to reaction conditions i.e., 200 C and 1atm

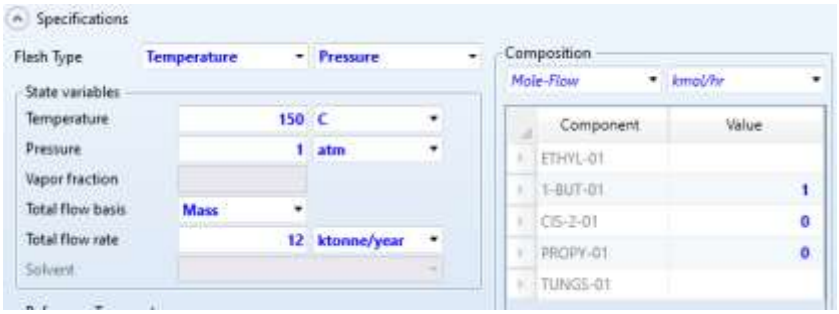
Storage Conditions [3] of butene is almost similar to the reaction's conditions.



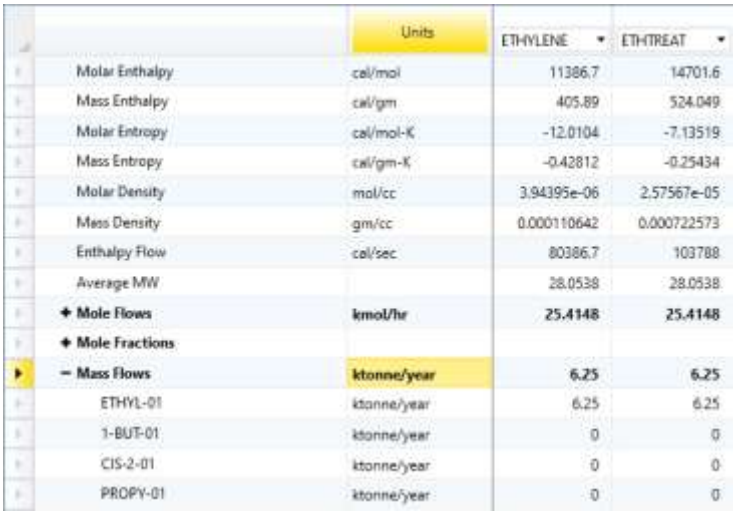
Ethylene Feed



Heater for ethylene pre-treatment



Butene Feed



	Units	ETHYLENE	ETHTREAT
Molar Enthalpy	cal/mol	11386.7	14701.6
Mass Enthalpy	cal/gm	405.89	524.049
Molar Entropy	cal/mol-K	-12.0104	-7.13519
Mass Entropy	cal/gm-K	-0.42812	-0.25434
Molar Density	mol/cc	3.94395e-06	2.57567e-05
Mass Density	gm/cc	0.000110642	0.000722573
Enthalpy Flow	cal/sec	80386.7	103788
Average MW		28.0538	28.0538
+ Mole Flows	**kmol/hr**	**25.4148**	**25.4148**
+ Mole Fractions			
- Mass Flows	**ktonne/year**	**6.25**	**6.25**
ETHYL-01	ktonne/year	6.25	6.25
1-BUT-01	ktonne/year	0	0
CIS-2-01	ktonne/year	0	0
PROPY-01	ktonne/year	0	0

Heater Input -ETHYLENE

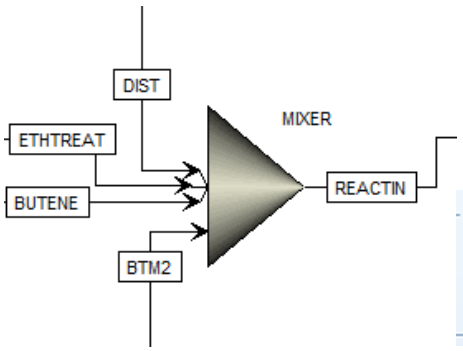
Heater Output - ETHTREAT

MIXER:

INPUT: DIST, ETHREAT, BUTENE, BTM2

OUTPUT: REACTIN – Input to reactor

ETHTREAT AND BUTENE are feed streams. DIST and BTM2 are recycle streams from the distillation columns.



Mixer specifications

Pressure	2	atm
Valid phases	Vapor-Only	

	Total	Units	In	Out	Relative difference
▶	Mole	kmol/hr	110.695	110.695	2.46235e-06
	Mass	kg/hr	3945.16	3945.15	2.11444e-06
	Enthalpy	cal/sec	294249	294249	2.65206e-06

	Units	BTM2	BUTENE	DIST	ETHTREAT	REACTIN
− **MIXED Substream**						
Phase		Liquid Phase	Vapor Phase	Vapor Phase	Vapor Phase	Vapor Phase
Temperature	C	49.5263	150	-70.5265	200	61.8752
Pressure	bar	5.06625	1.01325	5.06625	1.01325	2.0265

	Units	BTM2	BUTENE	DIST	ETHTREAT	REACTIN
Molar Enthalpy	cal/mol	-5327.47	2867.29	11657.1	14701.6	9569.48
Mass Enthalpy	cal/gm	-94.9511	51.1035	415.526	524.049	268.506
Molar Entropy	cal/mol-K	-72.5598	-48.509	-19.5122	-7.13519	-23.1656
Mass Entropy	cal/gm-K	-1.29323	-0.864572	-0.695529	-0.25434	-0.649994
Molar Density	mol/cc	0.0102179	2.88002e-05	0.000300725	2.57567e-05	7.27515e-05
Mass Density	gm/cc	0.573301	0.00161591	0.00843647	0.000722573	0.00259284
Enthalpy Flow	cal/sec	-8190.63	19432.5	179219	103788	294249
Average MW		56.1075	56.1075	28.0538	28.0538	35.6398
+ **Mole Flows**	**kmol/hr**	**5.53476**	**24.3983**	**55.3476**	**25.4148**	**110.695**
+ **Mole Fractions**						
− **Mass Flows**	**ktonne/year**	**2.72221**	**12**	**13.611**	**6.25**	**34.5832**
ETHYL-01	ktonne/year	1.50051e-15	0	13.611	6.25	19.861
1-BUT-01	ktonne/year	1.10257	12	7.10484e-26	0	13.1025
CIS-2-01	ktonne/year	1.61964	0	1.08599e-28	0	1.61964
PROPY-01	ktonne/year	2.07828e-06	0	5.39097e-12	0	2.07822e-06

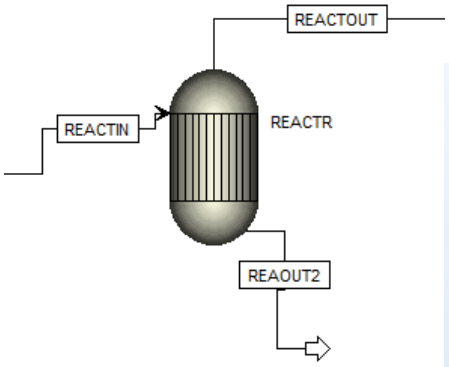
Reactor:

Ethylene reacted with 2-butene, which is produced by isomerisation of 1-butene is converted to propylene by metathesis reaction. The reaction is carried out at high temperatures (~150-300 °C) and low pressures (~1-2 bar), and results in the formation of a mixture of propylene, ethylene and butenes which are then separated by distillation.

INPUT: REACTIN – OUTPUT of MIXER

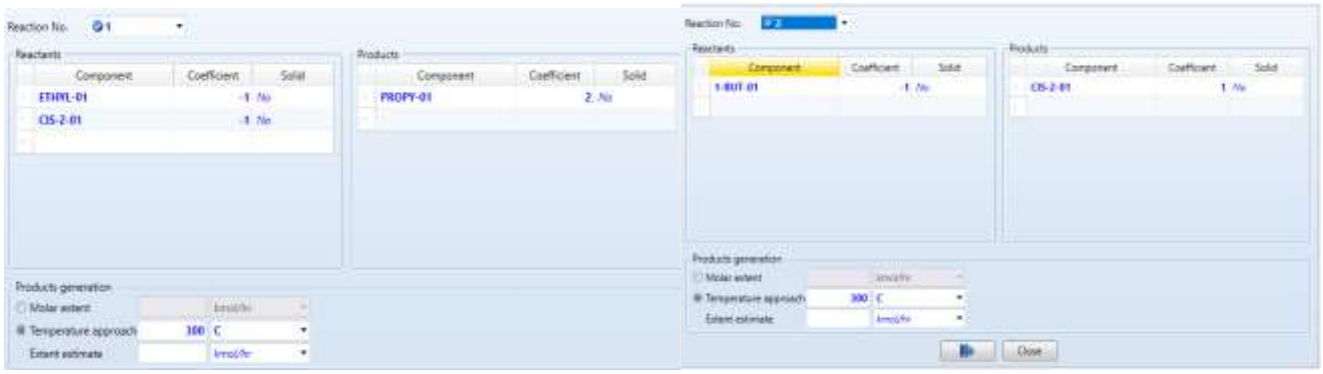
OUTPUT: REACTOUT, REAOUT2

Utilised **REquil** for the reactions. Reactants are fed into the reactor to produce two outlet streams (one for liquid and other for vapor). Since the reactions are in vapor phase there is no product in the REAOUT2 stream (liquid stream).



Operating conditions

Flash Type	Temperature	Pressure
Temperature	300	C
Pressure	2	atm
Duty		cal/sec
Vapor fraction		



Outlet temperature	300	C
Outlet pressure	2.0265	bar
Heat duty	112010	cal/sec
Net heat duty	112010	cal/sec
Vapor fraction	1	

	Total	Units	In	Out
▶	Mole	kmol/hr	110.695	110.695
	Mass	kg/hr	3945.16	3945.16
	Enthalpy	cal/sec	294249	406259

	Rxn No.	Equilibrium constant	Equilibrium temperature
			C
▶	1	11.1713	600
	2	0.917088	600

	Units	REACTIN	REACTOUT	REAOUT2
Description				
From		MIXER	REACTR	REACTR
To		REACTR	COMPRESS	
Stream Class		CONVEN	CONVEN	CONVEN
Maximum Relative Error				
Cost Flow	$/hr			
− MIXED Substream				
Phase		Vapor Phase	Vapor Phase	
Temperature	C	61.8751	300	
Pressure	bar	2.0265	2.0265	2.0265

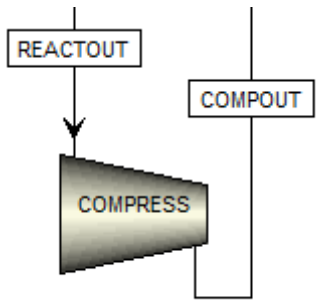
	Units	REACTIN	REACTOUT	REAOUT2
Molar Enthalpy	cal/mol	9569.48	13212.2	
Mass Enthalpy	cal/gm	268.506	370.716	
Molar Entropy	cal/mol-K	-23.1656	-12.999	
Mass Entropy	cal/gm-K	-0.649994	-0.364732	
Molar Density	mol/cc	7.27515e-05	4.25257e-05	
Mass Density	gm/cc	0.00259284	0.0015156	
Enthalpy Flow	cal/sec	294249	406259	
Average MW		35.6397	35.6397	
+ Mole Flows	**kmol/hr**	**110.695**	**110.695**	**0**
+ Mole Fractions				
− Mass Flows	**ktonne/oper-year**	**34.5832**	**34.5832**	
ETHYL-01	ktonne/oper-year	19.861	14.1937	
1-BUT-01	ktonne/oper-year	13.1026	1.76701	
CIS-2-01	ktonne/oper-year	1.61964	1.62051	
PROPY-01	ktonne/oper-year	2.07833e-06	17.002	

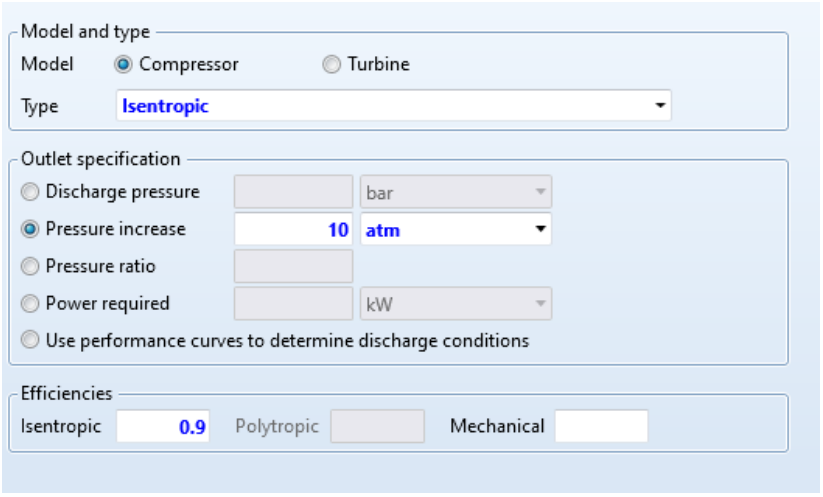
COMPRESSOR:

INPUT – REACTOUT – Outlet of the reactor

OUTPUT- COMPOUT

The OCT reactor effluent is a gas mixture consists of unreacted ethylene, butenes and propylene. To separate these gases the products are cooled and chilled prior to entering the product recovery section.





Compressor model	Isentropic Compressor
Phase calculations	Vapor phase calculation
Indicated horsepower	316.926 kW
Brake horsepower	316.926 kW
Net work required	316.926 kW
Power loss	0 kW
Efficiency	0.9
Mechanical efficiency	1
Outlet pressure	12.159 bar
Outlet temperature	410.46 C
Isentropic outlet temperature	399.958 C
Vapor fraction	1

	Total	Units	In	Out
▶	Mole	kmol/hr	110.695	110.695
	Mass	kg/hr	3945.16	3945.16
	Enthalpy	cal/sec	406259	481956

Head developed	26541.0541	m-kgf/kg
Isentropic power requirement	285.234	kW
Inlet heat capacity ratio	1.10479	

	Inlet	Outlet	
Volumetric flow rate	43383.8	8624.15	l/min
Compressibility factor	1	1	

	Isentropic	Actual
Average volume exponent	1.09856	1.10909
Average temperature exponent	1.09856	1.10909

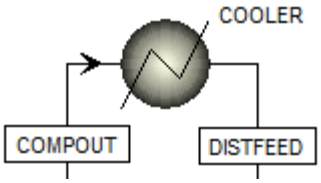
	Units	REACTOUT	COMPOUT
Description			
From		REACTR	COMPRESS
To		COMPRESS	HEATER
Stream Class		CONVEN	CONVEN
Maximum Relative Error			
Cost Flow	$/hr		
− MIXED Substream			
Phase		Vapor Phase	Vapor Phase
Temperature	C	300	410.46
Pressure	bar	2.0265	12.159

	Units	REACTOUT	COMPOUT
Molar Enthalpy	cal/mol	13212.2	15674
Mass Enthalpy	cal/gm	370.716	439.79
Molar Entropy	cal/mol-K	-12.999	-12.636
Mass Entropy	cal/gm-K	-0.364732	-0.354549
Molar Density	mol/cc	4.25257e-05	0.000213925
Mass Density	gm/cc	0.0015156	0.00762424
Enthalpy Flow	cal/sec	406259	481956
Average MW		35.6397	35.6397
+ Mole Flows	**kmol/hr**	**110.695**	**110.695**
+ Mole Fractions			
− Mass Flows	**ktonne/year**	**34.5832**	**34.5832**
ETHYL-01	ktonne/year	14.1937	14.1937
1-BUT-01	ktonne/year	1.76701	1.76701
CIS-2-01	ktonne/year	1.62051	1.62051
PROPY-01	ktonne/year	17.002	17.002

Cooler: The compressed products from the compressor are then cooled to convert the gas mixture into liquid mixture for the separation process

INPUT: COMPOUT – Outlet of compressor

OUTPUT: DISTFEED



Flash specifications

Flash Type	Temperature	
	Pressure	
Temperature	-35	C
Temperature change		C
Degrees of superheating		C
Degrees of subcooling		C
Pressure	10	atm

Outlet temperature	-35	C
Outlet pressure	10.1325	bar
Vapor fraction	0	
Heat duty	-346378	cal/sec
Net duty	-346378	cal/sec
1st liquid / Total liquid	1	
Pressure-drop correlation parameter		
Pressure drop	2.0265	bar

	Total	Units	In	Out
▶	Mole	kmol/hr	110.695	110.695
	Mass	kg/hr	3945.13	3945.13
	Enthalpy	cal/sec	481952	135574

	Units	COMPOUT	DISTFEED
Description			
From		COMPRESS	COOLER
To		COOLER	RADFRAC
Stream Class		CONVEN	CONVEN
Maximum Relative Error			
Cost Flow	$/hr		
− **MIXED Substream**			
Phase		Vapor Phase	Liquid Phase
Temperature	C	410.46	-35
Pressure	bar	12.159	10.1325

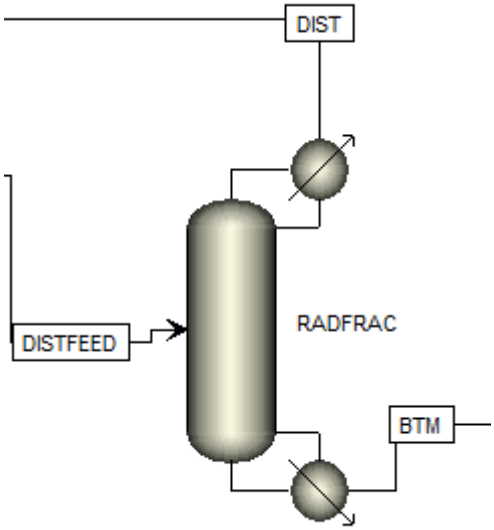
	Units	COMPOUT	DISTFEED
Molar Enthalpy	cal/mol	15674	4409.12
Mass Enthalpy	cal/gm	439.789	123.713
Molar Entropy	cal/mol-K	-12.6361	-42.506
Mass Entropy	cal/gm-K	-0.35455	-1.19266
Molar Density	mol/cc	0.000213925	0.0152777
Mass Density	gm/cc	0.00762426	0.544493
Enthalpy Flow	cal/sec	481952	135574
Average MW		35.6398	35.6398
+ **Mole Flows**	**kmol/hr**	**110.695**	**110.695**
+ **Mole Fractions**			
▶ − **Mass Flows**	ktonne/year	**34.583**	**34.583**
ETHYL-01	ktonne/year	14.1935	14.1935
1-BUT-01	ktonne/year	1.76702	1.76702
CIS-2-01	ktonne/year	1.62052	1.62052
PROPY-01	ktonne/year	17.002	17.002

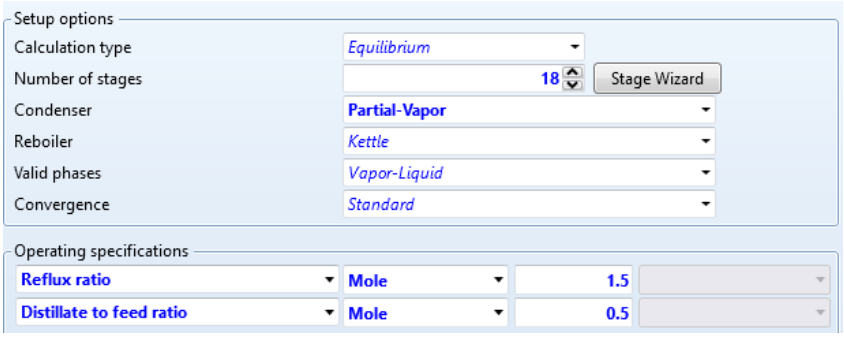
Distillation Column 1:

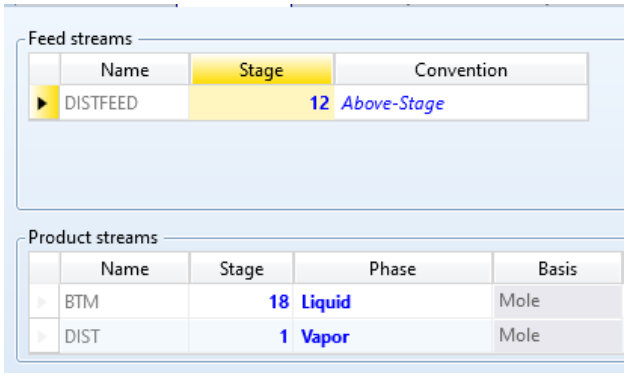
Input: DISTFEED – Outlet of cooler

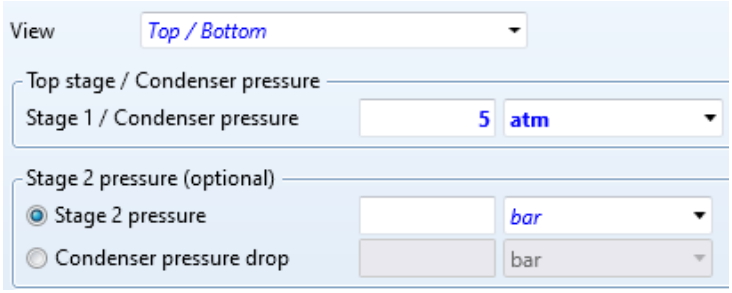
Output – DIST(Distillate), BTM(Bottoms).

After cooling, the reactor effluent is sent to the recovery section, which consists primarily of two towers. The first tower separates unreacted ethylene for recycle to the OCT reactor. The second tower processes bottoms from the ethylene recovery tower to produce a polymer-grade propylene overhead product and a C -C recycle stream.[1]
The outlet of the cooler is distilled to separate the liquid mixture. The distillate which consists of mainly ethylene is then recycled back to the mixer and the bottoms product are then distilled again to separate propylene and butenes. The parameters such as distillate to feed ratio, no of stages are found using the **Design specification of Aspen** in order to get required propylene purity.









Reboiler / Bottom stage performance

Name	Value	Units
Temperature	-9.70838	C
Heat duty	106921	cal/sec
Bottoms rate	55.3473	kmol/hr
Boilup rate	88.948	kmol/hr
Boilup ratio	1.60709	
Bottoms to feed ratio	0.5	

Condenser / Top stage performance

Name	Value	Units
Temperature	-70.5265	C
Subcooled temperature		
Heat duty	-65709.9	cal/sec
Subcooled duty		
Distillate rate	55.3473	kmol/hr
Reflux rate	83.021	kmol/hr

Total	Units	In	Out
Mole	kmol/hr	110.695	110.695
Mass	kg/hr	3945.13	3945.13
Enthalpy	cal/sec	135574	176785

Component	DIST	BTM
ETHYL-01	0.958956	0.0410435
1-BUT-01	0	1
CIS-2-01	0	1
PROPY-01	3.17079e-13	1

	Units	DISTFEED	BTM	DIST
Description				
From		COOLER	RADFRAC	RADFRAC
To		RADFRAC	RADFRAC2	MIXER
Stream Class		CONVEN	CONVEN	CONVEN
Maximum Relative Error				
Cost Flow	$/hr			
− MIXED Substream				
Phase		Liquid Phase	Liquid Phase	Vapor Phase
Temperature	C	-35	-9.70838	-70.5265
Pressure	bar	10.1325	5.06625	5.06625

	Units	DISTFEED	BTM	DIST
Molar Enthalpy	cal/mol	4409.12	-158.274	11657.1
Mass Enthalpy	cal/gm	123.713	-3.66157	415.526
Molar Entropy	cal/mol-K	-42.506	-54.7255	-19.5122
Mass Entropy	cal/gm-K	-1.19266	-1.26604	-0.695529
Molar Density	mol/cc	0.0152777	0.013143	0.000300725
Mass Density	gm/cc	0.544493	0.568116	0.00843647
Enthalpy Flow	cal/sec	135574	-2433.35	179219
Average MW		35.6398	43.2258	28.0538
+ Mole Flows	**kmol/hr**	**110.695**	**55.3473**	**55.3473**
+ Mole Fractions				
− Mass Flows	**ktonne/year**	**34.583**	**20.9721**	**13.611**
ETHYL-01	ktonne/year	14.1935	0.582553	13.611
1-BUT-01	ktonne/year	1.76702	1.76702	7.1046e-26
CIS-2-01	ktonne/year	1.62052	1.62052	1.08595e-28
PROPY-01	ktonne/year	17.002	17.002	5.39097e-12

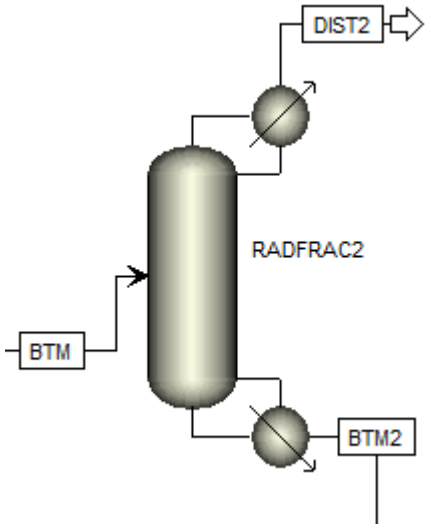
Distillation Column 2:

Input: BTM – Bottoms of the distillation column 1

Output: DIST2(Distillate), BTM2(Bottoms).

The outlet of the distillation column 1 is then distilled to separate the mixture of butene and propylene. The distillate which consists of mainly

propylene and the bottoms products that consists of butenes are then recycled back to the mixer.



Setup options

Calculation type	*Equilibrium*	
Number of stages	25	Stage Wizard
Condenser	**Partial-Vapor**	
Reboiler	*Kettle*	
Valid phases	*Vapor-Liquid*	
Convergence	*Standard*	

Operating specifications

Reflux ratio	**Mole**	1.5	
Distillate to feed ratio	**Mole**	0.9	

Feed streams

	Name	Stage	Convention
▶	BTM	15	*Above-Stage*

Product streams

	Name	Stage	Phase	Basis
	DIST2	1	**Vapor**	Mole
	BTM2	25	**Liquid**	Mole

View: *Top / Bottom*

Top stage / Condenser pressure

Stage 1 / Condenser pressure: 5 **atm**

Condenser / Top stage performance

	Name	Value	Units
	Temperature	-3.15471	C
	Subcooled temperature		
	Heat duty	-87130.5	cal/sec
	Subcooled duty		
	Distillate rate	49.8126	kmol/hr
	Reflux rate	74.7189	kmol/hr

Reboiler / Bottom stage performance

	Name	Value	Units
	Temperature	49.5264	C
	Heat duty	145668	cal/sec
	Bottoms rate	5.53473	kmol/hr
	Boilup rate	111.052	kmol/hr
	Boilup ratio	20.0646	
	Bottoms to feed ratio	0.1	

	Total	Units	In	Out
▶	Mole	kmol/hr	55.3473	55.3473
	Mass	kg/hr	2392.43	2392.43
	Enthalpy	cal/sec	-2433.35	56104.3

	Component	DIST2	BTM2
▶	ETHYL-01	1	2.57541e-15
	1-BUT-01	0.376041	0.623959
	CIS-2-01	0.000538642	0.999461
	PROPY-01	1	1.22234e-07

	Units	BTM	BTM2	DIST2
Description				
From		RADFRAC	RADFRAC2	RADFRAC2
To		RADFRAC2	MIXER	
Stream Class		CONVEN	CONVEN	CONVEN
Maximum Relative Error				
Cost Flow	$/hr			
− MIXED Substream				
Phase		Liquid Phase	Liquid Phase	Vapor Phase
Temperature	C	-9.70838	49.5264	-3.15471
Pressure	bar	5.06625	5.06625	5.06625

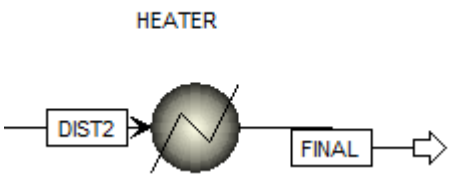
	Units	BTM	BTM2	DIST2
Molar Enthalpy	cal/mol	-158.274	-5327.48	4646.65
Mass Enthalpy	cal/gm	-3.66157	-94.9513	111.178
Molar Entropy	cal/mol-K	-54.7255	-72.5598	-37.6258
Mass Entropy	cal/gm-K	-1.26604	-1.29323	-0.900258
Molar Density	mol/cc	0.013143	0.0102179	0.000225685
Mass Density	gm/cc	0.568116	0.573301	0.0094324
Enthalpy Flow	cal/sec	-2433.35	-8190.61	64294.9
Average MW		43.2258	56.1075	41.7945
+ Mole Flows	**kmol/hr**	**55.3473**	**5.53473**	**49.8126**
+ Mole Fractions				
− Mass Flows	**ktonne/year**	**20.9721**	**2.72219**	**18.2499**
ETHYL-01	ktonne/year	0.582553	1.50031e-15	0.582553
1-BUT-01	ktonne/year	1.76702	1.10255	0.664473
CIS-2-01	ktonne/year	1.62052	1.61964	0.000872878
PROPY-01	ktonne/year	17.002	2.07822e-06	17.002

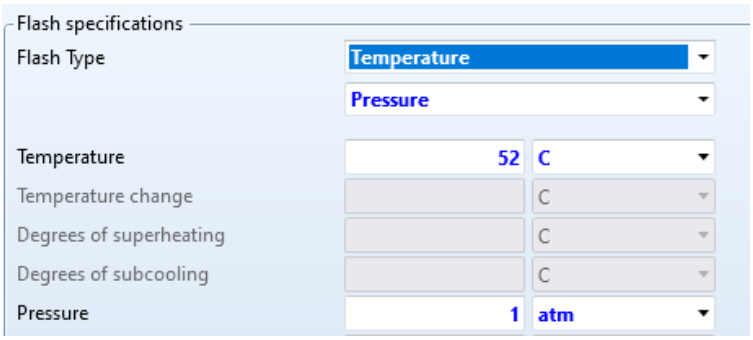
Heater:

INPUT: DIST2 – Distillate of the distillation column 2

OUTPUT: FINAL – Required product

Propylene is stored at 52 C [4]. Utilized heater to heat the distillate to required temperature.





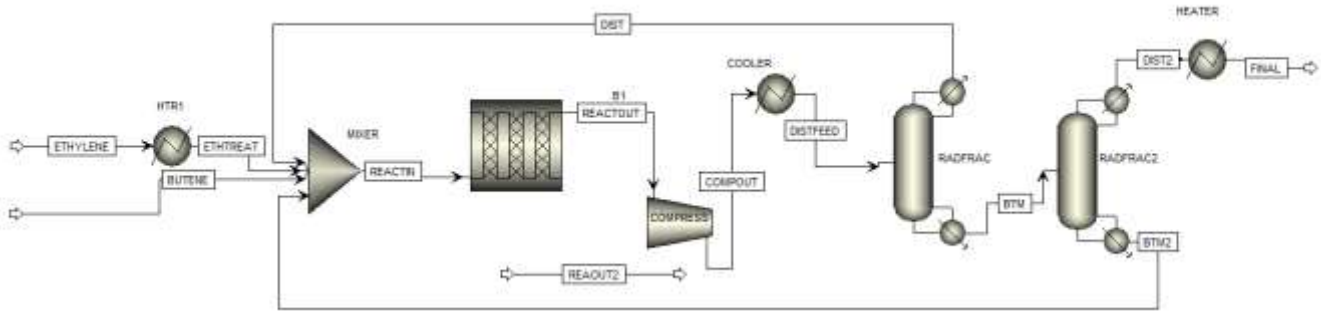
Outlet temperature	52	C
Outlet pressure	1.01325	bar
Vapor fraction	1	
Heat duty	11704.6	cal/sec
Net duty	11704.6	cal/sec
1st liquid / Total liquid		
Pressure-drop correlation parameter		
Pressure drop	4.053	bar

	Total	Units	In	Out
▶	Mole	kmol/hr	49.8128	49.8128
	Mass	kg/hr	2081.9	2081.9
	Enthalpy	cal/sec	64295.6	76000.2

	Units	DIST2	FINAL
Description			
From		RADFRAC2	HEATER
To		HEATER	
Stream Class		CONVEN	CONVEN
Maximum Relative Error			
Cost Flow	$/hr		
− **MIXED Substream**			
Phase		Vapor Phase	Vapor Phase
Temperature	C	-3.15501	52
Pressure	bar	5.06625	1.01325

	Units	DIST2	FINAL
Molar Enthalpy	cal/mol	4646.68	5492.58
Mass Enthalpy	cal/gm	111.179	131.419
Molar Entropy	cal/mol-K	-37.6257	-31.5848
Mass Entropy	cal/gm-K	-0.900257	-0.755718
Molar Density	mol/cc	0.000225685	3.74805e-05
Mass Density	gm/cc	0.0094324	0.00156648
Enthalpy Flow	cal/sec	64295.6	76000.2
Average MW		41.7944	41.7944
✦ **Mole Flows**	**kmol/hr**	**49.8128**	**49.8128**
✦ **Mole Fractions**			
− **Mass Flows**	**ktonne/year**	**18.2499**	**18.2499**
ETHYL-01	ktonne/year	0.582604	0.582604
1-BUT-01	ktonne/year	0.664444	0.664444
CIS-2-01	ktonne/year	0.00087286	0.00087286
PROPY-01	ktonne/year	17.002	17.002

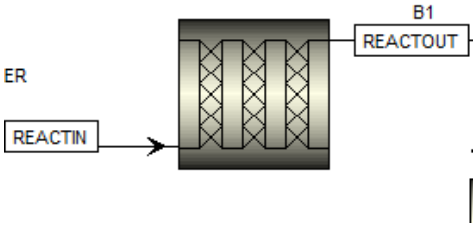
Design-2:



Used **RPlug** reactor for the reactions.

Input: REACTIN

Output: REACTOUT



Specifications | Configuration | Streams | Reactions | Pressure | Holdup | Cata

Multitube reactor Number of tubes 1000

Diameter varies along the length of the reactor

Reactor dimensions

Length 12 ft

Diameter 2 ft

Elevation

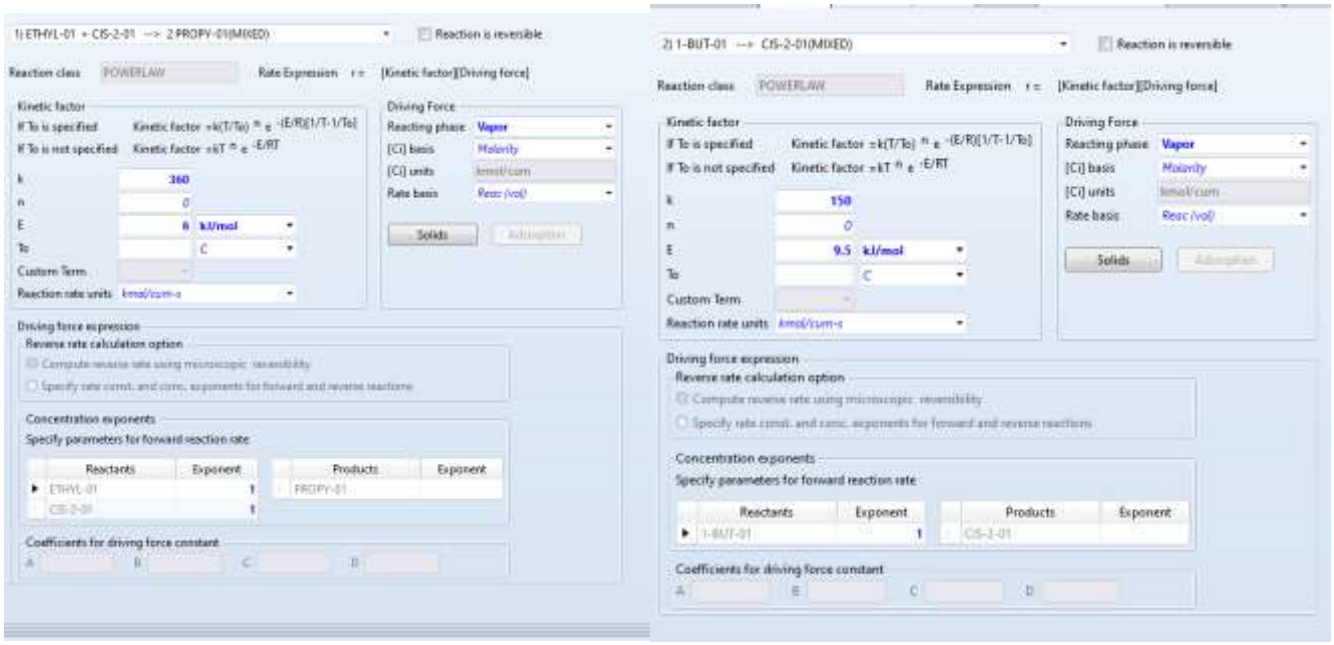
Reactor rise 0 meter

Reactor angle 0 deg

Valid phases

Process stream *Vapor-Only*

Thermal fluid stream Vapor-Liquid 2nd Liquid



	Units	BTM	BTM2	BUTENE	COMPOUT	DIST	DIST2	DISTFEED	ETHYLENE	REACTIN	REACTOUT	
Pressure	bar	5.08625	5.08625	1.01325	12.159	5.08625	5.08625	10.1525	1.01325	2.0265	2.0265	
Molar Vapor Fraction		0	0	1	1	1	1	0	1	1	1	
Molar Liquid Fraction		1	1	0	0	0	0	1	0	0	0	
Molar Solid Fraction		0	0	0	0	0	0	0	0	0	0	
Mass Vapor Fraction		0	0	1	1	1	1	0	1	1	1	
Mass Liquid Fraction		1	1	0	0	0	0	1	0	0	0	
Mass Solid Fraction		0	0	0	0	0	0	0	0	0	0	
Molar Enthalpy	cal/mol	-378.68	-6018.77	2867.29	14915.8	11857.1	4475.96	3167.98	14701.8	9045.22	13462.7	
Mass Enthalpy	cal/gm	-6.66268	-107.294	51.1035	399.784	415.526	106.366	84.9059	524.849	242.426	334.019	
Molar Entropy	cal/mol-K	-55.2876	-74.365	-48.509	-14.8033	-19.5122	-38.1126	-45.7667	-7.13519	-24.7891	-15.1676	
Mass Entropy	cal/gm-K	-1.27147	-1.32546	-0.864572	-0.396754	-0.695529	-0.905701	-1.22661	-0.25434	-0.664286	-0.406514	
Molar Density	mol/cc	0.0133488	0.0103266	2.88002e-05	0.000215497	0.000300725	0.000223786	0.0150146	2.57567e-05	6.92202e-05	4.25257e-05	
Mass Density	gm/cc	0.567432	0.579375	0.00161591	0.00804549	0.00843647	0.0094171	0.569216	0.000722573	0.0023627	0.00158869	
Enthalpy Flow	cal/sec	-5673.1	-9068.25	19432.5	374435	117043	60670.4	79520	99636.7	27046	31283.1	
Average MW		43.4832	56.1052	56.1075	37.3114	28.0538	42.0808	37.3114	28.0538	37.3113	37.3114	
Mole Flows	**kmol/hr**	**54.2188**	**5.42188**	**24.3983**	**90.3647**	**36.1459**	**48.7969**	**90.3647**	**24.3983**	**90.3643**	**90.3647**	
Mole Fractions												
ETHYL-01		0.0246802	3.58742e-10	0	0.414814	1	0.0274335	0.414814	1	0.670001	0.414814	
1-BUT-01		0	0	1	0	0	0	0	0	0.269999	0	
CIS-2-01		0.124881	0.999833	0	0.0748087	1.62685e-29	0.0274421	0.0748087	0	0.0599903	0.0748087	
PROPY-01		0.850629	0.000167182	0	0.510377	4.73979e-13	0.945124	0.510377	0	1.00309e-05	0.510377	
TUNGS-01		0	0	0	0	0	0	0	0	0	0	
Mass Flows	**ktonne/year**	**20.6668**	**2.06658**	**12**	**29.5558**	**8.88897**	**18.0002**	**29.5558**	**8**	**29.5555**	**29.5558**	
ETHYL-01	ktonne/year	0.329205	4.78327e-10	0	9.21817	8.88897	0.329205	9.21817	8	14.889	9.21817	
1-BUT-01	ktonne/year	0	0	12	0	0	0	0	0	12	0	
CIS-2-01	ktonne/year	3.32486	2.66624	0	3.32486	2.09578e-28	0.658617	3.32486	0	2.66624	3.32486	
PROPY-01	ktonne/year	17.0127	0.000334367	0	17.0127	6.31978e-12	17.0126	17.0127	0	0.000334364	17.0127	
TUNGS-01	ktonne/year	0	0	0	0	0	0	0	0	0	0	

Overall, Balance:

6 ktonne/year of ethylene is reacted with **12** ktonne/year of butylene to produce **17** ktonne/year (17,000 TPA) of propylene of **94.5%** purity

The material balances across other equipment are almost similar to that of design 1

References:

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3. https://www.cpchem.com/sites/default/files/2020-04/1-Butene%202018%20Final.pdf
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