CH4250: PROCESS ENGINEERING

Capstone Project Preliminary Analysis

Group: 7

Problem Statement

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

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Propylene

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

Market Analysis

The global propylene market grew from $104.04 billion in 2022 to $107.4 billion in 2023 at a compound annual growth rate (CAGR) of 3.2%. The propylene market is expected to grow to $121.74 billion in 2027 at a CAGR of 3.2%.

Selling Price: 356/- per kg [This price is highly doubtful but due to lack of other sources and the fact that propylene selling price is a constant factor across all process which means it is not going to influence the decision of which technology to choose, we decided to go with this)

Capacity: **17000 tonne per annum**

Total Revenue: 17000*1000*356 = **605 Crores INR per annum**

Production Process of Propylene:

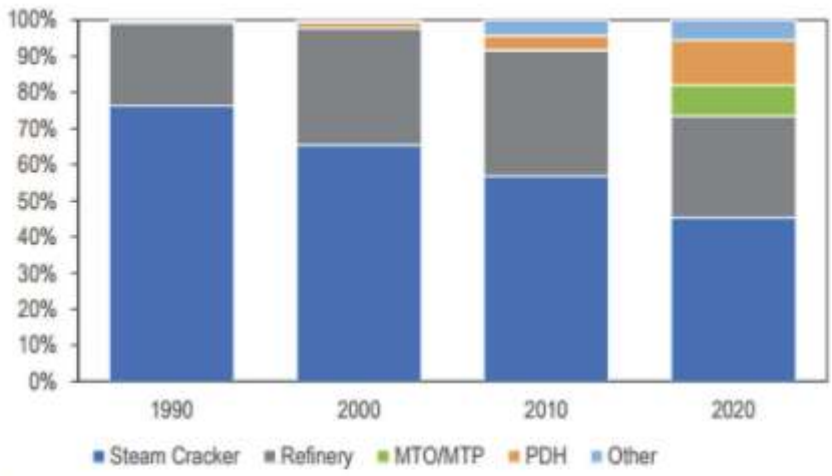


Figure 1. Evolution of the sources of propene by process type.

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

LURGI MTP Technology

INTRODUCTION

A catalytic process to produce on-purpose propylene using natural gas, coal or biomass as feedstock. These alternative feedstocks are first converted to synthesis gas which is cleaned and then converted to methanol. Methanol in turn is converted to DME (dimethyl ether), which produces a propylene-rich mixture containing various hydrocarbons. In 2011, the first fixed-bed MTP commercial unit was commissioned in Ningxia in China. The unit reached its full capacity close to 500 kt/a of propylene 1 year later
Based on a simple fixed-bed reactor system, usual processing elements and operating conditions including a commercially manufactured catalyst, Lurgi's MTP technology will provide an attractive way to "monetize" methanol.

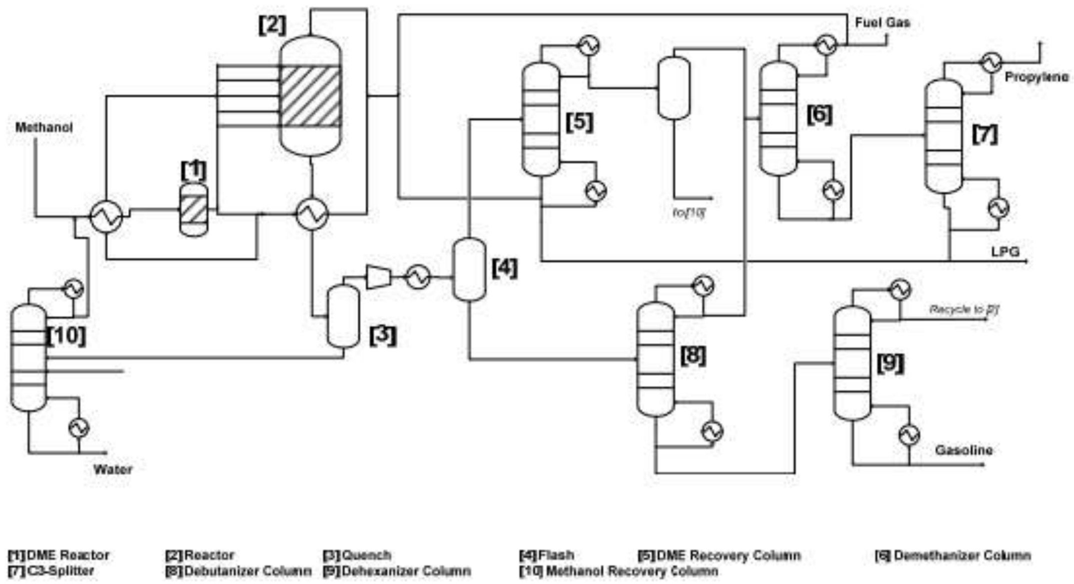
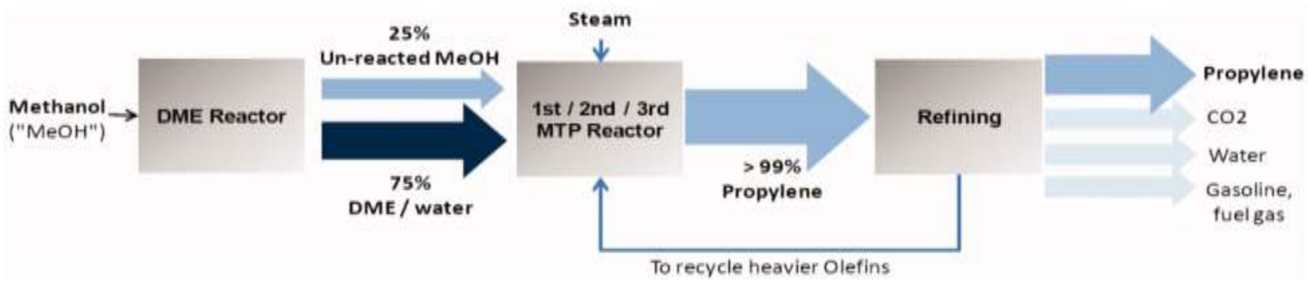


Figure 5. Flowsheet for the MTP process.

PRODUCTION:

The industrial production of propylene from methanol involves the following stages-

- Crude methanol is purified before the reaction. The purified methanol is fed into the pre-reactor to form dimethyl ether (DME) and water.
- The methanol/water/DME stream is routed to the first MTP reactor where also the steam is added. Methanol/DME are converted to more than 99%, with propylene as the predominant hydrocarbon product.
- Additional reaction proceeds in the 2nd and 3rd MTP reactors. The process conditions in the three MTP reactors are chosen to guarantee similar reaction conditions and maximum overall propylene yield. The product mixture is then cooled, and the product gas, organic liquid and water are separated.



- The catalyst used in the MTP process is developed by Süd Chemie (now Clariant). It has 99% conversion rate of methanol/DME with maximum propylene selectivity, low coking tendency and very low propane yield.
- The product gas is compressed and traces of water, CO2 and DME which are removed by standard techniques. The cleaned gas is then further processed yielding chemical-grade propylene with a typical purity of more than 60%.
- Different olefin-containing streams are sent back to the main synthesis loop as an additional propylene source.
- Water is recycled to the steam generation for the process; the excess water resulting from the methanol conversion is purged. Where suitable, this process water can be used for agricultural purposes after appropriate treatment. Therefore, we can consider that the water coming out is sent back into the process.

OPERATING CONDITIONS-

Pressure: 1.3-1.6 bar

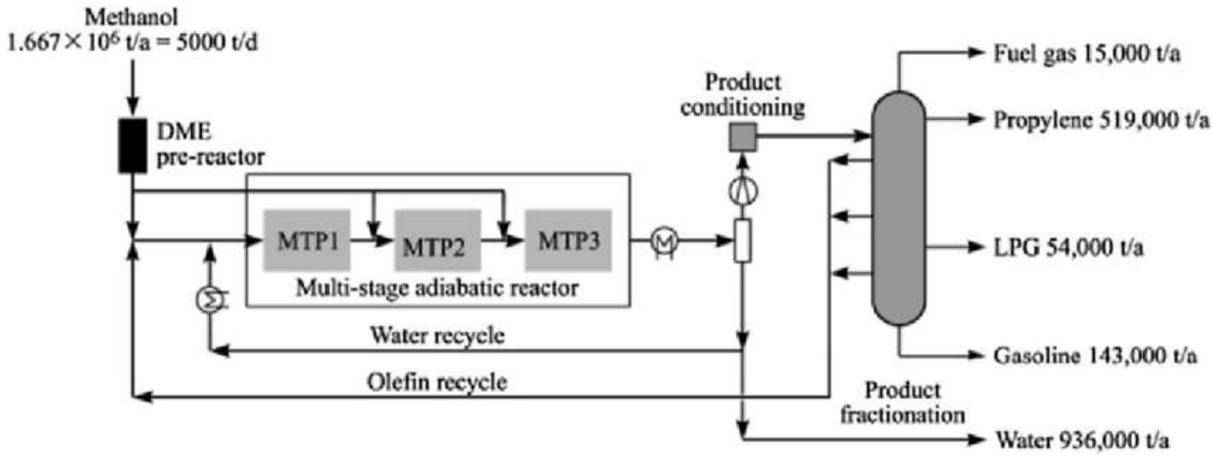
Inlet Temperature: 400-450°C

Catalyst used: ZSM-5

Catalyst Average lifetime - 3 years

The catalyst needs to be regenerated after 500-600 operating hours.

The regeneration is carried out at similar temperatures as the reaction itself, hence the catalyst particles do not experience any unusual temperature stress during the in-situ catalyst regeneration procedure.



MASS BALANCE-

The simplified overall mass balance is depicted in Figure 6 based on a combined Mega- Methanol / MTPplant. For a feed rate of 5000 t of methanol per day (1.667 million t/a), approx. 519,000 t of propylene are produced per year. By-products include fuel gas and LPG as well as liquid gasoline and process water.

QUALITATIVE ANALYSIS -

Optimised reforming: high flexibility in stoichiometric number

- High energy efficiency for MeOH synthesis
- On a normalized basis (per ton of combined products, the MTP process shows less emissions. Further improvement of the economic and environmental aspects may be achieved by applying process integration techniques.

- Fixed-bed reactor is preferred to fluid-bed reactors due to lower investment cost and less-complicated scale-up.

ECONOMIC ANALYSIS -

Reference plant- Ningdong, in the Chinese province of Ningxia

Capacity - 500,000 tons/year (TPA) Methanol-to-Propylene (MTP) plant.

Feed- 1.667 million t/a of Methanol

Yield - 519,000 t of propylene.

DATA-

Required capacity = 17000TPA (tonnes per annum)

Molecular weight of propylene = 42.08g/mol

This gives:

(17000*1000)/(42.08 *0.001) = 403992kmol/annum

From the above plant aiming a yield of 60%:

Conversion = 519000 / (1.667*10^6 *0.6) = 0.52

Therefore, we take conversion of methanol to be 52% and yield of propylene to be 60%

Required flow rate of Methanol:

403992/(0.52*0.6) => 1294846 kmol/annum

Calculations for the required 17000TPA Propylene in Chennai-

Price of Methanol = Rs 60 / litre [1 litre of methanol = 0.792kg]

= 75.7575 Rs /kg

= 2.4272 Rs / mol (Molecular weight of methanol = 32.04 g/mol)

Cost = 2.4272 * 1294846 *1000 = 3,142,850,585 Rs/ year

Steam addition = 0.5 kg/kg of methanol = 0.5 * (1294846 * 32.04) = 20743432kg/annum

Chennai City Water Supply source -> water purchased at 73Rs / KL

Steam cost = 1514270 Rs/ annum

[Since the steam is recycled back, we can neglect this cost]

Price of Propylene gas (we consider the LPG cylinder) = Rs. 356/kg

Revenue = 459,82,47,919 Rs/annum

Transportation costs -

Taking the Manali Petrochemicals Ltd plant,

Methanol from Astra Chemicals = 10.7km

(Assuming the plant that supplies raw materials is within the 10 km radius of the plant we setup (As there are abundant suppliers of raw materials for every technology) the transportation cost is assumed constant for all the technologies)

Taking all fuel, tolls, documentations, drivers' salary, maintenance etc into consideration = Rs 40/km = 428 Rs per Truck

Bulk trucks like 32 ft Mack truck are used to transport chemicals and each truck has a capacity of 5000 gallons = 18900 liters = 14968kg

Methanol = 1294846 kmol/ annum => 3547.82 kmol/day = 113662 kg/day

To transport around 113662 kg every day

We need around 8 trucks per day = 8*428 = 3424Rs/day = 1249760 Rs/ Yr. (We can avoid this by considering setting up a storage tank – which will be taken up in the further steps if deemed economically feasible)

Total cost = Cost of raw materials + Catalyst cost + Transportation cost

[Couldn't get the legitimate information on the amount of catalyst used]

= 314.28 + 0.125 = 314.405 crore Rs/yr.

Total Revenue = 459.82Cr / yr

Profit = 145.415 Cr/ yr

Return On Investment (ROI) = Profit * 100 / Total cost = 46%

Olefin conversion technology

Olefins Conversion Technology (OCT) process is the commercial on-purpose metathesis technology for propylene production. The design of 190 kTA.

Licensed by **ABB Lummus Global**

There are currently 49 licensed metathesis units worldwide, with a total licensed propylene capacity about 9200 kilo tons per annum (kTA)

PROCESS CHEMISTRY:

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:

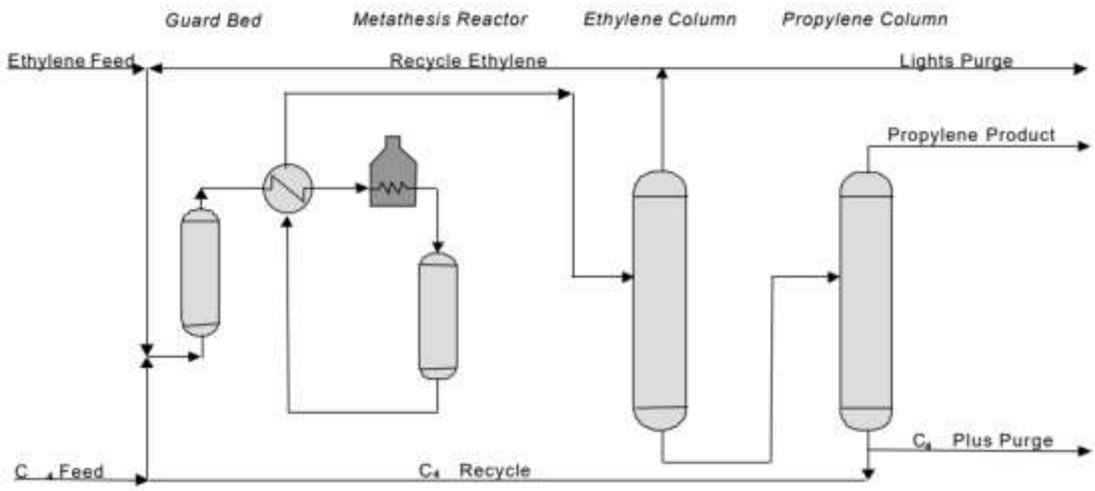
- **Metathesis** - Propylene is formed by the metathesis of ethylene and butene-2.
- **Isomerization** – The butene-2 consumed in the metathesis reaction is formed by isomerization of butene -1.

Main Reactions

Ethylene + Butene-2 ⟷ 2 Propylene

Butene-2 ⟷ Butene-1

PROCESS DESCRIPTION:



Flow schematic of Olefins Conversion Technology unit.

- **Feedstock Treatment -** The ethylene feed stream can vary from dilute ethylene (typical from an FCC) to polymer-grade ethylene.The C_4 stream is treated to remove bulk impurities such as metals, water, oxygenates, and sulphur compounds prior to entering the OCT reaction section.
- **Reaction and Regeneration –**
  - Feed C 's and C 's are mixed with ethylene and heated prior to entering the vapor-phase fixed-bed OCT reactor.

- The OCT catalyst promotes the metathesis reactions of butenes and pentenes with ethylene to form propylene and simultaneously isomerizes 1-butene to 2-butene.
- The OCT reactor effluent contains mainly propylene and unreacted feed. It is cooled and chilled prior to entering the product recovery section.
- For periodic regeneration, the coke deposited on the catalyst is burned in a controlled nitrogen-air atmosphere.
- The per-pass conversion of butylene is greater than 60% with overall selectivity to propylene exceeding 90%.

- **Recovery Section-**
  - The OCT reactor effluent contains a mixture of propylene, unconverted ethylene, butenes, and pentenes, and some C plus components from side reactions.
  - 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.

The key features of OCT are:

- Highest propylene yield.
- Lowest energy route for propylene production.
- Ultra-high-purity propylene.
- Lowest capital cost route to propylene production.
- Commercially proven process
- Simple reaction system
- Simple recovery system
- Lower emissions.

<u>Process Economics</u>

The key driver of process economics for OCT is the price differential between high-value propylene and lower-value C and C streams.

Typical OCT Unit Material Balance

Feeds, kTA	
C_4 raffinate	214
PG ethylene	82
Total	296
Products, kTA	
PG propylene	240
C_4+ by-product	54
Vent gas	2
Total	296

For every kTA of propylene produced

- ~0.9 kTA of Raffinate (C4 stream) is consumed
- ~0.34 kTA of ethylene is consumed

To produce 17000 TPA

- Amount of C4 stream(butene) required = 0.9*17 = 15.3 kTA
- Amount of ethylene required = 0.34*17 = 5.78 kTA

Raw material cost:

- Cost of butene = 100588.63 /- per metric ton
  - Cost of 15.3 kTA = 15.3*1000*100588 = 153 crores INR per annum
- Cost of ethylene = 82,925 /- per metric ton
  - Cost of 5.78 kTA = 5.78*1000*82925 = 47,93,06,500 /-
- Total raw material cost ~ 201 crores per annum

Transportation Cost:

To Transport butene

We need around 3 trucks per day = 3*428 = 3424Rs/day = 468660 Rs/yr

To transport ethylene

We need around 1 trucks per day = 428 Rs/day = 156220 Rs/yr

Total Transportation cost = 624880 Rs/yr

Total Cost ~ 202 crores Rs/yr

Toal profit = 605 – 202 = 403 Crores Rs / yr

OLEFLEX Process

OLEFLEX is a continuous catalytic dehydrogenation process technology utilized to produce light olefins from their corresponding paraffin; and specifically used to convert propane (feedstock) into propylene. OLEFLEX technology was commercialized in 1990, and by 2002 more than 1,250,000 MTA of propylene was produced from various OLEFLEX units located in different places in the world.

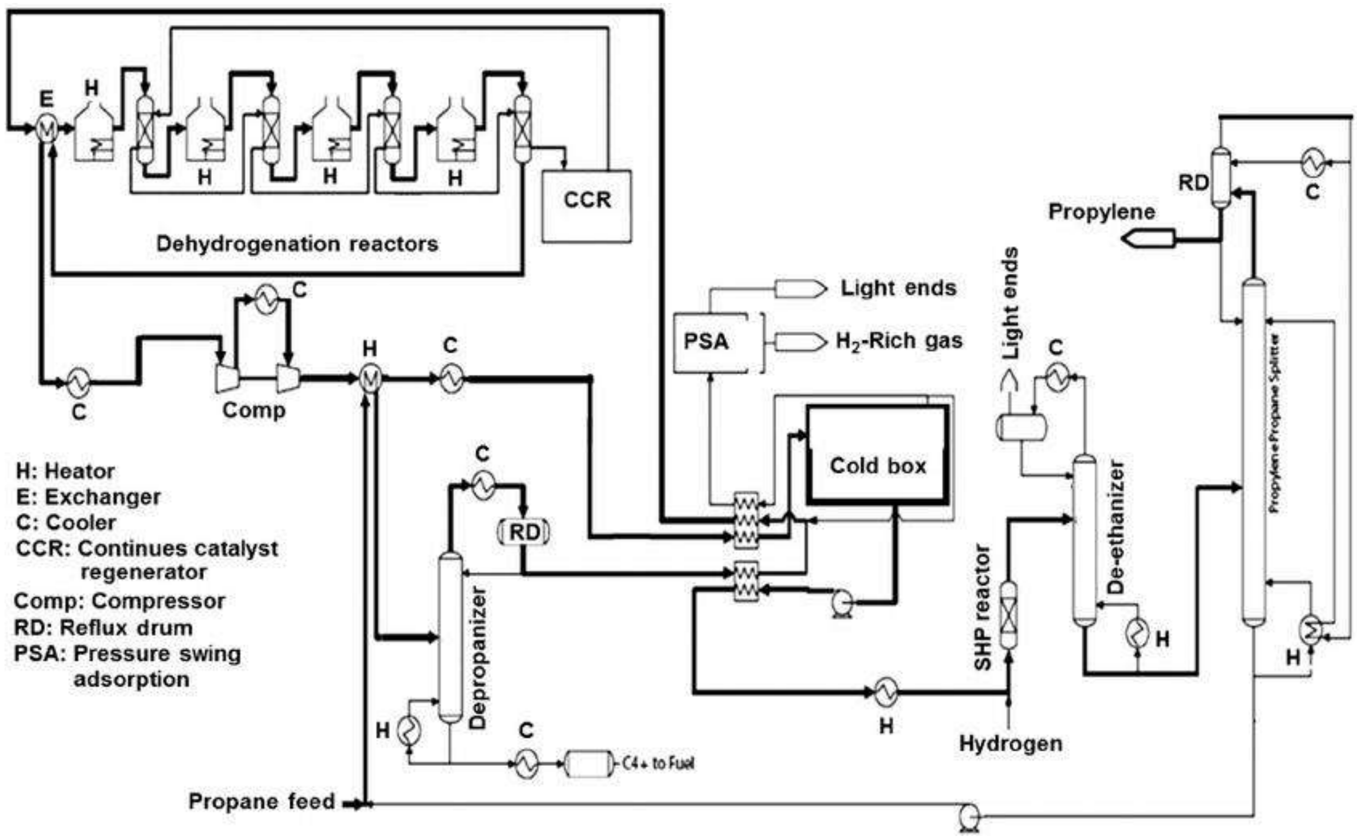
Licensed by **Honeywell** and has various units like Al-Waha Petrochemical Co, The National Petrochemical Industrial Co. (NATPET).

PROCESS CHEMISTRY:

C_3H_8 + (Catalyst + heat) -> $C_3H_6 + H_2$

The OLEFLEX process uses a platinum-based catalyst (DeH-14) to promote the dehydrogenation reaction.

PROCESS DESCRIPTION :



OLEFLEX consists of three main sections:

- *Reactor section*
    - Fresh and recycled propane are fed into a depropanizer tower for pre-treatment purposes.
    - Purified propane is mixed with small amounts of recycled hydrogen-rich gas and then passed by a heat exchanger that raise feed (propane) temperature.
    - Combined feed enters the 1st-heater which furtherly and rapidly increases feed temperature to the spontaneous endothermic reaction temperature 630 ~ 650 °C.
    - Propane moves through the four reactors in series (with a moving-bed catalyst) where 1st-reactor product is heated again in a 2nd-heater to maintain reaction temperature for the feed and prior entering the 2nd-reactor.

    - The same procedure is repeated for the last two stages (4 stages in total) to have a maximum propane/propylene conversion of 35 ~ 40%.

- *Catalyst regeneration section*

    - A small amount of catalyst is continuously removed from the bottom of the 4th-reactor while an equivalent amount of a regenerated catalyst is added to the top of the 1st-reactor.
    - Spent catalyst is sent to a CCR unit to be regenerated. Catalyst regeneration is necessary because coke formation reduces propylene conversion and hydrogen recycling.
    - Regeneration catalyst system is designed to burn the coke off the catalyst, redistribute platinum, remove excess moisture and return the catalyst its fresh state. Typically, the regeneration cycle takes around five to ten days to be done completely.

- *Product separation section*

    - Propylene/propane product is cooled, compressed, dried from excess moisture and contaminants and sent to a low-temperature separation system where a propylene-rich product (liquid phase) is separated from light products (gas phase).
    - The liquid stream is mainly composed of propylene and unreacted propane where the gas stream is approximately 90% hydrogen with methane and ethane.
    - The liquid stream is pumped to a selective hydrogenation unit (Hüls SHP) to eliminate undesired di-olefins and acetylenes, to be < 5 wt. % ppm, and then sent to a two-column deethanizer system to remove hydrogen and light ends.
    - The treated liquid stream enters a C3 splitter unit to separate propylene/propane product into polymer-grade propylene and propane that is recycled.

It is worth to mention that the reactor/product separation section and regeneration section are totally independent where catalytic dehydrogenation process operates continuously regardless of catalyst regeneration progress.

PROCESS ECONOMICS:

~for 467000 tons of propylene yield

Parameter	**unit**	**Description/value**
Reference Plant		NATPAT & ALWAHA
PLANT SIZE	m×m	188x92
Catalyst type	N/A	Platinum-based
Catalyst quantity	MT	119
Catalyst life	years	3
Average Propane consumption	MT/MT	1.23
Reactor inlet temperature	°C	648
Conversion per pass	%	36.4
Propylene Selectivity	%	85
Propylene Yield per pass	%	31
CO2 emissions	N/A	Low
Reactor pressure	atm	Above atmosphere
Ethylene refrigeration system	N/A	Not required
Project cost	MM US$	174
Electricity	kW	95.7
Fuel	mW	0.76
DM (De-Mineralized) water	MT	0.17
Cooling water	m3	81.3
Nitrogen	m3	4.49
DMDS consumption	Kg/day	816

Using above table as reference we can estimate required amount and the cost for 17000 TPA yield of propylene

Propane cost:

For 17000TPQ yield of propylene we have to use 1.23*17000 = 20910 TPA of propane

1. Propane – Rs 108/kg
    a. Total cost (for 20,910TPA)= Rs 225,82,80,000 (As per Link)
2. Water/Steam - Chennai City Water Supply source -> water purchased at 73Rs / KL
    a. Since there is a very small requirement here we can neglect the cost for now
3. Catalyst cost (Taking the price of Platinum based catalysts) = 100rs/g

Total cost = 100,000*4.33*1000 = 43,00,00,000 Rs

Other raw materials are minimum so we neglect for sake of simplicity

Total raw cost = 225,82,80,000+43,00,00,000=268,82,80,000 Rs

Revenue = 605 Cr

Transportation cost (Assuming the unit lies within 10 km from source) = 0.12 Cr

Total profit = Revenue – Transportation cost – Raw material cost
= 605 – 0.12 - 268.82 = 336.36 cr

Fluid catalytic cracking

FCC unit is becoming increasingly important as a source of propylene supply to meet future demand growth into the world petrochemical markets.

The main operating regime of this novel refining process is high reaction temperature (about 600 C or more in riser), short contact time, high catalyst–oil ratio (higher than 10), and a special downflow reactor system

Process Description

The most common process is FCC, in which the oil is cracked in the presence of a finely divided catalyst that is maintained in an aerated or fluidized state by the oil vapours.

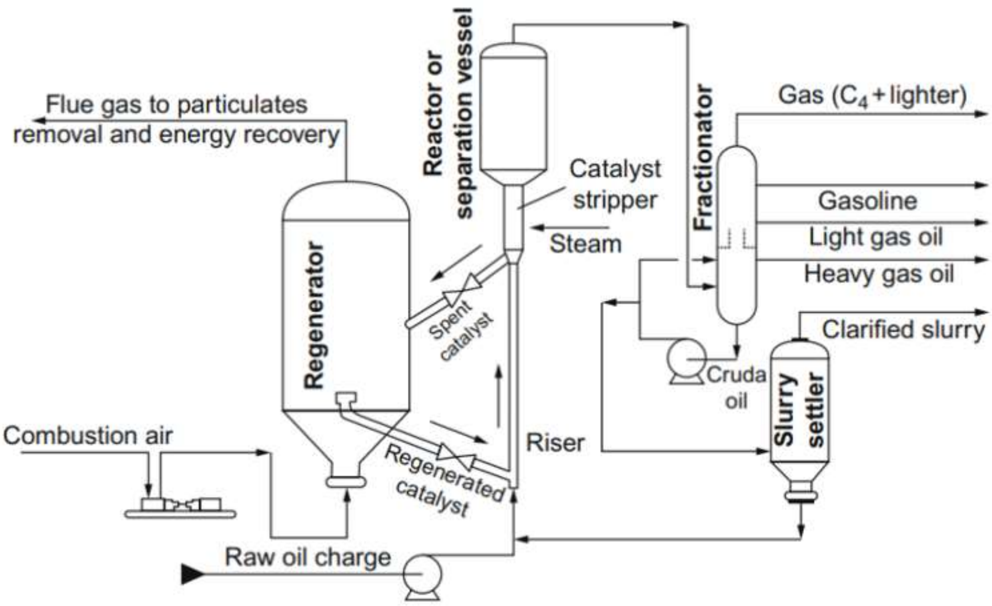
The fluid cracker consists of a catalyst section and a fractionating section, which operate together as an integrated processing unit

The catalyst section contains the reactor and regenerator, which, with the standpipe and riser, forms the catalyst circulation unit. The fluid catalyst is continuously circulated between the reactor and the regenerator using air, oil vapours, and steam as the conveying media

A typical FCC process involves mixing a preheated hydrocarbon charge with hot, regenerated catalyst as it enters the riser leading to the reactor. The charge is combined with a recycle stream within the riser, vaporized, and raised to reactor temperature (900 F–1000 F) by the hot catalyst.

This cracking continues until the oil vapors are separated from the catalyst in the reactor cyclones. The resultant product stream (cracked product) is then charged to a fractionating column where it is separated into fractions, and some of the heavy oil is recycled to the riser

Licensed by **Lummus Global**



	FCC
Reaction temp/ °C	500–550
Reactor pressure/barg	1–3
Residence time/s	1–5
Cat./oil ratio (wt/wt)	4–8
Dispersion steam (%)	1–3
Cracking environment	Riser
Reaction mechanism	Carbonium

Reaction conditions of downer and riser pilot plants

Parameter	Type of reactor: Downer	Riser
Reactor outlet temperature, °C	600	600
Pressure (stripper top), kPa	98	98
Hydro-treated VGO feed		
Rate, kg/h	0.4–0.2	0.7–1.0
Preheat, °C	280	280
Catalyst		
Proprietary catalyst		
Inventory, L	8	2
Steam pretreatment for 6 hr, °C	810	810
Circulation rate, kg/hr	13–40	13–18
Catalyst–oil ratio, kg/kg	13–40	13–30

Propylene Yield:

The conventional fluid catalytic cracking unit is typically operated at low to moderate severity with flexibility to swing between maximum distillate and maximum gasoline mode. This unit yields 3%–4% w/w propylene

Improvements in fluid catalytic cracking catalysts, process design, hardware, and operation severity can boost propylene yield up to 25% w/w or higher.

One cost-effective way to increase the propylene yield from the fluid catalytic cracking unit is the use of specialized catalysts that contain ZSM-5 zeolite.

ZSM-5-based additive acts mainly by cracking C6+ naphtha olefin derivatives to smaller olefin derivatives such as propylene. These catalysts and additives increase the yield of propylene and other low molecular weight olefin derivatives at the expense of gasoline and distillate products

Economic Analysis:

The yield of propylene will vary depending upon the feed oil and catalyst used.

The average yield of propylene of propylene would be around 20% wt of the crude oil feed stock

To produce 17000 TPA of propylene

- Amount of feedstock (crude oil) required = 17000/0.2
  = 85000 TPA
- Cost of crude oil = 70 /- per litre

= 87.5 /- per kg (Density of crude oil ~ 800 kg/m3)

- Cost of 85000 TPA crude oil = 85000*1000*87.5 = 743 crores per annum

[Couldn’t get the legitimate information on the amount of catalyst used]

CATOFIN PROCESS

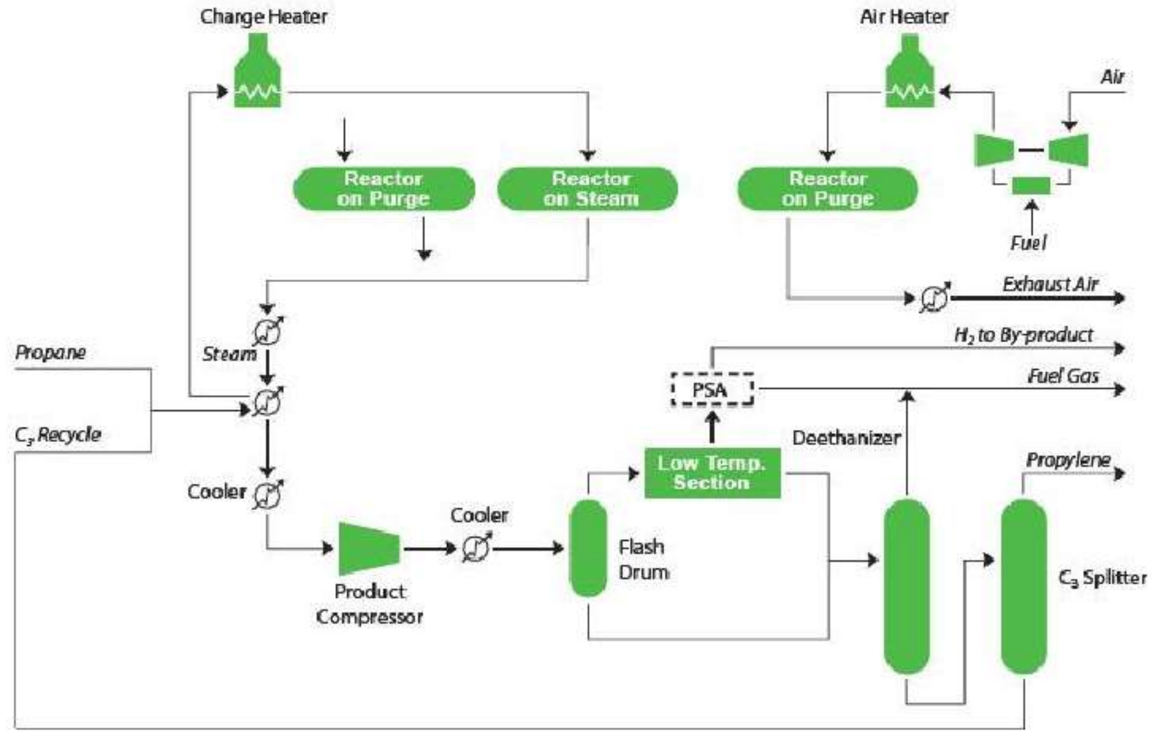
CATOFIN dehydrogenation technology is a reliable and commercially proven process to produce propylene from propane. CATOFIN facility is capable of producing high-purity grade propylene from propane rich streams through the following steps: dehydrogenation of propane to make propylene, compression of reactor effluent, recovery and purification of the product.

Using Catofin technology currently there are two plants in Saudi, Saudi Polyolefin Co. and Advanced Petrochemical Company (APC) with capacity of 420 and 450 KTA respectively.

PROCESS CHEMISTRY:

Like Oleflex process, we perform propane dehydrogenation, but CATOFIN uses chromium-oxide catalysts in horizontal fixed-bed parallel reactors

PROCESS DESCRIPTION:



- CATOFIN dehydrogenation is a continuous process that is carried out in cyclic-multiple reactors (four horizontal reactors connected in parallel) with a controlled sequence of reaction and reheat/regeneration.
- The process starts with the endothermic reaction, as discussed in Eq. (1), followed by steam purging, evacuation, catalyst air-regeneration and another evacuation.
- Propane enters the first reactor to be converted to propylene within 7 ~ 15 minutes. Two parallel reactors carry out the conversion process (reaction) to increase the weight percent of propylene and achieve a propylene conversion of 45 ~ 50%.
- Propane/propylene product is furtherly cooled in a trim cooler unit before being compressed (7 ~ 20 atm), dried and cooled again to enter a flash drum which separates light products (tail gas, light gas, H2, C1) at the distillate and liquid products (C2 & C3/C3'') at the bottom.
- Distillate products are sent to a low-temperature recovery section to reject light ends where a pressure swing adsorption (PSA) unit receives and process light gases to produce a hydrogen-rich gas (99.9%), fuel gas and CO/CO2/C2 as by-products.

- Both bottom-liquid streams of the low-temperature recovery section (C4 and oil) and the flash drum (C2 & C3/C3'') are combined and passed through a deoiler unit to separate heavy materials while remaining products are sent to a deethanizer unit to extract C2 as a fuel gas at the distillate.
- The unconverted propane/propylene mixture at the C3 splitter bottom is recycled and heated to go over the whole conversion process again.
- Removal of deposited carbon on the catalyst is achieved by placing spend catalysts in a heater and injecting fuel/air, through a gas turbine, into the heater. Hot air 800 ~ 1000 °C reactivates spent catalysts to be furtherly used in the purge reactor

Feedstock & Utility Consumption

The CATOFIN PDH unit can be designed to process a wide variety of feedstocks. It can easily handle feedstocks that typically contain 95 to 97 mol % propane (Table 10.5.2), unlike other technologies that require higher-purity feedstocks. Lower-purity propane streams (containing as much as 3 mol % olefins and about 7 mol % C 's) have been handled in the commercial CATOFIN PDH units without any feed pretreatment; however, any increase in the level of the main impurities would increase the amount of offgas and/or other by-products and would affect the utility consumption, etc.

Feedstock composition

Propane	95–97 mol %
Ethane	1.0–3.0 mol %
Butanes	1.0–3.0 mol %
Pentanes and heavier	Nil
Water	10 ppmw max
Sulfur	30 ppmw max
Metals	5 ppmw max

With the given purities required raw material: -

Propane - 20,060 TPA for the required 17,000 TPA product

(Since the composition of Ethane and Butane is very minimal we can mostly neglect that)

Water/Steam - 10ppmw = 10mg/kg => Req - 170kg

(For the preliminary analysis we are not considering sulfer and metals)

Catalyst – Chromium oxide

PROCESS ECONOMICS:

Raw Material cost:

1. Propane – Rs 108/kg
   b. Total cost (for 20,060TPA)= Rs 216,64,80,000 (As per Link)
2. Water/Steam - Chennai City Water Supply source -> water purchased at 73Rs / KL
   c. Since there is a very small requirement here we can neglect the cost for now
3. Catalyst cost – Factor as per reports – Rs 705/ton of propylene product (Source - Link)
   d. Total cost – 705*17000 = 1,19,85,000

Total raw material cost – 217,84,65,000

Propylene selling price – 356/kg [This price is highly doubtful but due to lack of other sources and the fact that propylene selling price is a constant factor across all process which means it is not going to influence the decision of which technology to choose, we decided to go with this)

Total Revenue – 17,000*1000*356 = Rs 605 cr

Total profit – Revenue – Transportation cost – Raw material cost

= 605 – 0.12 - 217.85 = 387.3 cr

Conclusion:

As per the preliminary economic analysis we obtain the following table

Technology	Profits
Lurgi MTP	145.415cr/yr
Olefin Conversion	403cr/yr
Oleflex	336.36cr/yr
Fluid Catalytic cracking	-139cr/yr
Catofin	387.3cr/yr

As per the above table and process simulation complexity and purity we have chosen Olefin conversion technology as our process for this project (Purity – 95%)

Table 1. Comparison of selected propene production technologies.

Technology	Feedstock	Temperature (°C)	Pressure (atm)	Propene selectivity (wt.%)	Main by-products	Investment requirement	Operation cost	Sensitivity to $C_3^=$ price
Steam cracking	Ethane, LPG, naphtha	750–900°C	2–3	1–14[a]	$C_2^=$, $C_4^=$, BTX	Very high	High	Positive
FCC		550	1.7	4–6	FG, LPG, naphtha,		Medium	
FCC + ZSM-5	VGO	560–600	1.7	7–10	LCO, DO	Very high	Medium	No
HS-FCC		>600	1.7	20			Medium	
PDH	Propane	540–700	0.1–4	Up to 100	-	High	High	Neutral
MTO, MTP	Methanol	350–500	1	Up to 90	$C_2^=$, water	High	High	Positive
Olefin metathesis	$C_2^=$ and $C_4^=$	25–50 (Re-alumina) 300–375 (WO_3-silica)	5–15	Up to 100	-	Low	Low	Negative
Olefin cracking	$C_4^=$–$C_8^=$	400–550	1–2	Up to 90	C_1–C_4 alkanes, $C_2^=$, C_{5+}, BTX	Medium	Low	Positive
ETP	$C_2^=$	250–550	1	Up to 90	C_1–C_4 alkanes, $C_4^=$, C_{5+}, BTX	Low	Low	Negative

[a]Feed dependent: 1 wt.% from ethane, 14 wt.% for naphtha.

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MTP Lurgi process

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