A
PROJECT REPORT
ON

PRODUCTION OF PROPYLENE VIA METATHESIS

By

MOIN KHAN

Roll No.1008251016

Submitted to

Department of Chemical Engineering

In partial fulfilment of the requirement
For the degree of

Bachelor of Technology
In

Chemical Engineering

In Pursuit of Excellence

Moradabad Institute of Technology, Moradabad
U.P. Technical University (U.P.T.U)
Session: 2013-2014

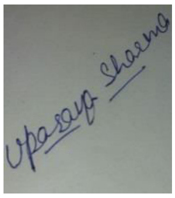
DECLARATION

I hereby declare submission of my own work and that to the best of my knowledge and belief, it contains no material previously published or written by another person or which to a substantial extent has been excepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgement has been made in the text.

Signature	:	
Name	:	Moin Khan
Roll no.	:	1008251016
Date	:	

CERTIFICATE

This is to certify that the project report entitled **“Production of Propylene via Metathesis”** which is submitted by **Moin Khan** in partial fulfilment of the requirement of the award of B.Tech degree in the Department of Chemical Engineering, Moradabad Institute of Technology, U.P. Technical University, is a record of candidate’s own work carried by him under my supervision. The matter embodied in this thesis is original and has not been submitted for the award of any other degree.



Date:

Supervisor

ACKNOWLEDGMENT

It gives me great sense of pleasure to present the report of the B.Tech project under taken by me during B.Tech final year. I owe special debt of gratitude to **Ms. UPASNA SHARMA**, Department of Chemical Engineering, Moradabad Institute of Technology, Moradabad, for his continuous support and guidance throughout the course of my work. His sincerity, thoroughness and perseverance have been a constant source of inspiration for me. It is only through his cognizant efforts that my endeavour has seen light of the day.

I also take the opportunity to acknowledge the contribution of Professor **T.N.S. MATHUR**, Head of the Department of Chemical Engineering, Moradabad Institute of Technology, Moradabad, for his full support and assistance during the development of the project.

I also do not like to miss the opportunity to acknowledge the contribution of all faculty members of the department for their kind assistance and cooperation during the development of our project. Last, but not the least, I acknowledge our friends for their contribution in the completion of the project.

Signature :

Name : Moin Khan

Roll no. : 1008251016

Date :

ABSTRACT

PROPYLENE is a common synonym for the chemical compound of alkene group. It is commonly used for glycol production, polypropylene, ABS resin production and the most common use in Cumene production and as in cleaning compounds, Alcohol like Isopropanol and other type Alcohol like 2-Ethylhexanol.

There are many processes which are used in the manufacturing of Propylene. But this project concerned with the study of 3300 TPA Production of 'Propylene' using Ethylene and 2-Btene by Metathesis process. The fundamentals of detailed chemical engineering processes like material balance, energy balance, designing of equipment, and costing of overall plant. Thus, in this work theoretical design approach is studied.

LIST OF FIGURES

LIST OF SYMBOL

Π	Pi (22/7)
Q	Rate of Energy
F	Feed
C_p	Specific Heat
V	Volume

CONTENTS

CHAPTER 1
INTRODUCTION

1.1 PROBLEM STATEMENT

To provide impactful design and process description to produce propylene from ethylene and butene for chemical company **M/s VAMCA Pvt. Ltd.** The capacity of the plant is about **3300 Tonnes/Annum**. The objective of this plant is to provide propylene economically with high quality. There are several kind of processes are available for the manufacturing of propylene but on the basis of economy and high yields only one of them will be selected.

1.2 PROCESS DESCRIPTION

The Metathesis process for propylene consists of two main areas: purification & reaction, and separation. The simplified block flow diagram summarizes the process. Ethylene feed plus recycled ethylene are mixed with the butane feed plus recycled butene and heated prior to entering the fixed-bed metathesis reactor. The catalyst promotes the reaction of ethylene and butene-2 to form propylene, and simultaneously isomerizes butene-1 to butene-2. A small amount of coke is formed on the catalyst, so the beds are periodically regenerated using nitrogen-diluted air. The ethylene-to-butene feed ratio to the reactor is controlled to minimize C5+ olefin by-products and maintain the per-pass butene conversion above 60%. Typical butene conversions range between 60 to 75%, with about 90% selectivity to propylene. The reactor product is cooled and fractionated to remove ethylene for recycle. A small portion of this recycle stream is purged to remove methane, ethane, and other light impurities from the process. The ethylene column bottom is fed to the propylene column where butene is separated for recycle to the reactor, and some is purged to remove butanes, isobutylene, and heavies from the process. The propylene column overhead is high-purity, PG propylene product. This process description is for a stand-alone metathesis unit that can be added onto any refining/petrochemical complex. The utility requirements – which include cooling water, steam, electricity, fuel gas, nitrogen, and air – are typically integrated with the existing complex.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Propylene

Propylene is an unsaturated organic compound having the chemical formula C_3H_6. It has one double bond, is the second simplest member of the alkene class of hydrocarbons, and is also second in natural abundance. Propylene is produced primarily as a by-product of petroleum refining and of ethylene production by steam cracking of hydrocarbon feedstock. Also, it can be produced in an on-purpose reaction. It is a major industrial chemical intermediate hat serves as one of the building blocks for an array of chemical and plastic products, and was also the first petrochemical employed on an industrial scale. Commercial propylene is a colourless, lower boiling, flammable and highly volatile gas. Propylene is treated commercially in three grades:-

- **Polymer grade (PG):- minimum 95% purity.**
- **Chemical grade (CG):- 90-96% of purity.**
- **Refinery grade (RG):- 50-70% of purity.**

2.1.1 Chemical Formula

Propylene is an unsaturated organic compound having the chemical formula C_3H_6. It has one double bond and is the second simplest member of alkene class of hydrocarbons.

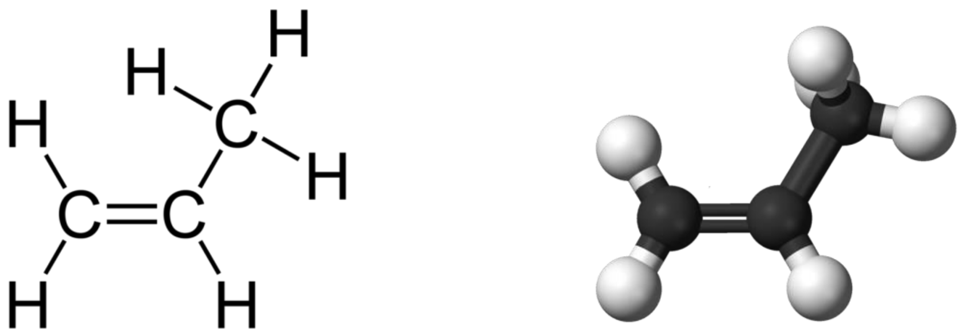


Fig: 2.1 Molecular Structure of Propylene

2.2 Properties

2.2.1 Physical Properties

Table 2.1: Physical Properties of Propylene

Property	Value
Chemical formula	C_3H_6
Molecular weight	42.08 lb/mol
Critical temperature	91°C
Critical pressure	46.1 bar
Boiling point	-47.8 °C
Melting point	-185 °C
Specific gravity	1.501
Physical appearance	Colourless gas

At room temperature and atmospheric pressure, propylene is gas, and as with many other alkenes, it is also colourless with a weak but unpleasant smell.

2.2.2 Chemical Properties

Propylene has a higher density and boiling point than ethylene due to its greater mass. It has a slightly lower boiling point than propane and is thus more volatile. It lacks strongly polar bonds, yet the molecule has a small dipole moment due to its reduced symmetry (its point group is C_s). Propylene has the same empirical formula as cyclopropane but their atoms are connected in different ways, making these molecules structural isomers.

2.3 Application of Propylene

The dominant outlet for propylene is polypropylene (PP), accounting for nearly two-thirds of global propylene consumption.

Propylene is also used to produce acrylonitrile (ACN), propylene oxide (PO), a number of alcohols, cumene and acrylic acid.

2.3.1 Polypropylene

Polypropylene is one of the most versatile of the bulk polymers due to a combination of good mechanical and chemical properties. Hence PP has secured its position in a wide range of consumer and industrial products, manufactured by several high-volume forming methods. In the automotive sector, PP and its alloys have become the polymer of choice accounting for over a third of plastics used in automobiles.

Injection moulded PP, the largest of the PP grades, can be used in electronic and electrical appliances, house wares, bottle caps, toys and luggage. Film grade PP can be found in the packaging of sweets and cigarettes, tapes, labels and electronic films. PP fibres are used in carpets, clothing and the replacement of sisal and jute in ropes and string. PP can be extruded into pipes and conduit, wire and cable.

During the 1990s, PP demand grew at about 10%/year, outpacing the other major thermoplastics. Some of this growth was due to substitution of other polymers as PP was less expensive due to low propylene prices. Since then propylene prices have risen relative to other base chemicals and PP prices are now similar to other polymers. Growth in PP demand has slowed to an average of 5-6%/year.

2.3.2 Acrylonitrile

The second largest derivative, acrylonitrile is used in a variety of elastomeric polymers and fibre applications. The largest outlet for ACN is acrylic fibres, which are used in clothing such as sweaters and jumpers, socks and sportswear as well as home furnishings and bedding such as carpets, upholstery, cushions and blankets. Other uses for ACN include nitrile rubber,acrylonitrile-butadiene-styrene (ABS)/styrene acrylonitrile (SAN) resins, acrylamide and adiponitrile.

2.3.3 Propylene oxide

The next largest outlet for propylene is propylene oxide. PO is used to make polyether polyols, which are reacted with an isocyanate to form polyurethanes. Polyurethane end uses include flexible foams for the furniture and automotive industries, and rigid foams for appliance and building insulation. PO is also used to make propylene glycol, which is used in unsaturated polyester resins, antifreeze and aircraft de-icing fluids, and propylene glycol ethers with applications in paints, coatings, inks, resins and cleaners.

2.3.4 Alcohols

A number of alcohols are made from propylene. Isopropanol (IPA) is used mainly as a solvent in cosmetics and personal care products, paints and resins, pharmaceuticals, food, ink and adhesives.

The oxo-alcohol 2-ethylhexanol is used mainly in the production of phthalate plasticisers but it is also used in adhesives and paints. Butanols are employed in paints, coatings, resins, dyes, pharmaceuticals and polymers.

2.3.5 Cumene and Acrylic acid

Cumene, which is produced from propylene and benzene, is the main feedstock for the manufacture of phenol and acetone. They are used to produce a variety of products such as polycarbonate, phenolic resins, epoxy resins and methyl methacrylate (MMA).

Acrylic acid is used in the production of acrylic esters and resins for paints, coatings and adhesives applications.

2.4 Introduction to raw material

2.4.1 Ethylene

Ethylene is a hydrocarbon with the form C_2H_4 or $H_2C{=}CH_2$. It is a colourless flammable gas with a faint "sweet and musky" odour when pure. It is the simplest alkene (a hydrocarbon with carbon-carbon double bonds), and the simplest unsaturated hydrocarbon after acetylene (C_2H_2).

Ethylene is widely used in chemical industry, and its worldwide production (over 109 million tonnes in 2006) exceeds that of any other organic compound. Ethylene is also an important natural plant hormone, used in agriculture to force the ripening of fruits.

High-purity ethylene (min. 99.5 wt.% purity) can be obtained from olefins plants. The use of PG ethylene in metathesis processes is desired because it requires minimal pre-treatment for trace components, while other sources of ethylene typically require more rigorous pre-treatment. Although PG ethylene prices are higher, capital expenditure for the metathesis unit is lower because no investment in pre-treatment is required.

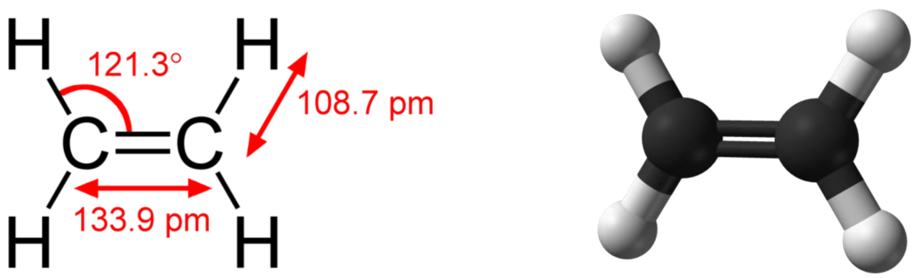


Fig 2.2 Molecular structure of Ethylene

2.4.2 - 2-Butenes

Butene, also known as butylene, is an alkene with the formula C_4H_8. It is a colourless gas that is present in crude oil as a minor constituent in quantities that are too small for viable extraction. It is therefore obtained by catalytic cracking of long chain hydrocarbons left during refining of crude oil. Cracking produces a mixture of products, and the butene is extracted from this by fractional distillation.

Butene can be used as the monomer for polybutene but this polymer is more expensive than alternatives with shorter carbon chains such as polypropylene. Polybutene is therefore commonly used as a co-polymer (mixed with another polymer, either during or after reaction), such as in hot-melt adhesives.

The 2-butenes used as feedstock for the metathesis process are obtained from the crude C4 stream produced in olefins plants. This C4 stream consists of C4 acetylenes, butadiene, iso-/n-butene, and iso-/n-butane.

The desired C4 stream in a metathesis process consists of n-butene (mainly 2-butenes), low amounts of isobutene (to avoid excess capacity due to excess recycling) and is almost devoid of butadiene (to avoid rapid catalyst fouling) and acetylenes. Iso-/n-butanes are inert to the metathesis process.

Fig 2.3 Molecular structure of 2-Butene

CHAPTER 3
MARKET PROSPECTS

3.1 Market prospects of propylene

Propylene is an organic compound primarily used in the manufacturing of polypropylene, acrylonitrile, propylene oxide, Oxo-alcohols, cumene, and isopropyl alcohol. The applications of propylene include those in acrylic fibres and coatings, polyurethane resins and in other chemicals, PVC plasticizers and coatings, epoxy resins and polycarbonate, and in solvents. The global demand for propylene is showing dynamic development. In 2011 the global market for propylene was more than USD 90 billion and it is expected to grow at a considerable rate.

A perspective of exciting chemical industry in India of fast growing four countries Brazil, Russia, India, China. India is today attracting attention as an emerging power with remarkable economic growth suppressed by china.

India shifted its stance to economic deregulation in 1991 and is continuing to grow with a high annual GDP grow rate of 7.5 – 9.6 % over the period of 2003 to 2008. In 2012, the total global production capacity of propylene was about 104 million tons, the cracking propylene accounted for 57 % of the total production capacity, refinery propylene accounted for 33 % and the propylene from other process accounted for about 10 %. Asia, North America, and West Europe have been always the world's most concentrated production place of propylene. The production of propylene is increases 6-10 % per year in the world, this propylene is mainly used for making fibre, wire, and resin. At present the total production of propylene in the world is around 124 million tons in Asia and 50 million tons in North America.

We are currently witnessing a significant change in the propylene supply chain with a move away from co-production and towards on-purpose production. These are several reasons for this change:

- The growth in demand for propylene has outpaced the growth in demand for ethylene for many years and will continue to do so.
- Several on-purpose propylene production technologies such as propane dehydrogenation (PDH) and metathesis have achieved technical maturity and acceptance, and significant development efforts have made them competitive with co-production technologies in the market.

- The tight propylene market and high oil prices have continuously driven up prices for propylene and propylene derivatives.

As a result while in 2003

Co-production	On-purpose production
97 %	3 %

By the year 2012 on-purpose production increases to 10 % by mainly metathesis process. Propylene price are expected to remain above $800/Tonnes.

CHAPTER 4
PROJECT DESCRIPTION

4.1 AVAILABLE PROCESSES

There are so many processes available for propylene manufacturing:

- Propylene production by olefin metathesis.
- Propylene production by propane dehydrogenation.
- Propylene production by fluid catalytic cracking.
- Propylene production by catofin process.

4.1.1 Propylene Production by Olefin Metathesis

Propylene metathesis also known as disproportionation, is a reversible reaction between ethylene and butene in which double bonds are broken and then reformed to form propylene, propylene yields about 95 wt.% are achieved. This option may also be used when there is no butene feed stock. In this case, part of the ethylene feed goes to the ethylene dimerization unit that convert ethylene into butene.

4.1.2 Propylene Production by Propane Dehydrogenation

Convert propane into propylene and by-product hydrogen. The propylene from propane yield about 85 wt%, reaction by-products (mainly hydrogen) are usually as fuel for propane dehydrogenation. As a result propylene tends to be the only product, unless local demand exists for hydrogen. This route is popular in regions such as middle-east.

4.1.3 Propylene Production by Fluid Catalytic Cracking

FCC technology uses under severe conditions (higher catalyst to oil ratios, higher injection rate, higher temperature), in order to maximize the amount of propylene and other light products. A high severity FCC unit is usually fed with greater volumes of motor gasoline's and distillate by-products. The propylene from this process yields 50-70 wt.%.

4.1.4 Propylene Production by Catofin Process

In this technology we use refinery product LPG for the production of propylene. This technology uses fixed bed adiabatic reactors in which there is an alternation between reaction and regeneration cycles. Many reactors are used in parallel in a plant to permit continuous production along with a short reaction period, it is compatible with the choice of the catalyst i.e. chromium catalyst typical operating condition at high temperature of 587-647 °C and 33-50 kPa pressure.

4.2 BASIS OF PROCESS SELECTION

	Metathesis	Olefin metathesis	Propane dehydrogenation	Methanol to olefin	High severity FCC	Olefin cracking
Yield wt.%	99 %	90 %	85 %	87 %	20-25 %	78 %
Catalyst	Required	Required	Required	Not required	Required	required
Other additional unit	Not required	Required	Required	Not required	Required	not required
Raw material	Ethylene and 2-Butene	Ethylene and Butene	Propane	Methanol	Paraffin's (gas oil)	Olefin
By-product	Heavier product	Water	Hydrogen	Water	Motor gas oil	Ethylene

4.3 Production of propylene via metathesis process

The Metathesis process for propylene consists of two main areas: purification & reaction, and separation. The simplified block flow diagram summarizes the process. Ethylene feed plus recycled ethylene are mixed with the butene feed plus recycled butene and heated prior to entering the fixed-bed metathesis reactor. The catalyst promotes the reaction of ethylene and butene-2 to form propylene, and simultaneously isomerizes butene-1 to butene-2. A small amount of coke is formed on the catalyst, so the beds are periodically regenerated using nitrogen-diluted air. The ethylene-to-butene feed ratio to the reactor is controlled to minimize C5+ olefin by-products and maintain the per-pass butene conversion above 60%. Typical butene conversions range between 60 to 75%, with about 90% selectivity to propylene. The reactor product is cooled and fractionated to remove ethylene for recycle. A small portion of this recycle stream is purged to remove methane, ethane, and other light impurities from the process. The ethylene column bottom is fed to the propylene column where butene are separated for recycle to the reactor, and some is purged to remove butanes, isobutylene, and heavies from the process. The propylene column overhead is high-purity, PG propylene product. This process description is for a stand-alone metathesis unit that can be added onto any refining/petrochemical complex. The utility requirements – which include cooling water, steam, electricity, fuel gas, nitrogen, and air – are typically integrated with the existing complex. Propylene production via olefin metathesis process contains various steps.

4.3.1 Purification and Reaction

First, fresh ethylene from ISBL storage tank and recycled ethylene are mixed with fresh and recycled butene, and are fed through reactor feed treater. The treater consist of guard beds to remove potential catalyst poisons for the metathesis reaction, such as oxygenates, sulphur, alcohols, carbonyls, and water. The guard beds have a cyclic operation. One is normally in operation, while the other is regenerating. After treating, the stream is vaporized in a heat exchanger and superheated in a fired heater to the reaction temperature, typically between 280-320°C. The reactor feed contains ethylene and n-butene, mainly 2-butenes, at the desired reaction ratio. Although the theoretical molar ratio between ethylene and butene is 1:1, it is common to employ significantly greater ethylene/butene ratios to minimize undesirable side reactions, and to minimize C5+ olefin formation. The per pass butene conversion is between 60 and 75%. The metathesis reaction occurs in a fixed bed catalytic reactor. The main reaction that occurs is between ethylene and 2-butenes, to produce propylene. Side reactions also occur, producing by-products, primarily C5-C8 olefins. The reactor exit stream is cooled prior to the separation area. The process selectivity to propylene is typically about 90%. The catalyst used is tungsten oxide supported on silica. (WO3/SiO2). Also, the co-catalyst magnesium oxide ($_{MgO}$) is used to perform a double bond isomerization of 1-butene to 2-butene. The raffinate-2 stream used in the metathesis unit is typically free of butadiene and has low isobutene content. Butadiene is typically removed below 50 wt. ppm level and it is done to minimize fouling of the catalyst. Isobutene is removed to reduce the size of the metathesis unit. Isobutene is not a poison to the catalyst, but it reacts in the metathesis reactor at low conversion, which results in build-up of this molecule in the internal butene recycle stream and increases hydraulic requirement and sizes of the equipment. Commercial units are in operation with about 7 wt.% isobutene in the raffinate-2 feed stream. Coke, a by-product of the reaction, is deposited on the catalyst throughout the process. During regeneration the coke is burned in a controlled atmosphere. Systems required for regeneration include a fired regeneration gas heater and a supply of inert gas (usually nitrogen), compressed air, and hydrogen. Each reactor can run for about 30 days before requiring regeneration.

4.3.2 Separation

The reactor exit stream contains a mixture of propylene, unconverted ethylene and butene, butane, and some C5+ components from side reactions. Propylene purification is carried out in two columns. The first column separates unreacted ethylene for reuse in the reactor. The second column produces PG propylene as an overhead product and a bottom heavy stream. The stream leaving the reactor is first cooled against the reactor feed stream in an exchanger, and then cooled against cooling water before being sent to the deethylenizer column. The column is re-boiled by low pressure (LP) steam, and uses propylene refrigeration in the top condenser. Cryogenic temperatures exist due to the presence of unconverted ethylene in the top of the column. Pressure of the column is dependent upon the available refrigeration. The deethylenizer column overhead (unconverted ethylene) is recycled back to the reaction area through the column reflux pumps. The recycled ethylene stream is mixed with fresh ethylene, fresh butene (raffinate-2) stream and recycled butene stream. A small vent stream containing light paraffin's and a small amount of unconverted ethylene leaves the overhead of the deethylenizer reflux vessel as a lights purge stream. This stream can be returned to the ethylene cracker for recovery. The bottom stream of the deethylenizer column is sent to the depropylenizer column for propylene recovery. The depropylenizer column separates PG propylene in the overhead from a heavies product stream (C4+) in the bottoms. PG propylene and heavies streams are sent to the product ISBL storage tank and C4+ purge storage tank respectively. LP steam is used in the reboiler and cooling water in the top condenser. A side-stream from the bottoms of the column is sent back as butene recycled stream to the fresh/recycle C4 tank. This rate is set to maintain a high overall n-butene conversion in the metathesis reactors. The column's bottoms can be sent to another column for recovery of gasoline and fuel oil.

4.4 BLOCK DIAGRAM

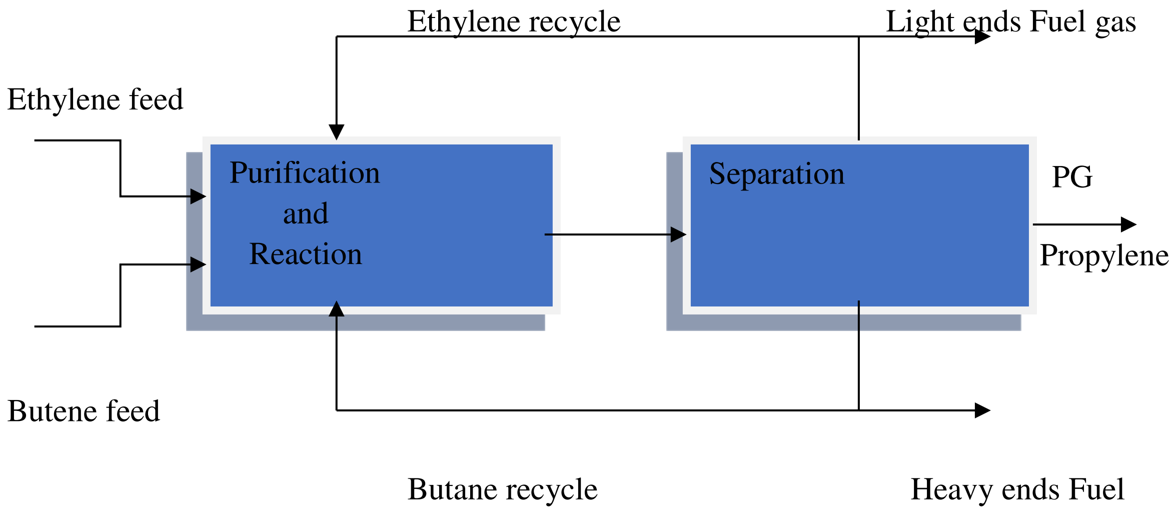


Fig: 4.1 Block Diagram of Production of Propylene via metathesis process.

4.5 PROCESS FLOW DIAGRAM

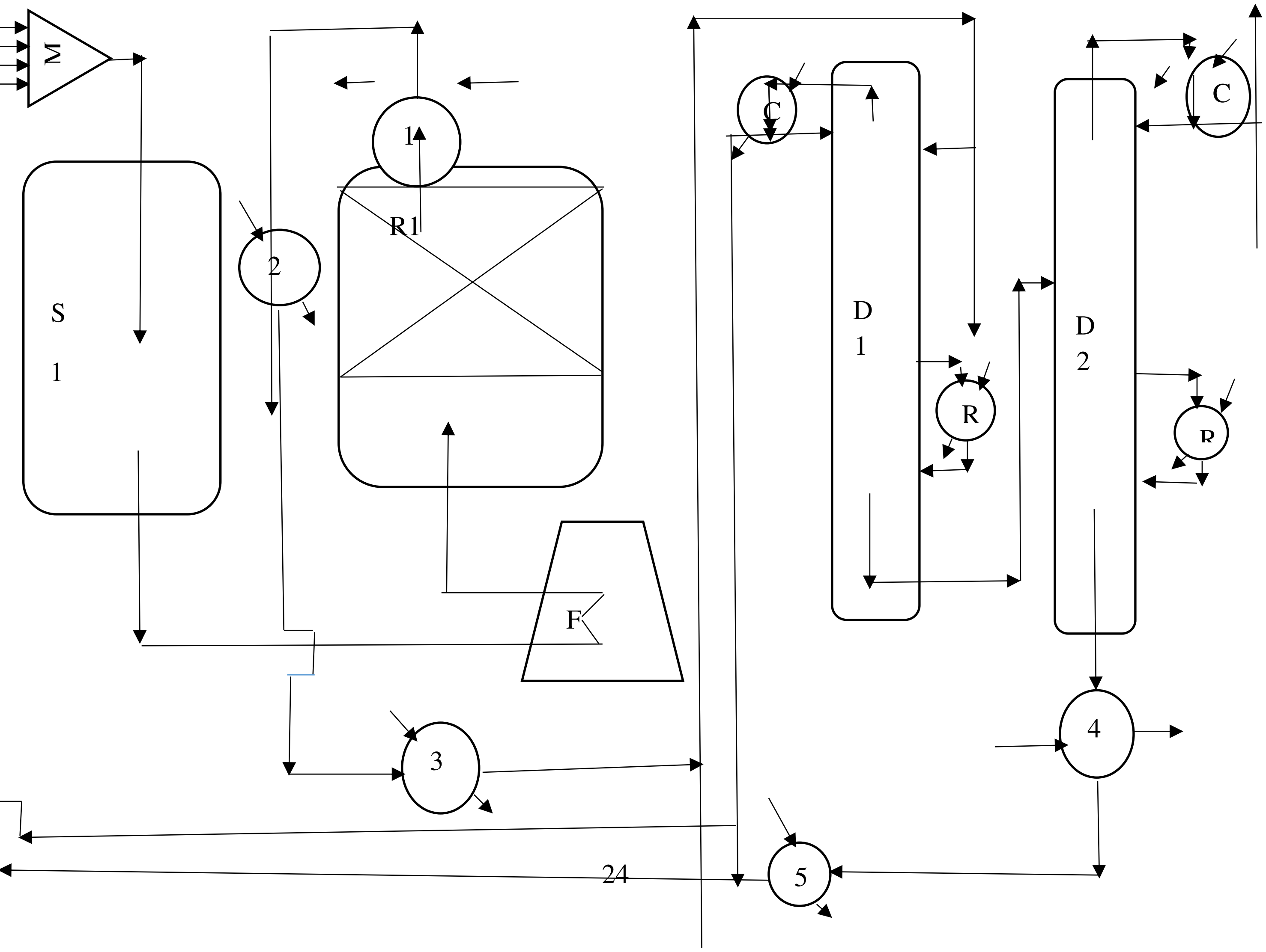


Fig 4.2 Flow Sheet of Production of Propylene

4.6 PFD NOMENCLATURE

Table 4.1: Equipment Nomenclature in PFD

Equipment No.	Equipment Name
1	Heat Exchanger
2	Heat Exchanger
3	Heat Exchanger
4	Heat Exchanger
5	Heat Exchanger
S1	Storage Tank
R1	Reactor
F	Furnace
D1	Distillation Column
D2	Distillation Column
M	Mixture
C	Condenser
R	Reboiler

CHAPTER 5
MATERIAL BALANCE

5.1 Available Data

Table 5.1 Molecular Weight of Component

Component	Molecular weight (kg/kmol)
Propylene	**42.08**
Ethylene	**28.05**
Butene	**56.106**
Butane	**56.106**
Water	**18**
Carbon	**12**

5.2 Assumption

- Continuous process
- Steady state process
- Whole material balance is on mole basis.
- 65% conversion of ethylene and butene both occur.
- 1% overall loss in the plant.
- Plant Working duration 335 days in a year.

5.3 Plant Capacity

Plant capacity = 3333 T/A

Plant capacity in Kg/day = 9949.25 Kg/day

Plant capacity in Kmol/hr = 9.870 Kmol/hr

5.4 Reaction

$$C_2H_4 + C_4H_8 \longrightarrow 2C_3H_8$$

(A) (B) (C)

1 kmol A =2 kmol C

1/2 kmol A = 1 kmol C

1/2* 9.870 kmol/h A = 9.870 kmol/h C

A feed = 4.935 kmol/h

B feed = 4.935 kmol/h (By stoichiometry)

Total feed = 9.870 kmol/h

5.5 Material Balance in Distillation Column

Amount of propylene produce (D2) = 9.870 kmol/hr

Conversion of propylene = 99.5%

$X_f = 0.315$

$X_D = 0.995$

$X_w = 0.001$

$F_2 = D_2 + W_2$

$F_2 - W_2 = 9.870$ ⟶ (1)

$X_f F_2 - Xw W_2 = X_D D_D$

$0.315 F_2 - 0.001 W_2 = 0.995*9.870$

$0.315 F_2 - 0.001 W_2 = 10.865$ ⟶ (2)

On solving equation (1) and (2)

$F_2 = 34.569$ kmol/hr

$W_2 = R_2 = 24.69$ kmol/hr

5.6 Material Balance in Distillation Column

$W_1 = 34.569$ kmol/hr

$X_f = 0.249$

$X_D = 0.05$

$X_W = 0.315$

$F_1 = D_1 + W_1$

$F_1 - D_1 = 34.569$ ⟶ (1)

$X_f F_1 - X_D D_1 = X_w W_1$

$0.249 F_1 - 0.05 D_1 = 0.315*34.569$

$0.249 F_1 - 0.005 D_1 = 10.88$ ⟶ (2)

On solving equation (1) and (2)

$F_1 = 45.987$ kmol/hr

$W_1 = R_1$ =11.418 kmol/hr

5.7 Material Balance in Reactor

Conversion of Ethylene and Butene = 23.79%

Output from the reactor = 45.987 kmol/hr

Total feed = Ethylene feed + Butene feed + R1 + R2

= 4.935 + 4.935 + 11.418 + 24.69

= 45.978 kmol/hr

Propyelne in feed = 0.003*45.978

= 0.137934 kmol/hr

Butene and Ethylene feed in the reactor = 45.978 – 0.137934

= 45.840 kmol/hr

23.79% conversion of Ethylene and Butene,

Propylene produced = 0.2379*45.840

= 10.905 kmol/hr

Butene and Ethylene Unreacted = 45.840 – 10.905

= 34.934 kmol/hr

Output from the reactor = Propylene produced + Butene and Ethylene unreacted + Propylene In feed

= 10.905 + 34.934 + 0.137934

= 45.977 kmol/hr

CHAPTER 6
ENERGY BALANCE

6.1 Energy Balance Equation

Heat input – heat output + heat generated – heat consumption = accumulation.

At Steady State-
Heat input – heat output + heat generated – heat consumption = 0

6.2 Reactor

$\Delta H^{\circ}_{25^{\circ}c} = \sum n\ \Delta H^{\circ}f\ - \sum n\ \Delta H^{\circ}f$
(Product) (Reactant)

Component	A	B	c	d
Propylene	59.58	0.1771	$-1.017*10^{-4}$	$24.60*10^{-9}$
Ethylene	40.75	0.1147	$-6.89*10^{-5}$	$17.66*10^{-9}$
Butene	82.88	0.2564	$-1.72*10^{-4}$	$50.50*10^{-9}$
Butane	89.49	0.3013	$-1.89*10^{-4}$	$48.87*10^{-9}$
Carbon	11.18	0.0109	733.5	–
Water	18.29	0.4721	$-1.33*10^{-4}$	$13.1*10^{-10}$

$=2\ \Delta H^{\circ}f\,(C_3H_6) - [(\ \Delta H^{\circ}f\,(C_2H_4) + \ \Delta H^{\circ}f\,(C_4H_8)]$

=2*19710-(52510-540)

= -12550 J/mol

Heat of Reaction

$\Delta H_{r304^{\circ}}c = \Delta H^{\circ}_{25^{\circ}}c + \int_{25}^{304} [(\sum nc_p) - (\sum nc_p)]dt$

(P) (R) P = Product

R = Reactant

$= -12550 + [(a\text{-}a\text{-}a)T + (b\text{-}b\text{-}b/2)T^2 + (c\text{-}c\text{-}c/3)T^3 + (d\text{-}d\text{-}d/4)T^4]_{25}^{304}$

= -12550 + [(59.58-40.75-82.88)(304-25) + (17.71-11.47-25.64*10^{-7})/2 (304^2-25^2) + (24.60-7.66-50.5)*10^{-9}(304^4-25^4)+(-10.17+6.891+17.27) (10^{-5})/3 (304^5-25^5)]

= -12550+[-17869.95-8908.31655+1309.503455-93.004154]

= -3814.76125J/mol.

Cooling media=Water

$Q = mc_p\Delta T$

C_p H_2O = 29.2831 J/mol°C

T_2=33°C, T_1=25°C

38111.76125=m*29.2831(33-25)

m=146.4180066 kmol/h

m=0.729 kg/sec.

6.3 Heat Exchanger

$Q_{PROPYLENE}=\int_{304}^{218} nc_p\ dt$

n=11.418

$Q_{PROPYLENE}= n \int_{304}^{218}[a + bT + cT2 + dT3]\ dT$

=11.418[59.58(218-304) +17.71*10^{-2}/2(218^2-304^2)-10.17*10^{-5}/2(218^3-304^3) + 2406*10^{-9}/4(218^4-304^4)]

=11.418[.5723.88-3975.1866+54.6536-154.5417874]

= - 105335.0511 kJ/h

$Q_{ETHYLENE}=\int_{304}^{218} nc_p\ dt$

n=9.65

$Q_{ETHYLENE}$ $=n \int_{304}^{218}[a + bT + cT2 + dT3]\ dT$

=9.65[40.75(218-304)+11.47*10^{-2}/2(218^2-304^2)-6.891*10^{-5}/3(218^3-304^3)+17.66*10^{-9}/4(218^4-304^4)]

=9.65[-3504.5-2574.5562+407.355309-27.735853]

= -54999.5626 kJ/h.

$Q_{BUTENE} =\int_{304}^{218} nc_p\ dt$

n=4.138

$\mathbf{Q_{BUTENE}} = n \int_{304}^{218} [a + bT + cT2 + dT3]\, dT$

$=4.138[82.88(218-304)+2.564*10^{-2}/2(218^2-304^2)-17.27*10^{-5}/3(218^3-304^3)+50.5*10^{-4}/4(2184-304^4)]$

$=4.138[-7127.68-5755.1544+1020.9-79.3126]$

$= -49422.79$ kJ/h.

$\mathbf{Q_{BUTANE} = \int_{304}^{218} nc_p\, dt}$

n=18.44

$\mathbf{Q_{BUTANE}} = n \int_{304}^{218} [a + bT + cT2 + dT3]\, dT$

$=18.44[89.46(218-304)+30.13*10^{-2}/2(218^2-304^2)-18.91*10^{-5}/3(218^3-304^3)+49.87*10^{-9}/4(218^4-304^4)]$

$=18.44[-7693.56-6762.9798+1117.8477-78.3231]$

$= -247409.7603$ kJ/h

$\mathbf{Q_{CARBON} = \int_{304}^{218} nc_p\, dt}$

n=2.29935

$\mathbf{Q_{CARBON}} = n \int_{304}^{218} [a + bT + cT2 + dT3]\, dT$

$=2.29935[11.18(218-304)+1.095*10^{-2}/2(218^2-304^2)-4.89*10^{-5}/3(218^3-304^3)]$

$=2.29935[-961.48-245.7837+2.890679816*10^{-8}]$

$= -2775.92$ KJ/h.

$\mathbf{Q_{TOTAL} = Q_{PROPYLENE+} Q_{ETHYLENE+} Q_{BUTENE+} Q_{BUTANE+} Q_{CARBON}}$

$= [-105335.0511-54999.5626-49422.79-247409.7601-2775.92]$

$= -459943.0838$ KJ/h.

COOLANT=CHILLER COOLER

$\mathbf{Q = \int_{4}^{90} mc_p\, dt}$

$459943.0838=m[18.2964(90-4)+47.212*10^{-2}/2(90^2-4^2)-133.88*10^{-5}/3(90^3-4^3)+13.142*10^{-9}/4(90^4-4^4)]$

$459943.0838=m\ [1573.4903+1908.50404-325.2798+21.556]$

m = 144.724 kmol/h

6.4 Heat Exchanger-2

$\mathbf{Q_{PROPYLENE}} = \int_{218}^{138} nc_p\ dt$

n= 11.418

$\mathbf{Q_{PROPYLENE}} = n \int_{218}^{138} [a + bT + cT2 + dT3]\ dT$

$=11.418[59.58(138-218)+17.71*10^{-2}/2(138^2-218^2)-10.17*10^{-5}/3(138^3-218^3)+24.6*10^{-9}/4(138^4-218^4)]$

=11.418[-4766.4-2521.904+262.120024-11.6595]

= - 80358.09681 kJ/h.

$\mathbf{Q_{ETHYLENE}} = \int_{218}^{138} nc_p\ dt$

n=9.65

$\mathbf{Q_{ETHYLENE}} = n \int_{218}^{138} [a + bT + cT2 + dT3]\ dT$

$=9.65[40.75(138-218)+11.4*10^{-2}/2(138^2-218^2)-6.89*10^{-5}/3(138^3-218^3)+17.66*10^{-9}/4(138^4-218^4)]$

=9.65[-3260-1633.328+177.607715-8.37]

= - 45587.47125 kJ/h.

$\mathbf{Q_{BUTENE}} = \int_{218}^{138} nc_p\ dt$

n=4.138

$\mathbf{Q_{BUTENE}} = n \int_{218}^{138} [a + bT + cT2 + dT3]\ dT$

$=4.138[82.88(138-218)+25.64*10^{-2}/2(138^2-218^2)-17.27*10^{-5}/3(138^3-218^3)+50.5*10^{-9}/4(138^4-218^4)]$

=4.138[-6630.4-3651.136+445.1146773-23.935]

= -40802.15446 kJ/h.

$\mathbf{Q_{BUTANE}} = \int_{218}^{138} nc_p\ dt$

n=18.44

$\mathbf{Q_{BUTANE}} = n \int_{218}^{138} [a + bT + cT2 + dT3]\ dT$

$=18.44[89.46(138-218)+30.13*10^{-2}/2(138^2-218^2)-18.91*10^{-5}/3(138^3-218^3)+49.87*10^{-9}/4(138^4-218^4)]$

=18.44[-715.68-4290.512+487.83817-23.63659]

= - 83754.30303 kJ/h.

Q_{CARBON} =$\int_{218}^{138} nc_p\ dt$

n=2.29935

Q_{CARBON} = n $\int_{218}^{138}$[a + bT + cT2 + dT3] dT

=2.29935[11.18(138-218)+1.095*10^{-2}/2(138^2-218^2)-4.89*10^{-5}/3(138^3-218^3)]

=2.29935[-894.4-130.0456+1.26034*10^{-8}]

= - 2355.558981 kJ/h.

Q_{TOTAL} = $Q_{PROPYLENE+}$ $Q_{ETHYLENE+}$ $Q_{BUTENE+}$ $Q_{BUTANE+}$ Q_{CARBON}

=[-80358.09681-45587.47125-40802.15446-83754.30303-2355.558981]

= -252857.5845 kJ/h

6.5 Heat Exchanger-3

$Q_{PROPYLENE}$ =$\int_{138}^{52} nc_p\ dt$

n=11.418

$Q_{PROPYLENE}$ = n $\int_{138}^{52}$[a + bT + cT2 + dT3] dT

=11.418[59.58(52-138)+17.71*10^{-2}/2(52^2-138^2)-10.17*10^{-5}/3(52^3-138^3)+24.6*10^{-9}/4(52^4-138^4)]

=11.418[-5123.88-1466.907+84.3250-2.1854]

= - 74087.37601 kJ/h.

$Q_{ETHYLENE}$ =$\int_{138}^{52} nc_p\ dt$

n=11.418

$Q_{ETHYLENE}$ = n $\int_{138}^{52}$[a + bT + cT2 + dT3] dT

=11.418[40.75(52-138)+11.4*10^{-2}/2(52^2-138^2)-6.89*10^{-5}/3(52^3-138^3)+17.66*10^{-9}/4(52^4-138^4)]

=11.418[-3504.5-937.099+57.137-1.5689]

= - 42325.19819 kJ/h.

$Q_{BUTENE} = \int_{138}^{52} nc_p \; dt$

n=4.138

Q_{BUTENE} = n $\int_{138}^{52}$[a + bT + cT2 + dT3] dT

=4.138[82.88(52-138)+25.64*10^{-2}/2(52^2-138^2)-17.27*10^{-5}/3(52^3-138^3)+50.5*10^{-9}/4(52^4-138^4)]

=4.138[-7127.68-2094.788+143.195-4.486449]

= -37588.59659 kJ/h.

$Q_{BUTANE} = \int_{138}^{52} nc_p \; dt$

n=4.138

Q_{BUTANE} = n $\int_{218}^{138}$[a + bT + cT2 + dT3] dT

=4.138[89.46(52-138)+30.13*10^{-2}/2(52^2-138^2)-18.91*10^{-5}/3(52^3-138^3)+49.87*10^{-9}/4(52^4-138^4)]

=4.138[-7693.56-2461.21+156.7931-4.430479]

= - 184451.9709 kJ/h.

$Q_{CARBON} = \int_{138}^{52} nc_p \; dt$

n=2.29935

Q_{CARBON} = n $\int_{138}^{52}$[a + bT + cT2 + dT3] dT

=2.29935[11.18(52-138)+1.095*10^{-2}/2(52^2-138^2)-4.89*10^{-5}/3(52^3-138^3)]

=2.29935[-961.48-89.4615+4.05456*10^{-9}]

= - 2416.476222 kJ/h.

$Q_{TOTAL} = Q_{PROPYLENE+} Q_{ETHYLENE+} Q_{BUTENE+} Q_{BUTANE+} Q_{CARBON}$

= [-74087.37601-42325.19819-37588.59659-184451.9709-2416.476222]

= -340869.6179 KJ/mol.

Coolant=Chiller Water

$Q = \int_{4}^{90} mc_p \; dt$

340869.6179= m*3178.05564

m = 0.536 kg/sec.

6.6 Distillation 1

6.6.1 Condenser:

$Q_{PROPYLENE} = \int_{-104}^{-25} nc_p \, dt$

n=0.5709

$Q_{PROPYLENE}$ = n $\int_{-104}^{-25} [a + bT + cT2 + dT3]\, dT$

=0.5709[59.58(-25+104)+17.71*10^{-2}/2(-25^2-104^2)-10.17*10^{-5}/3(-25^3+104^3)+94.6*10^{-9}/4(-25^4-104^4)]

=0.5709[-4706.82-902.41305+37.6032-0.71706067]

= 2150.058 kJ/h.

$Q_{ETHYLENE} = \int_{-104}^{-25} nc_p \, dt$

n=2.9275752

$Q_{ETHYLENE}$ = n $\int_{-104}^{-25} [a + bT + cT2 + dT3]\, dT$

=2.9275752[40.75(-25+104)+11.47*10^{-2}/2(-25^2-104^2)-6.891*10^{-5}/3(-25^3+104^3)+17.66*10^{-9}/4(-25^4-104^4)]

=2.9275752[3219.25-584.45385+25.479219-0.51476]

= 7637.46465 kJ/h.

$Q_{CARBON} = \int_{-104}^{-25} nc_p \, dt$

n=4.45302

Q_{CARBON} = n $\int_{-104}^{-25} [a + bT + cT2 + dT3]\, dT$

=4.45302[11.18(-25+104)+1.095*10^{-2}/2(-25^2-104^2)-4.89*10^{-5}/3(-25^3+104^3)]

=4.45302[883.22-55.79572+1.808*10^{-9}]

= 3684.536 kJ/h.

$Q_{BUTENE} = \int_{-104}^{-25} nc_p \, dt$

n=3.4665

Q_{BUTENE} = n $\int_{-104}^{-25} [a + bT + cT2 + dT3]\, dT$

=3.4665[89.46(-25+104)+30.13*10^{-2}/2(-25^2-104^2)-18.91*10^{-5}/3(-25^3+104^3)+49.87*10^{-9}/4(-25^4-104^4)]

=3.4665[7067.34-1535.27415+69.9103163-1.45365]

= 18929.5492 kJ/h.

$Q_{TOTAL} = Q_{PROPYLENE} + Q_{ETHYLENE} + Q_{BUTENE} + Q_{CARBON}$

= [2150.058+7637.46465+18929.5492+3684.536]

=32401.60785 KJ/h.

Coolant= Steam

Q=$\int_{110}^{20} mc_p\ dt$

32401.60785= m [18.2964(20-110)+47.21*10^{-2}/2(20^2-110^2)-133.88*10^{-5}/3(20^3-110^3)+1314.2*10^{-9}/4(20^4-110^4)]

32401.60785= m [-1646.76-2761.902+590.4108-48.0504375]

32401.60785= m [3866.3016]

m = 8.3805 kmol/h

=0.0419 kg/sec.

6.6.2 Reboiler:

$Q_{PROPYLENE}$ =$\int_{89}^{-2} nc_p\ dt$

n=10.889

$Q_{PROPYLENE}$ = n $\int_{89}^{-2}[a + bT + cT2 + dT3]\ dT$

=10.889[59.58(-2-89)+17.71*10^{-2}/2(-2^2-89^2)-10.17*10^{-5}/3(-2^3-89^3)+94.6*10^{-9}/4(-2^4-89^4)]

=10.889[-5421.78-701.05035+23.8987-0.385864]

= - 66415.468 kJ/h.

$Q_{ETHYLENE}$ =$\int_{89}^{-2} nc_p\ dt$

n=5.185

$Q_{ETHYLENE}$ = n $\int_{89}^{-2}[a + bT + cT2 + dT3]\ dT$

=5.185[40.75(-2-89)+11.47*10^{-2}/2(-2^2-89^2)-6.891*10^{-5}/3(-2^3-89^3)+17.66*10^{-9}/4(-2^4-89^4)]

=5.185[-3708.25-454.039+16.9129-1.1080]

= - 21499.52059 kJ/h

Q_{BUTENE} =$\int_{89}^{-2} nc_p\ dt$

n=3.940

Q_{BUTENE} = n $\int_{89}^{-2}[a + bT + cT2 + dT3]\ dT$

=3.940[82.88(-2-89)+25.64*10^{-2}/2(-2^2-89^2)-17.27*10^{-5}/3(-2^3-89^3)+50.5*10^{-9}/4(-2^4-89^4)]

=3.940[-7542.08-1014.9594+40.58225-0.7921]

= - 33557.96204 kJ/h

$\mathbf{Q_{BUTANE}} = \int_{89}^{-2} nc_p\ dt$

n=12.3065

$\mathbf{Q_{BUTANE}}$ = n $\int_{89}^{-2}[a + bT + cT2 + dT3]\ dT$

$=12.3065[89.46(-2-89)+30.13*10^{-2}/2(-2^2-89^2)-18.9*10^{-5}/3(-2^3-89^3)+49.87*10^{-9}/4(-2^4-89^4)]$

=12.3065[-8140.86-1192.69605+44.4360417-0.782233689]

= - 114326.1812 kJ/h.

$\mathbf{Q_{CARBON}} = \int_{89}^{-2} nc_p\ dt$

n=2.246985

$\mathbf{Q_{CARBON}}$ = n $\int_{89}^{-2}[a + bT + cT2 + dT3]\ dT$

$=2.246985[11.18(-2-89)+1.095*10^{-2}/2(-2^2-89^2)-4.89*10^{-5}/3(-2^3-89^3)]$

$=2.246985[-1017.38-43.345575+1.149*10^{-9}]$

= - 2383.4344 kJ/h.

$\mathbf{Q_{TOTAL} = Q_{PROPYLENE+}\ Q_{ETHYLENE+}\ Q_{BUTENE+}\ Q_{BUTANE+}\ Q_{CARBON}}$

= [-66415.468-21499.52059-33517.96204-114326.1812-2383.4344]

= -238182.5662 KJ/h

Media = Chilled Water

$\mathbf{Q} = \int_{4}^{96} mc_p\ dt$

$238182.5662=m[18.2964(96-4)+47.21*10^{-2}/2(96^2-4^2)-133.88*10^{-5}/3(96^3-4^3)+1314.2*10^{-9}/4(96^4-4^4)]$

238182.5662= m[1683.2688+2171.752+394.7996-27.9051]

238182.5662= m[3488.1262]

m = 68.283 kmol/h

=0.341 kg/sec

6.7 Distillation 2

6.7.1 Condenser 2:

$\mathbf{Q_{PROPYLENE}} = \int_{-48}^{39} nc_p\ dt$

n=9.820

$\mathbf{Q_{PROPYLENE}}$ = n $\int_{-48}^{39}[a + bT + cT2 + dT3]\ dT$

$=9.820[59.58(39+48)+17.71*10^{-2}/2(39^2-48^2)-10.17*10^{-5}/3(39^3+48^3)+94.6*10^{-9}/4(39^4-48^4)]$

=9.820[5183.46-69.33465-5.992152-0.018419]= 54246.852 kJ/h.

$Q_{ETHYLENE}$ =$\int_{-48}^{39} nc_p \ dt$

n=0.00987

$Q_{ETHYLENE}$ = n $\int_{-48}^{39}[a + bT + cT2 + dT3]$ dT

=0.00987[40.75(39+48)+11.47*10^{-2}/2(39^2-48^2)-6.891*10^{-5}/3(39^3+48^3)+17.66*10^{-9}/4(39^4-48^4)]

=0.00987[3545.25-44.90505+3.9028-0.013222]

= 34.5 kJ/h.

Q_{BUTENE} =$\int_{-48}^{39} nc_p \ dt$

n=0.00987

Q_{BUTENE} = n $\int_{-48}^{39}[a + bT + cT2 + dT3]$ dT

=0.00987[82.88(39+48)+25.64*10^{-2}/2(39^2-48^2)-17.27*10^{-5}/3(39^3+48^3)+50.5*10^{-9}/4(39^4-48^4)]

=0.00987[7210.56-66.9204+2.95161-0.050415412]

= 70.5363 kJ/h.

Q_{BUTANE} =$\int_{-48}^{39} nc_p \ dt$

n=0.02961

Q_{BUTANE} = n $\int_{-48}^{39}[a + bT + cT2 + dT3]$ dT

=0.02961[89.46(39+48)+30.13*10^{-2}/2(39^2-48^2)-18.9*10^{-5}/3(39^3+48^3)+49.87*10^{-9}/4(39^4-48^4)]

=0.02961[7783.02-117.9585+10.71-0.0373398]

= 226.643 kJ/h.

Q_{TOTAL} = $Q_{PROPYLENE}$+ $Q_{ETHYLENE}$+ Q_{BUTENE}+ Q_{BUTANE}

= [54246.852+34.5+70.5363+226.643]

= 54578.53201 KJ/h.

Coolant= Steam

Q=$\int_{110}^{20} mc_p \ dt$

54578.53201 = m[18.2964(20-110)+47.21*10^{-2}/2(20^2-110^2)-133.88*10^{-5}/3(20^3-110^3)+1314.2*10^{-9}/4(20^4-110^4)]

54578.53201 = m [-1646.76-2761.902+590.4108-48.0504375]

54578.53201= m [-3866.3016]

m = 14.1167 kmol/h

=0.0705 kg/sec.

6.7.2 Reboiler:

$Q_{PROPYLENE}$ =$\int_{-58}^{-48} n\, c_p\ dt$

n=0.02469

$Q_{PROPYLENE}$ = n $\int_{-58}^{-48}[a + bT + cT2 + dT3]\ dT$

=0.02469[59.58(-48+58)+17.71*10^{-2}/2(48^2-58^2)-10.17*10^{-5}/3(-48^3+58^3)+94.6*10^{-9}/4(48^4-58^4)]

=0.02469 [595.8-93.3063-2.8652-0.0369496]

= -12.3329 kJ/h.

$Q_{ETHYLENE}$ =$\int_{-58}^{-48} nc_p\ dt$

n=0.3876

$Q_{ETHYLENE}$ = n $\int_{-58}^{-48}[a + bT + cT2 + dT3]\ dT$

=0.3876[40.75(-48+58)+11.47*10^{-2}/2(48^2-58^2)-6.891*10^{-5}/3(-48^3+58^3)+17.66*10^{-9}/4(48^4-58^4)]

=0.3876 [407.5-60.582-1.9422-0.0265250]

= - 133.702 kJ/h

Q_{BUTENE} =$\int_{-58}^{-48} nc_p\ dt$

n=3.068

Q_{BUTENE} = n $\int_{-58}^{-48}[a + bT + cT2 + dT3]\ dT$

=3.068[82.88(-48+58)+25.64*10^{-2}/2(48^2-58^2)-17.27*10^{-5}/3(-48^3+58^3)+50.5*10^{-9}/4(48^4-58^4)]

=3.068 [828.8-135.892-4.865-0.0758]= 1899.798 kJ/h

Q_{BUTANE} =$\int_{-58}^{-48} nc_p\ dt$

n=15.678

Q_{BUTANE} = n $\int_{-58}^{-48}[a + bT + cT2 + dT3]\ dT$

=15.678[89.46(-48+58)+30.13*10^{-2}/2(48^2-58^2)-18.9*10^{-5}/3(-48^3+58^3)+49.87*10^{-9}/4(48^4-58^4)]

=15.678[894.6-159.869-5.32757-0.07490]

= 11473.336 kJ/h.

Q_{CARBON} =$\int_{-58}^{-48} nc_p\ dt$

n=5.53

Q_{CARBON} = n $\int_{-58}^{-48}[a + bT + cT2 + dT3]\ dT$

=5.53[11.18(-48+58)+1.095*10^{-2}/2(48^2-58^2)-4.89*10^{-5}/3(-48^3+58^3)]

=5.53[111.8-5.8035-1.377*10^{-10}]

= 586.159 kJ/h.

Q_{TOTAL} = $Q_{PROPYLENE}$+ $Q_{ETHYLENE}$+ Q_{BUTENE}+ Q_{BUTANE}+ Q_{CARBON}

= [12.3329+133.702+1899.798+11473.336+586.159]

= 14105.328 KJ/h

Media = Chilled Water

Q=$\int_{25}^{10} mc_p\ dt$

14105.328 = m [18.2964(10-25)+47.21*10^{-2}/2(10^2-25^2)-133.88*10^{-5}/3(10^3-25^3)+1314.2*10^{-9}/4(10^4-25^4)]

14105.328 = m[405.0292]

m = 34.825 kmol/h

= 0.1741 kg/sec

6. 8 Heat Exchanger 4

$Q_{PROPYLENE}$ =$\int_{-58}^{42} nc_p\ dt$

n=0.02469

$Q_{PROPYLENE}$ = n $\int_{-58}^{42}$[a + bT + cT2 + dT3] dT

=0.02469[59.58(42+58)+17.71*10^{-2}/2(42^2-58^2)-10.17*10^{-5}/3(42^3+58^3)+94.6*10^{-9}/4(42^4-58^4)]

=0.02469[5958-141.68-9.12588-0.05045]

= 129.0519 kJ/h.

$Q_{ETHYLENE}$ =$\int_{-58}^{42} nc_p\ dt$

n=0.3876

$Q_{ETHYLENE}$ = n $\int_{-58}^{42}$[a + bT + cT2 + dT3] dT

=0.3876[40.75(42+58)+11.47*10^{-2}/2(42^2-58^2)-6.891*10^{-5}/3(42^3+58^3)+17.66*10^{-9}/4(42^4-58^4)]

=0.3876[4075-91.76-2.7792-0.036224]

= 1542.8119 kJ/h

Q_{BUTENE} =$\int_{-58}^{42} nc_p\ dt$

n=3.0689

Q_{BUTENE} = n $\int_{-58}^{42}$[a + bT + cT2 + dT3] dT

=3.0689[82.88(42+58)+25.64*10^{-2}/2(42^2-58^2)-17.27*10^{-5}/3(42^3+58^3)+50.5*10^{-9}/4(42^4-58^4)]

=3.0689[8288-205.12-15.49-0.1035]

= 24.757 kJ/h

$Q_{BUTANE} = \int_{-58}^{42} nc_p \; dt$

n=15.678

Q_{BUTANE} = n $\int_{-58}^{42}[a + bT + cT2 + dT3]\; dT$

$=15.678[89.46(42+58)+30.13*10^{-2}/2(42^2-58^2)-18.9*10^{-5}/3(42^3+58^3)+49.87*10^{-9}/4(42^4-58^4)]$

=15.678 [8946-241.04-16.968573-0.102293]

= 136208.722 kJ/h.

$Q_{CARBON} = \int_{-58}^{42} nc_p \; dt$

n=5.53

Q_{CARBON} = n $\int_{-58}^{42}[a + bT + cT2 + dT3]\; dT$

$=5.53[11.18(42+58)+1.095*10^{-2}/2(42^2-58^2)-4.89*10^{-5}/3(42^3+58^3)]$

$=5.53[1118-8.76-4.3879*10^{-10}]$

= 6133.926 kJ/h.

$Q_{TOTAL} = Q_{PROPYLENE} + Q_{ETHYLENE} + Q_{BUTENE} + Q_{BUTANE} + Q_{CARBON}$

= [129.0519+1542.8119+24.757+13620.722+6133.926]

=144039.2697 KJ/h

Media = Steam

$Q = \int_{110}^{5} mc_p \; dt$

$144039.2697 = m[18.2964(5-110)+47.21*10^{-2}/2(52^2-110^2)-133.88*10^{-5}/3(52^3-110^3)+1314.2*10^{-9}/4(52^4-110^4)]$

144039.2697 = m [-1921.122-2850.4245-593.9251-48.1028]

144039.2697= m[5404.574]

m = 26.65 kmol/h

m = 0.133 kg/sec

6.9 Heat Exchanger 5

$Q_{PROPYLENE} = \int_{42}^{60} nc_p \; dt$

n=0.02469

$Q_{PROPYLENE}$ = n $\int_{42}^{60}[a + bT + cT2 + dT3]\; dT$

$=0.02469[59.58(60-42)+17.71*10^{-2}/2(60^2-42^2)-10.17*10^{-5}/3(60^3-42^3)+94.6*10^{-9}/4(60^4-42^4)]$

=0.02469[1054.44+162.5778-4.810816+0.060570]

= 29.93J/h.

$Q_{ETHYLENE}$ =$\int_{42}^{60} nc_p\ dt$

n=0.3876

$Q_{ETHYLENE}$ = n $\int_{42}^{60}$[a + bT + cT2 + dT3] dT

$=0.3876[40.75(60-42)+11.47*10^{-2}/2(60^2-42^2)-6.891*10^{-5}/3(60^3-42^3)+17.66*10^{-9}/4(60^4-42^4)]$

=0.3876[733.5+105.2946-3.2597+0.04348]

= 323.872 kJ/h

Q_{BUTENE} =$\int_{42}^{60} nc_p\ dt$

n=3.0689

Q_{BUTENE} = n $\int_{42}^{60}$[a + bT + cT2 + dT3] dT

$=3.0689[82.88(60-42)+25.64*10^{-2}/2(60^2-42^2)-17.27*10^{-5}/3(60^3-42^3)+50.5*10^{-9}/4(60^4-42^4)]$

=3.0689[1491.84+235.3752-8.1694+0.1243348]

= 5275.949 kJ/h

Q_{BUTANE} =$\int_{42}^{60} nc_p\ dt$

n=15.678

Q_{BUTANE} = n $\int_{42}^{60}$[a + bT + cT2 + dT3] dT

$=15.678[89.46(60-42)+30.13*10^{-2}/2(60^2-42^2)-18.9*10^{-5}/3(60^3-42^3)+49.87*10^{-9}/4(60^4-42^4)]$

=15.678 [1610.28+276.5934-8.945186+0.1227]

= 29444.078 kJ/h.

Q_{CARBON} =$\int_{42}^{60} nc_p\ dt$

n=5.53

Q_{CARBON} = n $\int_{42}^{60}$[a + bT + cT2 + dT3] dT

$=5.53[11.18(60-42)+1.095*10^{-2}/2(60^2-42^2)-4.89*10^{-5}/3(60^3-42^3)]$

$=5.53[201.24+10.5521-2.31316*10^{-10}]$

= 1168.445 kJ/h.

Q_{TOTAL} = $Q_{PROPYLENE}$+ $Q_{ETHYLENE}$+ Q_{BUTENE}+ Q_{BUTANE}+ Q_{CARBON}

= [29.93+323.872+5275.949+29444.078+1168.445]

= 36242.27427 KJ/h

Media = Steam

Q=$\int_{110}^{85} mc_p\ dt$

$36242.27427 = m\ [18.2964(85-110)+47.21*10^{-2}/2(85^2-110^2)-133.88*10^{-5}/3(85^3-110^3)+1314.2*10^{-9}/4(85^4-110^4)]$

36242.27427 = m [-457.41-1150.7925-319.9174-30.9524]

36242.27427 = m [1959.072]

m = 18.4997 kmol/h

m = 0.0924 kg/sec

CHAPTER 7
PROCESS UTILITY

The utilities such as water, air, steam, electricity etc. are required for most of the chemical process industries. These utilities are located at a certain distance from processing area, from processing area hazardous and storage area etc, where a separate utility department works to fulfill the utilities requirements.

- Steam Generation
- Cooling water
- Water
- Electricity
- Compressed air

The utilities required for the plant are summarized as below.

7.1 Steam Generation

Steam is used in plants for heating purpose, where direct contact with substance is not objectionable. The steam, for process heating, is usually generated in water tube boiler using most economical fuel available i.e. coal, fuel oil on the site. In reboiler of distillation column, drying column and evaporator steam is used at different temperature depending on requirement.

7.2 Cooling Water

Cooling water is generally produced in plant by cooling towers. Cooling tower is used to cool the water of high temperature coming from process. Cooling tower mainly decreases temperature of water from process. There are two types of cooling tower.

7.2.1 Natural Type

In this cooling tower the water from the process is allowed to fall in a tank. From Some Height When Falling it Comes In Contact With an Air & Gets Cool.

7.2.2 Mechanical Type

They are classified in three types:

- Induced draft
- Forced draft
- Balanced draft

In induced draft a fan is rotating at the bottom while in balanced draft fan is rotating at the centre. In forced draft a fan rotating at top.

- Cooling by sensible heat transfer
- Cooling by evaporation

7.3 Water

A large reservoir has to be made which received water from nearby river. Storage also must provide to such extent that turbidity is settling and then sent to raw water plant for further treatment. Chlorine dose must be given to kill bacteria which prevent organic matter. Then this water is sent to further treatment. To cooling tower, DM plant, service water system, drinking water system, fire water system.

Cooling water is required for heat cooler, condenser etc. for cooling effect. Here in cooling tower water is fall from high level and contacted with cross flow of air. Latent heat of water is high that even a small amount of water evaporates produce large cooling effect. The temp of CW is up to 25 to 30 ˚C.

DM water is use for process. DM water is produced by removing impurities salts, pass through anion exchanger.

7.4 Electricity

It is required for motor drives, lighting and general use. It may be generated on site or purchase from GEB & G.I.P.C.L. Transformers will be to step-down the supply voltage to the voltage used on the site. A three-phase 415-volt system is used in general industrial purposes and 240-volt single phase for lighting and other low power requirements. For large motors, high voltage 600 to 1100 is used.

7.5 Compressed Air

Compressed air is used during the chocking of pipes and for cleaning purpose. Compressed air can be obtained from air compressor.

CHAPTER 8
PROCESS AND MECHANICAL DESIGN

8.1 Process and mechanical design of mixing tank

Volumetric flow rate of ethylene fresh feed = mass flow rate/density

=138.18/1.178 kg/hr/kg/m^3

=117.3005 m^3/hr

Volumetric flow rate of butane fresh feed = mass flow rate/density

=286.47675/2.48 kg/hr/kg/m^3

=115.514819 m^3/hr

Volumetric Flow rate of recycle ethylene steam =mass flow rate/density

=319.704/1.178 kg/hr/kg/m^3

=271.39 m^3/hr

Volumetric flow rate of butane recycle steam =1433.25/2.48 kg/hr/m^3/hr

=577.925202 m^3/hr

So, total volumetric flow rate(v_0)= $V_{ethylene} + V_{butene} + V_{recycle\ ethylene} + V_{recycle\ butene}$

=(117.3005+115.514819+271.39+577.925202)

=1082.13052 m^3/hr

But residence time = V_{tank}/total volumetric flow rate

$10=V_r/1082.13052$

$V_r=10*1082.13052$

=10821.3052 m^3

Actual volume of tank = 1.3*10821.3052

=14067.6968 m^3

The tank has cylindrical shape the volume = $\pi r_1^2 L$

Where,

r_1=inner radius of tank

L=length

$\pi D_1^2 L/4 = 14067.6968$

we know that (L/D = 3.5)

L = 3.5*d Put in above

$\pi D_1^2*3.5D_1/4 = 14067.6968$

$\pi D_1^2 * 3.5 D_1 = 14067.6968*4$

$D_1^3 = 14067.6968/3.14*3.5$

$D_1^3 = 5120.18083\ m^3$

$D_1 = 17.23568\ m$

$L = 17.23568*3.5$

$L = 60.32488\ m$

8.1.1 Head design

We will consider torispherical head

Knuckle radius (r_i) = $0.06*D_0$

$= 0.06*17.23568$

$= 1.034m$

Crown radius (r_0) = D_0 = 17.23568

where

w = stress concentration factor for torispherical head

$=1/4(3+\sqrt{p_{r0}/r_i})$

$=1/4(3+\sqrt{17.23568/1.034})$

$=1/4(3+4.293326)$

$=1.8233$

F = allowable stress (stainless steel)

$=80MN/m^2$

J = joint efficiency = 0.85

$T = 25^0C$

8.1.2 Thickness of head

$t = pd * di * Cs \div 2fj - 0.2pd$

pd = 5% *(1) * (1) = 0.05 × (1 + 1)

= 1.05 atm

$= 1.05 \times 1.013 \times 10^5\ N/m^2$

$= 1.06 \times 10^5\ N/m^2 = 0.106$

Put the value of pd in above equation

$t = 0.106 \times 17.23568 \times 1.77 / (2 \times 80 \times 0.85) - 0.2 \times 0.106$

$=3.23375/135.9788$

$=3.23375/135.9788$

=0.023781341m

=23.781341 mm

So, we will consider 21mm thickness for both top and bottom head because they are subjected to same external pressure.

8.1.3 Agitator design

The impeller used for agitation is a 6-disk flat blade turbine type impeller. Impeller diameter

d_i= 0.4*D_i

=0.4*17.23568

=6.894272 m

Blade Length

L = d_i/4

=6.894272/4

=1.723568 m

Disk Diameter

d_d = 2*d_i /3

=2*6.894272/3 = 4.576181333 m

Distance Between Impeller:

=1.5*d_i

=1.5*6.894272

=10.341408 m

Distance of the impeller from tank bottom = D/3

=17.23568/3

=5.745226667 m

8.1.4 Speed of The Impeller

Because we are using turbine type impeller and it have the r.p.m. range generally 40-80 r.p.m. It is enough because have tangential and axial both type of mixing occur.

So

N = (40+80)/2

=120/2

=60 r.p.m.*1/60 second

=1 r./second

8.1.5 Power Required For Impeller

$P = K*N^3*d_i^5*\rho$

Density range = (1050-1090)kg/m^3

Where

K = constant = 6 at N_{re}>10000

N = speed of impeller

So,

$P = 6*1^3*(6.894272)^5*1050$

$= 9.8*10^7$ w

$= 9.8*10^4$ kw

Power required to drive three impellers will be

$P = 2*9.8*10^4$

$=19.62*10^4$ kw

8.1.6 **Hub and key Design**

Hub diameter of the agitator = 2*shaft diameter

=2*6.894272

= 13.788544 m

Hub Length, = 2.5*6.894272

= 17.23568 m

Say, = 17 m

Key length, = 1.5*6.894272

= 10.341408 m

Say, = 10 m

$T_m/(d/2) = b*l*f_s$

b $=534*10^3/[(6.894272/2)*65*10] = 238.324$ m

8.1.7 Stuffing Box and Gland

The vessel internal Pressure = 1.5atm

Design pressure = 2atm

$b = d+(d)^{1/2}$

$= 6.894272+(6.894272)^{1/2}$

= 9.5199665 m

Say, = 10 m

The thickness,

$t = [(p*d)/2f]+6$

$= (1.5*10)/(2*95)]+6$

= 6.07 mm

The load on the gland,

$F=(\pi/4)p(b^2-d^2)$

$= (3.14/4)*1.5*(10^2-6.894272^2)$

= 61.78226N

Assume No, of studs = 4

Then stud diameter,

$F=(\pi/4)*d^2*n*f$

$d=[4*61.78226/(3.14*4*58.7)]$

= 0.33 mm

Minimum stud diameter if 15 mm

The flange thickness = 1.75*15

= 8.75 mm

Say, = 30mm

8.1.8 Coupling

The coupling used is a clamp coupling.

On Assuming no. of bolt(n=8)

$P=2*T_m/(\pi*\mu*d*(n/2)$

Where the cofficent of friction μ is assumed 0.35

$P = 2*534*10^3/(\pi*0.35*10*(8/2))$

= 2429 N

Area of bolts = P/f

= 2429/58.7

$= 41.37\ m^2$

8.2 HEAT EXCHANGER DESIGN

Total C_p of solvent =74.15 KJ/kg ^oC

Heat load=7.88 Kw

Cooling water flow rate=11.1984 kmol/hr.

ΔT_{lm}=[(T_1-T_2)-(t_1-t_2)]/ln[(T_1-T_2)/(t_1-t_2)]

=[(60-42)-(110-85)]/ln[(60-42)/(110-85)]

= 21.30^{o}C

SHELL PASS

R=(60-42/110-85)

= 0.72

S=(85-42/85-60)

= 1.72

F_t = {√(R^2+1)ln[(1-S)/(1-RS)]}/{(R-1)ln[2-S[R+1-√(R^2+1)]/ [2-S[R+1-√(R^2+1)]]}

= √(0.72^2+1) ln [(1-1.72)/(1-0.72*1.72)]}/{(0.72-1)ln[2-1.72[0.72+1-√(0.72^2+1)]/ [2-1.72[0.72+1-√(0.72^2+1)]]}

=1.232 ln [(.72)/(0.2384)]}/{(0.28)ln[2-0.8359]/ [1.2384}

=1.3616/0.0173

=0.79

ΔT_{lm}=0.79*21.30

= 16.287

U=640

Area= (6.4827*1000)/(16.827/260)

= 1.541 m^2

O.D = 16 mm

I.D = 14.4 mm

Area of one tube=∏ D_O L

=0.0803

Number of tubes= 1.541/0.0803

= 19

As the shell side fluid is relatively clean use 1.25 triangular bundle diameter.

$D_b = 16[19/0.249]^{1/1.2}$

$= 592.8mm$

Clearance= 6/mm

Shell diameter= 653.8mm

8.2.1 Tube side coefficient

Mean water temperature = (110+85)/2 = 97.5°C

Tube cross-sectional area= ∏/4 * 14.5^2 = $165mm^2$

Tube per pass= 19/2 = 9

Total flow area= $9*165*10^{-6}$

$= 1.48*10^{-3} m^2$

Water mass velocity= $11.19/(1.48*10^{-3})$

$= 2.09 kmol/s.m^2$

Density of water = 995 kg/m^3

Water linear velocity= $2.1*10^{-3}$ m/s

$h_i=4200(1.35+0.02*97.5)(0.0021)^{0.8}$

$= 58.51 w/m^2\ ^oC$

8.2.2 Shell side coefficient

Choose baffles spacing = 653.8/5

= 130.76

Tube pitch = 10mm =1.25*16

Cross flow area = $[(20-16)*653.8*130.76*10^{-6}]/20$

$= 0.017 m^2$

Mass velocity = 11.169/(3600*0.017)

$= 32.88kg/s. m^2$

Equivalent diameter = $1.10(p_t^2-0.917d_i^2)/d_o$

$=1.10(20^2-0.917*1.6^2)/16$

=11.36mm

Density of Butene=2.840 kg/m^3

Viscosity = 7.76 N.m/s

Heat Capacity = 74.15 KJ/kg ^oC

Mean Shell Side Temperature = 51^oC

Thermal Conductivity =

$R_S = G_S D_E/\mu = (3.28*11.36*10^{-3})/0.776*10^{-3} = 481$

CHAPTER 9

PROCESS INSTRUMENTATION AND CONTROL

9.1 Why Required?

Instruments are provided to monitor the key process variables during plant operation. Instruments monitoring critical process variables will be fitted with automatic alarms to alert the operators to critical and hazardous situations.

The primary objectives of the designer when specifying instrumentation and control schemes are:

9.1.1 Safe Plant Operation

- To keep process variables within known safe operating limits.
- To detect dangerous situations as they develop and to provide alarms and Automatic shutdown systems.
- To provide interlocks and alarms to prevent dangerous operating procedures.

9.1.2 Production Rate And Quality

- To achieve the designed product output.
- To maintain the product composition within the specified quality standards.

9.1.3 Cost

- To operate at the lowest production cost and to compensate with other objectives.

Process instrumentation is thus brain and nerves of a process plant. The instrumentation can be pneumatic, hydraulic or electric. The recent trend is to go for electronic instrumentation, but pneumatic instrumentation is still in use. The instrumentation is required to measure temperature, pressure, flow rate, level, physical properties as density, pH, humidity, chemical composition etc.

9.2 Typical Monitoring Systems

9.2.1 Flow Measurement

Due to nature of flow it is necessary to provide effective flow measuring devices in each supply lines. The various types of flow meters available are orifice meter, venturi meter, pitot tube etc. In spite of these the various types of area flow meters can also be used. Depending on temperature and velocity condition the suitable meter is selected for Measurement of Flow Rates and Velocity.

9.2.2 Temperature Measuring Devices

Many devices are used to measure the temperature variations in the process such as mercury in glass thermometer, bimetallic thermometer, pressure spring thermometer, thermocouples, resistance thermocouples, radiation pyrometers and optical pyrometers are used.

Out of all these the industrial thermocouples are competitively good as they provide large measuring range, without introducing error. Automatic control is also possible with such devices.

Table 10.1: List of Thermometers with Temperature Range

Measuring Instrument	**Temp. Range ºC**
Mercury in glass – thermometer	-27 to 400
Mercury in pressure thermometer	-40 to 540
Vapor pressure thermometer	-85 to 425
Resistance	-200 to 1700
Thermocouple	-250 to 1700
Thermister	Up to 300
Pyrometer	1300 to 2500

9.2.3 Pressure Measuring Devices

Equipments, in which the important monitoring parameter is pressure, pressure measuring devices like pressure gauges are widely used. Safety of chemical plants depends up on the timely measurement of pressure and its control at a specified level. Any excess pressure development than the design pressure may damage the equipment in addition to the fire and other explosion hazard.

Mainly in filter pressures where the pressure is an important criterion, this device is used.

Various pressure measuring devices are:

- U – Tube Manometer
- Differential Manometer
- Inclined Manometer
- Bourdon Tube
- Bellows
- Diaphragm valve
- Mc Leod gauge
- Pirani gauge

In addition to all measuring devices described above various measurements like density, viscosity, pH measurements etc. are installed.

For measuring quality standards in laboratory various laboratory instruments are also necessary.

9.2.4 Liquid Level

Liquid level detectors measure either the position of a free liquid surface above a datum level or the hydrostatic head developed by the liquid is measured.

The liquid level is measured both by direct and indirect means. Direct methods involve direct measurement of the distance from the liquid level to a datum level. Indirect method follows changing liquid surface position on bubble tube method, resistance method, radiation method, etc.

9.3 Distributed Control System (DCS)

Caprolactum production process deals with the benzene and cyclohexane which are having low boiling points. So the process is risky and also the product quality is important. Therefore for the faster control DCS can be used. It provides ease of constant monitoring the process at a distance much far away from the site and the changes can be made in the process parameters very accurately from the control room itself.

9.3.1 Merits of DCS

1. From quality point of view:

- More accuracy and reliability.
- Self-tuning of any control loop is possible, so optimization of any process is possible.

2. Management Consideration:

- Less cost of cables.
- Less cost of installation.
- Less space required.
- Less hardware required.
- Inventory information can be made available.
- Less man power is required.
- Less production cost.
- Management information can be generated at regular intervals which assist management to take decisions.

3. Operational point of view:

- Ease in operation.
- Any combination of control group, trend group, over view path can be formed.
- Because of dynamic graphic role picture of process is available.
- Easy diagnostics of trip and emergency conditions.
- Automatic logging of data is done by printer and hence eliminating weakness related human being.
- Control is available through dynamic graphics which gives feeling to operator as if he is inside the plant and controlling the process.
- Alarm systems can be regrouped to various sub groups so that operator can detect the error and causes easily.

4. Engineer's Point of view:

- Latest software is available for all types of complex function.
- Required less time for designing and detail engineering.
- Operators action can be logged which eliminates confusions in the event of plant trips and consequent analysis.
- Flexibility is available at each level of hardware and software.

9.3.2 Demerits of DCS

In present control room lot of paramagnets are seen without any intentional, efforts hence operator feels himself existing in between the information.

In case of new DCS systems, all information and data though presented in a systematic format, is hidden behind the CRT and hence to be called by operator. This requires more skill and knowledge. With acceptance of DCS, number of operators in control room decreased and hence, in case of emergency decision has to be taken by almost single handed as against group decision in present situation.

In single loop control system failure of one controller affects only one control loop, while case of DCS one component / card carries out lot of functions and hence failure of it causes failure of many loops.

This calls for very high MTBF (Mean Time Between Failures) and high degree of redundancy making such systems costly.

A limitation may be felt in operating number of control loops simultaneously in case of emergency, if adequate numbers of CRT consoles are not installed. Skilled personnel are required.

CHAPTER 10

SAFETY, HEALTH AND POLLUTION CONTROL

10.1 Safe Operations

The goal of chemical plant is not only to produce the chemicals, but to produce them safely. In the plant's chain of processes and operations, loss of control anywhere can lead to accidents and losses of life and property from hazards. Attempts should be to prevent troubles from the inspection, while designing, fabricating and operating.

Safety generally involves:

- Identification and assessments of the hazards
- Control of hazards
- Control of the process by provision of automatic control system, interlocks, alarm trips, etc.
- Limitation of the loss, by press relief, plant layout, etc.

10.2 Good Manufacture Techniques to Prevent Accidents

- **Filling drum** - Keep hose pipe little inside the drum rather than on the hole.
- **Using fuming chamber** - In laboratory while working with hazardous chemicals like H2S,
- **Reduce heat of reaction** -Add sulphuric acid to bucket full of water and not water to bucket full of sulphuric acid.
- **Opening flanges** - While opening a flange on pipeline containing corrosive liquid, chances of liquid coming out with a spray are there. To avoid accident due to such spray or acid or alkali use plastic sheet while opening valve. So that it will not contact with body.
- **Location of gauge glass** - Gauge glass for reading level in the tank should be located away from path where many people may be working.
- **Location of safety valve/ vent line** - The vent pipe should not be located in a closed area.
- **Location of flammable material** - Storage should be away from any source of flame.
- **Smoking** - Do not smoke in unauthorized area where flammable materials are likely to be present.

- **Purging with inert atmosphere** - Before entering a reactor or a distillation column containing hazardous vapours, the equipment must be purged with air/inert gas for sufficiently long time.
- **Machinery guards** - Install guards on moving machinery parts.
- **Incompatible chemicals** - Do not mix incompatible materials together.
- **Earthling of equipment** - When two phase mixture is being separated into different tanks, the tank should be earthed to avoid spark due to accumulation of static electricity.
- **Explosion due to dust** - In the operation of fine grinding, solid temperature increases which can lead to dust explosion initiated by hot metal. It can be prevented by cooling grinder with water or inert gas purging.
- **Drying and ignition of flammable liquids** - Keep air flow rate high so that air vapour mixture is not near flammable limit.
- **Mixing** - It should be effective to take care of exothermic heat of reaction.
- **Good housekeeping** - Do not store waste flammable materials near flame source.
- **Labelling of chemicals** - Label the chemicals so that they do not get mixed up with incompatible chemicals.
- **Pipetting** - Do not suck with mouth, use rubber bulb.
- **Free excess energy exit** - Do not store anything in passage way destructing free movement in emergency.

10.3 Fire Prevention and Protection

1. Regulation for the prevention of Fire:

Ban on carrying of a potential source of ignition, Ban on lighting fires in battery area. Ban on smoking. Ban on carrying lamps. Use of Spark's arrestors.

2. General Precautions:

Maintain good housekeeping. Follow the laid down procedure strictly. Sampling and draining of hydrocarbon should be done under strict supervision. Do not operate an equipment unauthorized. Use only approved type of tools. Anticipate the hazards during vessel cleaning and take prevention steps in advance.

3. Fire emergency mock drill

An emergency manual can be prepared to outline procedures and drills and detail responsibilities of each individual involved.

- Training
- Valuable Check On The Adequacy and Condition of exits and Alarm system
- In stills a sense of security among the Occupiers if Careful Plans Are Made.
- Exits Drills
- Plant Drills (Mock drills in plant area)
- Mutual Aid Drills
- On-Site / Off site Drills etc.

10.4 Safety in Process Design

Accidents are minimized by correct deign using scientific and performance data without false economy.

10.4.1 Reactor

The reactor is a heart of plant and vital for safety. Most reactions have hazard potential. Here, reaction is exothermic and at higher pressure compared to atmospheric pressure and also deals with the materials like Benzene and Cyclohexane which are highly volatile.

10.4.2 Heat Transfer

For safe operation,

- Prevent mixing.
- Provide different surface, for cleaning, insulation, expansion.
- Prevent flame travel in furnace.
- Use safety over design factor of 15 – 20 %.

10.4.3 Mass Transfer

Safe guards are,

- Prevent liquid injection and vigorous flashing in hot column.
- Provide both pressure and vacuum relief.
- Use detection and warning devices for build up of hazardous material.
- Provide thermal expansion in system.

10.4.4 Pressure Vessels

It includes,

- Corrosion allowance must be provided.
- Take care weld joint efficiency.
- Design pressure is maximum operating pressure plus static pressure plus 5 %.
- Design temperature is 25-30 ºC above maximum operating temperature.
- Use safety over design factor of 15 – 20 %.

10.4.5 Instrumentation and Safety Devices

- Thermocouple burnout, stem or cooling water failure.
- Fusible plugs to relive pressure above design value.
- Combustible gas monitor with alarms for flammable.
- Over temperature switch.

10.5 Environmental Considerations

The environmental considerations include:

- Control of all emission from the plant.
- Waste management.
- Smells.
- Noise pollution prevention.
- The visual impact.
- Liquid effluent specifications
- Environmental friendliness of the products.

10.5.1 Waste Management

Waste arises mainly as by products or unused reactants from the process, or as off specification product produced through mis-operation. In emergency situations, material may be discharged to the atmosphere through vents normally protected by bursting discs and relief valves.

10.5.2 Gaseous Wastes

It is to be remembered that practice of relying on dispersion from tall stacks is seldom entirely satisfactory. The gaseous pollutants can be very easily controlled by using adsorption or absorption. Dispersed solids can be removed by scrubbing, or ESP If the gas is flammable it is to be burnt. As in the present case the gaseous waste being carbon dioxide. But the gases should not be sent to vent or to atmosphere and hence the suitable scrubber system requires to be installed downstream to minimize pollution.

10.5.3 Liquid Waste

If the liquid effluent is flammable, it can be burnt in the incinerator. But as in this case if it contains salts; acids and substantial amount of alkali it is to be subjected to effluent treatment. Generally common effluent treatment plant (if the facility is situated in and Industrial area with the CETP) serves the purpose. The level of effluent treatment up to secondary treatment is sufficient for the effluent from the plant like one on the hard.

10.5.4 Solid Waste

Solid wastes can be burnt in suitable incinerators or disposed by burial at licensed landfill sites. Dumping of toxic solid waste should be avoided.

10.5.5 Aqueous Waste

The principle factors which determine the nature of an aqueous industrial effluent and on which strict controls will be placed by responsible authority are:

- pH
- Suspended solids
- Toxicity
- Biological oxygen demand

For the present case pH of the effluent stream is expected to be alkaline and hence addition of acids is recommended to neutralize the same. The suspended solids can be removed by settling, using Chemical treatment may be given to remove some of the chemicals.

Oxygen concentration in waste course must be maintained at a level sufficient to support aquatic life. For this reason the biological oxygen of an effluent is of paramount importance. Standard BOD 5 tests can be applied for the determination of the same. The test measures the quantity of oxygen which a given volume of effluent will absorb in 5 days at constant temperature of 20 0C. It is a measure of the organic matter present in the effluent. Ultimate oxygen demand test can be performed if required.

Waste water should be discharged into sewers with the agreement of the local water pollution control authorities or state pollution control boards.

10.5.6 Noise

Noise can cause serious nuisance in the neighbourhood of a process plant. Care need to be taken when selecting and specifying equipment such as compressors, air-cooler fans, induced and force draft fans for furnaces, and other noisy plant. Excessive noise can also be generated when venting through steam and other relief valves, and from flare stacks. Such equipment should be fitted with silencers. Noisy equipment should be as far away from the site boundary.

10.5.7 Visual Impact

The appearance of the plant should be considered at the design stage. Few people object to fairyland appearance of a process plant illuminated at the night, but it is different scene at daytime. There is little that can be done to change the appearance of modern style plant, where most of the equipment and piping will be outside and in full view but some steps should be taken to minimize the visual impact.

10.5.8 Environmental Auditing

The company should go for a systematic examination of how a business operation affects the environment. It will include all emissions to air, land and water and cover the legal constraints the effect on the community the landscape and the ecology.

Following are some of the objectives of the environmental audit:

- To identify environmental problems associated with the manufacturing process and the use of the products before they become liabilities.
- To develop standards for good working practices.
- To ensure compliance with environmental legislation.
- To satisfy requirements of insurers.
- To be seen to be concerned with environmental questions: important for public relation
- To minimize the production of waster: an economic factor

CHAPTER 11

SITE SELECTION AND PLANT LAYOUT

11.1 Site Selection

The geographical location of the final plant can have a strong influence on the success of an industrial venture. Much care must be exercised in choosing the plant site and many different factors must be considered. Primarily the plant should be located where the minimum cost of production and distribution can be obtained. The Location of the plant can have a crucial effect on the profitability of a project, and the scope for future expansion. Many factors must be considered.

An appropriate idea as to the plant location has to be obtained before a design project reaches the detailed estimate stage. A firm location established upon the completion of detailed estimate design. The factors which are considered for choosing a plant size are:

11.1.1 Raw Material

One of the main factors is the availability and price of suitable raw materials which often determines the site location. Plants producing bulk chemicals are best located close to the source of the major raw material; where this is also close to the marketing area.

11.1.2 Market

It affects the cost of product and market distribution and time for shipping nearby market for by-product as well as the final products.

11.1.3 Energy Availability

Power requirements and steam requirement are high in most industries and fuel or electricity is required to supply the utility.

11.1.4 Climate

Extreme hot and cold weather and excessive humidity can have a serious effect on the economic operation of the plant.

11.1.5 Transportation Facilities

Water, Rail Roads and highways are the common means of transportation used by means of transportation used by many industrial concerns. The kind of raw material and production determine the most kind of transportation. A site should have access to at least two modes of transport between the plant and main office and transportation facilities for employees are also desirable.

11.1.6 Water Supply

The process industries use large quantities of water for cooling, washing, steam generation and as well as raw material. The plant therefore requires a dependable supply of water. The temperature, mineral content, silt or sand content, bacteriological content and cost for the purification treatment must also be considered when choosing a water supply.

11.1.7 Water Disposal

The site selected for a plant should have adequate capacity and facilities for effective waste removal.

11.1.8 Labour Supply

The type and supply of labour availability in the vicinity of a proposed plant site is to be examined.

11.1.9 Taxation and Legal Restrictions

State and local tax rate on property, income, unemployment, insurance and similar items various from location to another. Similarly local regulations on zone building codes and effects. Transportation facilities also affect the final choice of plant site.

11.1.10 Site Characteristics

The site characteristics of topography and structure must be considered also land, building cost, expansion area should also be considered.

11.1.11 Flood and Fire Protection

The risk to floods, hurricane, and earthquakes should be accessed. Fire department should be nearby and loss fire hazards should be there.

11.1.12 Community Factors

The character and facilities of a community also affects the location of the plant. We have selected the upper western coastal Region and Northern Plains because of the above reasons.

The industrial possibilities near Moradabad has to be assessed not only based on the resources and demand prospects within the region but on a broad frame work of agricultural products and other resources coming to the main market in the city from the other states where there is very limiting storing and marketing facilities.

Scope for setting up industries near Moradabad has not been very inspiring. Emission of gases, near residential area is not tolerated by the pollution control board. More over with ever increasing land price, of setting up citric acid plant near the city would increase the fixed capital enormously.

11.2 Government Industrial Policies 2011

11.2.1 Industrial Policy

The Government's liberalization and economic reforms program aims at rapid and substantial economic growth, and integration with the global economy in a harmonized manner. The industrial policy reforms have reduced the industrial licensing requirements, removed restrictions on investment and expansion, and facilitated easy access to foreign technology and foreign direct investment.

11.2.2 Industrial Licensing

All industrial undertakings are exempt from obtaining an industrial license to manufacture, except for

1. Industries reserved for the Public Sector (Annex I),

2. Industries retained under compulsory licensing (Annex II), 3. Items of manufacture reserved for the small scale sector and

4. If the proposal attracts location restriction.

11.2.3 Industrial Entrepreneurs Memorandum

Industrial undertakings exempt from obtaining an industrial are required to file an Industrial Entrepreneur Memoranda (IEM) in Part „A" (as per prescribed format) with the Secretariat of

Industrial Assistance (SIA), Department of Industrial Policy and Promotion, Government of India, and obtain an acknowledgement. No further approval is required.

11.2.4 Location Policy

Industrial undertakings are free to select the location of a project. In the case of cities with population of more than a million (as per the 1991 census), however, the proposed location should be at least 25 KM away from the Standard Urban Area limits of that city unless, it is to be located in an area designated as an „"industrial area"" before the 25th July, 1991. (List of cities with population of 1 million and above is given at Annexure-V).

11.2.5 Policy Relating to Small Scale Undertakings

An industrial undertaking is defined as a small scale unit if the investment in fixed assets in plant and machinery does not exceed Rs. 10 million. The small scale units can get registered with the Directorate of Industries/District Industries Centre in the State Government concerned. Such units can manufacture any item including those notified as exclusively reserved for manufacture in the small scale sector. Small scale units are also free from locational restrictions cited in paragraph 1.3 above. However, a small scale unit is not permitted more than 24 per cent equity in its paid up capital from any industrial undertaking either foreign or domestic.

11.2.6 Environmental Clearances

Entrepreneurs are required to obtain Statutory clearances relating to Pollution Control and Environment for setting up an industrial project. A Notification (SO 60(E) dated 27.1.94) issued under The Environment (Protection) Act, 1986 has listed 30 projects in respect of which environmental clearance needs to be obtained from the Ministry of Environment, Government of India. This list includes industries like petrochemical complexes, petroleum refineries, cement, thermal power plants, bulk drugs, fertilizers, dyes, paper etc. However, if investment is less than Rs. 1000 million, such clearance is not necessary, unless it is for pesticides, bulk drugs and pharmaceuticals, asbestos and asbestos products, integrated paint complexes, mining projects, tourism projects of certain parameters, tarred roads in Himalayan areas, distilleries, dyes, foundries and electroplating industries.

11.2.7 Government Approval

Proposals attracting compulsory licensing

1. For the following categories, Government approval would be necessary:

(b) Items of manufacture reserved for the small scale sector

(c) Proposals involving any previous joint venture or technology transfer/trademark agreement in the same or allied field in India. The definition of „"same"" and „"allied"" field would be as per 4 digit NIC 1987 Code and 3 digit NIC 1987 Code.

(d) Extension of foreign technology collaboration agreements (including those cases, which may have received automatic approval in the first instance)

(e) Proposals not meeting any or all of the parameters for automatic approval as given in para

The items of foreign technology collaboration, which are eligible for approval through the automatic route, and by the Government, are technical knowhow fees, payment for design and drawing, payment for engineering service and royalty.

Table12.1: Details of Selected agencies/ Department involve with various clearance/ Approvals & their website

Subject Matter	Concerned Ministry/Department of Govt. of India	Website address
Registration as a company & certificate of commencement of business	Department of Company Affairs (Registrar of Companies)	http://dca.nic.in
Approval for foreign collaboration & Technology Transfer: (i) Automatic route (ii) Government approval (FIPB)	Reserve Bank of India Department of Economic Affairs	http://www.rbi.org.in http://finmin.nic.in
Matters relating to FDI policy and its promotion and facilitation as also promotion and facilitation of investment by Non- resident Indians (NRIs) and Overseas Corporate Bodies (OCBs)	Department of Industrial Policy & Promotion	http://dipp.nic.in
Matters relating to Foreign Exchange	Reserve Bank of India	http://www.rbi.org.in
Matters relating to Taxation Matters relating to Direct Taxation Matters relating to Excise & Customs	Department of Revenue Central Board of Direct Taxes Central Board of Excise & Custom	http://finmin.nic.in http://incometaxindia.gov.in http://www.cbec.gov.in
Matters relating to Industrial Relations	Ministry of Labour	http://labour.nic.in
Import of Goods	Directorate General of Foreign Trade	http://dgft.delhi.nic.in
Matters relating to Environment & Forest clearance	Ministry of Environment and Forests	http://envfor.nic.in
Overseas investment by Indians	India Investment Centre, Department of Economic Affairs	http://iic.nic.in
Allotment of land/Shed in Industrial areas, acquisition of land, change in land use, approval of building plan, release of water connection etc.	Concerned Departments of State Governments	Click on 'State Policies' of the website – http://dipp.nic.in

11.3 Plant Layout

Plant layout must have arrangement for processing area and sewage area, in efficient coordination and with regard to such factor as

1. New site development
2. Future expansion plan
3. Economic distribution of service water, process steam and power
4. Weather condition: if amendable to outdoor construction

5. Safety consideration: possible hazards of fire, explosion and fumes
6. Waste disposal

The layout should be such that the very aim of effective construction planning and solving in engineering design construction, operating and maintenance cost is achieved.

11.3.1 Roadways

For multi-purpose service following factors must be taken in account

1. A means for intersection movement for road traffic both prod strain and vehicular.
2. Routing of heavy traffic outside the operation area.
3. Roadways for access to initial construction, maintenance and repair points.
4. Roadways to isolated points, storage tanks and safety equipments.

11.3.2 Utilities Services

Distribution of water, steam, power and electricity is not always a major item, in as much as flexibility of distribution of these services permit design to meet almost any condition. But a title regard for proper placement each of these services, adds in case of operation, order lines and reduction in cost of maintenance.

11.3.3 Storage

Hazardous material becomes a decided means to life and property when stored in large quantities and should consequently isolated arranging storage of material so as to facilitate or simply handling is also a point to be considered in design. Besides, a great deal of planning layout is governed by local and national safety fire code requirements. Expansion must always be kept in mind. Selection of building and floor space are also points to be considered in designing layout.

11.4 Equipment Layout

In making layout, sample space should be assigned to each piece of equipment, accessibility i9s an important factor for maintenance unless a process is well seasoned, it is not always possible to predict just how its various units may change in order to be in harmony with each other it is well known that in chemical manufacturing processes may be adopted which may be appear to be sound after reasonable amount of investigations in pilot plant stage yet frequently require minor or even major changes before all parts are properly operating together.

11.5 Plant Layout Diagram

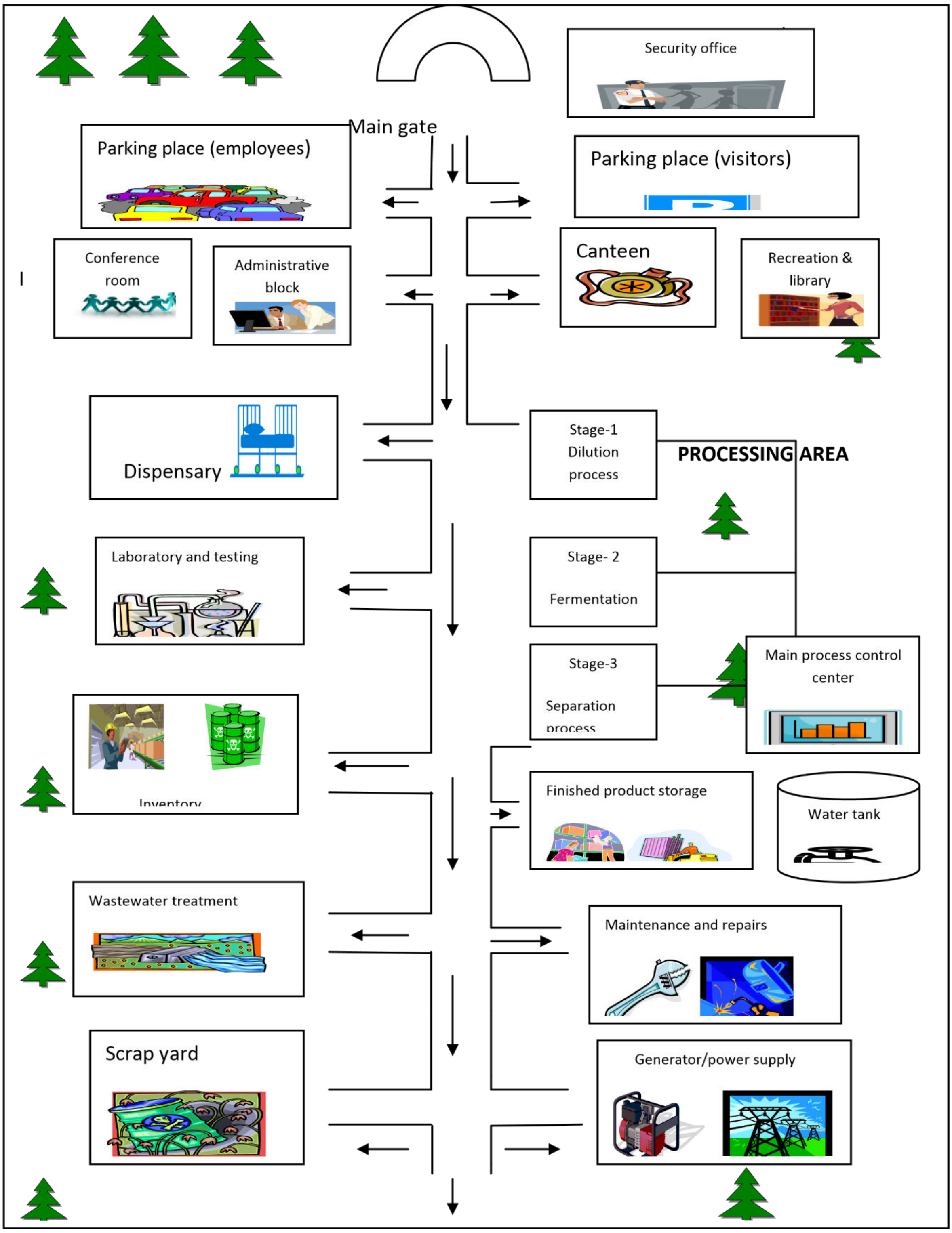


Fig 12.1 Plant Layout Diagram

CHAPTER 12

PLANT ECONOMICS AND PROFITABILITY

12.1 Equipment Estimation

TABLE 12.1 EQUIPMENT COST

ITEM NAME	NO. OF ITEM	PURCHASING COST($)
MIXING TANK	1	564,600
FURNACE	1	16770
HEAT-EXCHANGER	5	150000
PRESSURE VESSEL	1	56000
DISTILLATION COLUMN	2	1596000
MOLECULAR SIEVES	1	2746200
TOTAL PURCHASING EQUIPMENT COST		5129570

12.2 Estimation of Total Capital Investment Cost

12.2.1 Direct Costs

Material and labor involved in actual installation of complete facility (70-85% of fixed-capital investment) and Equipment cost + installation cost + instrumentation cost + piping cost + electrical cost + insulation cost + painting cost (50-60% of Fixed capital investment)

a. Purchased equipment cost = $ 5129570

b. Installation, including insulation and painting

Range = 25 – 55 % of PEC

Let Installation Cost = 40 % of PEC

= 40 % of $ 5129570

= $ 2051828

c. Instrumentation and controls installation cost

Range = 6 – 30 % of PEC

Let Instrumentation Cost = 15 % of PEC

= 10 % of $ 5129570

= $ 512957

d. Piping Installation cost

Range = 10 – 80 % of PEC

Let Piping Cost = 40% of PEC

= 40% of $ 5129570

= $ 2051828

e. Electrical installation cost

Range = 10 – 40 % of PEC

Let Electrical cost = 25% of PEC

=25 % of $ 5129570

=$ 1282393

f. Buildings, process and Auxiliary

Range = 10 – 70 % of PEC

Let Buildings, process and auxiliary cost = 30% of PEC

= 30 % of $ 5129570

= $ 1538871

g. Service facilities and yard improvement cost

Range = 40 – 100 % of PEC

Let Facilities and yard improvement cost = 62 % of PEC

=62 % of $ 5129570

= $ 3180333.4

h. Land cost Range = 3 – 7 % of PEC

Let the cost of land = 5 % of PEC

= 5% of $ 5129570

=$ 256478.5

Therefore, Total Direct Cost = $ 16004258.9

12.2.2 Indirect costs

Expenses, which are not directly involved with material and labour of actual installation of complete facility (15-30% of Fixed-capital investment)

a. Engineering and Supervision

Range = 5 – 30 % of DC

Let the cost of engineering and supervision = 10 % of DC

=10% of $ 16004258.9

= $ 1600425.89

b. Construction Expenses

Range = 6 – 16 % of DC

Let construction expense = 10 % of DC

= 10 % of $ 16004258.9

= $ 1600425.8

c. Contractor's fee Range = 2 – 6 % OF DC

Let the contractor's fee = 4 % of DC

= 4 % of $ 16004258.9

= $ 640170.35

d. Contingency cost

Range = 5 – 15 % of DC

Let the contingency cost = 10 % of DC

= 10 % of 16004258.9

= $ 1600425.89

Thus, Total Indirect Costs = $ 5441447.93

12.2.3 Fixed Capital Investment

Fixed capital investment = Direct costs + Indirect costs

= 16004258.9 + 5441447.93

s

Fixed capital investment = $ 21445706.8

12.2.4 Working Capital

Range = 10 – 20 % of TCI

Let the Working Capital = 15 % of TCI

$\Rightarrow$

$\Rightarrow$

We know that TCI = FCI + WC

TCI = FCI + 0.15 TCI

TCI = $^{FCI}/_{5}$ = $183.38^{10^5}/_{0.85}$

TCI = $ 24662562.82

Hence, WCI = 15% of 21445706.8

= **$ 3216856.02**

Working Capital

12.2.5 Total Capital Investment

Total capital investment = FCI + WCI

= 21445706.8 + 3216856.02

Total capital investment = **$ 24662562.82**

12.3 BREAK DOWN OF TOTAL CAPITAL INVESTMENT

Component	% of TCI	Cost ($)	Cost (INR)
Purchased equipment cost	20.01	5129570	297515060
Purchased equipment installation	0.791	2051828	119006024
Purchased equipment insulation	.0791	2051828	119006024
Purchased equipment instrumentation and control	3.001	512957	29751506
Piping Installation	.0791	2051828	119006024
Electrical installation	5.026	1282393	74378794
Building, Process & Auxiliary Cost	6.0031	1538871	89254518
Service facilities	12.406	3180333.4	184459337.2

1Land	1.005	256478.5	14875753
Direct cost	**63.0433**	**16004258.9**	**9282470162**
Engineering and supervision	6.343	1600425.8	928224696.4
Construction expense	6.343	1600425.8	92824696.4
Contractor fees	2.5373	640170.35	37129880.3
Contingencies	6.343	1600425.81	92824696.98
Indirect cost	**21.567**	**5441447.93**	**315603979.9**
Fixed Capital Investment	85.00	21445706.8	1243850994
Working Capital Investment	15.00	3216856.02	186577649.2
Total Capital Investment	**100**	**24662562**	**1430428596**

12.4 ESTIMATION OF TOTAL PRODUCT COST

12.4.1 Fixed Charges

a. Depreciation

Depends on life period, salvage value and method of calculation-about 10 % of FCI for machinery and equipment and 2 – 4 % for Building Value for Buildings

Depreciation = 10 % of FCI for machinery & equipment + 2.5 % of BPA for building Value for Buildings

= 10 % of $21445706.8 + 3 % of $1538871

= $ 2190736.81

b. Local Taxes Range = 2 – 4 % of FCI

Consider the local taxes = 3 % of FCI

=3 % of $ 21445706.8

= $ 643371.204

c. Insurances Range = 0.4 – 1 % of FCI

Consider the Insurance = 0.7 % of FCI

= 0.7 %of 21445706.8

= $ 1501199.47

d. Rent Range = 8 – 12 % of value of land & building

Consider rent = 10% of (LC + BPA)

=10 % of (256478.5+1538871)

= $ 179534.95

Thus, Total Fixed Charges

= $ 4514842.434

12.4.2 Direct Production Cost

a. Raw Materials (for 1 year stock)

Purchasing and storing cost = $ 4.861 kg

Total Raw material cost

$$= \frac{Raw\ material\ used\ (kg)}{hour} \times \frac{Total\ working\ hours}{day} \times \frac{Total\ working\ days}{year} \times \frac{Purchasing\ and\ storing\ cost\ (\$)}{kg}$$

$$= \frac{3300\ kg}{hour} \times \frac{24\ hour}{day} \times \frac{335\ day}{year} \times \frac{4.861}{kg}$$

= $ 128972052

b. Operating Labour (OL) Range = 40 – 60 % of RMC

Consider the cost of operating labour = 50 % of RMC

=50 % of $ 128972052

=$ 64486026

c. Direct Supervisory and Clerical Labour cost

Range = 10 – 15 % of OL

Consider direct supervisory and clerical labour cost

= 12 % of OL

Direct supervisory and clerical labour cost = 12 % of $ 64486026

=$ 7738323.12

d. Utilities cost Range = 60 – 100 % of OL

Consider the cost of Utilities = 80 % of OL

Utilities cost =80 % of $ 64486026

= $ 51588820.8

e. Maintenance and repairs costs

Range = 2 – 8 % of OL

Consider the maintenance and repair cost = 5 % of OL

Maintenance and repair cost = 5 % of $ 64486026

=$ 3224301.3

f. Operating Supplies cots Range = 10 – 20 % of M & R

Consider the cost of Operating supplies = 15 % of M & R

Operating supplies cost = 15 % of $ 2931183

=$ 483645.195

g. Laboratory Charges Range = 10 – 20 % of OL

Consider the Laboratory charges = 15 % of OL

Laboratory charges = 15 % of $ 64486026

= $ 9672903.9

h. Patent and Royalties Range = 1/3 of OL

Patent and Royalties costs = 1/3 of $ 64486026

= $ 21495342

Thus, Direct Production Cost = $ 287661414.3

12.4.3 Plant overhead Costs

Range = 50 – 70 % of OL, DS & CL and M&R

Plant overhead cost includes the following: general plant upkeep and overhead, payroll overhead, packaging, medical services, safety and protection, restaurants, recreation, salvage, laboratories, and storage facilities.

Consider the plant overhead cost = 60 % of (OL + DS&CL + M&R)

Plant overhead cost = 60% of $ (64486026+7738323.12 +3224301.3)

= $ 75448650.42

Thus, Manufacturing cost = DPC + FC + POC

Manufacture cost = 287661414.3+4514842.434 +75448650.42

Manufacture cost = $367624907.2

12.4.4 General Expenses

a. Administrative costs Range = 40 – 60 % of OL

Consider the Administrative costs = 50 % of OL

Administrative costs = 50 % of $64486026

= $ 32243013

b. Distribution and Selling costs

Range = 2/3 of OL

Includes costs for sales offices, salesmen, shipping, and advertising.

Distribution and selling costs = 2/3 of $ 58623660

=$ 42990684

c. Research and Development costs

Range = 15 – 25 % of OL

Let the Research and development costs = 20 % of OL

Research and Development costs = 20 % of $ 64486026

= $ 12897205.2

d. Financing (interest) charges

Range = 0 - 10 % of TCI

Consider interest = 5 % of TCI

Interest = 5% of $24662562

= $ 12331281

Thus, General Expenses = $ 100462183.2

12.4.5 Total product cost

Total product cost= Manufacture cost + General Expense

= 367624907.2+100462183.2

Therefore Total product cost = $ 468087090.4

12.5 Estimation of Profitability

12.5.1 Total selling cost

Total selling income = Sum of total selling price of all by products and product

There is main product is Propylene and remaining are the butane& ethylene both are recycle to feed stream.so there is no by-product which can be selling out .

12.5.2 Total selling price of propylene

As we know Propylene production plant operates only 335 days in a year and the production of propylene per hour is 3300 kg/hr (from material balance). The working hours per day are 24.

Total selling price = $\frac{propylene\ produced(kg)}{hour} \times \frac{total\ working\ hour}{day} \times \frac{total\ working\ day}{year} \times \frac{selling\ cost(\$)}{kg}$

$$= \frac{3300}{hour} \times \frac{24}{day} \times \frac{335}{year} \times \frac{1}{kg}$$

Total selling price of Propylene = $ **26532000**

12.6 Gross Profit

Gross profit	=	Total Income – Total Product Cost
	=	26532000–468087090.4
Gross profit	=	441555090.4

12.7 Taxes

50 % of the gross income is payable to Govt. of India

Taxes	=	50 % 441555090.4
Taxes	**=**	**$ 220777545.2**

12.8 Net Profit

Net Profit	=	Gross income □ Taxes
	=	441555090.4 - 220777545.2

Net profit = 220777545.2

12.9 Rate of Return

$$\text{Rate of return} = \frac{Net\ Profit}{Total\ Capital\ Investment} \times 100$$

$$\text{Rate of return} = \frac{220777545.2}{24662562} \times 100$$

Rate of Return = 8.95 %

12.10 Pay Out Period

Payout period is defined as the minimum length of time theoretically necessary to recover the original capital investment in the form of cash flow to the project. Payout period = Total capital investment/net profit

12.11 Break-Even Point

Pay out Period = .11 years

Assumption: We are selling 100 % products.

Production per year (n)

= (Sum of plant overhead cost +Depreciation+ General expenses)/(14.5-4.55)

= (75448650.42+(1884020 +100462183.2)/(14.5-4.55)

= 17868829.51 kg

Breakeven point = (n/Total production)*100

= (17868829.51/3300/1000)*100

= 54.14% of capacity

Break-Even Point = 54.14 %

I.e. When the 54.14 % of product units are sold than break-even point will achieved. And after selling more product units the profit will start to be gained by the plant

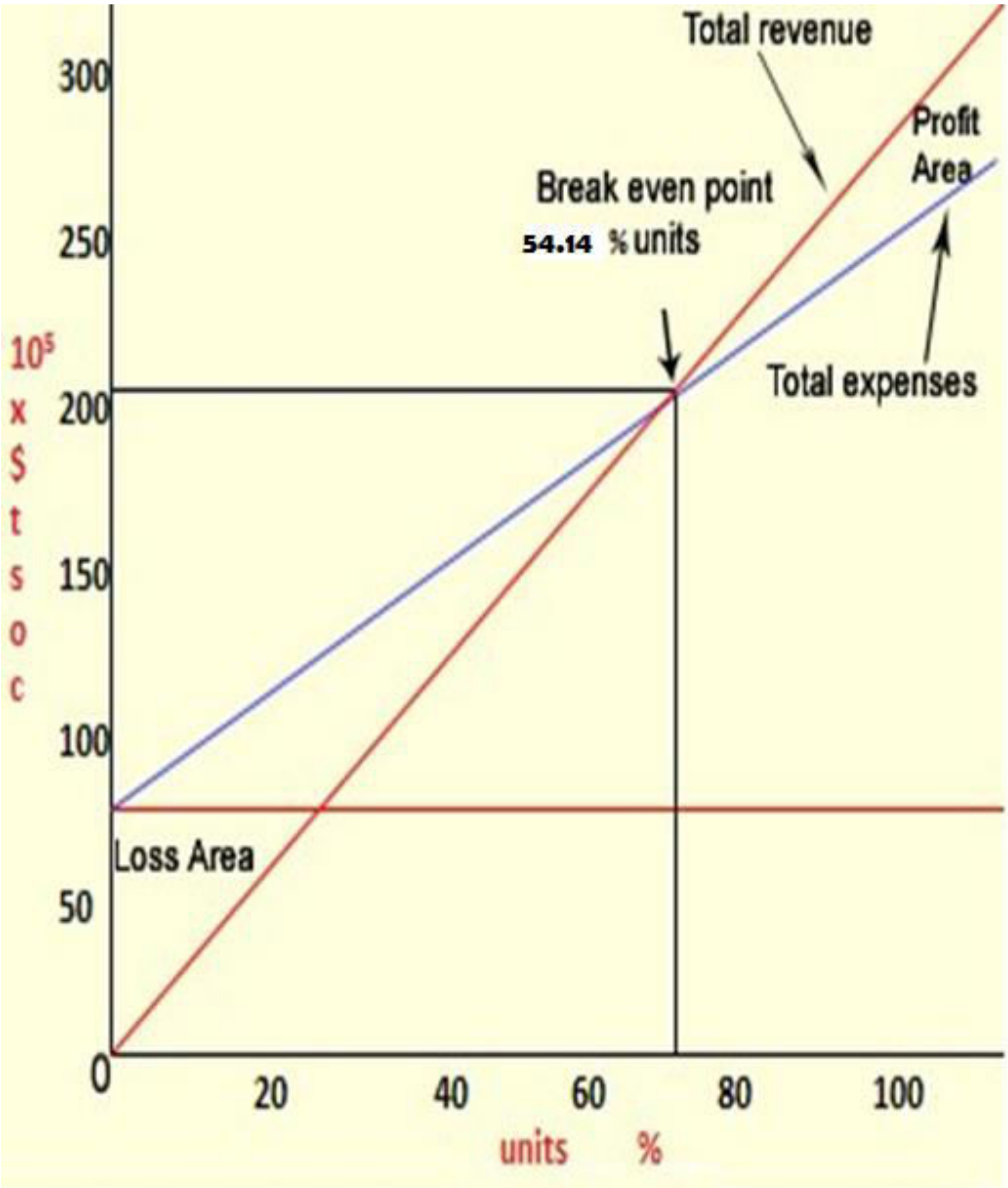


Fig 12.2 Break Even Graph

12.12 Cash Flow Chart

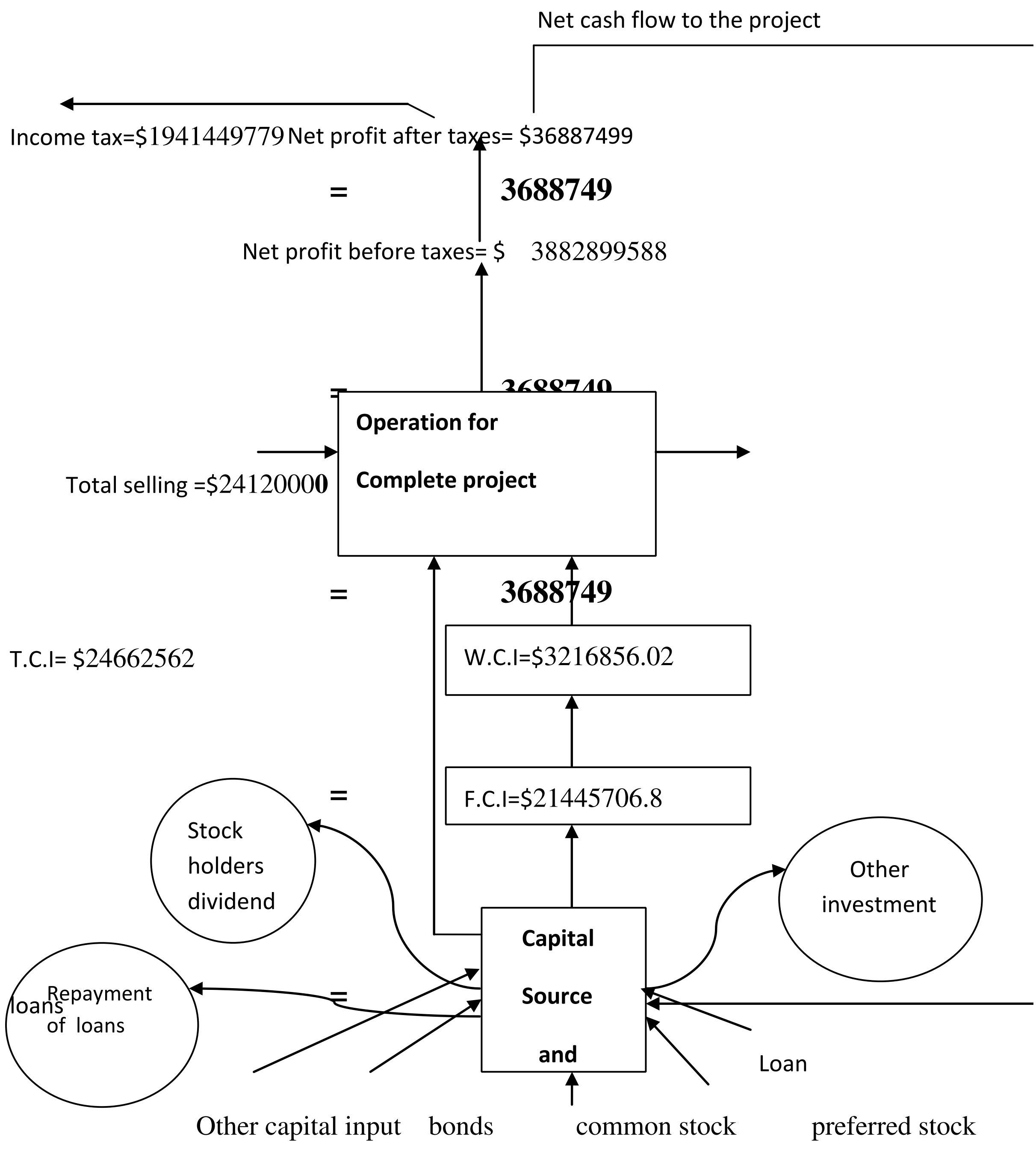


Fig 12.3

CHAPTER 13
ORGANIZATION STRUCTURE AND MAN POWER REQUIREMENT

13.1 ORGANIZATION STRUCTURE AND MAN POWER REQUIREMENT

Table 13.1 Man Power Requirement

POST	QUANTITY	SALARY(INR/MONTH)
General Manager	1	160000
Managing Director	1	135000
General Engineer	1	110000
Deputy General Manager	1	124000
Administrative Director	1	115000
Production Director	2	96000
Supply Manager	1	54000
Sales Manager	1	47000
Assistant Sales Manager	2	34000
HR Manager	1	72000
Chief Financial Officer	1	83000
Cashier	2	14000
GL Accountant	2	11000
Procurement Director	1	25000
Plant Superintendent	1	41000
Accountant In Charge	1	13500

Maintenance Superintendent	1	34000
Trainee Specialist	1	27000
HOD Chemical Section	1	83000
Chemical Engineer	9×3	36000
Chemical Operator	18×3	18000
HOD Mechanical Section	1	83000
Mechanical Engineer	16×3	36000
Mechanical Operator	16×3	18000
HOD Electrical Section	1	83000
Electrical Engineer	7×3	36000
HOD Fire & Safety	1	83000
Civil Engineer	14×3	36000
Transportation Supervisor	2	20500
Chemist	3×3	18000
Mechanic	3×3	18000
Electrician	2×3	16000
Fitter	2×3	12000
Labors	20×3	7000
Security Head	1×3	8000
Security Guard	24×3	5000
TOTAL EMPLOYEE	**434**	**1748000**

13.2 ORGANIZATION STRUCTURE

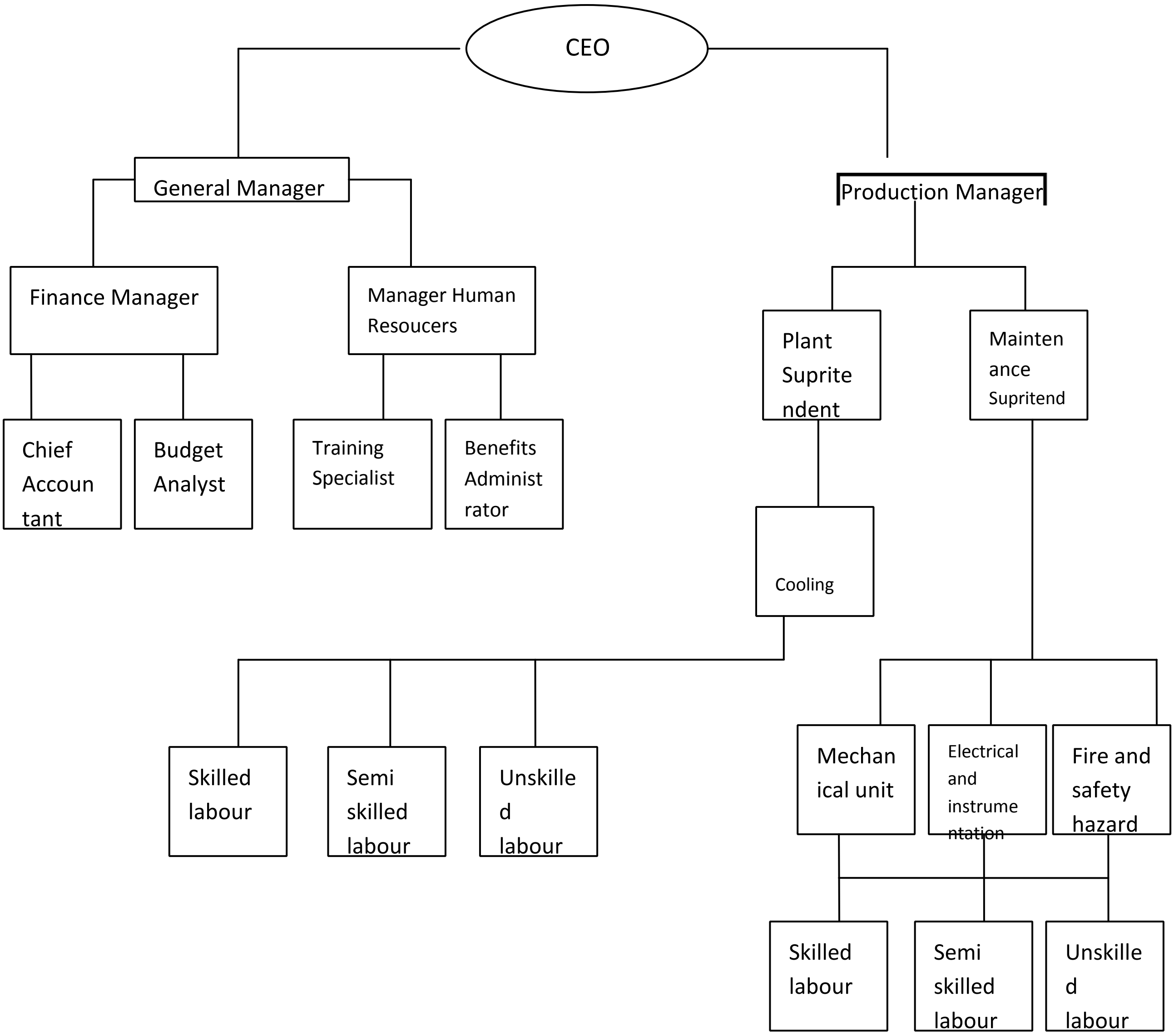


Fig: 13.1 Organization Structure

CHAPTER 14

CONCLUSION

Plant design is collaborative effort by the design and engineering firm with the plant owners to optimize the yield, mass balance and integration with existing or new feed stock facilities. It is unlikely any new plant will be constructed as "stand alone" facilities. This allows optimization of feed stock and product storage and integration with transportation and utilities.

A continuous plant leads to better heat economization, better product purity from phase separation by removing only the portion of the layer furthest from the interface, better recovery of Propylene in order to save on Propylene cost and regulatory issues, minimal operator interference in adjusting plant parameters, and lower capital cost per unit of Propylene produced.

The trend is towards large Facilities instead of small. As with almost any process industry, a large plant is more efficient than a small plant due to "economy of scale". Based on contemporary production processes and using current best values for equipment, and supply costs employed to estimate the capital and production costs for the production of Propylene from Butene and Ethyelene by Metathesis Process. It is not meant to replace the thorough engineering analysis that is required in the final design and construction of such a plant, but rather is meant for use as a tool in estimating capital and operating costs. The model is flexible, and is meant for use in assessing the effects on estimated Propylene production cost of changes in feed stock in chemical or process technology employed, or in equipment specified for the facility.

Feed to the Propylene production should be as consistent as possible. The best feed stock for Ethylene & Butene plant would be provide feed. The safety of the process has been somewhat challenging not because it is not known how to make the process safer, but because of determining what is actually necessary for plant safety from the processor's point of view.

While working on the project, I achieved practical and thought full knowledge regarding various aspect of chemical engineering subject. This project work is a milestone for me as it has increased my knowledge. According to my point of view, it is compulsory for every student as it has enhanced knowledge which will be helpful in my future. I came to know what's the exact work us in chemical industry.

The production of Propylene from Metathesis Process is a bone to many industries used for many purposes. The growing demand of Propylene has evoked the demand for Ethylene &

Butene-l at much medium rate. Ethylene & Butene both are the other industry product which is a cheap raw material compare to other raw material for the production of producing of Propylene-l. The profitability analysis proves the project to be economically visible for industries to setup such a plant as it would yield Propylene at a cheaper rate compare to availability of Ethylene and Butene.

REFERENCES

1. Perry, R.H. & Green, D.W., "Perry"s chemical engineers" Handbook.
2. Doe. N., "Control system principles", John Wiley, N.Y. (1999).
3. Martyn S..Ray; David W. Johnston-chemical engineering design project: A case study Approach (1998).
4. Luyben, process modeling, simulation, and control for chemical engineers, Mc. Graw Hill international edition (1996).
5. Reid, Prausnitz, and Sherwood, "The properties of gases and liquids" Mc Graw Hill international edition (2003).
6. "Biofuels and Glycerol." The Glycerol Challenge. 30 Mar 2009 <http://theglycerolchallenge.org/>.
7. "Cap and Trade 101." 16 January 2008. Center for American Progress. 5 April 2009
8. <http://www.americanprogress.org/issues/2008/01/capandtrade101.html>.
9. "Chemical Economics Handbook." SRI Consulting. 2009. 5 April 2009
10. <http://www.sriconsulting.com/CEH/>.
11. Czarniak, Michelle, Elisa Lau and Candice McLeod. The Capture and Sequestration of Carbon Dioxide.
12. Philadelphia: Penn Press, 2008.
13. "Disposables in Bioprocessing, Corn to Ethanol Conversion, Biodiesel Production, etc." 2008. Intelligen,
14. Inc. 5 April 2009 <http://www.intelligen.com/literature.shtml>.
15. Dharmadi, Y., A. Murarka, and R. Gonzalez. "Anaerobic Fermentation of Glycerol by Escherichia Coli: A
16. New Platform for Metabolic Engineering."Wiley InterScience; New York. 20 May 2006.
17. "Economy-wide Cap-and-Trade Proposals in the 110th Congress." 30 January 2008. Pew Center on