CONFIGURATION OF VARIOUS PROCEDURES INVOLVED IN PRODUCTION OF CUMENE

Submitted in partial fulfillment of the requirements for the award Of

Bachelor of Technology degree in Chemical Engineering

By

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DEPARTMENT OF CHEMICAL ENGINEERING

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SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)
Accredited with Grade "A" by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119

APRIL – 2021

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **JACK J RICHARDS(37190023)** who carried out the project entitled **“CONFIGURATION OF VARIOUS PROCEDURES INVOLVED IN PRODUCTION OF CUMENE”** under our supervision from October 2020 to April 2021.

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Submitted for Viva voce Examination held on

Internal Examiner **External Examiner**

DECLARATION

I JACK J RICHARDS(Reg.No.37190023) hereby declare that the Project Report entitled "CONFIGURATION OF VARIOUS PROCEDURES INVOLVED IN PRODUCTION OF CUMENE" done by us under the guidance of Dr. J. ARAVIND KUMAR M.E,PH.D., at Sathyabama Institute of Science and Technology, Jeppiaar nagar, Rajiv Gandhi Salai, Chennai-600 119 is submitted in partial fulfillment of the requirements for the award of Bachelor of Technology degree in Chemical Engineering.

SIGNATURE OF THE CANDIDATE

DATE:

PLACE:

ACKNOWLEDGEMENT

I am pleased to acknowledge our sincere thanks to the Board of Management of **SATHYABAMA** for their kind encouragement in doing this project and for completing it successfully. We are grateful to them.

I convey our thanks to **Dr. S. SATHISH, M.E., Ph.D.,** and **Dr. D. PRABHU, M.S., Ph.D.,** Head of the Department, **Department of Chemical Engineering** for providing us necessary support and details at the right time during the progressive reviews.

I would like to express our sincere and deep sense of gratitude to our Project Guide **Dr. J. ARAVIND KUMAR M.E., Ph.D., Department of Chemical Engineering** for her valuable guidance, suggestions and constant encouragement paved the way for the successful completion of our project work.

I wish to express our thanks to all Teaching and Non-teaching staff members of the Department of Chemical Engineering who were helpful in many ways for the completion of the project.

ABSTRACT

To produce 1000 tons of Cumene per day, it is conveyed out by the interaction of response of Benzene and Propylene. The principle reaction combined with a side response. A special unit operation is done where catalytic distillation is combined with fractionation. This distillates and gives high quality Cumene that gets stored in the internal floating roof tank.

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CHAPTER 1

INTRODUCTION

Cumene is also called as isopropyl benzene, which is a natural compound and furthermore aromatic hydrocarbon. It comprises of unrefined petroleum.It is a combustible fluid. Practically cumene created is changed over cumene hydro-peroxide, an amalgamation of synthetics like phenol and $(CH3)_2CO$. Cumene might be utilized to build high efficient fuels, however essential used as feedstock for assembling phenol(C_6H_5OH) and $(CH3)_2CO$. Cumene synthesis was portrayed in 1841. The utilization of aluminum chloride to alkylate benzene was accounted for by Radziewanowski in 1892. Before the advancement of the cumene course to phenol and $(CH3)_2CO$, Cumene was utilized widely during World War II as fuel. Right now, more than 80% of the produced substance is created by utilizing zeolite catalyst. First cycles utilizing zeolite based impetus framework were created in the last part of the 1980s.

1.1 PROPERTIES OF CUMENE:

Cumene is insoluble in water ,is colorless and soluble in alcohol, ether and benzene.

1.1.1 Physical Properties

Table 1.1 Physical properties of cumene

PROPERTY	VALUE
MW	120.19
BP, ºC	152.39
FP, ºC	-96.03
Density, gm/cm^3	
0ºC	0.8786
20ºC	0.8169
40ºC	0.8450
Thermal conductivity, w/m.k	
25ºC	0.124
Viscosity, mPa.s (cp)	
0ºC	1.076
20ºC	0.791
40ºC	0.612
Surface tension, mN/m	
20ºC	0.791
Flash point, ºC	44
Autoignition temperature, ºC	523
Antoine Constants	
A	13.99
B	3400
C	207.78

1.1.2 Thermodynamic Properties

Table 1.2 Thermodynamic properties of cumene

PROPERTY	VALUE
Relative molarmass	120.2
Criticaltemperature, ºC	351.4
Criticalpressure, Kpa	3220
Criticaldensity, g/cm^3	0.280
Heatofvaporization at bp, J/g	312
Heatofvaporization at 25ºC, J/g	367

1.1.3 Chemical Properties

1. Cumene oxidizes to cumene hydroperoxide in the presence of Oxygen/Air.

$$\underset{\text{Cumene}}{C_6H_5CH(CH_3)_2} + \underset{\text{Oxygen}}{O_2} \longrightarrow \underset{\text{Cumene Hydroperoxide}}{C_6H_5C(CH_3)_2OOH}$$

2. Cumene Hydroperoxide gives Phenol and Acetone by catalytic reaction in the presence of dil. H_2SO_4 .

$$\underset{\text{Cumene Hydroperoxide}}{C_6H_5C(CH_3)_2OOH} \longrightarrow \underset{\text{Phenol}}{C_6H_5OH} + \underset{\text{Acetone}}{CH_3COCH_3}$$

1.2 USES

It is utilized as

(i) feed for C_6H_5OH & $(CH3)_2CO$ production

(ii) $(CH3)_2CO$ is utilized to make ‘bisphenol A’and ‘methylacrylate’.

(iii) Splitting of Cumene Hydroperoxide forms Methylstyrene in limited amount which is also formed by dehydrogenating Cumene.

(iv) In small quantity can be used as thinner in paints and enamels & also used to form acetophenone.

(v) Is also additionally utilized as solvent in raisin & fasteners.

1.3 MANUFACTURING PROCESSES OF CUMENE

Cumene in manufactured using the following methods:

1. Liquid phase alkylation by the use of Phosphoric acid.
2. Liquid phase alkylation by the use ofAluminiumchloride.
3. Q-Max process.
4. CD-Cumene process.

1.3.1 Liquid Phase Alkylation by the use of Phosphoric Acid

1.3.1.1 Introduction

SPA (Solid phosphoric acid) is the best known catalyst for Cumene synthesis. Recently manufacturers are given prizes for better product quality of the phenol, acetone and especially alpha-methyl styrene.

1.3.1.2 Chemical Reaction

Main Reaction

$C_6H_6 + CH_3.CH=CH_2$ -------> $C_6H_5.C_3H_7$;

Side Reaction

$C_6H_6 + nCH_3CH=CH_2$ --------> $C_6H_{6-n}.(CH)_n$

1.3.1.3 Process Description

Napthas-steam cracking plant off gases consisting of Propylene-propane is used as feed and is mixed with benzene into fixed bed reactor with pressure of 3-4MPa and at temperature range of 200-260C. Into the highest point of reactor pressed stage shrewd with H3PO4 impregnated impetus. The SPA impetus gives a basically complete change of propylene on a one pass premise. The desired temperature of 250C is achieved by adding cold propane on every step thus absorbing reaction heat.

Depropanized reactor waste splits into quench/product stream. The propanized bottoms are isolated into benzene, cumene, and polycumenes in the leftover two stills. A general reactor contains 3.1% DIPB,94.8% Cumene,2.1% heavy aromatics on weight basis. Thus 99.9% pure cumene is produced in such high quantity without needing transalkylation of DIPB is a major advantage of this process. 97to98% cumene is produced with transalkylation and without that 94 to 96%.

1.3.1.4 Process Flow Sheet

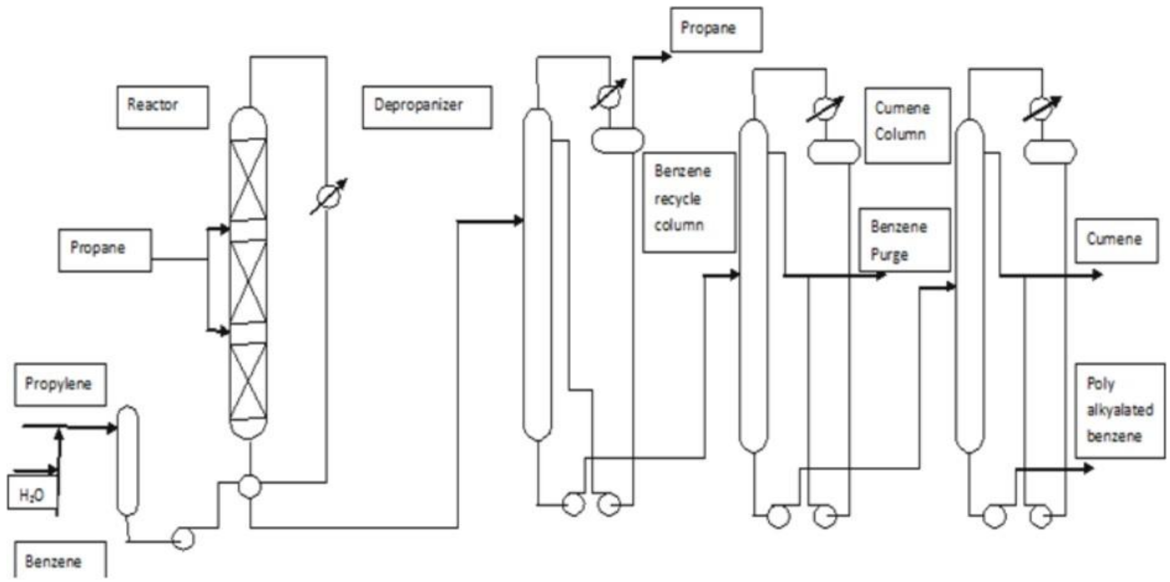

Fig: 1.1: Flow sheet of liquid phase alkylation by the use of phosphoric acid

1.3.2 Liquid Phase Alkylation by the use of Aluminium Chloride

1.3.2.1 Introduction

Cumene production prefers the use of $AlCl_3$ for alkyation.Fundamentally the same design that is used in other processes is used here too. The unique factors are the conditions for the reaction.

1.3.2.2 Process Description

If the feed requires treatment, Propylene is dried and ethane is removed. The bottom stream is fed and heavier carbons are removed. Liq Propylene vapors are fed to the reactor. Benzene containing water is added with recycled benzene and fed. After buildup, benzene and water isolated in a decanter.

The section where reaction takes place is divided into two or more sections by brick-lined compartments called reaction zone and settling zone. Every one of the reactants and reuse streams are brought into the response zone. Since unsettling is required, propylene fumes are conceded at the base where impetus complex, which is insoluble in a hydrocarbon, will in general settle. The reactants get blended with the complex. $AlCl_3$ is fed to the reactor top and the advertiser generally HCI goes in with the reactant. The advertiser is fundamental for balancing out the impetus complex, for just a steady unpredictable will catalyze the response. Notwithstanding the vaporous feed to disperse the impetus complex, there might be given a siphon to recycle settled complex to the highest point of the response zone and a blower where the impetus complex is set up in a different vessel. The off gases contains HCl in addition to others and must be treated with atmost care. The benzene is recuperated in a safeguard containing reusing PAB and the HCI is scoured out of the off-gas in two pinnacles, one containing water and the other containing scathing soft drink arrangement. The lingering gas can be packed and utilized as fuel. The material heavier than cumene isn't discarded as fuel, is gotten back to the reactors for transalkylation subsequent to eliminating the max.polyalkylbenzenes. The later activity is directed in a little segment under high vacuum.

1.3.2.3 Process Flow Sheet

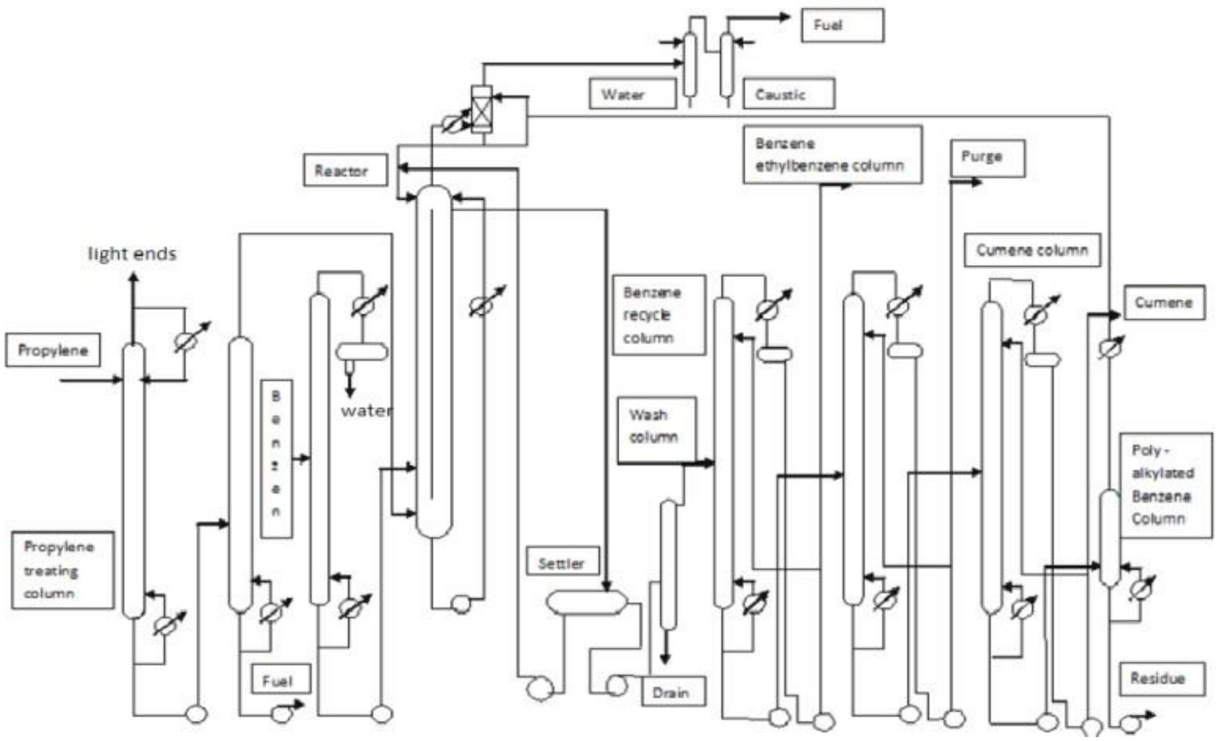

Fig: 1.2: Flow sheet of liquid phase alkylation by the use of aluminium chloride

1.3.3 Q-MAX Process

1.3.3.1 Introduction

This is a liquid phase based process that produces equal level of cumene in the range of 85-90 mol% & DIPB ranging from 5-15mol% using betazeolite as catalyst.

1.3.3.2 Process Description

A Q-max unit comprises of an alkylation reactor, a refining segment, and a transalkylation reactor. The two reactors are fixed bed. The alkylation reactor isolated into four impetus beds contained in a solitary reactor vessel. Propylene and a combination of new and reuse benzene are charged to the alkylation reactor, where the propylene responds to consummation to shape essentially cumene. Gushing from the alkylation reactor is shipped off the depropanized section, which eliminates the propane that entered the unit with the propylene feed, alongside any overabundance water which may have went with the feeds. The Depropanizer section base is shipped off benzene segment where benzene is gathered overhead and reused. Benzene segment base is shipped off the cumene section where cumene item is recuperated overhead. the base from the DIPB section comprise of a little stream of hefty sweet-smelling side-effect which are regularly utilized as high octane fuel mixing part.

The regular plan cycle length between recoveries is 2years, yet the unit can be intended for fairly longer cycles whenever wanted. Extreme impetus life is in any event three cycle. Gentle working conditions and a consumption free interaction climate license the utilization of carbon steel development and customary cycle gear.

1.3.3.3 Process Flow Sheet

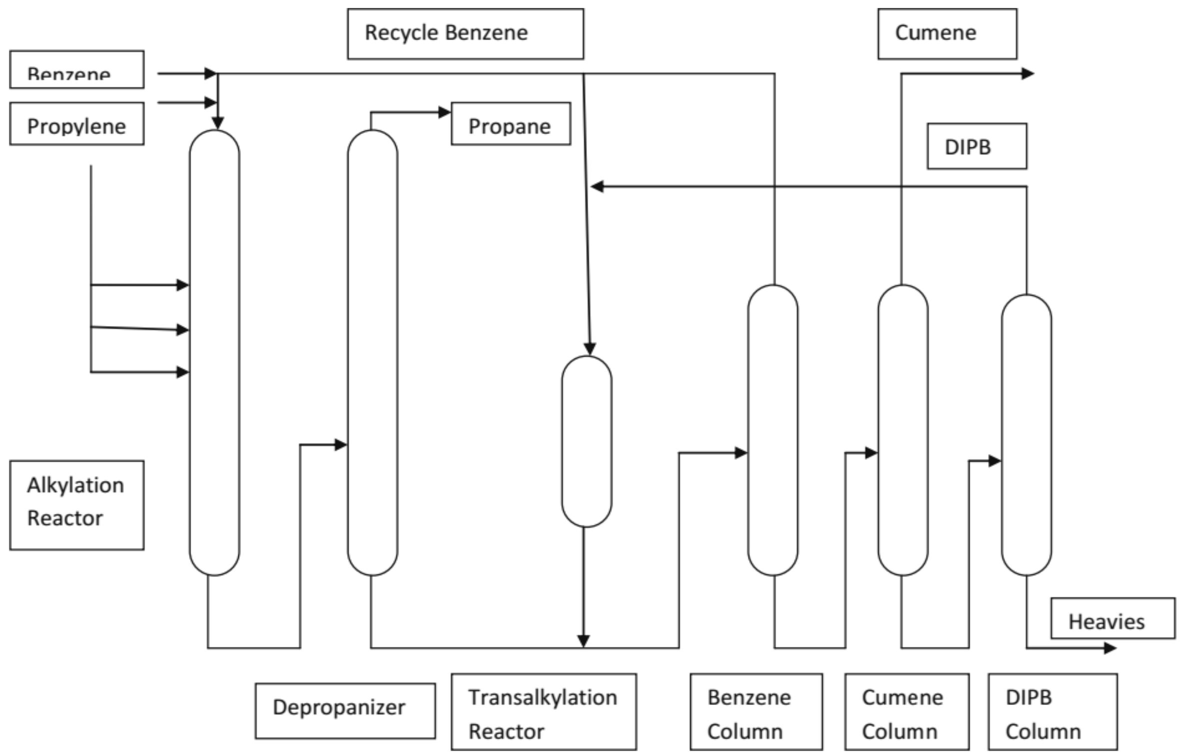

Fig: 1.3: Flow sheet of Q-max process

1.3.4 CD Cumene Process

1.3.4.1 Introduction

This process produces high quality cumene with the help of a noncorrosive and ecofriendly catalyst called Zeolite.

1.3.4.2 Process Description

Cumene is shaped by the synergist alkylation of benzene with propylene. Album cumene measure utilizes an exclusive zeolite impetus. The impetus is non-destructive and harmless to the ecosystem. This cutting edge measure highlights higher item production with less initial cost, compared to ecologically obsolete corrosive based handled.

A special unit operation is done where catalytic distillation is combined with fractionation. The products from the reaction are removed regularly with the help of distillation since the alkylation reaction happens isothermally at very low temperatures. Thus limiting the formation of by-products&impurities, resulting in more product yield making sure that the reactor runs for more than 2 years.This also helps in reducing the setup cost and safety during the operation. The heat from the operation are also recovered and reused.

This process has the capability to produce high quality propylene. It also uses dil.propylene stream with low purity only in the case of other olefins are under certain conditions.

1.3.4.3 Zeolite Catalyst

Other than the combined process all other zeolite based processes maintain the same flow sheet config. When compared to other processes this takes place in a fixed bed reactor at very low temperature. In case of using refinery quality propylene as feed to alkylation column, the waste is sent to depropanizer removing propane as overhead. A different transalkylation reactor changes over reused PIPB and benzene to extra cumene. The bottoms of the depropanizer are then blended in with the transalkylation reactor profluent and took care of to a progression of three refining segments. Benzene, items cumene, and PIPB are individually isolated in the overhead of every section, with PIPB and benzene reused to the response framework. A little stream of weighty aromatics is isolated in the bottoms of the PIPB segment. Like the AICI3 impetus, zeolites are adequately dynamic to transalkylate PIPB back of cumene. In general selectivity of benzene to cumene is very high, fluctuating from 99.7% to practically stoichiometric, contingent upon the idea of the zeolite utilized. Item purities as high as 99.97% to practically stoichiometric, contingent upon the idea of the zeolite utilized. Item purities really high got, with B/P feed proportions somewhere in the range of 3 and 5. A specific benefit of the zeolite impetuses is that they are regenerable and can be utilized for a few cycles. Accordingly, the garbage removal issues related with SPA and AICI3 impetuses are extraordinarily decreased. Likewise, carbon steel can be utilized as the material of development all through the plant in light of the gentle working conditions and the shortfall of exceptionally destructive mixtures. One limits of the zeolite innovation is possible harming of the impetus by toxins in the feed.

Different treatment methods are used based on the quality of the feed used. On the off chance that processing plant quality propylene is being fed, its ‘Sulfur’ content should be firmly controlled.

1.3.4.4 Process Flow Sheet

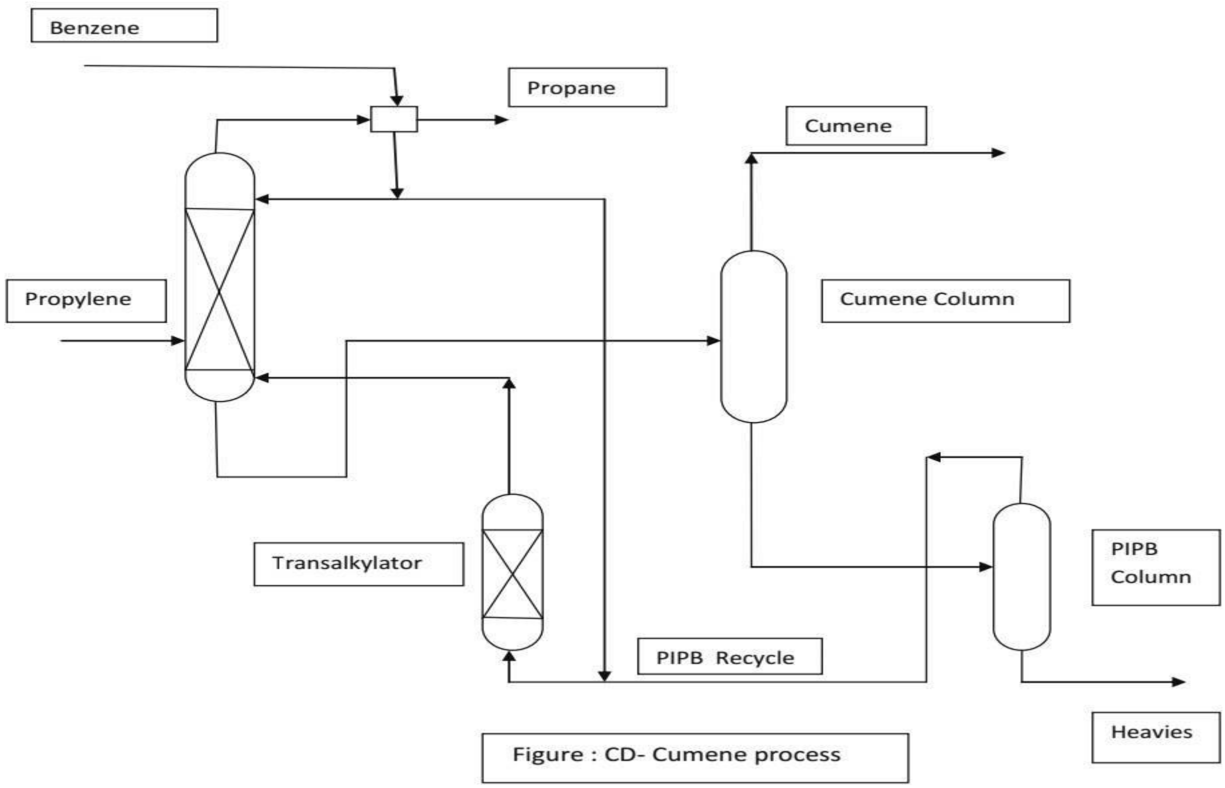

Fig: 1.4: Flow sheet of CD-cumene process

1.4 SELECTION OF PROCESS

1.4.1 Advantages

1.4.1.1 Liquid Phase Alkylation by the use of Phosphoric Acid

a. Complete conversion is achieved with the help of the catalyst
b. Cumene products 99.9 wt% pure.
c. By product removal is relatively simple.

1.4.1.2 Liquid Phase Alkylation by the use of Aluminium Chloride

a. Propane is recovered as LPG.
b. By-product can be easily removed.

1.4.1.3 Q-Max Process

a. The catalyst is regenerated and used.
b. Catalyst is expected to be used for 2-3 cycles.
c. This process require little treatment of feed, which further minimizes the captial costs.

1.4.1.4 CD-Cumene Process

a. Product selectivity is high and the by-product formation is low. High product yield; reduced plot area.
b. Lower maintenance Cost.
c. Existing cumene plant can be converted to use this method which decreases initial investment.
d. Reduction is cost of operation and waste heat is also recovered.
e. Plant can be designed to our needs which include using lowcost feed.
f. Meets evolving environmental requirements.
g. Two processses are done in a single unit operation which includes catalytic reaction and distillation.

1.4.2 Disadvantages

1.4.2.1 Liquid Phase Alkylation by the use of Phosphoric Acid

a. Limited cumene production.
b. It requires high benzene propylene molar feed to keep up the yield.
c. Catalyst cannot be used again.

1.4.2.2 Liquid Phase Alkylation by the use of Aluminium Chloride

a. Pretreating the feed is necessary.
b. HCl present around the reactor causes troubles.

Q-Max Process and CD-Cumene process has no disadvantages. When compared CD-Cumene is likeable to Q-max process due to the following,

a. High conversion & selectivity with extended reactor run time.
b. Low initial cost, improved safety and operability.
c. High waste heat recovery and low operational cost.
d. Plant can be designed to our needs which include using lowcost feed.

This is the reason for selecting this process over the other processes for the manufacture of CUMENE.

CHAPTER 2
AIM AND SCOPE

This process produces high quality Cumene using a non-corrosive and ecofriendly zeolite catalyst .

Catalytic Alkylation takes place in the presence of non-corrosive and ecofriendly catalyst of benzene and propylene producing Cumene.Here higher yield of product is achieved with less capital investment compared to other processes.

A special unit operation is done where catalytic distillation is combined with fractionation. The products from the reaction are removed regularly with the help of distillation since the alkylation reaction happens isothermally at very low temperatures. Thus limiting the formation of by-products&impurities, resulting in more product yield making sure that the reactor runs for more than 2 years.This also helps in reducing the setup cost and safety during the operation. The heat from the operation are also recovered and reused.

CHAPTER 3

MATERIAL BALANCE

Assumed capacity of the plant is 300,000 tonne/year.

Total number of operating days assumed - 300.

Basis = 1000 ton / day cumene production

= 41666.67 kg/hr

= 346.67 kmol/hr

Reaction

Main reaction:

$$C_3H_6 + C_6H_6 \longrightarrow C_9H_{12}$$

Side reaction:

$$C_9H_{12} + C_3H_6 \longrightarrow C_6H_4(CH(CH_3)_2)_2$$

Let us assume that 95% is converted in 1st reactor, 90% cumene and 5% propylene reacts to form Poly Iso-propyl Benzene (PIPB)

Propylene fed = 346.67 Kmol/hr

4:1 is the ratio of benzene&propylene fed.

Benzene fed = 1400 Kmol/hr

Reacted propylene = 0.95 * 346.67

= 329.33 kmol/hr

Unreacted propylene = 346.67 - 329.33

= 17.34 kmol/hr

Benzene reacted = 0.9 * 346.67

= 312 kmol/hr

Since the reaction is exothermic.

Heat produced in the column is

= 0.95 * propylene feed * heat of reaction

= 0.95 * 346.67 * 96.428

= 31757.26 kJ

Amount of evaporated benzene = (Heat produced in column) / (latent heat of benzene)

=(31757.26) / (30.75)

= 1032.75 kmol

Benzene input to CD-column

= amount of evaporated benzene in CD-column+amount of reacted benzene

= 1032.75 + 312

= 1344.75 kmol/hr

Unreacted benzene = 1344.75 - 312

= 1032.75 kmol/hr

Cumene formed = 312 kmol/hr

PIPB containing DIPB&TIPB is produced by the reaction of 5% propylene with cumene.

Cumene formed = 312 - 0.05 * 346.67

= 294.67 kmol/hr

Cumene formed in last reactor = 0.05 * 346.67

= 17.33 kmol/hr

From given,

Selectivity of propylene to cumene = 81.7

Amt of benzene that reacted with DIPB to form Cumene = 0.05 * 346.67

= 17.33 kmol/hr

DIPB produced = 0.98 * 17.33

= 16.98 kmol/hr

Total cumene produced = 312 + 17.33 + 16.98

= 346.13 kmol/hr

PIPB produced = 0.02 * 17.33

= 0.3466 kmol/hr

Material balance of cumene column:

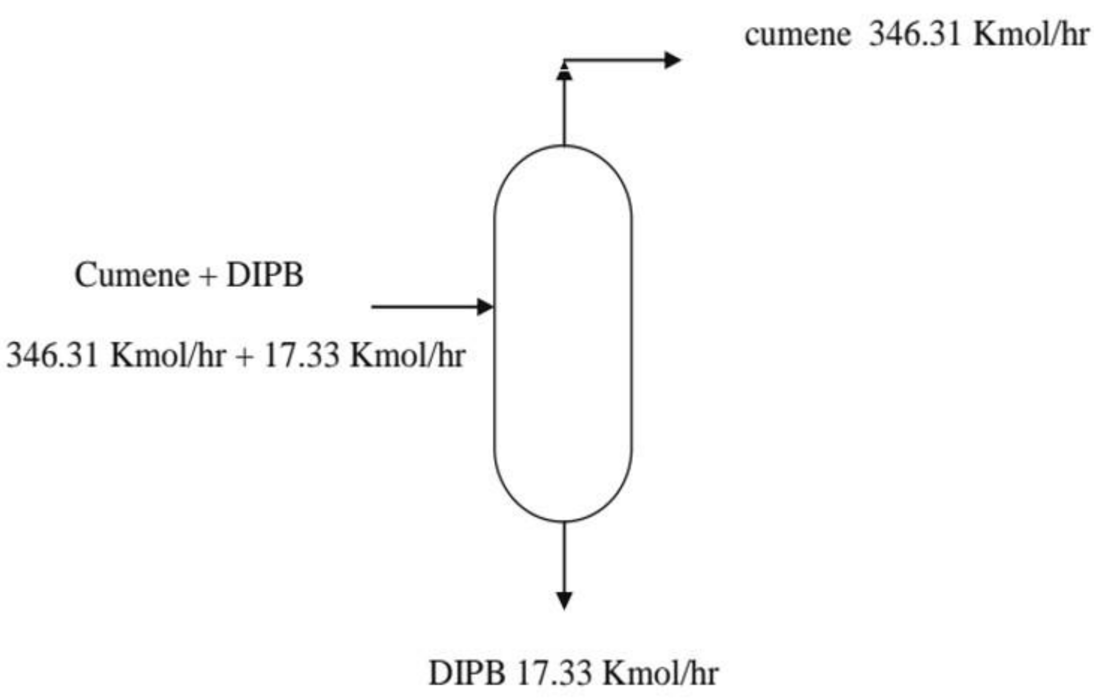

Fig: 3.1: Material balance on cumene column

Material balance of DIPB column:

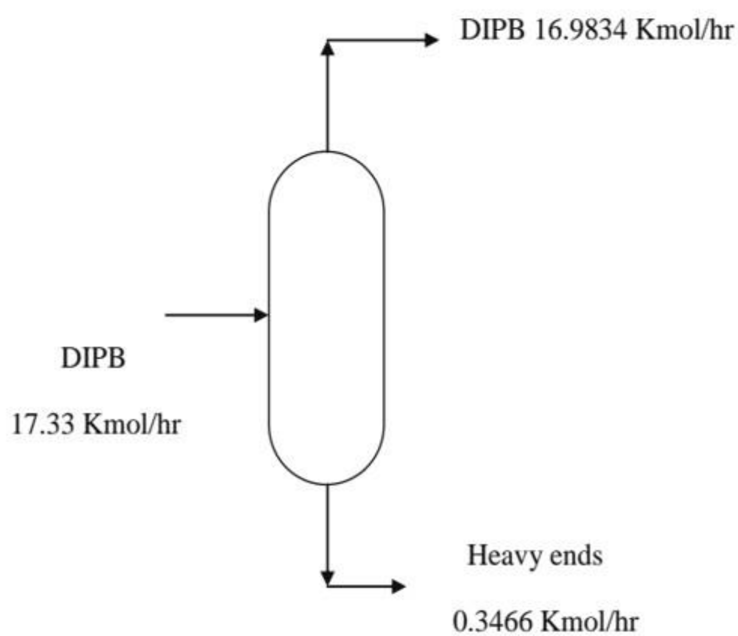

Fig: 3.2: Material balance on DIPB column

Material balance for transalkylation reactor:

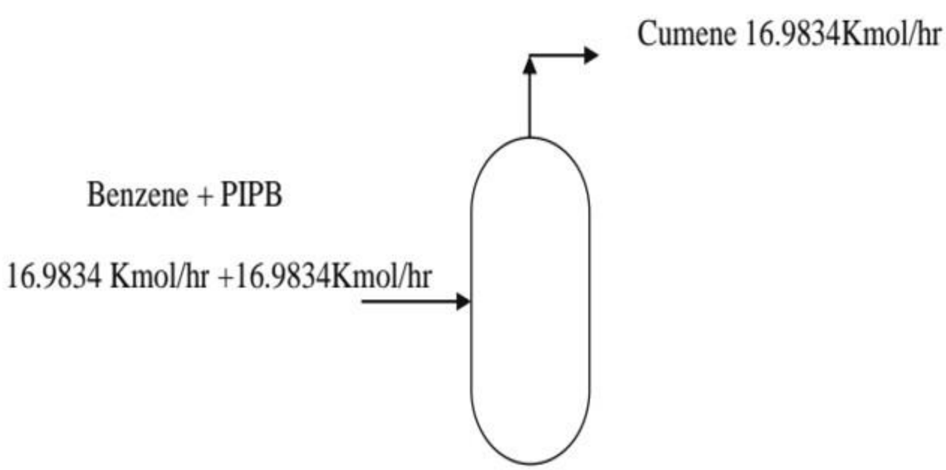

Fig: 3.3: Material balance for transalkylation reactor

Material balance for finishing reactor:

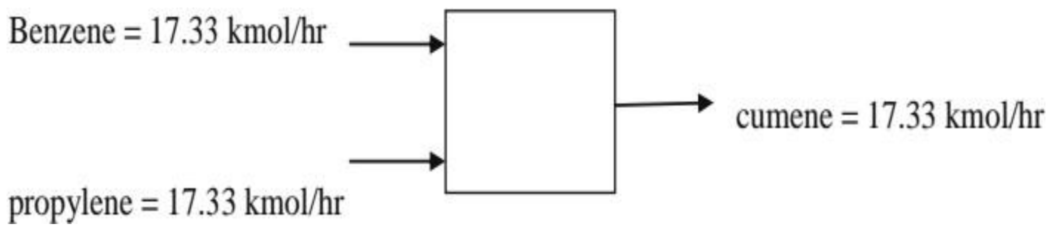

Fig: 3.4:Material balance for finishing reactor

Table 3.1: Overall material balance

Component	Feed		Distillate		Bottom	
	Moles	Mol. Fraction	Moles	Mol. Fraction	Moles	Mol. Fraction
Propylene	17.34	0.0123	17.34	0.0166	-	-
Benzene	1032.75	0.721	1022.42	0.98	10.33	0.0277
Cumene	346.31	0.245	1.732	0.166	344.58	0.926
DIPB	17.33	0.0122	-	-	17.33	0.0465
Total	1413.73				372.24	

CHAPTER 4
ENERGY BALANCE

Plant capacity is 300,000 ton / year. Assuming 300 working day.

Basis is taken as 1000 tonne/day

= 346.67 kmol/hr

Table 4.1: Cp values data

Component	A	B	C	D
Cumene	10.149	5.1138E-1	-1.7703E-5	-2.2612E-7
Propylene	31.298	7.2449E-1	1.9481E-4	-2.1582E-7
Benzene	-31.368	4.7460E-1	-3.1137E-4	8.5237E-8

Energy balance on CD-column:

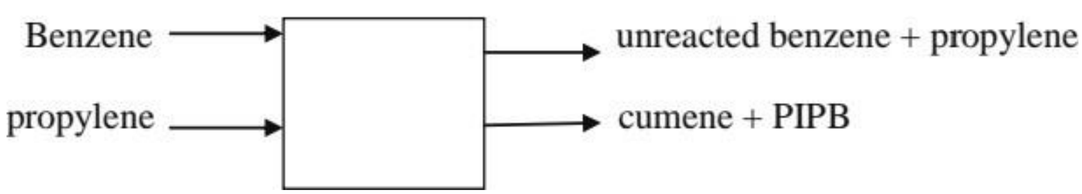

Fig: 4.1: Energy balance on CD-column

Cumene synthesis is exothermic reaction.

Heat formed when 1mol propylene reacts = 96.428 kJ

Hence total heat given out = 333.93.98 kJ/hr

heat taken out in condenser is,

Condenser load = 33393.98 kJ/hr

Energy balance on cumene column:

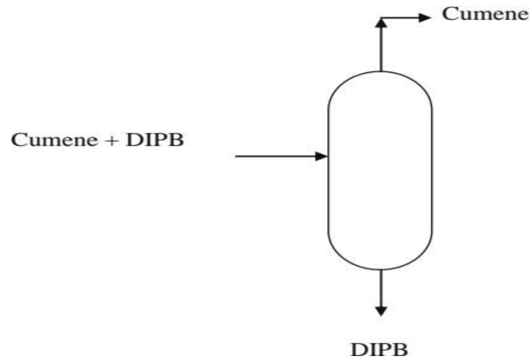

Fig: 4.2: Energy balance on cumene column

Heat load on reboiler = $mCp\Delta T$

= [346.67 * 217.96 * (170-152)] + [17.33 * 382.42 * (170-152)]

= 1477.96 * 10^3 kJ/hr

Vapor cumene gets reduced to liquid Cumene,

Load on condenser = mCp(35-170)

= 346.67 * 217.96 * (35-170)

= 10200.63 * 10^3 kJ/hr

Energy balance on PIPB column:

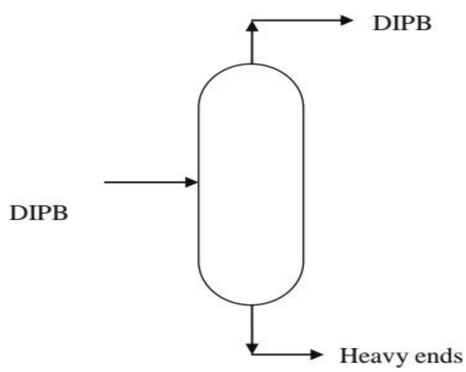

Fig: 4.3: Energy balance on PIPB column

When heated to 200C the reaction mixture containing PIPB gets separated to DIPB and heavier ends.

Reboiler load = 17.33 * 382.42 * (200-170)

= $1988.35 * 10^2$ kJ/hr

Energy balance on transalkylation reactor:

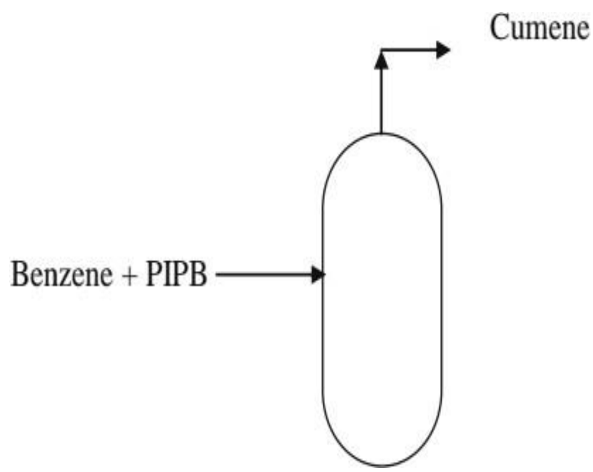

Fig: 4.4: Energy balance on transalkylation reactor

The net heat given out from the reaction = 96.428 * 17.33

= 1671.09 kJ/hr

Condenser load = 1671.09 kJ/hr

CHAPTER 5

EQUIPMENT DESIGN

5.1 DESIGN OF MULTICOMPONENT DISTILLATION COLUMN

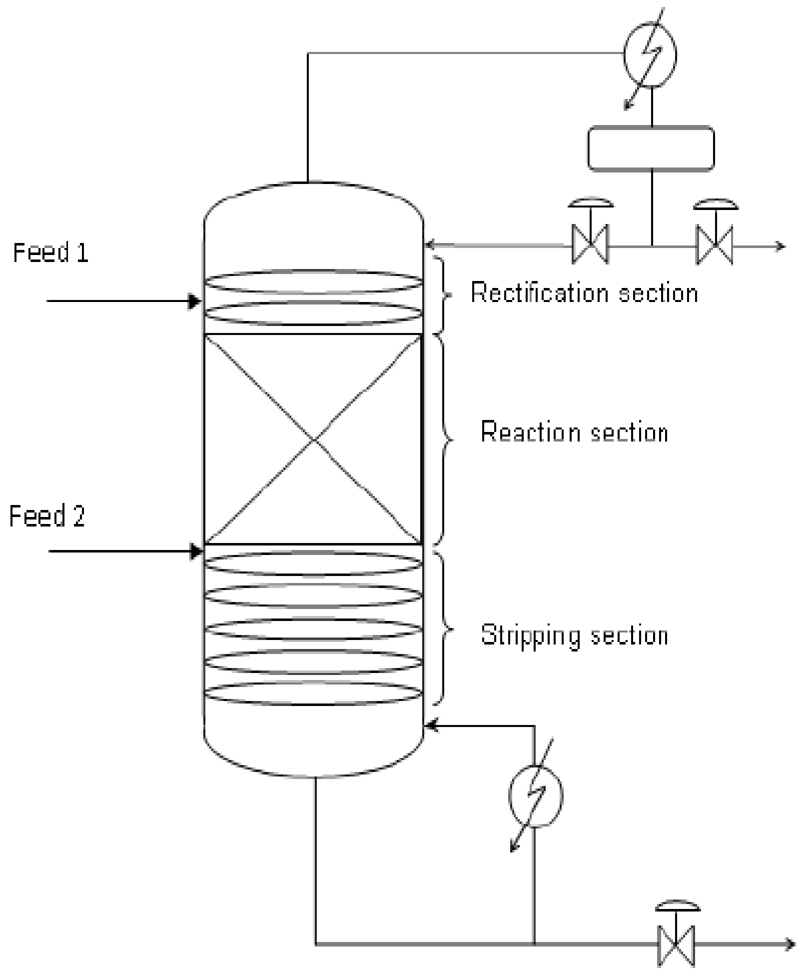

Fig: 5.1: Multi-componentDistillation column

Assume 99% benzene is separated as an overhead & 99.5% cumene is separated as bottom product

In our case

1. Propylene lighter than light key
2. Benzene light key
3. Cumene heavy key
4. PIPB heavier than heavy key

Table 5.1: Material balance

Component	Feed		Distillate		Bottom	
	Moles	Mol. Fraction	Moles	Mol. Fraction	Moles	Mol. Fraction
Propylene	17.34	0.0123	17.34	0.0166	-	-
Benzene	1032.75	0.721	1022.42	0.98	10.33	0.0277
Cumene	346.31	0.245	1.732	0.166	344.58	0.926
DIPB	17.33	0.0122	-	-	17.33	0.0465
Total	1413.73				372.24	

Vapour pressure data

Log p = A-B/(T+C)

Table 5.2: Calculation of top temperature

Component	yi	pi	ki	xi=yi/ki
Propylene	0.0166	31627.13	17.15	0.000968
Benzene	0.98	927.68	1	0.98
Cumene	0.00166	96.31	0.09	0.018
				0.999

Top temperature = 87^{o}C

Table 5.3: Calculation of bottom temp

Comp	Xi	Pi	Ki	Yi=Ki*Xi
Propylene	0.0277	4521.18	5.43	0.150411
Benzene	0.926	733.30	0.9	0.8334
Cumene	0.0465	185.11	0.188	0.008742
				0.993

Bottom temperature = 152^{o}C

$$N_{min} = \frac{\text{Log}[(xlk/xhk)d(xhk/xlk)b]}{\text{Log}\alpha avg}$$

$$= \frac{\text{Log}[(0.98/0.018)(0.926/0.0277]}{\text{Log } 7.7}$$

$= 3.67$

Minimum reflux ratio

Lower pinch temperature = column top temp. + 2/3 (temp. of bottom-temp of top)

= 87 + 2/3 (152-87)

= 130.33

Upper pinch temperature = column top. Temp + 1/3 (temp. of bottom-temp of top)

= 87 + 1/3 (152-87)

= 108.67

Table 5.4: Vapour pressure calculation

Component	Vapour pressure at 108.67	Ai	Vapour pressure at 130.33	αi	αavg
Propylene	45881.14	219.17	64840.97	158.53	186.4
Benzene	1684.86	8.05	2865.66	7.0	7.51
Cumene	209.34	1.0	409.01	1.0	1.0
DIPB	38.91	0.186	89.26	0.218	0.2

By underwood's method,

$$RR_{min} + 1 = \frac{\alpha A x AD}{\alpha A - \theta} + \frac{\alpha B x BD}{\alpha B - \theta} + \text{.................for all component}$$

= 1 – q

q = 1.

By trail and error method,

Θ lies between, $\alpha B < \theta < \alpha A$

$\alpha A = 7.51$ $\alpha B = 1$

$1 < \theta < 7.51$

Table 5.5 : Trial and error method

θ	L.H.S	R.H.S	△ = L.H.S – R.H.S
7	10.58	0.000358	10.579642
5	2.1	0.000508	2.099492
1.2	-0.354	0.00244	-0.356
2	0.749	0.001355	0.74
1.5	0.423	0.00187	0.421

R R_{min} = 0.238

Assume,

$R/R_{min} = 1.5$

R = 1.5 * 0.238

= 0.367

Rm/Rm+1 = (0.238/1.238)

= 0.2

R/R+1 = (0.36/1.36)

= 0.264

By Erbar-Maddox correlation (R/R+1 vs Nm/N)

$Nm/N = 0.38$

$N = 3.67/0.38$

$= 9.66 \approx 10$

Assuming stage efficiency as 50%

Theoretical no. of stages = 10/0.5 = 20

Gas velocity is an important factor determining the diameter of the tower, which is fixed by flooding condition. Flooding velocity is determined by

$$V_{fl} = K(\rho l - \rho v/ \rho v)^{0.5}$$

here, ρv = 2.7 Kg/m3

ρl = 862 Kg/m3

Assuming plate spacing to be 0.45m

K = 0.08

V_{fl} = 1.42 m/s.

Assuming flooding condition to be 85%

$V_{fl} = 0.85 \times 1.42$

= 1.21 m/s

Maximum flow rate

$$V_{max} = \frac{\text{Maximum volumetric flowrate}}{\text{Flooding velocity}}$$

= 22.58 / 2.7

= 8.36 m/s

Net area required = A_n

= Vmax / Vfl

= 8.36 / 1.42

$= 5.88\ m2$

$A_n = At - Ad$

$= At – 0.12\ At$

$= 0.88\ At$

$A_t = 5.88 / 0.8$

$= 6.68\ m2$

Column Diameter

$D_t = \sqrt{At \times 4/\pi}$

$= \sqrt{6.68 \times 4/\pi}$

$= 2.91\ m$

5.1.1 Liquid Flow Pattern

The two factors that determine Liquid Flow Pattern are

1. Maximum liquid flowrate
2. Column diameter

Here, Max Liq Flowrate(L_{max})= 23.12 / 862

$= 0.0238\ m3/s$

Area of hole, A_h = 10% of active area

$A_a = At – 2Ad$

$= 6.68 – 2 \times 0.8$

$= 5.08\ m2$

$A_h = 0.10 \times 5.08$

$= 0.508\ m2$

Weir length = 0.77 x Dt

$= 0.77 \times 2.91$

$= 2.24\ m$

Let's take

Diameter of the hole = 7 mm

Thickness of the plate= 5 mm

5.1.2 Plate Design

Diameter of the Column = 2.91 m

Cross section of the column,

A_t = 6068 m2

Weir height:

wkt the column is operating above atm pressure,

h_w = 50 mm

Thickness of the plate = 5 mm

5.1.3 Cross Check: (For Plate Dimensions)

Max Liq Flowrate = 23.12 Kg/s

Assume turndown ratio of max liq flow is at 70%

So that min liq flowrate = 70/100 * 23.12

= 16.184 kg/s

Liquid crest height above the segmental weir:

$(h_{ow})_{max}$ = 0.70 (23.12/862*2.24)(2/3) = 36 mm of

$(h_{ow})_{min}$ = 0.75 (16.184/862*2.24)(2/3)

= 30 mm

At minimum flowrate, d_h

$$h_w + h_{ow} = 50 + 30 = 80 \text{ mm}$$

$K_w = 30.2$

Hence Minimum vapour velocity,

$$V_{min} = 1/\sqrt{\rho v}\ (K_w - 0.9(25.4 - d_h)$$

$$V_{min} = 1/\sqrt{2.7}\ (30.2 - 0.9\ (25.4 - 5)$$

$$= 7.20 \text{ m/s}$$

But actual vapour velocity

= Minimum vapour flowrate / Hole area

= 0.7*7.20/0.58

= 9.92 m/s

Thus the minimum operating velocity (9.92 m/s) lies well above the weep point (i.e when vapour velocity = 7.20 m/s)

Plate pressure drop:

The total plate pressure drop is given by,

$$h_t = h_d + h_l + h_r$$

Dry plate drop

$$h_d = K_1 + K_2\ (vgh)2\ (\rho g/\rho l)$$

For sieve plate,

$$K_1 = 0,$$

$$K_2 = 0.05885/Cv2$$

Discharge coefficient C_v is determined as follows,

Plate thickness/hole diameter = 5/7 = 0.714

$$A_h/A_p = 0.508/5.08 = 0.1$$

$$C_v = 0.765$$

Velocity through holes

$$Vgh = 8.36/0.508 = 16.45 \text{ m/s}$$

$$h_d = 50.85*10\text{-}3\ (16.45/0.765)*(2.7/862)$$

$$= 3.42 \text{ mm}$$

Pressure drop due to staric liquid head,

$$h_l = h_w + h_{ow}$$

$$= 50 + 36$$

$$= 86 \text{ mm of clear liquid}$$

Residual head,

$$h_r = 12.5/\rho l = 12.5/862$$

$$= 14 \text{ mm of clear liquid}$$

The total pressure drop

$$h_t = h_d + h_l + h_r$$

$$= 3.42 + 86 + 14$$

$$= 103.42 \text{ mm of clear liquid}$$

Downcomer area backup:

Backup in downcomer is given by,

$$h_{dc} = h_t + h_w + h_{ow} + h_{ad}$$

Head loss in the downcomer due to liquid flow under the downcomer apron:

$$h_{da} = 0.166*(ml/\rho l*Am)$$

now,

$$A_{ap} = h_{ap}*l_w$$

h_{ap} = height of lower edge of the apron above the tray

$$= hw - 10 = 50 - 10 = 40 \text{ mm}$$

$$l_w = 2.24 \text{ m}$$

A_{ap} = Area under the downcomer apron

$$= 0.04 * 2.24 = 0.0896 \text{ m2}$$

Since Aap < Ad we take Ad as Am

h_{da} = 0.166 (23.12/862*0.80)2

= 1.12 mm of clear liquid

h_{dc} = 103.42 + 50 + 36 + 1.12

= 190.54 mm of clear liquid

Check:

To avoid flooding:

h_{dc} < 1/2 (Plate spacing + weir height)

Now,

1/2 (Plate spacing + weir height)

= 0.5*500 = 250 mm

Since h_{dc} < 0.250 m, so there will ne no flooding at specified operating condition that means tray spacing is acceptable.

Residence time:

$t_r = A_d*h_{dc}*\rho_l/m_l$

= 0.80*0.19054*862/23.12

= 5.68 s

Total height of tower

= (no of plates*tray spacing) + clearance at top + clearance at bottom

= (20*0.5) + 0.5 + 0.5 = 10 m

So the design is satisfactory.

5.1.4 Shell Thickness

For thickness of shell of distillation column we required following data,

1. Design Pressure, P = 1.1 * operating pressure

= 1.1 * 2.757

= 3.0327 N/mm2

2. Permissible tensile stress, f = 95 N/mm2 (MOC = Carbon Steel)
3. Joint efficiency factor, J = 0.85
4. Inner diameter, D_i = 2.91 m
5. Corrosion allowance, C = 1.5 mm

Shell thickness is given by,

$t_s = (PD_i/2fj-P) + C$

$t_s = (3.0327*2910/2*95*0.85-3.027) + 15$

$t_s = 57.19$ mm

Head thickness:

For safety we use hemispherical head at top & bottom of distillation column. The head thickness is given by,

$t_h = PDi/4fj$

$t_h = 3.0327*2910/4*95*1$

$t_h = 23$ mm

Table 5.6: Overall design data for multicomponent distillation column

Total Height of the Tower	10 m
Diameter	2.91 m
Cross Section	6.68 m^2
Top Temperature	87ºC
Bottom Temperature	152ºC
Theoritical no. of stages	20
Material used	Carbon Steel
Permissible tensile stress	95 N/mm^2
Total Pressure Drop	103.42 mm of clear liquid
Residence Time	5.68 s
Head Thickness	23 mm

5.2 DESIGN OF INTERNAL FLOATING ROOF TANK

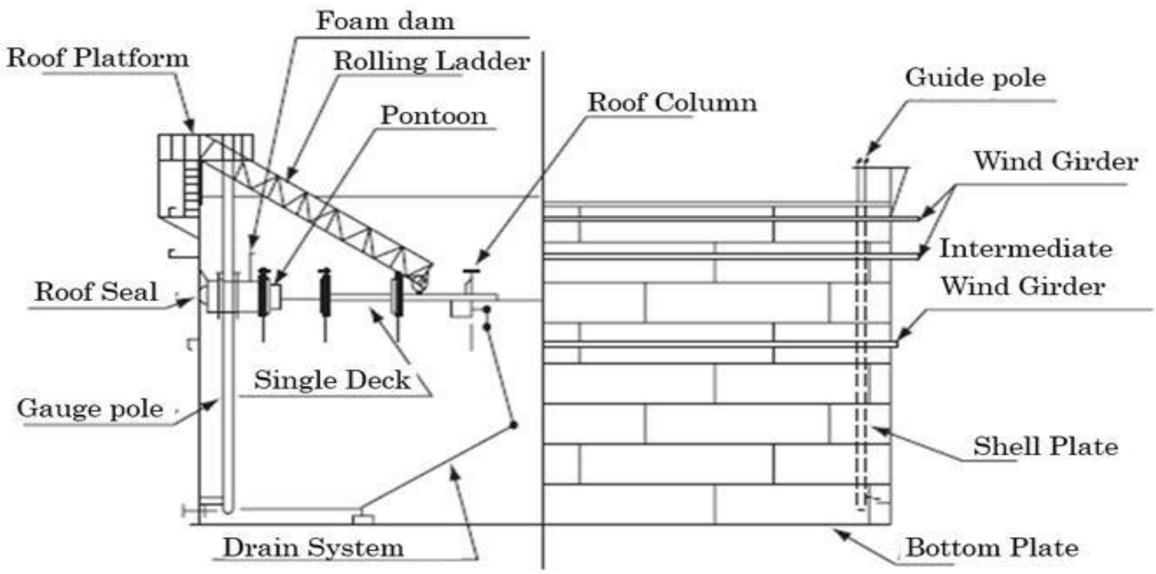

Fig: 5.2: Internal floating roof tank

The design of tank is based on API 650 (11th edition 2007) standards.

5.2.1 Tank Selection

Cumene is highly volatile product and has to be stored in an internal floating roof tank.

5.2.2 Height And Diameter

For fixing the height and diameter of the tank, the criterion to be maintained as per API 650 is that ratio of the total height of the tank to the internal diameter must be less than 1.5

$$\frac{\text{Height of the tank (H)}}{\text{Diameter of the tank (D)}} < 1.5$$

Height and diameter mostly depends upon the space available on the site, distance between two consecutive tanks etc.

5.2.3 Design Capacity of the Tank

Cumene Produced = 312 kmol/hr

= 312 x 120.19 x 24

= 899982.72 Kg/day

= 899.98 ≈ 900 Tons/day

Cumene produced in volume, $V = m/\rho$

= 9000000/816.90

= 11017.26 ≈ 12000 m^3

Diameter of the tank = 32.8

Height of the tank = 14.2 m

Volume of the tank = $\pi/4 \times D^2H$

= $\pi/4 \times (32.8)^2 \times 14.2$

= $3.14/4 \times (32.8)^2 \times 14.2$

= 11998.47 ≈ 12000 m^3

Here, H/D ratio = 14.2/32.8 = 0.43<1.5

So it is possible according to API650. (Also the economic condition is maintained).

5.2.4 Design Data

1. Design Code : API 650
2. Internal Diameter : 32.8 m
3. Height : 14.2 m
4. Product Stored : Cumene
5. Specific Gravity of Product : 0.86
6. Design Specific Gravity : 0.86
7. Corrosion Allowance : 1.6 mm for annular and bottom plate

   : 3 mm for shell plates

   : 1.5 mm for roof plates

8. Design pressure : Atmospheric pressure
9. Material specification : IS 2062 grade A (As per API 650)
   IS 2062 is the metal readily available in Indian markets and also it has got an acceptable value of yield strength (36236 psi or 247.6 Mpa) and tensile strength (59428 psi or 410.6 Mpa).
10. Wind Speed : 100 mph (max) or 160.93 km/h
11. Maximum rainfall intensity : 57 mm in one hour or 254 mm or 254 mm in 24 hours.

5.2.5 Design of Bottom Plate

Bottom plate thickness = 6 + 1.6 = 7.6 mm ≈ 8 mm
Length of bottom plate = 6m/8m/10m
Width of bottom plate = 1.5m/ 2m/ 2.5m

5.2.6 Design of Annual Bottom Plates

Radial width of annular plates depends upon the shell course thickness. So annular bottom plate designing is done after the shell designing.

5.2.7 Design of Shell Plates:

Tank is made of plates. Plates of same width have been welded together to form a course of equal diameter. The course contains a number of vertical joints of length equal to plate width. A number of courses are welded together horizontally to form the total height of the tank.

According to API 650, the shell thickness from the tank of diameter in the range of 36m-60m should not be less than 8 mm. The shell thickness is calculated taking into account the material specification and allowable stresses.

Yield strength of selected material (IS 2062) = 247.6 MPa
Tensile strength of selected material = 410.6 MPa
Maximum allowable design stress, (S_d) = 2/3 x yield strength

$= 2/3 \times 247.6 = 165$ MPa or

$(S_d) = 2/5 \times$ tensile strength

$= 2/5 \times 410.6 = 164.24$ MPa

So design stress is taken as 165 MPa.

Maximum allowable hydrostatic stress, $(S_t) = 3/4 \times$ yield strength

$= 3/4 \times 247.6 = 185.7$ MPa or

$(S_t) = 3/4 \times$ tensile strength

$= 3/4 \times 410.6$

$= 175.97$ MPa ≈ 176 MPa

According to API 650 thickness of tanks less than 60m in diameter is calculated using 1-foot method, and if the diameter is above 60m, the thickness is found out using variable design point method. So here 1-foot method is used.

1-foot method calculates the thickness required ae design points 0.3m (1 dt) above the bottom of shell course. In this method we find out the design shell thickness (t_d) and hydrostatic test shell thickness (t_t) and the maximum of the two values is taken.

Where,

$t_d = (4.98 D \times (H-0.3) \times G)/S_d + CA$

$t_t = 4.9 D \times (H-0.3)/S_t$

t_d – design shell thickness in mm

t_t – hydrostatic shell thickness in mm

D – nominal tank diameter in m = 36.58m

H – height from the bottom of course under consideration to the top of the shell

G – Design specific gravity of the liquid to be stored = 0.86

CA – corrosion allowance in mm = 3mm

S_d – allowable design stress = 165 Mpa

S_t – allowable hydrostatic stress = 176 MPa

Since the height of the tank is 14.2m, we have divided it into numbers of courses considering the economic condition.

5.2.8 Shell Thickness

We divide the total height 14.2m to 7 courses 2, 2, 2.125, 2.425, 2.425, 2.425 & 0.790m respectively.

From the above formula shell thickness is calculated.

5.2.8.1 1st Course

H = 14.2m

D = diameter of the tank in m= 36.58m

Shell thickness, t_d = (4.98 D x (H-0.3) x G)/S_d + CA

= (4.9 x 32.8 x (14.2-0.3) x 0.86)/165+3 = 14.83mm

t_t = 4.9 D X (H-0.3)/S_t

= 4.9 x 32.8 x (14.2-0.3)/176 = 12.38mm

Design condition is to select max of t_d or t_t. In this case max value is 15.83mm.

Thickness selected (as per market size) t = 16mm = 0.016m

Width of the shell course (W) = 2m

Volume of shell course = π x D x W x t = π x 36.58 x 2 x 0.016 = 3.68m^3

5.2.8.2 2nd Course

H = 14.2 – 2 = 12.2m

D = 36.58m

t_d = (4.9D x (H-0.3xG)/S_d+CA = $\frac{4.9 \times 36.58 \times (12.2 - 0.3) \times 0.86}{165}$ + 3 = 13.98mm

t_t = (4.9D x (H-0.3)/S_t = $\frac{4.9 \times 36.58 \times (12.2 - 0.3)}{176}$ = 12.12mm

Design condition is select max of t_d and t_t. In this case max value is 13.98mm.

Thickness selected (as per market size) t = 14mm = 0.014m

Width of shell course, W = 2m

Volume of shell course, $V = \pi \times D \times W \times t = \pi \times 36.58 \times 2 \times 0.014 = 3.22m^3$

5.2.8.3 3rd Course

$H = 12.2 - 2.125 = 10.075m$

$D = 36.58m$

$t_d = (4.9D \times (H-0.3xG)/S_d+CA = \frac{4.9 \times 36.58 \times (10.075 - 0.3) \times 0.86}{165} + 3$

$= 12.03mm$

$t_t = (4.9D \times (H-0.3)/S_t = \frac{4.9 \times 36.58 \times (10.075 - 0.3)}{176} = 9.96mm$

Design condition is select max of t_d and t_t. In this case max value is 12.03mm.

Thickness selected (as per market size) t = 12mm = 0.012m

Width of shell course, W = 2.125m

Volume of shell course, $V = \pi \times D \times W \times t = \pi \times 36.58 \times 2.125 \times 0.012$

$= 2.93m^3$

5.2.8.4 4th Course

$H = 10.075 - 2.425 = 7.65m$

$D = 36.58m$

$t_d = (4.9D \times (H-0.3xG)/S_d+CA = \frac{4.9 \times 36.58 \times (7.65 - 0.3) \times 0.86}{165} + 3 = 9.79mm$

$t_t = (4.9D \times (H-0.3)/S_t = \frac{4.9 \times 36.58 \times (7.65 - 0.3)}{176} = 7.48mm$

Design condition is select max of t_d and t_t. In this case max value is 9.79mm.

Thickness selected (as per market size) t = 10mm = 0.010m

Width of shell course, W = 2.425m

Volume of shell course, $V = \pi \times D \times W \times t = \pi \times 36.58 \times 2.425 \times 0.010$

$= 2.79m^3$

5.2.8.5 5th Course

$H = 7.65 – 2.425 = 5.225m$

$D = 36.58m$

$t_d = (4.9D \times (H-0.3xG)/S_d+CA = \frac{4.9 \times 36.58 \times (5.225 – 0.3) \times 0.86}{165} + 3$

$= 7.56mm$

$t_t = (4.9D \times (H-0.3)/S_t = \frac{4.9 \times 36.58 \times (5.225 – 0.3)}{176} = 5.02mm$

Design condition is select max of t_d and t_t. In this case max value is 7.56mm.

Thickness selected (as per market size) t = 8mm = 0.008m

Width of shell course, W = 2.425m

Volume of shell course, $V = \pi \times D \times W \times t = \pi \times 36.58 \times 2.425 \times 0.008$

$= 2.23m^3$

5.2.8.6 6th Course

$H = 5.225 – 2.425 = 2.8m$

$D = 36.58m$

$t_d = (4.9D \times (H-0.3xG)/S_d+CA = \frac{4.9 \times 36.58 \times (2.8 – 0.3) \times 0.86}{165} + 3 = 5.31mm$

$t_t = (4.9D \times (H-0.3)/S_t = \frac{4.9 \times 36.58 \times (2.8 – 0.3)}{176} = 2.56mm$

Design condition is select max of t_d and t_t. In this case max value is 5.31mm.

Thickness selected (as per market size) t = 8mm = 0.008m

Width of shell course, W = 2.425m

Volume of shell course, $V = \pi \times D \times W \times t = \pi \times 36.58 \times 2.425 \times 0.008$

$= 2.23m^3$

5.2.8.7 7th Course

$H = 2.8 - 0.790 = 2.01m$

$D = 36.58m$

$$t_d = (4.9D \times (H-0.3 \times G)/S_d + CA = \frac{4.9 \times 36.58 \times (2.01 - 0.3) \times 0.86}{165} + 3 = 4.58mm$$

$$t_t = (4.9D \times (H-0.3)/S_t = \frac{4.9 \times 36.58 \times (2.01 - 0.3)}{176} = 1.74mm$$

Design condition is select max of t_d and t_t. In this case max value is 4.58mm.

Thickness selected (as per market size) t = 8mm = 0.008m

Width of shell course, W = 0.790M

Volume of shell course, $V = \pi \times D \times W \times t = \pi \times 36.58 \times 0.790 \times 0.008$

$= 0.73m^3$

5.2.8.8 Annular Plate

As per API 650, 16mm 1st shell course thickness, the minimum annular plate thickness is 6mm.

So minimum thickness required = 6 + 1.6 (C.A) = 7.6mm ≈ 8mm

Here we provide 10mm thick annular plate, since annular plate thickness should be greater than bottom plates.

5.2.8.9 Radial width of bottom plate

Minimum radial width = minimum projection from outer surface of shell plate + minimum dimension between surface of shell plate to lap joint + lap of annular and bottom plate + 1st shell course thickness

From API standards,

The minimum projection form outer surface of shell plate = 65 mm (min 50mm)

Minimum dimension between inside surface of shell plate to lap joint = 610 mm (min 600)

Lap of annular and bottom plate = 65 mm (standard)

1^{st} shell course thickness = 16 mm

So required minimum radial width = 65 + 610 + 65 +16 = 756 mm.

We provide annular plate of radial width 1000 mm (to be on safer side)

5.2.9 Design of Wind Girder

5.2.9.1 Basic wind speed

speed of wind, V = 100 mile/hr = 160.93 km/hr

Section modulus required for primary wind girder, $Z = \frac{D^2 H_2}{17} (V/190)^2$ cm^3

t= Shell thickness at the attachment = 8mm

Portion of tank shell to be considered for calculating $L = 32 \times t_s + t$

$= 32 \times 8 + 8$

$= 264$ mm

5.2.9.2 Location of Primary Wind Girder

The primary wind girder is provided as a walk way distance 1067 mm from the top. Here there is no change in design and location of primary wind girder, because of there is no maintenance work.

5.2.9.3 Design calculation of Second Wind Girder

Maximum height of the un stiffened shell = $H1 = 9.47 \times t\sqrt{(r/D)^3}\ (190/V)^2$

t = Thickness of top shell course = 5 mm

D = Nominal tank diameter = 36.58 m

$H = 9.47 \times 5 \times \sqrt{(5/36.58)^3} \times (190/160.93)^2 = 3.370$ m

5.2.10 Shell Openings

5.2.10.1. Man Hole (Shell)

One man hole provided to the tank shell at the bottom shell course. It is enough to provide 600 mm manhole.

Minimum thickness of cover plate, t_c = 16 mm

Thickness of bolting flange t_f = 11 mm

Man hole diameter, D_m = 914.4 mm

Cover Plate Diameter, D_c = 820 mm

5.2.10.2 Bolts

Number of bolts = 42

Diameter of bolts = 22 mm

Diameter of bolt hole = 24 mm

5.2.10.3 Draw Off Sump

Two draw off sumps is provided at the bottom plate in order to store water content in the product and to remove it.

Diameter of sump, A = 1220 mm

Depth of sump, B = 610 mm

Distance from center pipe to shell, C = 150 mm

Thickness of plates in sump = 10 mm

Minimum internal pipe thickness = 114.3 mm

Minimum nozzle neck thickness = 3 mm

5.2.11 Cooling Water System Data

Cooling water system is provided to the tank. The cooling water is sprayed onto the tank with the help of nozzles.

5.2.11.1 Design Data

Type of tank – floating roof tank

Tank diameter– 36.58 m

Tank height – 14.2 m

Wind girder from bottom – 13.2 m

Area below primary wind girder (Al) = π x 36.58 x 13.2

Total surface area = 1556.1 m^2

Since OISD specifies that a minimum of 3 liters has to be sprayed per minute per unit.

Area of the shell, the total amount of water required = 1556.16 x 3

= 4668.48 lpm

Considering the pressure losses in the pipes connecting the ring and the water tank, the operating pressure of the nozzle is calculated to be between 1.5 to 3.5 kg/cm^2. Two sets of cooling water rings are provided, one above the primary wind girder, and the other below the secondary wind girder.

Ring no.1

Surface area to be cooled by the water from top ring = πDh

D = dia of the tank = 36.58 m

H = distance between two wind girders = 6 m

Surface area = π x 36.58 x 6 = 689.16 m^2

Water required = 3 x surface area

= 3 x 689.16 = 2067.50 lpm

5.2.11.2 Foam System Provided

Foam recommended = AFFF

Foam application rate = 12 litres/min/m^2 of seal area

Foam dam width = 1 m

D, diameter of the tank = 36.58 m

Height of the foam dam = 600 mm = 0.6 m

5.2.12 Floating Roof

The design of the roof and the accessories are in a way that it floats maximum level and also return to the level below the tank shell without causing any harm to any part of the roof and its accessories.

5.2.12.1 Deck Plate Data

As per the API 650 standards deck plate should be of 5 mm min. Thickness.

So the thickness of the deck plate selected = 5 mm

Dimensions = 6300 x 1500 x 5

Total weight = 31527.56 kg

5.2.12.2 Pontoon Data

No. of components (N) = 38+1 = 39 qty

Pontoon bottom plate = 6300 x 1500 x 5

Weight of single pontoon = 39.25 kg

Total weight of pontoon = 15318.17 kg

5.2.12.3 Data of Rolling ladder and spiral stairways

Rolling ladder rolls over a certain path with the help of wheels which are made of steel and having a brass cap to prevent spark.

Length of ladder = 17960 mm

Track slope = 1 : 100

5.2.12.4 Supporting legs

Supporting legs provide support to the floating roof and its length is adjusted from the rooftop. By API 650 standards the supporting legs should be designed to lift load of atleast 1.2 KPa.

Table 5.7: Overall design data for internal floating roof tank

Dia.of the tank	32.8 m
Hei.of the Tank	14.2 m
Vol.of the Tank	12000 m^3
Product Stored	Cumene
Material of Construction	Mild Steel (IS 2062 Grade A)
Annular plate thickness	10 mm
Annular plate width	1000 mm
Height of Primary Wind Girder	6.38 M
Height of Secondary Wind Girder	3.37 M
Design speed of Wind	100 mile/hr
Man Hole Diameter	914.4 mm
No. of blots	42
Diameter of sump	1220 mm
Total amount of water required	4668.48 lpm

CHAPTER 6
ECONOMICS

6.1 ESTIMATION OF CAPITAL INVESTMENT COST:

6.1.1 Direct Costs

70-80% of capital investment is alloted to material and labor for installing the facility.

InstallationCost+Electrical Installation+service facility+building process and auxiliary+yard improvement+land+Purchase cost+piping+Instrumentation and controls installation

Purchased equipment cost (PEC):
(15-40% of FCI)
$= 0.25 \times 25.40 \times 10^8$
$= Rs.6.35 \times 10^8$

Paint&Insulation installment: (25-55% of PEC)
installationcost
$= 0.40 \times 6.35 \times 10^8$
$= Rs.2.54 \times 10^8$

Instrumentation controls: (6-30% of PEC)
= 20% of PEC
$= 0.20 \times 6.35 \times 10^8$
$= Rs.1.27 \times 10^8$

Pipinginstalled: (10-80% of PEC)
= 40% PEC
$= 0.40 \times 6.35 \times 10^8$
$= Rs.2.54 \times 10^8$

Electricalinstalled: (10-40% of PEC)

= 25% of PEC

= 0.25 x 6.35 x 10^8

= Rs.1.58 x 10^8

Buildings,process& Auxiliary: (10-70% of PEC)

= 40% of PEC

= 0.40 x 6.35 x 10^8

= Rs.2.54 x 10^8

Servicefacilities: (40-100% of PEC)

= 60% of PEC

= 0.60 x 6.35 x 10^8

= Rs.3.81 x 10^8

Land: (1.2% FCI)

= 6% of PEC

= 0.06 x 6.35 x 10^8

= Rs.0.03 x 10^8

Thus, Direct cost = Rs.20.66 x 10^8------------ (82.74% of FCI)

6.1.2 Indirect cost

It involves the expenses that do not directly contribute to material and labour of installing the facility and it uses 15-30% of FCI.

Supervision&Engineering: (5-25% of direct costs)

= 0.1 of Direct Costs

= 0.1 x 20.66 x 10^8

= Rs.2.06 x 10^8

ConstructionFee: (6-28% of direct costs)

= 0.1 of Direct Costs

= $0.1 \times 20.66 \times 10^8$

= Rs.2.06×10^8

(c) Contigency: (5-15% of FCI)

= 12% of FCI

= $0.12 \times 25.40 \times 10^8$

= Rs.3.048×10^8

Thus, Indirect Costs = Rs.7.168×10^8

6.1.3 Fixed Capital Investment

= DC+IDC

= $(20.66 \times 10^8) + (7.168 \times 10^8)$

= Rs.27.828×10^8

6.1.4 Working Capital: (10-20% of FCI)

= 15% of FCI

= $0.15 \times 27.828 \times 10^8$

= Rs.4.17×10^8

6.1.5 Total Capital Investment (TCI)

Total capital investment = FCI + Working capital

= $(27.828 \times 10^8) + (4.17 \times 10^8)$

= Rs.31.998×10^8

6.2 PRODUCT COST ESTIMATION:

6.2.1 Manufact. Cost = Direct production+ Fixed charges + overhead cost.

(a) Fixed Charges: (10-20% total product cost)

(i) Depreciation: (13% of FCI for machinery and equipment and 2-3% for Building value for)

Consider depreciation = 13% of FCI

$= (0.13 \times 27.828 \times 10^8) + (0.03 \times 2.54 \times 10^8)$

$=$ Rs.3.6862×10^8

(ii) Local Taxes: (1-4% of FCI)

Consider the local taxes = 3% of FCI

$= 0.03 \times 27.828 \times 10^8$

$=$ Rs.0.8348×10^8

(iii) Insurances: (0.4-1% of FCI)

Consider the Insurance = 0.7% of FCI

$= 0.007 \times 27.828 \times 10^8$

$=$ Rs.0.1947×10^8

(iv) Rent: (8-12% of value of rented land and buildings)

Consider rent = 10% of value of rented land and buildings

$= 0.010 \times 2.57 \times 10^8$

$=$ Rs.0.0257×10^8

Thus, Fixed Charges = Rs.4.7414×10^8

(b) Direct Production Cost: (about 60% of total production cost)

Now we have Fixed charges = 10-20% of total product charges - (given)

Consider the Fixed charges = 15% of the total product cost

Charge for product = fixed charges/15%

$= 4.7414 \times 10^8/15\%$

$= 4.7417 \times 10^8/0.15$

$= Rs.31.61 \times 10^8$

Raw Material

= 25% of the total product cost

$= 25\%$ of 31.61×10^8

$= 0.25 \times 31.61 \times 10^8$

$= Rs.7.9025 \times 10^8$

Operating Labour(OL)

= 12% of total product cost

$= 12\%$ of 31.61×10^8

$= 0.12 \times 31.61 \times 10^8$

$= Rs.3.7932 \times 10^8$

Direct Supervisory and Clerical Labour(DS&CL)

= 12% of OL

$= 12\%$ of 3.7932×10^8

$= 0.12 \times 3.7932 \times 10^8$

$= Rs.0.4551 \times 10^8$

Utilities

= 12% of total product cost

$= 12\%$ of 31.61×10^8

$= 0.12 \times 31.61 \times 10^8$

$= Rs.3.7932 \times 10^8$

Maintenance and repair (M & R)

= 5% of FCI

= 0.05 x 27.828 x 10^8

= Rs.1.3914 x 10^8

Operating Supplies

= 15% of M & R

= 15% of 1.3914 x 10^8

= 0.15 x 1.3914 x 10^8

= Rs.0.2087 x 10^8

Laboratory Charges

= 15% of OL

= 15% of 3.7932 x 10^8

= 0.15 x 3.7932 x 10^8

= Rs.0.5689 x 10^8

Patent and Royalties:

= 4% of total product cost

= 4% of 31.61 x 10^8

= 0.04 x 31.61 x 10^8

= Rs.1.2644 x 10^8

Direct Production Cost = Rs.19.3774 x 10^8 --------- (61% of TPC)

(c) Plant overhead Costs

= 60% of OL, DS & CL and M & R

= 60% of ((3.7932 x 10^8) + (0.4551 x 10^8) + (1.3914 x 10^8))

= 0.60 x 5.6397 x 10^8 = Rs.3.3838 x 10^8

Thus, manufacturing cost

$= (19.3774 \times 10^8) + (27.828 \times 10^8) + (3.3838 \times 10^8)$

$= Rs.50.5892 \times 10^8$

6.3.1 Administrative costs

= 5% of total product cost

$= 0.05 \times 31.61 \times 10^8$

$= Rs.1.5805 \times 10^8$

6.3.2 Distribution and selling costs

includes costs for sales offices, salesman, shipping and advertising.

= 15% of total product cost

= 15% of 31.61×10^8

$= 0.15 \times 31.61 \times 10^8$

$= Rs.4.7415 \times 10^8$

6.3.3. Research and Development costs

= 5% of total product cost

= 5% of 31.61×10^8

$= 0.05 \times 31.61 \times 10^8$

$= Rs.1.5805 \times 10^8$

6.3.4. Financing (interest)

= 5% of 31.998×10^8

$= 0.05 \times 31.998 \times 10^8$

$= Rs.1.5998 \times 10^8$

Thus, General Expenses = $Rs.9.5023 \times 10^8$

Total Product Cost = Manufacture cost + General Expenses

$= (50.5892 \times 10^8) + (9.5023 \times 10^8)$

$= Rs.60.0915 \times 10^8$

6.4 GROSS EARNINGS/INCOME:

Cumene/kg price = Rs.75

Total income = Selling price x Quantity of product manufactured

= 75 x 30000000

= Rs.22.50 x 10^8

Gross income = Total capital investment - Total Income

= (31.998 x 10^8) - (22.50 x 10^8)

= Rs.9.498 x 10^8

Net Profit = Gross income - Taxes

= Gross income x (1-Tax rate)

= 9.498 x 10^8 (1-0.45)

= Rs.5.2239 x 10^8

Pay back period = FCI / net profit

= 27.828 x 10^8 / 5.2239 x 10^8

= 5.32 years

Rate of return = net profit*100/(total capital investment)

= 5.2239 X 10^8 x100 / 19.3774 x 10^8

= 26.95%

CHAPTER 7
ENVIRONMENTAL AND HAZOP STUDY

7.1 ENVIRONMENTAL CONSIDERATIONS:

Planning and interacting with the plant should be made in a way that there is no harm made to the environment. They are:

1. All outflows to land, air, water.
2. Squander the board.
3. Scents.
4. Commotion.
5. The visual effect
6. Some aggravations
7. natural agreeableness items.

7.1.1 Waste Management

Waste from a reactor consists mainly of by-products/unreacted reactants from the process or in special cases products produced due to misoperation.

7.1.2 Gas Waste

Gas effluents may contain several impurities including small scattered dust particles that can be eliminated by cleaning and toxic impurities should be treated before released into the atmosphere.

7.1.3 Liquid Waste

The waste fluids from a substance interaction, other than watery mechanical profluent will for the most part be combustible and can be discarded by copying in reasonable planned incinerators. The gases leaving an incinerator might be scoured, corrosive gases killed.

7.1.4 Aqueous Waste

The factors that account for the nature of industrial aqueous waste that are strictly monitored by the authorities are:

(1) pH of the effluent

(2) Suspended solid particles present in the liquid.

(3) Toxicity of the liquid.

(4) Biological oxygen demand.

7.1.5 Toxicological information

The toxicological information is normally expected accompanying qualities on the different ecological boundaries as given underneath: Threshold limit esteem 50 ppm, Skin impacts essential aggravation, Absorption through skin gradually consumed. Clinical assessment for laborers needed in certain nations different safety measures for all aromatics.

7.1.6 Noise

It can cause a genuine disturbance in the neighborhood of an interaction plant. Uproarious gear ought to, to the extent practicable, be sited well away from the site limit. Earth banks and screens of trees can be utilized to lessen the commotion level apparent external the site.

7.1.7 Visual Impact

Huge types of gear, for example, stockpiling tanks, can be painted to mix in with, or even differentiation with, the environmental factors. Finishing and screening by belts of trees cal likewise help improve the general appearance of the site.

7.2 MATERIAL SAFETY DATA SHEET

7.2.1 Hazards Identification

The hazards given under OSHA Hazards are:

Flammable liquid, Irritant, Carcinogen

GHS Classification:

Flammable liquids (Category 3)

Specific target organ toxicity - single exposure (Category 3), Respiratory system

Aspiration hazard (Category 1)

Acute aquatic toxicity (Category 2)

Chronic aquatic toxicity (Category 2)

GHS Label elements, including precautionary statements:

Pictogram

Signal word:

Danger

Hazard statement(s)

H226	Flammable liquid and vapour.
H304	May be fatal if swallowed and enters airways.
H335	May cause respiratory irritation.
H411	Toxic to aquatic life with long lasting effects.

Precautionary Statement(s)

P261	Avoid breathing dust/ fume/ gas/ mist/ vapours/ spray.

P273	Avoid release to the environment.
P301 + P310	If swallowed: Immediately call a POISON CENTER or doctor/ physician.
P331	Do not induce vomiting.

Potential Health Effects:

Inhalation - Breathing high concentration fogs/fumes damages lungs and throat.

Eye contact –It can damage the eye such as tearing, redness or stinging of eye and also obscured vision. Impacts may turn out to be more genuine with rehashed or delayed contact.

Skin Contact - causes redness and tingling or consuming inclination. Impacts may turn out to be more genuine with rehashed or delayed contact. Almost certainly, a few parts of this material can penetrate through the skin.

Ingestion - Gulping might be hurtful. Gulping this material may cause stomach or intestinal irritation. Limited quantities in the lungs can cause lung harm, potentially prompting ongoing lung brokenness or demise. Gulping this material may cause impacts.

Target Organs - May harm accompanying organs: kidneys, liver, mucous layers, spleen, upper respiratory plot, skin, adrenal, focal sensory system (CNS), eye, focal point or cornea.

Cancer-causing Potential - This item isn't known to contain any parts at fixations above 0.1% which are viewed as cancer-causing by OSHA, IARC or NTP

7.2.2 Compositon / Information On Ingredients

Component	-	Cumene
Also known	-	Isopropylbenzene
Formulae	-	C9H12
MW	-	120.19 g/mol
Concentration	-	90-100%

7.2.3 First Aid Measures

Before helping others make sure that you take appropriate precautions to ensure your health.

General Advice

Showing the safety data sheet to a physician and move out of the certain area.

Inhalation:

Move casualty to open environment. In the event that casualty isn't breathing, promptly start salvage relaxing. In the case of troublesome, 100% humidified oxygen ought to be managed by a certified person. Look for clinical consideration right away. Keep the influenced individual warm and very still.

Eye contact:

Check for and eliminate contact focal points. Flush eyes with cool, spotless, low-pressure water for in any event 15 moment while periodically lifting and bringing down eyelids. Try not to utilize eye salve except if coordinated to by a doctor. Look for clinical consideration if over the top tearing, bothering, or torment perseveres.

Skin Contact :

Take off polluted shoes and garments. Flush influenced region with a lot of water. In the event that skin surface is harmed, apply a spotless dressing and look for clinical consideration. Try not to utilize salves. On the off chance that skin surface isn't harmed, clean influenced territory altogether with gentle cleanser and water. Look for clinical consideration if tissue seems harmed or if torment or disturbance continues.

Ingestion:

Try not to prompt spewing. In the event that unconstrained retching is going to happen, place casualty's head underneath knees. On the off chance that casualty is languid or oblivious. Give nothing by mouth to an individual who isn't completely cognizant. Try not to leave casualty unattended. Look for clinical consideration right away.

CHAPTER 8
PLANT LAYOUT AND LOCATION

8.1 PLANT LOCATION

The area of a plant crucially affects the benefit of a project and the extension for future developments. Decision of area is regularly a national decision made after an evaluation of relative benefits of various for a particular business.

Major site location factors: While numerous components are significant in choice of a plant site, three are usually thought to be the most significant. These are

Location of Raw Materials

One conceivable area is a site close to the wellspring of the material.This helps in decreasing the transportation charges significantly.

Location of Market

Consumer items ought to be delivered to the circulation habitats located near the populace zones. From the plant, the item ought to be transported by truck to singular clients. This sort of office helps in speedy conveyance and better client care.

Transportation

Lower expense for transportation happens if the organization has good opportunities for acquiring a full burden on the bring trip back. The least expensive method of delivery is normally by water and the most costly is by road.

Few other significant area factors

a) Climatic conditions

b) Water source quality and quantity

c) Pollution problems

d) Corporation vital arranging

8.2 SITE LAYOUT

The spreading out of a plant is even a greater amount of a workmanship than a science. It involves putting off types of gear and structures with the goal accompanying are lessened.

1) Harm to people and nonliving things in the event of any harmful events
2) Cost for maintaining.
3) Manpower in the plant.
4) Other working costs
5) Construction costs
6) The expense of arranged future correction and development

8.3 PLANT LAYOUT

The principal thing that ought to be done is to decide the heading of the prevailing wind. Wind course will decide the overall area of manythings. All combustible supplies ought to be situated on the downwind side.

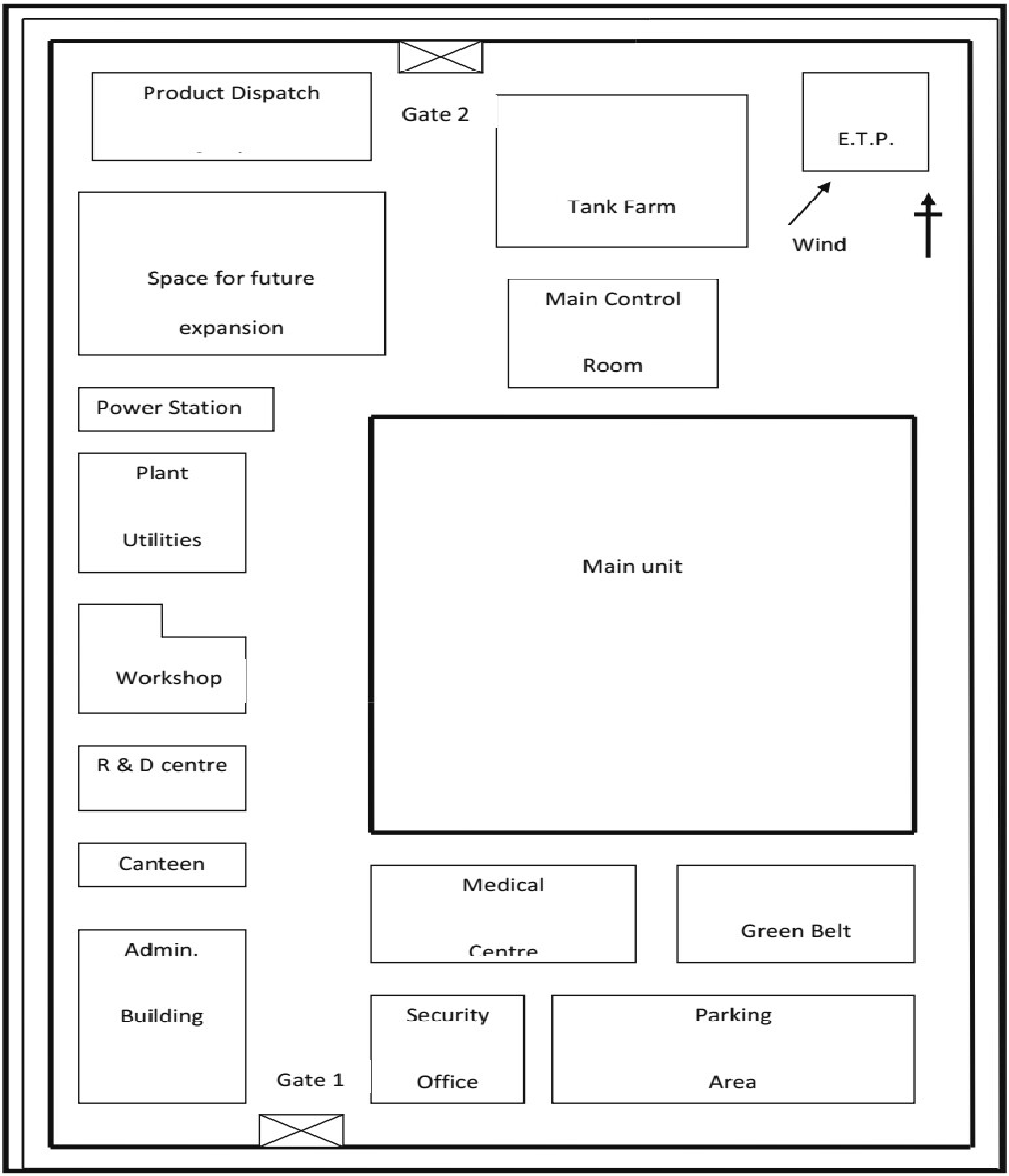

Fig 8.1 Site layout

CHAPTER 9
CONCLUSION

Assortment of highlights were inspected toward the finish of examination of these four distinctive cumene creation measures (Liquid stage alkylation utilizing Phosphoric corrosive, Liquid stage alkylation utilizing Aluminum Chloride, Q-MAX Process and CD-Cumene Process) to choose the genuine creation pathway. As indicated by cost assessment, mechanical applications and item immaculateness is in any event 99% and 312 kmol/hr Cumene limit is legitimate. Album Cumene measure has synergist refining reactor where is benzene alkylation and isolating unreacted propylene to reactor, it has benzene reflux. Benzene alkylation is exothermic response. It produces heat and is utilizing for refining in synergist refining energy recuperation. In different cycles, created heat is moving to isolating segments with utility. Cd Cumene measure is multiple times less expensive about energy prerequisite. Compact disc Cumene measure has the benefits about working expense and gear cost. Because of material adjusts measure of crude materials and the interaction has many benefit over its elective cycles. With benchmark in boundaries of monetary thought i.e., Profitability and monetarily.

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