PRODUCTION OF METHYL BENZOATE

Submitted in partial fulfillment of the requirements for the award of

Bachelor of Technology degree in Chemical Engineering

By

T ALI ABBAS (Reg. No. 37190007)

D HARI HARAN (Reg. No. 37190022)

DEPARTMENT OF CHEMICAL ENGINEERING SCHOOL OF

BIO AND CHEMICAL ENGINEERING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

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

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119

MARCH – 2021

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with “A” grade by NAAC

Jeppiaar Nagar, Rajiv Gandhi Salai, Chennai – 600 119

www.sathyabama.ac.in

ISO 9001:2015

DEPARTMENT OF CHEMICAL ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **T ALI ABBAS (37190007)** and **D HARI HARAN (37190022)** who carried out the project entitled **“PRODUCTION OF METHYL BENZOATE”** under our supervision from October 2020 to March2021.

Internal Guide

DR.D. PRABU (M.E., Ph.D.,)

Head of the Department

Dr. S. SATHISH (M.E., Ph.D)

Submitted for Viva voce Examination held on__________________

Internal Examiner **External Examiner**

DECLARATION

I T ALI ABBAS (Reg.No.37190007) and D HARI HARAN (Reg.No.37190022) hereby declare that the Project Report entitled “PRODUCTION OF METHYL BENZOATE” done by us under the guidance of Dr. D. PRABU PH.D., at Sathyabama institute of science and technology, Jeppiar nagar, Rajiv Gandhi Salai, Chennai-600 119 is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Chemical Engineering.

SIGNATURE OF THE CANDIDATE

DATE:

PLACE:

ACKNOWLEDGEMENT

I am pleased to acknowledge our sincere thanks to 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. D. PRABHU, Ph.D.,** and **Dr. S. SATHISH, 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. D. PRABU, Ph.D., Department of Chemical Engineering** for his valuable guidance, suggestions and constant encouragement paved 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

The project discloses a preparation method of methyl benzoate. The method comprises the following steps: pouring benzoic acid and methanol in a reaction tank according to a molar ratio of 1:(1.4-1.6), adding p-toluenesulfonic acid as catalyst which accounts for 15% of benzoic acid, stirring and heating, reacting 2-3 hours while controlling the reaction temperature to 95-105 °C, then reducing the temperature to 75-90 °C, continuously reacting for 1-2 hours; after the reaction, firstly vaporizing residual methanol in the reaction liquid at the atmospheric pressure, secondly vaporizing methyl benzoate at the negative pressure; introducing the mixture of water and methanol which are generated in the reaction tank to a receiving tank connected with the reaction tank, heating the receiving tank to control the solution of the tank in a gentle boiling state, introducing the mixture of water and methanol vapor in a rectification tower connected with the receiving tank to separate while controlling the reflux ratio R to be 1-4 and maintaining the overhead temperature of the rectification tower to be 65 °C, and condensing the rectified methanol with a condenser and sending the methanol back to the reaction tank to continuously react. The invention has the advantages that the dosage of methanol is low, the environment pollution is less, the reaction time is short, the yield is high and the catalyst can be reused.

TABLE OF CONTENTS

LISTS OF FIGURES

LISTS OF TABLES

CHAPTER 1

1. INTRODUCTION:

Methyl benzoate is an organic compound. It is an ester with the chemical formula. $C_6H_5CO_2CH_3$ It is a colorless liquid that is poorly soluble in water, but miscible with organic solvents. Methyl benzoate has a wonderful smell, firmly suggestive of the product of the feijoa tree, and it is utilized in perfumery. It additionally discovers use as a dissolvable and as a pesticide used to pull in bugs like orchid honey bees. Methyl benzoate is found in allspice. Methyl benzoate is available in different bloom oils, banana, cherry, pimento berry, ceriman (Monstera deliciosa), clove bud and stem, mustard, espresso, dark tea, dill, starfruit and cherimoya (Annona cherimola).

Methyl benzoate is utilized in flavourings. It is one of numerous mixtures that is alluring to guys of different types of orchid honey bees, who evidently assemble the substance to integrate pheromones; it is usually utilized as snare to pull in and gather these honey bees for study. Methyl benzoate is an ester with the compound recipe $C_6H_5CO_2CH_3$. It is shaped by the build-up of methanol and benzoic corrosive. It is a dismal to somewhat yellow fluid that is insoluble with water, however miscible with most natural solvents.

Methyl benzoate is shaped by the build-up of methanol and benzoic corrosive, in presence of a solid corrosive. Methyl benzoate responds at both the ring and the ester, contingent upon the substrate. Electrophiles assault the ring, shown by corrosive catalysed nitration with nitric corrosive to give methyl 3-nitrobenzoate. Nucleophiles assault the carbonyl community, delineated by hydrolysis with expansion of fluid NaOH to give methanol and sodium benzoate.

Methyl benzoate can be confined from the freshwater plant Salvinia molest. It is one of numerous mixtures that is appealing to guys of different types of orchid honey bees, which evidently assemble the synthetic to incorporate pheromones; it is generally utilized as lure to pull in and gather these honey bees for study. Cocaine hydrochloride hydrolyses in soggy air to give methyl benzoate; drug-sniffing canines are in this way prepared to identify the smell of methyl benzoate.

1.1 Properties of Raw material

Table 1.1 Properties of Methanol:

Properties of Methanol	
Chemical formula	CH_3OH or CH_4O
Molar mass	32.04 g mol^{-1}
Appearance	Colourless liquid
Odor	Sweet and pungent
Density	0.792 g/cm^3
Melting point	−97.6 °C (−143.7 °F; 175.6 K)
Boiling point	64.7 °C (148.5 °F; 337.8 K)
Solubility in water	miscible
Vapor pressure	13.02 kPa (at 20 °C)
Acidity (pK_a)	15.5
Magnetic susceptibility (χ)	$-21.40 \cdot 10^{-6}$ cm^3/mol
Refractive index (n_D)	1.33141

Table 1.2 Properties of Benzoic acid:

Properties of Benzoic acid	
Chemical formula	$C_7H_6O_2$
Molar mass	122.123 g·mol^{-1}
Appearance	Colorless crystalline solid
Odor	Faint, pleasant odor
Density	1.2659 g/cm^3 (15 °C) 1.0749 g/cm^3 (130 °C)
Melting point	122 °C (252 °F; 395 K)
Boiling point	250 °C (482 °F; 523 K)
Solubility	soluble in acetone, benzene, CCl_4, $CHCl_3$, alcohol, ethyl ether, hexane, phenyls, liquid ammonia, acetates
Solubility in methanol	30 g/100 g (-18 °C) 32.1 g/100 g (-13 °C) 71.5 g/100 g (23 °C)
Vapor pressure	0.16 Pa (25 °C) 0.19 kPa (100 °C) 22.6 kPa (200 °C)
Refractive index (n_D)	1.5397 (20 °C) 1.504 (132 °C)

Table 1.3 Properties of methyl benzoate:

Properties	
Chemical formula	$C_8H_8O_2$
Molar mass	136.150 g·mol^{-1}
Density	1.0837 g/cm^3
Melting point	−12.5 °C (9.5 °F; 260.6 K)
Boiling point	199.6 °C (391.3 °F; 472.8 K)
Magnetic susceptibility (χ)	−81.95×10^{-6} cm^3/mol
Refractive index (n_D)	1.5164

CHAPTER 2

2. VARIOUS PROCESS AND SELECTION OF PROCESS

2.1 Methodology:

- Methyl benzoate can be manufactured by the following methods

1. Fischer Esterification process
2. Methyl benzoate is a by product in the manufacture of dimethyl terephthalate

2.2 Process selection:

- Fischer esterification is selected as the suitable method based on the following reasons
- Fischer Esterification process synthesizes Methyl benzoate which is stable and non-explosive. The reagents used in Fischer Esterification process are direct, so. there is less ecological effect as far as side-effects and hurtfulness of the reagents Pollution emission caused due to this process is negligible.
- The raw materials used are economical and easily available when compared to the process in which methyl benzoate is obtained as by-product in the manufacture of dimethyl terephthalate. Plant requires less number of equipment's. This process is preferred over other methods because it is relatively simple, more efficient and cost effective.
- The purity obtained by Fischer Esterification process is approximately 99.99% which is an added advantage.

2.3 Process description:

- Fischer esterification is the method using which the process is carried out.

2.3.1 Raw Materials:

- Benzoic acid
- Methanol

2.3.2 Equipments Involved:

- Continuous stirred tank reactor
- Centrifugal Extractor
- Distillation Column

The raw materials benzoic acid and methanol are fed into the continuous stirred tank reactor where reaction takes place at 110°C in the presence of sulfuric acid catalyst. The catalyst is used to enhance the rate of the reaction. The reaction takes 10 hours for completion of the reaction in the reactor. The reactants are converted into methyl benzoate and water. The formed products along with the excess reactants enter into the extractor.

Methylene chloride is used as the solvent to extract the solute methyl benzoate from the mixture where separation of organic phase and aqueous phase takes place. The aqueous phase is separated as raffinate and methyl benzoate and Methylene chloride in the organic phase is the extract. The extract enters the distillation column where separation based on boiling point occurs. The operation temperature is maintained at 140°C. Methyl benzoate is recovered as residue from the distillation column.

Figure 2.1 Flow chart

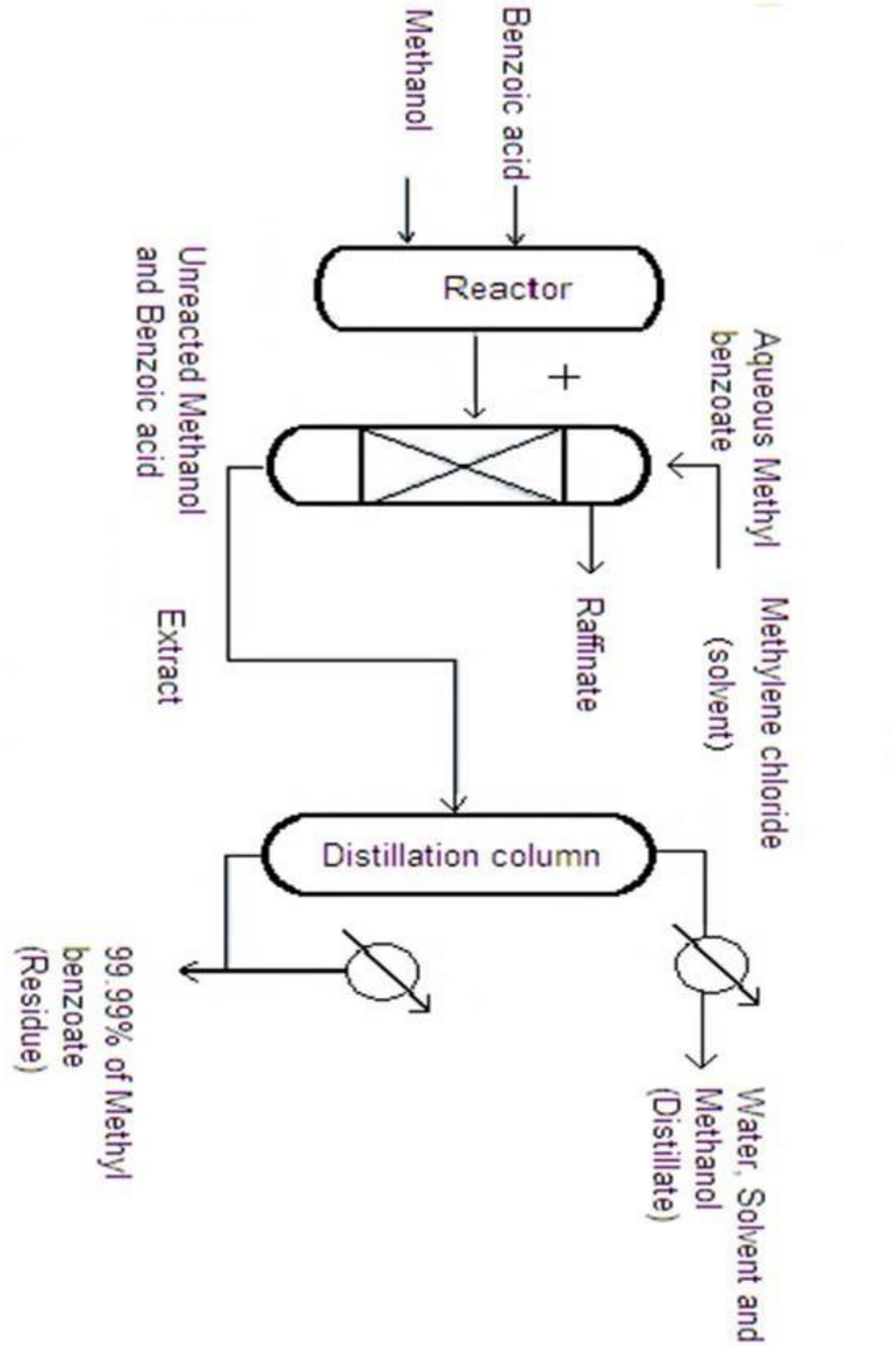
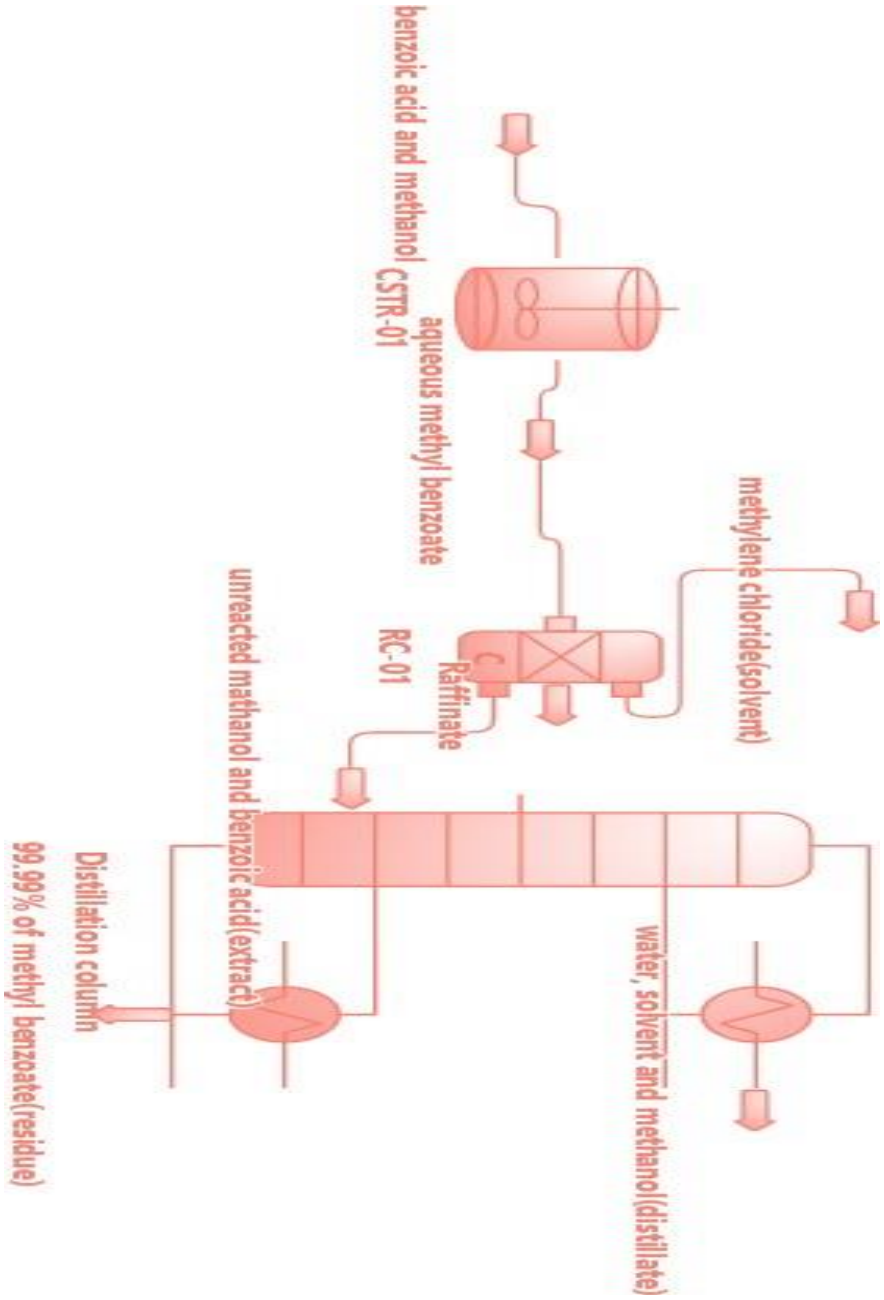


Figure2.2 Process Flow Diagram



CHAPTER 3

3.MATERIAL BALANCE

Material adjusts are the premise of interaction plan. A material equilibrium taken over complete cycle will decide the amounts of crude materials required and items delivered. Equilibriums over Individual cycle until set the interaction streams and organizations. The overall preservation condition for any interaction can be composed as

Material out = Material in + Accumulation

For a steady state process the accumulation term is zero. On the off chance that a compound response is occurring a specific synthetic animal category might be framed or devoured. However, on the off chance that there is no substance response, the consistent state balance diminishes to:

Material out = Material in

An equilibrium condition can be composed for each independently recognizable species present, components, compounds and for all out material.

BASIS:

Basis: Law of conservation of mass

Production of 1000 TPA of Methyl benzoate:

The process is planned and processed as a continuous process. The plant is operated for 300 days per year.

Number of Working days: 300

Plant maintenance : 65days

Reaction : $C_6H_5COOH + CH_3OH \rightarrow C_6H_5CO_2CH_3 + H_2O$

Weight basis = 1000*1000 / 300*24 = 80,000 kg/h

Mole Basis = 80,000 / 136 = 588.2352 kmol/h.

Input:

Benzoic acid

Methanol

Sulfuric acid

Methylene chloride

Output:

Methyl benzoate

Water

Methanol

Benzoic acid

Reaction Involved:

C_6H_5COOH	+ CH_3OH	$\rightarrow$	$C_6H_5CO_2CH_3$	+ H_2O
Benzoic acid	Methanol		Methyl benzoate	

3.1 MATERIAL BALANCE FOR INDIVIDUAL EQUIPMENT:

3.1.1 Material Balance for Reactor (100% conversion)

Input for the Reactor =Benzoic acid, Methanol in the mole ratio of 1:4

Table: 3.1: Molecular weight data

Components	Molecular weight (kg/kmol)
Benzoic acid	122
Methanol	32
Methyl benzoate	136
Water	18

Benzoic acid required producing 1000TPA

122kg/kmol C_6H_5COOH → 136kg/kmol $C_6H_5CO_2CH_3$

X kg/h C_6H_5COOH → 708.683 kg/h $C_6H_5CO_2CH_3$

X → 635.73kg/h

Methanol required

32 kg/kmol CH_3OH → 136kg/kmol $C_6H_5CO_2CH_3$

Y kg/h CH_3OH → 708.68kg/h $C_6H_5CO_2CH_3$

Y → 666.9963kg/h

Water produced

18 kg/kmol water → 122kg/kmol C_6H_5COOH

? kg/h water → 635.73kg/h C_6H_5COOH

→ 93.796kg/h

To calculate the amount of Excess Reactants:

Amount of Benzoic acid = 635.73 kg/h

= 5.2104 kmol/h

Benzoic acid and Methanol are taken in 1:4 mole ratio

Amount of Methanol = 5.2104 kmol/h*4 = 20.844 kmol/h

Excess Reactant = (20.844 – 5.2104) * 32

= 500.247 kg/h

Table: 3.2: For Reactor (100% Conversion)

Components	No. of Moles (kmol)	Input (kg/h)	Output (kg/h)
Benzoic acid	5.2109	635.73	-
Methanol	5.2109	666.996	500.247
Methyl benzoate	5.2109	-	708.683
Water	5.2109	-	93.796
Total		1302.726	1302.726

3.1.2 Material Balance for Reactor (90% conversion)

Input for the Reactor = Benzoic acid, Methanol in the mole ratio of 1:4

Benzoic acid required producing 1000 TPA

122kg/kmol C_6H_5COOH → 136kg/kmol $C_6H_5CO_2CH_3$

X kg/h C_6H_5COOH → 708.683 kg/h $C_6H_5CO_2CH_3$

X → 706.267kg/h

Methanol required

32 kg/kmol CH_3OH → 136kg/kmol $C_6H_5CO_2CH_3$

Y kg/h CH_3OH → 708.683 kg/h $C_6H_5CO_2CH_3$

Y → 741.107 kg/h

Water produced

18 kg/kmol water → 122 kg/kmol C_6H_5COOH

? Kg/h water → 706.267 kg/h C_6H_5COOH

→ 104.265 kg/h

To calculate the amount of Excess Reactants:

Amount of Benzoic acid = 706.267 kg/h

= 5.789 kmol/h

Benzoic acid and Methanol are taken in 1:4 mole ratio

Amount of Methanol = 5.789 kmol/h * 4 = 23.156 kmol/h

Excess Reactant = (23.156 – 5.789)*32

= 563.88 kg/h

Table: 3.3: For Reactor (90% Conversion)

Components	Input (kg/h)	Output (kg/h)
Benzoic acid	706.267	70.6267
Methanol	741.107	563.88
Methyl benzoate	-	708.683
Water	-	104.215
Total	1447.47	1447.47

3.1.3 Material Balance for Extractor:

Basis: 1000 kg/h of Methylene chloride (solvent)

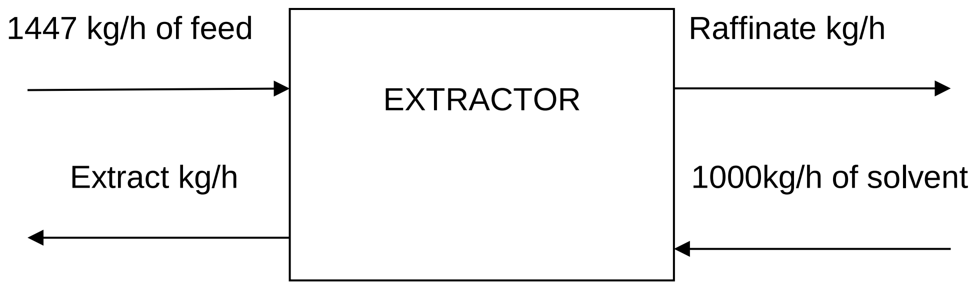


Fig: Extractor representation

F = E + R

2447.468 = 1689.285 + 758.183

Extract is 98% pure.

Table 3.4: Material Balance for Extractor

Components	Input (kg/h)	Output (kg/h)	Output (kg/h)
		EXTRACT	RAFFINATE
Benzoic acid	70.6376	1.4127	69.224
Methanol	563.88	11.277	552.6024
Methyl benzoate	708.683	694.509	14.174
Water	104.268	2.0854	102.1826
Methylene chloride	1000	980	20
Total	2447.468	169.285	758.183

INPUT=OUTPUT

F = E + R

2447.468 = 1689.285 + 758.183

3.1.4 Material Balance for Distillation column:

Table:3.5 Input data to the distillation column

Components	Mole Basis	Mole Fraction
Benzoic acid	0.012	$7.0253*10^{-4}$
Methanol	0.352	0.0214
Methyl benzoate	5.107	0.31
Water	0.116	$7.024*10^{-3}$
Methylene chloride	10.896	0.661
Total	16.483	0.999

kmol of Methyl benzoate in W = 16.483 * 0.31 * 0.999

= 5.106

W = 5.106 kmol/h

kmol of Benzoic acid in W = $5.106 * 10^{-4}$ kmol/h

F = D + W

D = 11.376 kmol/h

Component Material Balance:

$Fx_F = Dx_D + Wx_W$

Methyl benzoate = 16.483 * 0.31=11.376 * x_D

+ 5.106 * 0.999

x_D of Methyl benzoate = 4.489 * 10^{-4}

Benzoic acid = 16.483 * 7.025 *10^{-4}=11.376 * x_D

+ 5.106 *10^{-4}

x_D of Benzoic acid = 9.731 *10^{-4}

Methanol = 16.483 * 0.021 = 11.376 * x_D

x_D of Methanol = 0.031

Water = 16.483 * 7.024 * 10^{-3} = 11.376 * x_D

x_D of Water = 0.010

Methylene Chloride = 16.483 * 0.661 = 11.376 * x_D

x_D of Methylene Chloride = 0.958

Table:3.6 Distillation Column (Mole Basis)

Components	Input (kmol/h)	Output (kmol/h)	Output (kmol/h)
		Distillate	Residue
Benzoic Acid	0.012	0.011	0.001
Methanol	0.352	0.352	-
Methyl Benzoate	5.106	0.001	5.106
Water	0.116	0.116	-
Methylene Chloride	10.897	10.896	-

INPUT=OUTPUT

F = B + D

Table 3.7 DISTILLATION COLUMN (WEIGHT BASIS)

Components	Input (kg/h)	Output (kg/h)	Output (kg/h)
		Distillate	Residue
Benzoic acid	1.413	1.351	0.062
Methanol	11.278	11.278	-
Methyl benzoate	694.509	0.069	694.436
Water	2.085	2.085	-
Methylene chloride	980	979.999	-
Total	1689.285	994.783	694.502

1689.285 kg/h = 694.502kg/h + 994.783kg/h

CHAPTER 4

4. ENERGY BALANCE

The first law of thermodynamics demands that energy be neither created nor destroyed. The following is a systematic energy balance performed for each unit of the process. The datum temperature for calculation is taken as ^{0}C.

The various properties like explicit warmth, warmth of response, warmth of vaporization, and so on are taken to be consistent over the temperature range.

Formula used

$$Q = mc_p\Delta T$$

$$Q = m\lambda$$

4.1 FOR REACTOR:

(For Reactants)

Reactor is maintained at 110 °C

Table:4.1 Energy Balance for Reactor (Reactants)

Components	Mass Flow Rate (kg/h)	Specific Heat Capacity (kJ/kgK)	ΔT (K)	ΔH_f (kJ/mol)	Q_{In} (kJ/mol)
Benzoic acid	706.367	1.203	85	-385.2	72229.5603
Methanol	741.107	2.484	85	-238.6	156477.333
				Total	228706.8933

Table:4.2 Energy Balance for Reactor (Products)

Components	Mass Flow Rate (kg/h)	Specific Heat Capacity (kJ/kgK)	ΔT (K)	ΔH_f (kJ/mol)	Q_{out} (kJ/mol)
Methyl benzoate	708.683	1.590	85	-340.6	95778.51
Water	104.265	4.18	85	-285.8	37045.33
Benzoic acid	70.6367	1.203	85	-385.2	7222.96
Methanol	563.88	2.484	85	-238.6	119057.62
				Total	126280.58

4.1.1 Heat of Formation of Reactants

Benzoic acid = 706.36 kg/h

= 5789.9mol/h * (-385.2kJ/mol)

= -2230269.48 kJ/h

Methanol = 741.107 kg/h

= 23159.6 mol/h * (-238.6 kJ/mol)

= -5525880.56 kJ/h

Total $(\Delta H_f)_r$= -7756150.04 kJ/h

4.1.2 Heat of Formation of Products

Methyl benzoate = 708.683 kg/h

= 5210.904 mol/h * (-340.6 kJ/mol)

= -1774833.902 kJ/h

Water = 104.265 kg/h

= 5792.5 mol/h * (-285.8 kJ/mol)

= -3430330.402 kJ/h

Benzoic acid = 70.6367 kg/h

= 578.989mol/h * (-385.2)

= -223026.695 kJ/h

Methanol = 563.88 kg/h

= 17621.25 * (-238.6 kJ/mol)

= -4204430.25 kJ/h

Total $(\Delta H_f)_p$ = -7857787.347 kJ/h

Standard Heat of Reaction

$\Delta H_r = (\Delta H_f)_p - (\Delta H_f)_r$

= -101637.307 kJ/moles

Q_{in} +heat of reaction = Q_{out} + heat removed

Heat removed = -5754.28 kJ/h

4.2 ENERGY BALANCE FOR DISTILLATION COLUMN

Base temperature = 25 °C = 298 K

operation temperature = 140 °C = 413 K

Heat Input, Q_{in} = $m\ c_p \Delta T + m\lambda$

= 840325.846 kJ/h

Heat Output, Q_{out} = 2 83462.3803kJ/h

$Q = Q_{in} - Q_{out}$

= 556863.846 kJ/h

steam Q = m * λ

556863.846 = m * 2205.82 kJ/h

m = 252.4509kg/h

CHAPTER 5

5. EQUIPMENT DESIGN

5.1 CONTINUOUS STIRRED TANK REACTOR DESIGN:

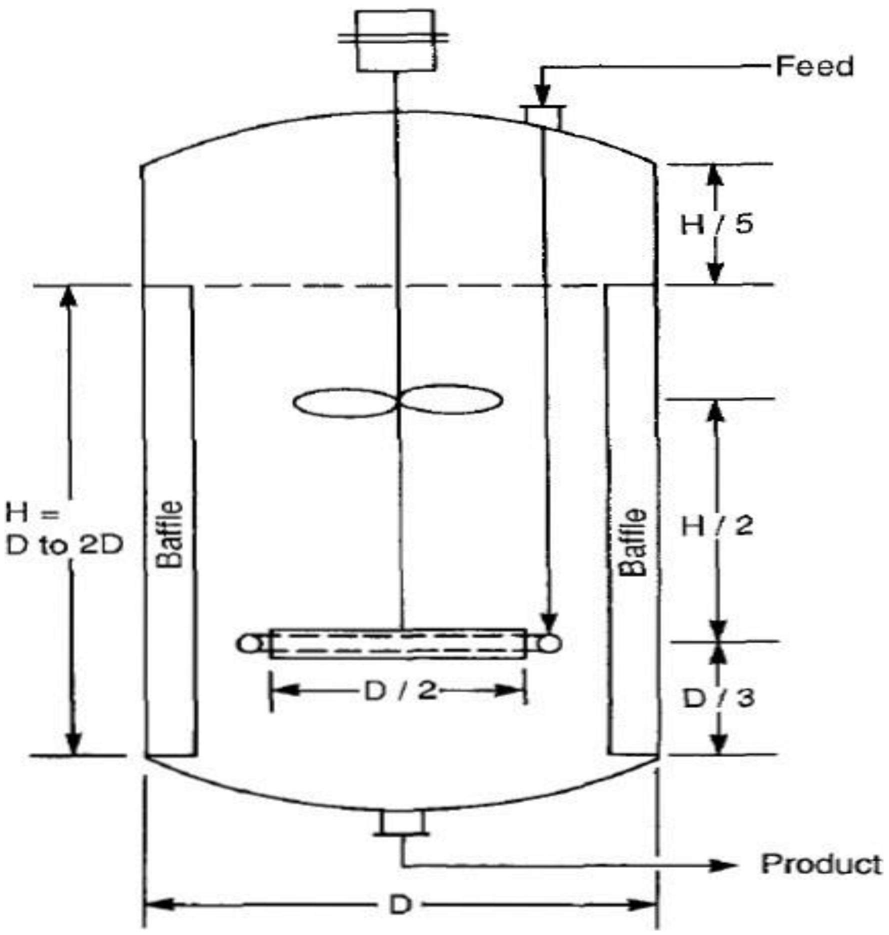


Fig: 5.1: Continuous stirred tank reactor

Reaction time = Ʈ = 10 Hours

Ʈ =V/V_o

V=Reactor volume

V_O = Volumetric flow rate

Benzoic acid inlet = 706.267 kg/h

Methanol inlet = 741.107 kg/h

Density of benzoic acid = 1270kg/m^3

Density of methanol = 791.8kg/m^3

Volumetric flow rate of Benzoic acid = Mass flow rate/Density

= 0.556115 m^3/h

Volumetric flow rate of methanol= 0.9359 m^3/h

Total volumetric flow rate = 1.49210 m^3/h

Volume of Reactor

V = 10* V_o

= 10* 1.49210 = 14.9210 m^3

H/D = 1.5m

H= 1.5D

V= (π/4) D^2H

14.921 m^3 = (π /4) D^2 (I.5D)

D^3= 12.6653m

D = 2.331m

H = 3.4964m

Calculation of Shaft Power Requirement

$P_0 = P/ (\rho_{mixture})*N^3 D_A{}^5$

Where P_0 = power number

P is power required for agitation

N is number of revolutions=200rpm

=3.33rps

Where, D_A =diameter of agitator

Diameter of impeller varies from 30%-50% of tank diameter

Diameter of reactor = 2.331m

Diameter of agitator = 0.3*2.331=0.6993m

i.e., using 30% of diameter of reactor as impeller diameter

Calculation of Reynolds Number

Re= $(D_A{}^2 * N * \rho_{mixture})/\mu_{mixture}$

Where density of mixture= summation of (ρ*mass fraction)

= (1270*0.4871) + (791.8*0.512)

=1024.01 kg/m^3

$\mu_{mixture}$ = ε of(viscosity*mass fraction)

= (0.0002*0.487) + (0.0002*0.512)

= $2.376*10^{-4}$ kg/ms

Re = $(0.699)^2*(3.33)\ (1024.01)/2.376*10^{-4}$

= $7.01*10^7$

Thus Reynolds number is greater than 10000, from power curve Po=6.1

Power required for agitation= 6.1*density of mixture*$N^3 * D_A{}^5$

P = 38573.08 W

Thus power required for agitation= 38.57 kW

Design Summary:

- Volumetric flow rate of Methanol= 0.9359 m^3/ h
- Volumetric flow rate of Benzoic acid= 0.5561 m^3 /h
- Total volumetric flow rate = 1.49210 m^3/h

- Volume of the reactor = 14.921 m^3
- Diameter of the reactor = 2.331m
- Height of the reactor = 3.4964m
- Power required for agitation = 38.57kW/h

5.2 CENTRIFUGAL EXTRACTOR DESIGN:

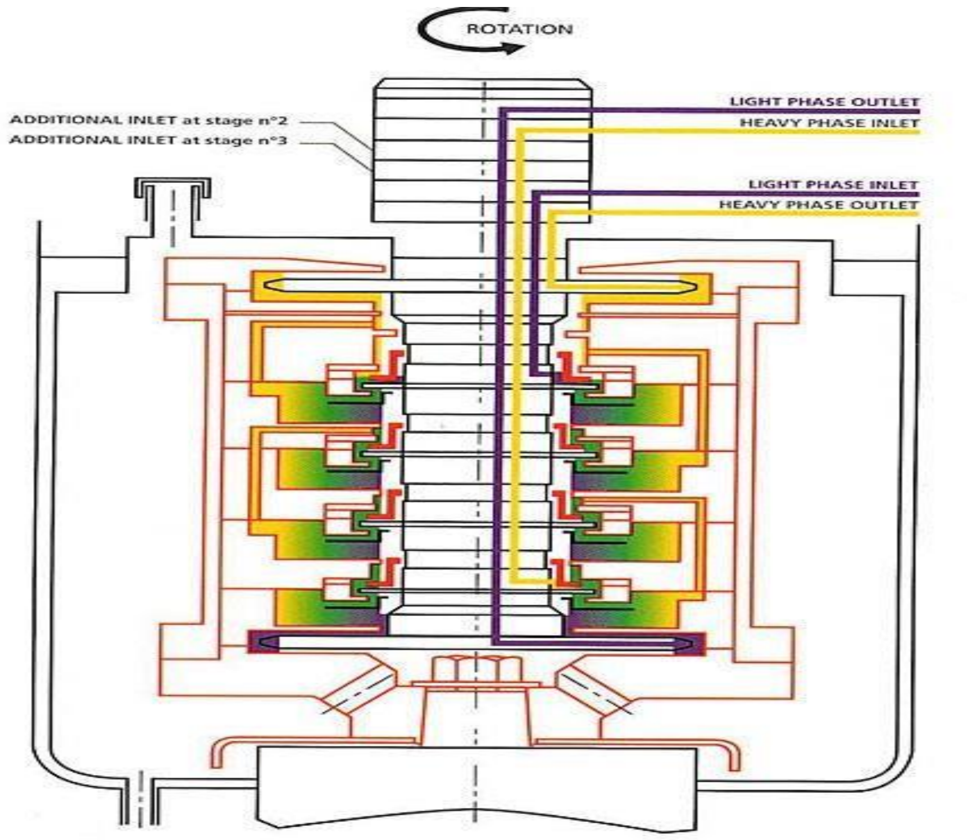


Fig: 5.2: Multistage Centrifugal Extractor

Feed composition:

Methyl benzoate	= 708.683kg/h
Aqueous mixture	= 738.786kg/h
Total	= 1447.47kg/h

Mass fraction of Methyl benzoate = 0.4896

Mass fraction of Aqueous mixture = 0.5104

Density of Methyl benzoate = 1.0837g/cm^3= 1083.7kg/m^3

Density of Aqueous mixture = 3.0577g/cm^3=3057.7kg/m^3

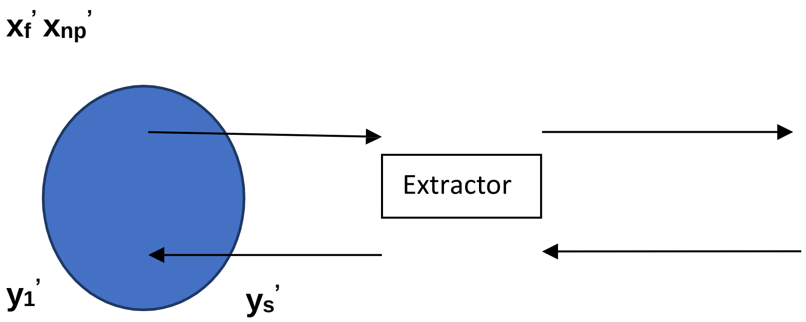


Fig: 5.3: Representation of Extractor Design

Where,

x_f' → mass fraction of solute in feed. $x_f' = x_f/(1-x_f)$ =0.959

x_f=A/(A+B) =0.4896

x_{np}' → mass fraction of solute in raffinate.

98% of separation is achieved hence 2% of the solute will be present in the raffinate.

x_{np}' = 2/(100-2)=0.0204

y_s' → mass fraction of solute in solvent.

Since there will be no solute in the solvent, y_s' = 0

y_1' → mass fraction of solute in extract.

To Calculate Minimum Operating Flow Rate (B_{min}):

Plotting a graph of x Vs y,

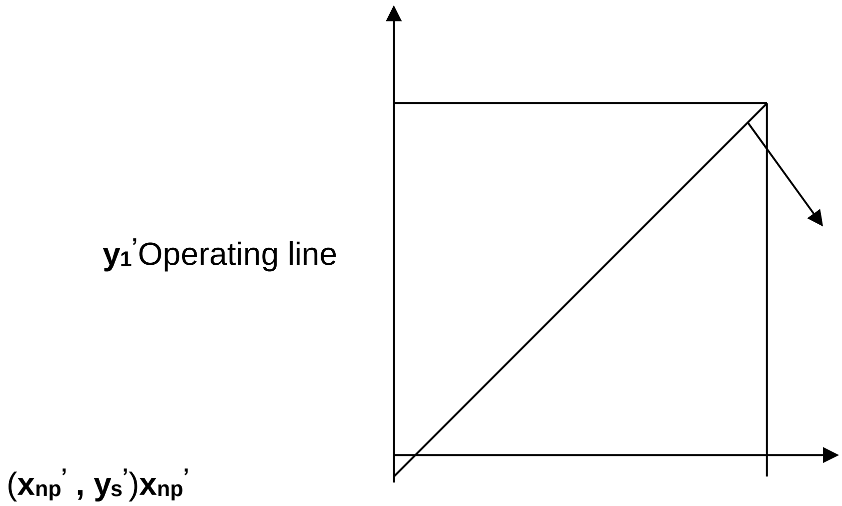


Fig: 5.4: Graph to calculate minimum solvent flow rate

From the graph,

We get y_1' → 0.96

To calculate B_{min}:

$A/B_{min} = y_1' - y_s' / x_f' - x_{np}'$

A = 738.786 kg/h

B = 1000 kg/h

C = 708.683 kg/h

= (0.96-0)/ (0.959-0.0204)

A/B_{min} =1.023

B_{min} =738.786/1.023

= 722.176kg/h.

To Calculate Operating Solvent Flow Rate:

$m_f / m_{sm} = 2.0043$

Where, $m_f \rightarrow$ feed input (1447.47kg/h)

$m_{sm} = B_{min}$

The Operating feed to the solvent ratio:

$m_f / m_{sm} = C (m_f / m_{sm})$

$=0.5(2.0043)$

$=1.00215$

$m_s = m_f / 1.00215$

$= 1444.365$kg/h

Where, $m_s \rightarrow$ Operating Solvent Flow Rate.

Extraction Factor:

$A_E = (m_f / m_{sm})/K_k$

$= 1.00215 /2$

$=0.501$

Number of Stages:

On plotting a graph of x Vs y

$A/B_{act} = 738.786/1000=0.739$

$\tan \theta =0.739$

$=\tan^{-1} \theta (0.739)$

$=36.5°$

We obtain the number of stages as

$N_E = 6$

$M_f / \rho_f = (708.683/1083.7) + (738.786/3057.7) = 0.8956\ m^3/h$

$M_s / \rho_s = 1444.365/1330 = 1.086\ m^3/h$

Extractor Diameter:

Area = $(A + C) / J_T$

= (708.683 + 738.786)/363

= 3.988 m^3

$D = (4A/\pi)^{(1/2)}$

=2.253m

Extractor Height:

$Z_E = N_E\ (HETS) + D$

=6(0.43) +2.253

=4.833m

Design Summary:

- Operating solvent flow rate = 1444.365kg/h
- Extractor factor = 0.501
- Number of Theoretical stages = 6
- Extractor Diameter = 2.253m
- Extractor Area = 3.988m^2
- Extractor Height = 4.833m

CHAPTER 6
6.COST ESTIMATION

Plant Capacity = 1000 tons (1000000 kg) per year .

Cost Estimated based on the following factors for the above plant capacity.

1. Equipment Cost
2. Project Cost
3. Accessories
4. Raw material Cost
5. Manpower Cost
6. Running Cost
7. Production Cost.

6.1 equipment cost and installation cost

Table 6.1

S.No	List of Equipment's	Capacity	No. of Equipment	Cost / Unit (Rs. in lakhs)	Total Cost (Rs. in lakhs)
1	Continuous stirred tank reactor	10KL	2	25	50
2	Centrifuge Extractor	1000 kg/hr	2	13	26
3	Distillation Column	50 tray	2	15	30
4	Storage Tank – Large	50 KL	20	5	100
TOTAL (Rs. in lakhs)					206

6.2project cost

Table6.2

S.No	Type	Total Cost (Rs. in lakhs)
1	Land Purchase	400
2	Drawing Preparation	5
3	Consultancy	12
4	Construction Charges	300
5	Erection & Start Up	50
TOTAL (Rs. in lakhs)		767

6.3 Direct And Indirect Cost

TABLE 6.3

S.No	Type	No.of Equipment	Total Cost (Rs. in lakhs)
1	Instrumentation	-	92
2	Valves	160	100
3	Pumps	70	75
4	Piping	-	80
5	Service equipment's	-	60
6	Electrical	-	110
TOTAL (Rs. in lakhs)			517

6.4 MANUFACTURING COST

TABLE 6.4

S.No	Raw Materials	Quantity (kgs)	Cost / Kg (Rs.)	Total Cost (Rs. in lakhs)
1	Benzoic acid	15264	500	76,32,000
3	Methanol	16008	32	5,12,256
TOTAL (Rs. in lakhs)				81.44

6.5 Manpower Cost:

TABLE 6.5

S.No	Designation	No. of Employees	Salary (Rs.)	Total Cost (Rs. in lakhs)
1	Managing Director (M.D)	1	2,50,000	2.5
2	General Manager (GM)	1	1,40,000	1.4
3	Plant Manager	4	60,000	2.4
4	Shift Engineers	40	35,000	1.4
5	Shift Operators	55	18,000	9.9
6	Maintenance	30	21,000	6.3
7	Skilled Process (utility)	50	15,000	7.5
8	Administrative Personnel	60	16,000	9.6
9	Security officers	40	12,000	4.8
10	Lab In charges	15	18,000	2.7
11	Safety Engineer	6	30,000	1.8
TOTAL (Rs. in lakhs)				50.3

6.6 Running Cost:

TABLE 6.6

S.No	Type	Total Cost (Rs. in lakhs)
1	Electricity Charges	10
2	Water Charges	2.5
3	Transportation	3
4	Miscellaneous	2
TOTAL (Rs. in lakhs)		17.5

6.7 Production Cost:

Table 6.7

S.No	Type	Total Cost (Rs. in lakhs)
1	Raw Material Cost	81.44
2	Manpower Cost	50.3
3	Running Cost	17.5
4	Miscellaneous	2
TOTAL (Rs. in lakhs)		151.24

Total Production Cost(Rs.) = 151.24 lakhs /day.

<u>Total Investments:</u>

Equipment Cost = 206lakhs

Project Cost = 767 lakhs

Accessories = 517 lakhs

Total Investments = 1490 lakhs.

Total Production Cost = 151.24 lakhs / day

<u>Profit:</u>

= 151.24 x 365 days

= 55202.6 lakhs / Year.

Margin = 60%

= 0.60 x 55202.6

Profit after Taxes = 33121.56 lakhs / year.

Pay back period:

$$P.B.P = \frac{\text{Total Investment + Total Production Cost}}{\text{Profit after Taxes}}$$

$$= \frac{1490\ L + 55202.6\ L}{33121.56\ L}$$

$$= 1.71 \text{years}$$

P.B. P	=	1.71 Years

CHAPTER 7

PLANT LAYOUT AND LOCATION

Plant layout

A plant design study is a designing examination used to investigate diverse actual setups for an assembling plant. It is otherwise called Facilities Planning and Layout.

Definition:

It refers to the arrangement of physical facilities such as machinery, equipment furniture etc., with in the factory building in such a manner so as to have quickest flow of material at the lowest costs & with minimal measure of taking care of in handling the item from the receipt of material to the shipment of the completed item.

According to James Lundy, "Layout identically involves the allocation of space and the arrangement of equipment in such a manner that overall operating costs are minimized."

Importance:

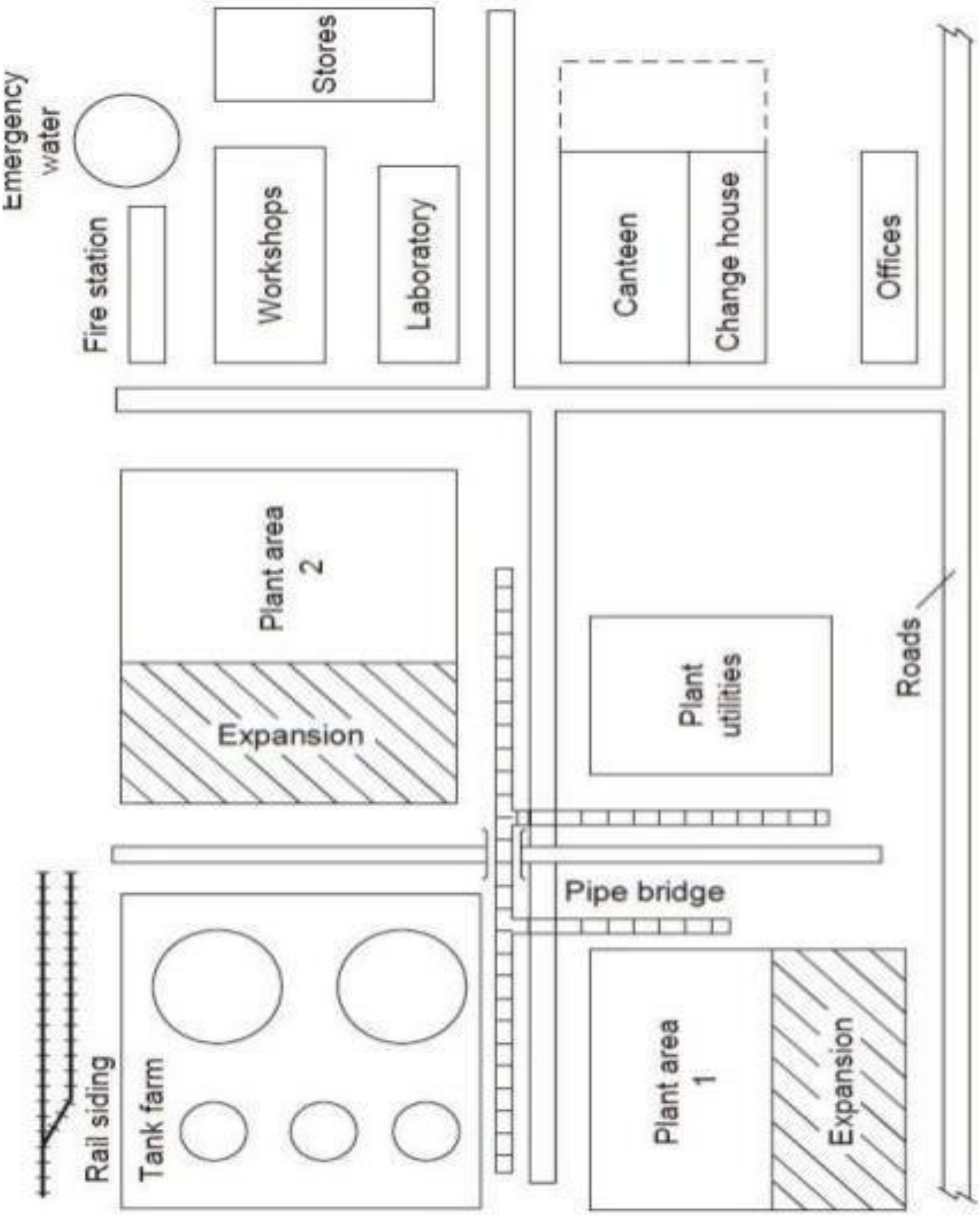
- It's a long-term commitment
- It facilitates the production process, minimum material handling, time and cost.
- Good plant layout facilitates accurate planning and control of production. A steady quantity of output is assured by proper layout of the productive capacity and its utilization. Idleness of machinery and man would be reduced to the minimum and production capacity would be maintained intact.
- Good plant layout ensures safety to the operating personnel. The risks or hazards in mechanical operations at work centres are eliminated by safety devices built into the design of the plant and the allied layout of the equipment. Plant layout which incorporates safety element will result in lesser accidents and lesser loss of man-hours.

7.1 Essentials:

The planning of a plant format ought to be with the end goal that it ought to augment the return and limit the expense of creation. Coming up next are the attributes of a plant layout. An effective plant format is one that can be instrumental in accomplishing the accompanying goals:

1. Smooth flow of production
2. Greatest usage of accessible space
3. Facilities the movement of men, materials and machines, etc.
4. Involves minimum handling
5. Gives better working conditions
6. Adaptability
7. Area of stores
8. Encourages management and control
9. Arrangement of security
10. Co-ordination and integration
11. Proper & efficient utilization of available floorspace

Figure 7.1 Plant Layout



CHAPTER 8

SAFETY

Wellbeing is the condition "safe", the state of being shielded from hurt or other non-alluring results. Wellbeing can likewise allude to the control of perceived perils to accomplish an adequate degree of danger.

Process safety focuses on preventing fires, explosions and accidental chemical releases in chemical process facilities or other facilities dealing with hazardous materials such as refineries, and oil and gas production installations. Occupational safety and health primarily covers the management of personal safety

Occupational safety and health primarily covers the management of personal safety. All around created the board frameworks additionally address measure security issues. The apparatuses, procedures, programs and so forth needed to oversee both cycle and word related wellbeing can once in a while be something similar (for instance a work license framework) and in different cases may have altogether different methodologies. LOPA (Layers of Protection Analysis) or QRA (Quantified Risk Assessment) for instance center around measure security though PPE (Personal Protective Equipment) is a lot of an individual centered word related wellbeing issue.

8.1 INDUSTRIAL SAFETY:

Industrial Safety refers to the management of all operations and events within an industry in order to protect its employees and assets by minimizing hazards, risks, accidents, and near misses.

Modern wellbeing covers various issues and themes influencing security of staff and the uprightness of hardware in a specific industry.

The accompanying themes are for the most part talked about:

- General Safety – General parts of wellbeing which are normal to all ventures
- Occupational Safety and Health – Particularly connected with the occupation

- Process and Production Safety
- Material Safety
- Workplace Safety – Safety issues straightforwardly identified with the work environment setting
- Fire Safety
- Electrical Safety – Arising from the hardware utilized
- Building and Structural Safety – Including establishments according to existing construction law
- Environmental Safety – Concerns the immediate and backhanded natural effect of the business

8.2 Plant safety and environment:

Introduction:

Altogether of the components that impacts the exhibition of the gear and the plant there are components of vulnerability and the chance of blunder, including mistake of actual information, fundamental connections of conduct, for example, pipe rubbing (or) plate proficiency (or) gas-fluid dissemination, essential approximations of plan strategies and counts not completely known practices of materials of development, vulnerability of future stamped requests and changes in working execution with time.

Safety of Plant & Environment:

The plan of plant and gear should limit likely damage to work force and public in the event of mishaps of which the fundamental driver are,

Human Failure.

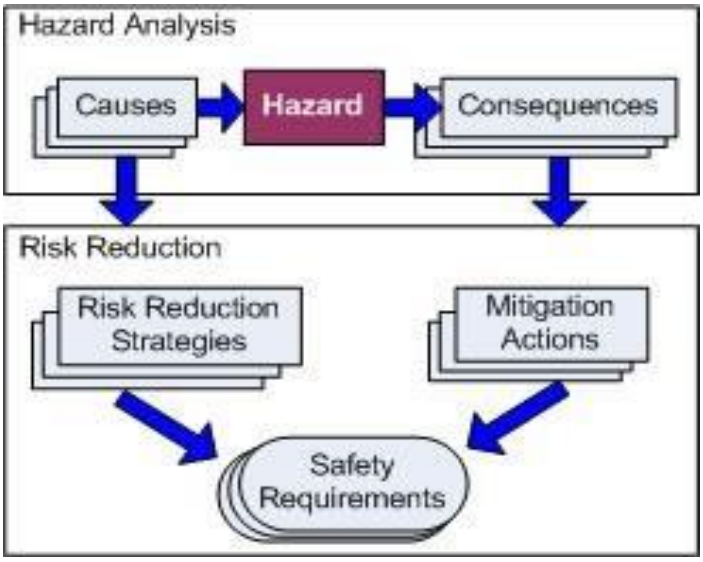
Disappointment of hardware and control instruments.

Disappointment of supply of utilities and key cycle streams. Natural occasions

Safety factors

The meaning of the security factor is basic. It is characterized as the proportion between the strength of the material and the greatest pressure in the part. What it advises us essentially is that in a particular region of the model, the pressure is higher than the strength the material can bear

8.3 Hazard Analysis Objectives



The objectives of a hazard analysis are to:

- Identify dangers: To decide the perils and risky occasions of the gear leveled out and the control framework (on the whole methods of activity), for all sensibly predictable conditions including shortcoming conditions and abuse

- Identify causes: To examine the occasion successions prompting the perilous occasions recognized

- Determine chances: To investigate the dangers related with the dangerous occasions.

Hazard Analysis Context

A risk examination may be acted in one of the accompanying settings:

- Development: Examining a framework being developed to distinguish and evaluate likely dangers and take out or control them
- Operations and the executives: Examining a current framework to recognize and evaluate risks to improve the degree of security; figuring wellbeing the board strategy; preparing staff; expanding inspiration for productivity and wellbeing of activity
- Certification: Examining an arranged or existing framework to exhibit its degree of wellbeing and to encourage acknowledgment by a client, an administration security authority or the general population.

Preliminary Hazard Analysis Objectives

A Preliminary Hazard Analysis (PHA) is directed in the beginning phases of a venture. Its destinations are to:

- Identify known dangers
- Determine the cause(s) of the risks
- Determine the impacts of the dangers
- Determine the likelihood that a mishap will be brought about by a danger
- Establish beginning plan and procedural prerequisites to wipe out or control risks.

Analysis of the hazard:

An analysis must be made of the source of hazards are classified into two major categories.

- Material Hazard
- Process Hazard

Material hazard:

Hazardous materials are substances that could hurt human wellbeing or the climate..... Peril correspondence, or HAZCOM is showing individuals how to function with perilous materials and waste. There are a wide range of sorts of dangerous materials, including: Chemicals, similar to some that are utilized for cleaning

Process hazard:

A process hazard analysis is an examination is a bunch of coordinated and orderly evaluations of the potential risks related with a modern cycle.

CHAPTER 9

PROCESS INSTRUMENTATION AND CONTROL

Process Instrumentation diagram

Cycle and instrumentation graphs are a group of utilitarian one-line outlines showing structure, mechanical and electrical frameworks like funnelling and link block charts. Truncated as P&ID, they show the interconnection of interaction gear and the instrumentation used to control the cycle. They are the essential schematic drawings utilized for spreading out an interaction control establishment in an industrial facility or plant. Simultaneously industry, a standard arrangement of images might be utilized to plan drawings of cycles.

A P & ID should include:

1. Instrumentation and assignments
2. Mechanical hardware with names and numbers
3. All valves and their distinguishing pieces of proof
4. Interaction channelling, sizes and distinguishing proof
5. Different - vents, channels, uncommon fittings, testing lines, reducers, increasers.
6. Perpetual beginning up and flush lines
7. Stream bearings
8. Interconnections references
9. Control sources of info and yields, interlocks, Interfaces for class change
10. Quality level
11. PC control framework input
12. Merchant and project worker interfaces
13. Distinguishing proof of segments and subsystems conveyed by others

A P & ID should not include:

1. Instrument root valves
2. Control transfers
3. Manual switches
4. Hardware rating or limit
5. Essential instrument tubing and valves
6. Pressure, temperature and stream information
7. Elbow, tees and comparative standard fittings
8. Broad informative notes

9.1 Instruments:

The different instruments used in the P & I diagram generally are Flow meters, Level meters, Thermometers, Quality Analysis, Radiation measurement concentration meters, Pressure transmitters and Weight calculation. The instruments are used for indicating, recording and controlling purposes. The instruments are all identified by a code number. The first letter of the code refers to the property measured. For Example, F for Flow meters, T for thermometers and L for Level meters. The second letter is either I, R or C which indicates to indicating, recording and controlling respectively. Then the letters are followed by a number used to identify the instrument uniquely amidst a number of similar instruments.

Aim:

To control the process variables that they are within known safe operating limits.

To maintain the product compositions within the specified quality standards.

To detect dangerous situations and develop alarm and automatic shut-down systems.

To operate at lowest possible production cost.

To achieve the desired product output

CHAPTER 10

SUMARRY AND CONCLUSION

Methyl benzoate is a volatile aromatic ester compound widely used in perfumery industries. It is naturally occurring in guava, mango, and kiwifruit. In this project we prepared methyl benzoate by reacting benzoic acid with methanol using sulfuric acid as a catalyst. The material balance and energy balance for each and every equipment has been worked out and shown. The detailed process and mechanical design of three equipment’s namely continuous stirred tank reactor, centrifuge extractor and distillation column has been studied extensively. The Instrumentation employed in the operation and the control methodizes have been outlined. This followed by a plant layout that has been proposed based on several conditions to economize the manufacturing process. The economics of the process has been worked and the project is considered feasible. This project has a payback period of 1.7 years with high profit margin. An overview of the safety aspect of the process has been made providing vital material safety information on the chemicals handled in the process.

CHAPTER 11

REFERENCE

1. https://pubchem.ncbi.nlm.nih.gov/compound/Methyl-benzoate

2. https://geographyandyou.com/chemical-industry-safety-in-india/

3. https://en.wikipedia.org/wiki/Methyl_benzoate

4. https://www.britannica.com/science/methanol

5. https://mymbaguide.com/plant-layout-meaning-top-10-characteristics-efficient-plant-layout/

6. https://www.chambers.com.au/glossary/hazard_analysis.php#:~:text=Hazard%20analysis%20is%20the%20process,and%20analyzing%20their%20potential%20causes.

7. https://www.sigmaaldrich.com/catalog/product/aldrich/m29908?lang=en&region=IN