

Designing of Reactor and Dryer for the production of Nitrocellulose Plant

Submitted in partial fulfilment of the requirements for the award of Bachelor of Technology degree in Chemical Engineering

By

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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

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **AISHWARYA BHAVANI D** (37190004) who carried out the project entitled "Designing of Reactor and Dryer for the production of Nitrocellulose Plant" under my supervision from FEBRUARY 2020 to APRIL 2021.

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DECLARATION

I **AISHWARYA BHAVANI D** hereby declare that the Project Report entitled “**Designing of Reactor and Dryer for the production of Nitrocellulose Plant**” done by me under the guidance of **Dr.D.Prabu, M.S (By Research), Ph.D.**, is submitted in partial fulfilment of the requirements for the award of Bachelor of Technology degree in CHEMICAL ENGINEERING.

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SIGNATURE OF THE CANDIDATE

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ABSTRACT

Nitrocellulose (otherwise called cellulose, streak cotton, guncotton, pyroxylin and glimmer string) is an exceptionally combustible compound framed to a combination of nitric corrosive and another corrosive, ordinarily either hydrochloric corrosive or sulfuric corrosive, or to another amazing nitrating specialist.

A process of designing nitrocellulose production plant for 1000 TPA is carried out by Bernigaut's Rayon Process. Cellulose from the cotton is reacted from the mixture of sulphuric acid and nitric acid. The sulphuric acid acts to take up the water that is formed in the reaction. This mixture of cellulose, sulphuric acid and nitric acid is passed on to the boiler, dryer, reactor and centrifuge. The study of material balance and energy balance is carried out for the production of 1000 TPA for the individual equipment as well as for overall equipment. Design of CSTR and Dryer is carried out. The detailed cost estimation is done for the calculation of rate of return and payback period. The detailed analysis of site selection and plant layout is mentioned. Instrumentation and Process Control is mentioned for all the equipment. The safety aspects of easy handling of the chemical compounds. First aid measures to follow and the efficient plant layout and safety measures are taken in care to reduce the loss by increasing the profit. In this project I have listed all the major aspects involved in the production of Nitrocellulose for 1000 TPA by Bernigaut's Rayon Process.

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CHAPTER 1

1.1 INTRODUCTION

Nitrocellulose (in any case called as pyroxylin) is an especially flammable compound molded by nitrating cellulose through receptiveness to nitric destructive, or to a blend of nitric destructive and another destructive, normally either hydrochloric destructive or sulfuric destructive, or to another extraordinary nitrating trained professional.

One of its first significant uses was as guncotton, a swap for explosive as charge in guns. It was additionally used to supplant black powder as a low-request hazardous in mining and different applications.

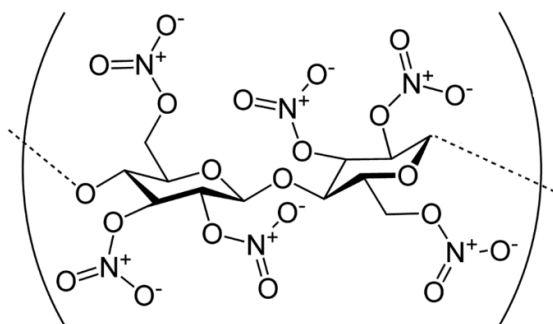


Fig 1.1: Structure of Nitrocellulose

Nitrocellulose has been distinguished in tissue tests gathered from grown-up fish living close to streams containing nitrocellulose, yet there was no bio magnification of nitrocellulose by sea-going species. In fluid conditions, arrival of nitrocellulose appears to have impacted the physical and substance properties of the living spaces. The adjustment to the territories was basic as nitrocellulose has low poison levels without anyone else.

1.2 PROPERTIES OF NITROCELLULOSE

Nitrocellulose is utilized in explosives, rocket fuel, veneer, streak paper, smokeless black powder, calfskin completing, as a printing ink base, in covering bookbinding material, in research center testing films, in ping-pong balls, in drugs and in celluloid utilized for early x-beam, photographic and film.

Blended in with dynamite, nitrocellulose is utilized as an impacting specialist and a rocket force.

Cellulose is a typically forming polymer got from wood squash or the small fibers that stick to the seeds of the cotton. It involves reiterating glucose units that have the substance condition

1.3 APPLICATIONS OF NITROCELLULOSE

A nitrocellulose slide, nitrocellulose layer, or nitrocellulose paper is a tacky film utilized for immobilizing nucleic acids in southern blotches and northern smudges.

It is additionally utilized for immobilization of proteins in western blotches and nuclear power microscopy for its vague proclivity for amino acids.

Nitrocellulose is an item that has discovered numerous utilizations in regular daily existence. Its actual structure can change generally from white strands to thin sheets to thick fluid.

Nitrocellulose is utilized to make everything from smokeless explosive to waterproof wires in fireworks, inks, glues, stains, gums, veneer coatings, implanting segments in microscopy, photography, electro techniques, galvanoplasty, and even certain plastics, for example, what is utilized in ping-pong balls.

It very well may be a white, yellow, or straightforward plastic, which can be anyplace from weak to adaptable.

It can have properties going from a solid, safe plastic to a shaky class B (profoundly combustible, dangerous when limited) touchy material, all controlled by the nitrogen content.

CHAPTER 2

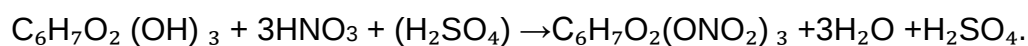
2.1 METHODS OF PREPARATION

Nitrocellulose can be manufactured by the following process:

1. Bernigaut's Rayon process
2. Cuprammonium process
3. Viscous process

2.1.1 BERNIGAUT'S RAYON PROCESS:

Cellulose from cotton is responded with a combination of sulphuric and nitric corrosive. An overall response to address the nitration of cellulose is:



The sulphuric corrosive demonstrations to take up the water that is shaped in this response.

Subsequent to changing over the cellulose in to nitrocellulose, and nitrocellulose taxi be constrained through a spinneret to create fiber. This is exceptionally combustible in nature.

2.1.2 CUPRAAMMONIUM PROCESS:

This interaction includes dissolving cellulose in a copper-ammonium hydroxide answer for structure a blender that is changed over in to nitrocellulose.

2.1.3 VISCOUS PROCESS:

Cellulose is permitted to absorbed an antacid arrangement and responded with carbon disulphide CS_2 , to deliver a cellulose xanthate arrangement called gooey.

2.2 JUSTIFICATION FOR THE SELECTION OF METHOD

From the overall study it is concluded that Bernigaut's rayon process is carried out as the raw materials are easily available as compared to the other two process.

The raw materials used here is,

- a) cellulose from cotton
- b) sulphuric acid
- c) nitric acid

The equipment's used in this process are,

- i) Boiling vessel
- ii) Continuous stirred tank reactor
- iii) Dryer
- iv) Centrifuge

Compared to the other two methods, Bernigaut's rayon process is effectively cheaper in production of nitrocellulose.

CHAPTER 3

3.1 FLOWSHEET FOR THE NITROCELLULOSE PRODUCTION

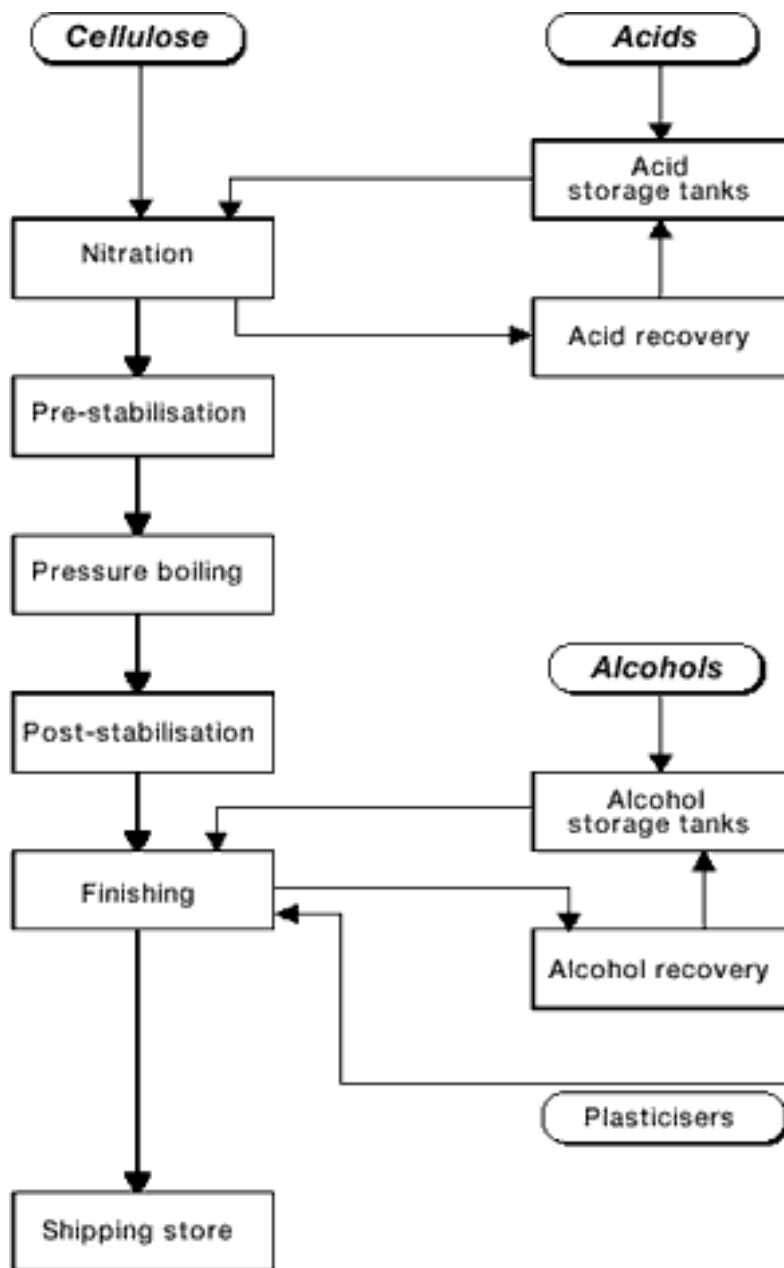


Fig:3.1 Flowsheet for the production of Nitrocellulose

3.2 PROCESS FLOW DIAGRAM

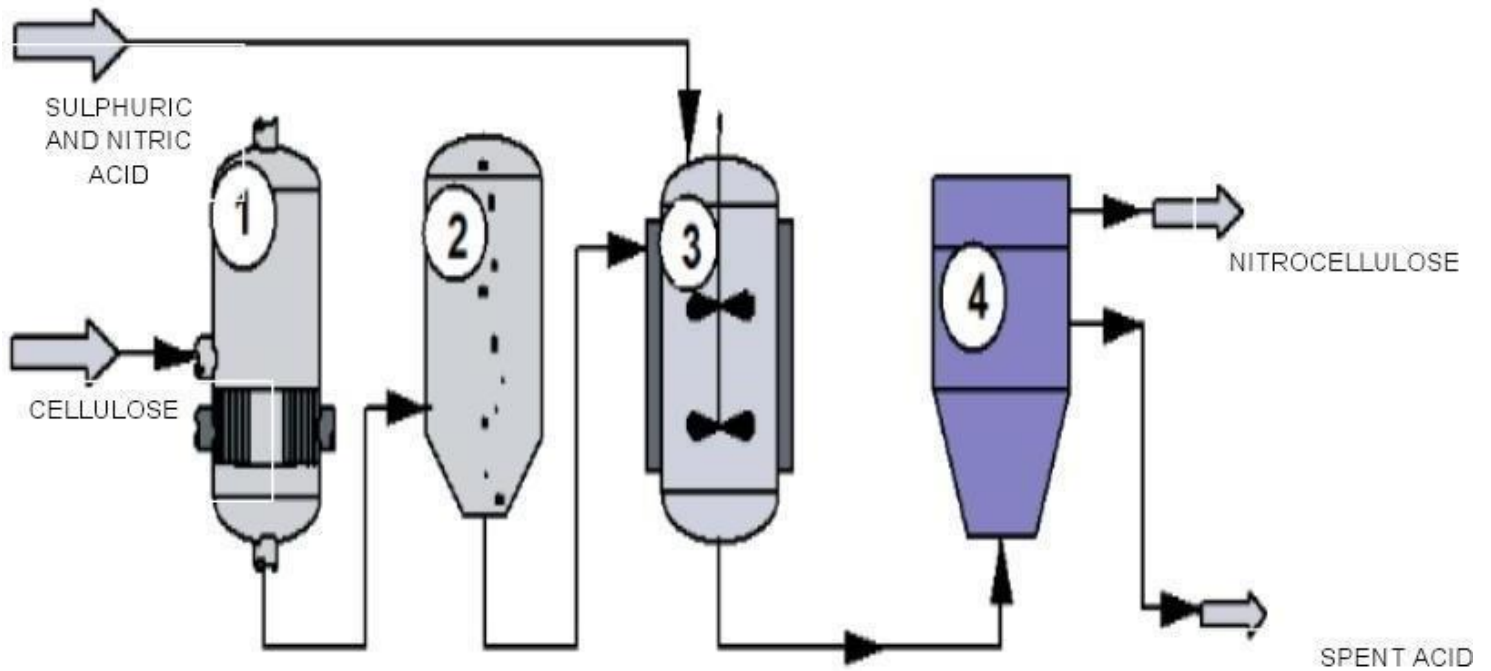


Fig: 3.2 Process Flow Diagram

- 1.Boiler
- 2.Dryer
- 3.Reactor
- 4.Centrifuge

3.3 PRODUCTION OF NITROCELLULOSE

Nitrocellulose is created by making cellulose respond with nitrating corrosive (a combination of nitric corrosive and sulfuric corrosive).

After nitration, rotators separate the nitrocellulose from the spent nitrating corrosive utilized in abundance amounts. This spent nitrating corrosive is isolated into nitric corrosive, sulfuric corrosive and water, and totally reused once again into the interaction.

The following stage is the pre-adjustment stage where the nitrocellulose is washed with water, subsequently isolating off any corrosive left on the filaments. Then, the thickness of the nitrocellulose is changed by pressure bubbling (warming constrained to temperatures above 100°C).

This is trailed by the post-adjustment stage where the nitrocellulose is washed with water and warmed to temperatures underneath 100°C. The water is in this manner isolated off to leave a water substance of 35%. This water-wet nitrocellulose would then be able to be bundled.

To create liquor damped Walsroder Nitrocellulose, the water is supplanted with the suitable damping liquor. To deliver Walsroder NC-Chips, the suitable plasticizer is added to water-wet nitrocellulose which is then dried.

The whole creation measures all important properties of the nitrocellulose and of the interaction are continually observed to guarantee the steady top notch of Walsroder Nitrocellulose and Walsroder NC-Chips.

Cotton linters, or wood mash high in cellulose, are sanitized by bubbling in kier (tanks) with weaken scathing soft drink arrangement. Fading is affected with CaClOCl , NaOCl , or Ca(OCl)_2 .

The cotton is dried, cushioned, and weight. Blended corrosive is made up from bra cing corrosive and spent corrosive, brought to legitimate temperature and run in to the nitrator.

Nitration (esterification) is generally directed under painstakingly controlled condition in the reactor then the blender is taken care of in to the rotator where its segments get isolated dependent on their thickness.

Nitrocellulose acquired which contain around 12-14 % of nitrogen.

Sulphuric corrosive which is utilized as an impetus comes out with water.

CHAPTER 4

MATERIAL BALANCE

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

$$\text{Material out} = \text{Material in} + \text{Accumulation}$$

For a consistent state measure, the amassing term is zero. In the event that a substance response is occurring a specific compound animal types might be framed or devoured. However, in the event that there is no substance response, the consistent state balance decreases to

$$\text{Material out} = \text{Material in}$$

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

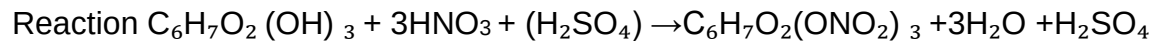
4.1 BASIS:

Basis: Law of conservation of mass

Production of 1000 TPA of Nitrocellulose

The process is planned to be a continuous operating process. The plant is operated for 365 days in a year.

Number of Working days: 365



Weight basis = $1000 \times 1000 / 365 \times 24 = 114.11 \text{ kg/h}$

Input:

Cellulose

Nitric acid

Sulphuric acid

Output:

Nitrocellulose

Sulphuric acid

Water

4.2 MATERIAL BALANCE FOR INDIVIDUAL EQUIPMENT:

4.2.1 Material balance for the boiler

Amount of cellulose in = 77.83 Kg/h

Amount of feed water in = 100 Kg/h

Amount of wet cellulose out = 96.54 Kg/h

Amount of water accumulated = 18.71 Kg/h

4.2.2 Material balance for the dryer

Overall mass balance

$$GS (Y_1 - Y_2) = MS (X_1 - X_2)$$

Here, GS = flow rate of air (dry basis, kg/h),

MS = flow rate of solid (kg/h, dry basis)

Solid contains 20% initial moisture

$$\text{Mass of dry solid} = MS = 97(1-0.2) = 77.6 \text{ kg/hr}$$

$$\text{Moisture in the wet solid} = X_1 = 20/80 = 0.25$$

$$\text{Moisture in the dry solid} = X_2 = 0.3/99.7 = 0.00301$$

$$Y_1 = 0.23$$

$$Y_2 = 0.015$$

$$\begin{aligned} \text{Water evaporated, MS, EVAPORATED} &= Ms (X_1 - X_2) = 77.6(0.25 - 0.00301) \\ &= 19.16 \text{ Kg} \end{aligned}$$

$$Gs (Y_1 - Y_2) = 89.14(0.23-0.015)$$

$$= 19.16 \text{ kg}$$

Material balance for dryer

Table:4.2.2 Material Balance for dryer

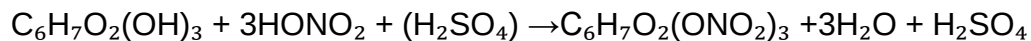
$GS (Y_1 - Y_2)$	$MS (X_1 - X_2)$
19.6Kg	19.6 Kg

4.2.3 Material balance for the CSTR

Nitrocellulose to be produce = 114.15 Kg/h

= 0.384 Kmol/h

OVERALL REACTION



1 Kmol of nitrocellulose produce by 1 Kmol of cellulose

So 0.384 Kmol of nitrocellulose is produced from 0.384 Kmol of cellulose Yield is 80% (assumed)

There for cellulose actually taken = $0.384/0.80$

= 0.48 Kmol

There for cellulose un-reacted = $0.48 - 0.384$

= 0.096 Kmol

1 Kmol of cellulose reacts with 3 Kmol of nitric acid

There for 0.48 Kmol of cellulose reacts with $0.48 \times 3 = 1.44$ Kmol of nitric acid

Yield 80% (assumed)

So nitric acid actually taken = $1.44/0.8 = 1.8$ Kmol

Un-reacted nitric acid = $1.8 - 1.44 = 0.36$ Kmol 3 Kmol of H_2O produced by 3 Kmol of nitric acid

Amount of H_2O produce by 1.8 Kmol/h nitric acid

= 1.8 Kmol/h Amount of sulfuric acid required = 0.384 Kmol/h

Input for CSTR

Table: 4.2.3 Input for CSTR

COMPONENT	MOLECULAR WEIGHT	Kmol/hr	WEIGHT
$\text{C}_6\text{H}_7\text{O}_2(\text{OH}_3)$	162.1406	0.48	77.83
HONO_2	63.01	1.8	113.42
H_2SO_4	98.0785	0.384	37.66

TOTAL=206.22Kg/hr

Output for CSTR

Table: 4.2.4 output for CSTR

COMPONENT	MOLECULAR WEIGHT	Kmol/hr	WEIGHT Kg/hr
$C_6H_7O_2(ONO_2)_3$	297.13 3	0.384	114.09
H_2O	18	1.152	20.736
H_2SO_4	98.078 5	0.384	37.66
Un-reacted $C_6H_7O_2(OH)_3$	162.14 06	0.096	15.57
Un-reacted $HONO_2$	63.01	0.36	22.68

TOTAL=206.22Kg/hr

4.2.4 Material balance for centrifuge

Amount of feed entering to the centrifuge=206.64 kg/h

After separation amount of nitrocellulose obtained=114.09 kg/h

Amount of spent acid obtained=92.55kg/h

CHAPTER 5

5.1 ENERGY BALANCE

The principal law of thermodynamics requests that energy be neither made nor obliterated. Coming up next is a deliberate energy balance performed for every unit of the interaction. The various properties like explicit warmth, warmth of response, warmth of vaporization, and so on are taken to be steady ludicrous reach.

Formula used:

$$Q = m c_p \Delta T \quad Q = m \lambda$$

Here, m = mass

C_p = Specific heat

ΔT = Temperature difference

5.2 ENERGY BALANCE FOR THE DRIER

1. Heat misfortunes from dryer surfaces are disregarded.
2. Once the limit of the dryer is known, the drying gas stream rate, its temperature and stickiness are chosen thinking about various variables. Furthermore, the accompanying dampness and enthalpy adjusts should be fulfilled.

$$GS (HG_2 - HG_1) = MS (HS_2 - HS_1)$$

Here, GS = flow rate of air (dry basis, kg/h), MS = flow rate of solid (kg/h, dry basis),

HS = humidity of air (kg/H₂O/kg dry air) HG_2 = enthalpy of exit gas

HG_1 = enthalpy of gas at inlet HS_2 = enthalpy of exit solid HS_1 = enthalpy of solid at inlet

$TS_1 = 26^\circ\text{C}$

$TG_1 = 135^\circ\text{C}$ $Y_2 = 0.015$

$$Y1 = 0.23$$

$$GS = 89.14 \text{ kg/h}$$

Let us assume that the exit temperature of the gas is $TG2 = 60^\circ\text{C}$ and for solid $TS2 = 100^\circ\text{C}$

Now enthalpy of different streams (suppose ref temp = 0°C)

$$\begin{aligned} HS1 &= [CPS + (4.187) X1] [TS1 - 0] = [0.85 + (4.187) 0.25] [26 - 0] \\ &= 49.31 \text{ KJ/kg dry air} \end{aligned}$$

$$\begin{aligned} HS2 &= [CPS + (4.187) X1] [TS1 - 0] = [0.85 + (4.187) 0.00301] [100 - 0] \\ &= 86.2 \text{ KJ/kg dry solid} \end{aligned}$$

$$H = [1.005 + (1.88) 0.015] [135 - 0] + (0.015) (97) = 140.97 \text{ KJ/kg}$$

$$\begin{aligned} HG1 &= [1.005 + (1.88) Y1] [60 - 0] + Y1 (97) = 60.3 + 209.8 \cdot 0.23 \\ &= 108.554 \text{ KJ/Kg} \end{aligned}$$

$$GS (HG2 - HG1) = MS(HS2 - HS1)$$

$$89.14 (140.97 - 108.554) = 77.6 (86.2 - 49.31)$$

$$2875.56 = 2872.6 \text{ KJ/Kg}$$

CHAPTER 6

EQUIPMENT DESIGN

6.1 CONTINUOUS STIRRED TANK REACTOR DESIGN

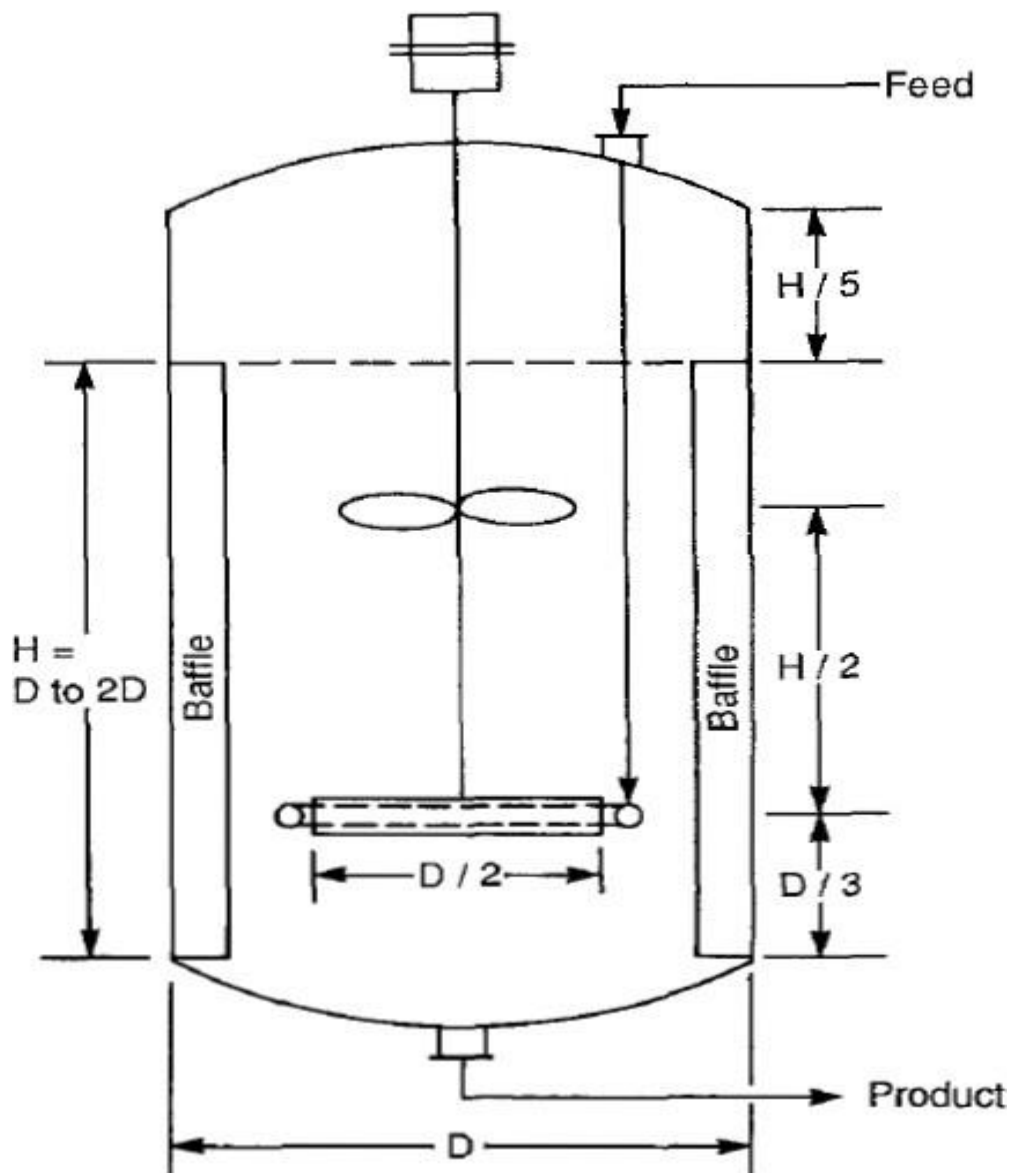


Fig:6.1 Design of CSTR

Reaction time = $\tau = 1$ Hour

$$\tau = V / V_o$$

V = Reactor volume

V_o = Volumetric flow rate

cellulose inlet = 77.83 kg/h

Nitric acid inlet = 113.42 kg/h

Sulfuric acid inlet = 37.66 kg/h

Density of cellulose = 1500 kg/m³

Density of nitric acid = 1513 kg/m³

Density of sulfuric acid = 1840 kg/m³

Volumetric flow rate of cellulose = Mass flow rate/Density

$$= 0.052 \text{ m}^3/\text{h}$$

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

$$= 0.075 \text{ m}^3/\text{h}$$

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

$$= 0.021 \text{ m}^3/\text{h}$$

Total volumetric flow rate = 0.15 m³/h

Volume of Reactor

$$V = 1 * V_o$$

$$= 1 * 0.15 = 1.5 \text{ m}^3$$

$$H/D = 1.5\text{m}$$

$$H = 1.5D$$

$$V = (\pi / 4) D^2 H$$

$$1.5 \text{ m}^3 = (\pi / 4) D^2 (1.5D)$$

$$D = 1.08\text{m}$$

$$H = 1.63\text{m}$$

6.1.1 Calculation of Shaft Power Requirement

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

Where P_0 = power number

P is power required for agitation

N is number of revolutions=200rpm

$$= 3.33\text{rps}$$

Where, D_A =diameter of agitator

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

Diameter of reactor = 1.08 m

$$\text{Diameter of agitator} = 0.3 * 1.08 = 0.35 \text{ m}$$

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

6.1.2 Calculation of Reynolds Number

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

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

$$= (1500 * 0.34) + (1513 * 0.495) + (1840 * 0.16)$$

$$= 1553.3 \text{ kg/m}^3$$

μ_{mixture} =summation of (viscosity*mass fraction)

$$= (0.0015 * 0.34) + (0.00025 * 0.495) + (0.00025 * 0.16)$$

$$= 6.376 \times 10^{-4} \text{ kg/ms}$$

$$\text{Re} = (0.35)^2 (3.33) * (1553.3) / (6.376 \times 10^{-4})$$

$$= 9.9 \times 10^4$$

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

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

$$P = 1837.6 \text{ W}$$

Thus power required for agitation = 1.837 kW

6.1.3 Design Summary:

Volumetric flow rate of cellulose = 0.052 m³/h

Volumetric flow rate of nitric acid = 0.075 m³/h

Total volumetric flow rate sulfuric acid = 0.021 m³/h

Volume of the reactor = 1.5 m³

Diameter of the reactor = 1.08 m

Height of the reactor = 1.63 m

Power required for agitation = 1.837 kW

6.2 DESIGN OF DRYER:

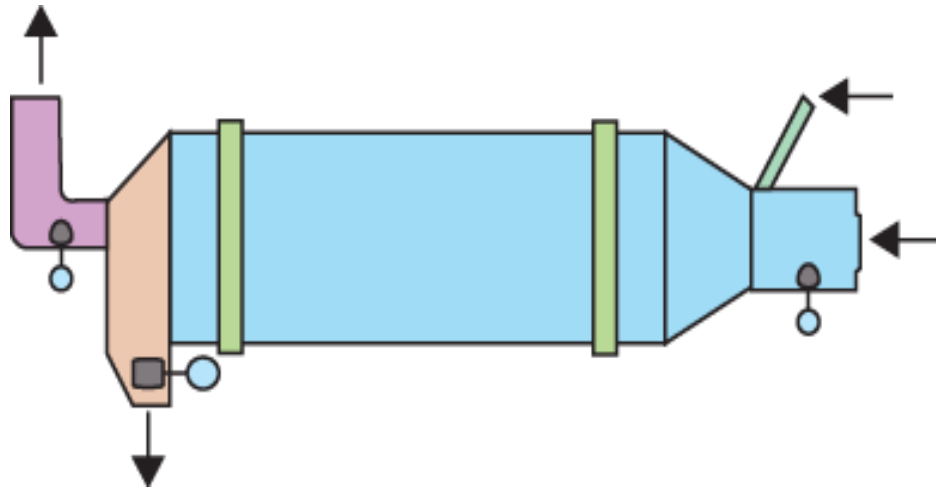


Fig: 6.2 Design of Dryer

6.2.1 Calculation of shell diameter

Volume of humid inlet gas (135 °C and $Y_2 = 0.015$)

$V_{H2} = 1.183 \text{ m}^3/\text{Kg dry air}$ Volume of humid exit gas (60 °C and $Y_1 = 0.04306$)

$V_{H1} = 1.008 \text{ m}^3/\text{Kg dry air}$

The max. Volumetric gas flow rate = $G_s \cdot V_{H2} = 766.64 \times 1.183 = 906.9 \text{ m}^3/\text{h}$

The working velocity i.e. superficial velocity = $1.5 - 0.2 \times 1.5$

$$= 1.2 \text{ m/s} / 4 \times d^2 (1.2)$$

$$d = 1.92\text{m}$$

6.2.3 Calculation of height of dryer

Heat Transfer Unit

From the heat balance;

$$H_{G1} = 108.554 \text{ KJ/Kg}$$

$$T_{S1} = 26^\circ \text{C}$$

$$T_{S2} = 135^\circ \text{C}$$

$$H_{G1} = 175.6 = [1.005 + 0.04306 (1.88)] [T_{GA} - 0] + 0.04306 (2500)$$

Consider solid is at T_{SB} , the wet bulb temperature of the air at location between, assume

$$T_{SB} = 41^\circ \text{C}$$

Enthalpy of solid at the inlet

$$H_{SB} = [0.85 + (0.00301) (4.187)] (41-0) = 35.37 \text{ KJ/kg dry solid}$$

$$\text{Humid heat of gas entering } C_{HB} = [1.005 + (1.88) (0.015)] = 1.003 \text{ KJ/KgK}$$

Heat balance over this stage

$$M_S [H_{S2} - H_{SB}] = G_S (C_{HB}) (135 - T_{GB})$$

$$T_{GB} = 98^\circ \text{C}$$

Adiabatic saturation temperature of air entering (98C & humidity of 0.015) is 41.3°C

$$\text{At the boundary, } \Delta T_B = 98 - 41 = 57^\circ \text{C}$$

$$\text{At end 2, } \Delta T_2 = 135 - 100 = 35^\circ \text{C}$$

$$\text{LMTD} = (\Delta T)_m = 57 - 35 / \ln(57/35) = 45^\circ \text{C}$$

$$(N_{TG}) = T_2 - T_{GB} / (\Delta T)_m = 135 - 98 / 45 = 1.74$$

Length of Transfer Unit:

$$\begin{aligned}\text{Avg. mass flow rate} &= [89.14(1.015) + 89.14(1.04306)]/2 \\ &= 91.6 \text{ Kg/h}\end{aligned}$$

$$\begin{aligned}\text{The gas mass flow rate, } G'' &= (91.6/3600)/\pi / 4 \times (2)^2 \\ &= 0.9 \text{ Kg/m}^2\text{S}\end{aligned}$$

$$\text{Volumetric heat transfer coefficient} = U = (237 (G'')^{0.67})/d$$

$$U = (237 \times (0.961)^{0.67})/2 = 7.2 \text{ W/m}^3\cdot\text{K}$$

Humid heat at the ends

$$C_{H2} = 1.005 + 1.88 (0.015) = 1.033$$

$$C_{H1} = 1.005 + 1.88 (0.04306) = 1.0$$

Avg. humid heat,

$$C_H = (1.033 + 1.083)/2 = 1.058 \text{ KJ/Kg. K}$$

$$\text{Length of transfer unit, } L_T = G'' \cdot C_H / U = (0.9 \times 1.058)/0.72 = 1.32\text{m}$$

$$\text{Length of dryer, } L = N_{tG} L_T$$

$$= 1.74 \times 1.32 = 2.3 \text{ m}$$

$$d = 1.92 \text{ m and } L = 2.3\text{m}$$

CHAPTER 7

INSTRUMENTATION AND PROCESS CONTROL

7.1 INTRODUCTION:

Instruments are given to screen the key cycle factors during plant action. They may be participated in modified control circles, or for the manual checking of the cycle movement. They may moreover be significant for a modified PC data loosen structure. Instruments which are checking for fundamental elements will be fixed with customized alerts to make their executives mindful of essential and perilous conditions. The fundamental objections of the maker while deciding instrumentation and control plans are:

Safe plant activity:

- To keep the cooperation factors inside acknowledged safe action limits.
- To distinguish dangerous conditions as they alert and customized shut-down systems.
- To provide interlocking and alerts to prevent unsafe working techniques.

Creation rate:

- To accomplish the plan item yield.

Item quality:

- To keep up the plan arrangement inside indicated quality norms.

Cost:

- To keep up the creation cost, equivalent with different destinations.

Instrumentation planning accepts fundamental part in controlling the association for needed yield from the plant. All instruments should be presented from standard producers by decision reliant on the past cycle knowledge.

Instrumentation is given to screen the significant cooperation limits while plant errands. They may be melded in modified power circles or used for the individual seeing of association limits. They may similarly be a piece of customized PC data getting. Instruments noticing essential communication limits will be fitted with customized pop-ups and explanations to alert the head at fundamental and dangerous conditions in prior. The essential objective of the maker while showing instrumentation and control plans is, to keep measure limits inside quite far, to recognize risky conditions that may make due to cooperation deviations and to give cautions/ringer and customized protect structures. What's more, moreover to keep up the thing course of action inside the foreordained quality rules and to work the plant at the most decreased creation cost. Components in a cycle ought to be assessed and a short time later controlled and fused for ideal taking care of conditions. Mechanical and electrical parts and systems have been arranged by instrumentation and association control experts to decrease work and improve feasibility of plant movement, and to allow wide external plant advancement.

7.2 CONTROL OF REACTOR:

7.2.1 Flow measuring Instruments:

For assessing the movement of Nitrocellulose from the reactor Mass stream meter will be used, it is important and tricky assessing instrument it will give exact and fast analysis to the control system. Mass stream meters are available in various scopes; in this communication immaculate bundling is fitting to get extraordinary results. Opening meters are sensible for stream assessment.

7.2.2 Temperature measurement:

For measuring the temperature of Nitrocellulose resistance thermometers or Thermocouples are used. Platinum- platinum rhodium thermocouples are used in most industries, since thermocouples are gives excellent transmission accuracies than other temperature measuring instruments. THF temperature is measured by thermocouples mentioned. For measuring the temperature of reactor the same thermocouples are used.

7.2.3 Pressure Measurement:

The bourdon tube estimating components are utilized in blend with the differential pressing factor transmitters with hardened steel inner parts are utilized for the estimating the reactor bed pressure drops in mm water section.

7.2.4 Emergency shutdown of the Reactor system

Because of the insecurity of the exothermic responses and the chance of a runaway response, the reactor is regularly outfitted with a crisis closure framework, just as other security gear, for example, burst stomachs and discharge regulation frameworks. The motivation behind the crisis closure framework is to stop the response in case of a runaway. The framework may achieve this by rapidly decreasing the temperature, infusing some material into the reactor, which will lessen the pace of the response; or venting the reactor to diminish the pressing factor. The crisis closure framework should be exceptionally solid.

In practically all businesses Computer based Distribution control frameworks and Programmable rationale regulators with human interface frameworks are introduced for simple control through PCs, in this framework the equipment necessities for pneumatic, electronic, and microchip based regulators are working, all pneumatic signs in the scope of 3 to 15 psig, the energy expected to work these pneumatic segments is a wellspring of perfect, dry air at a pressing factor of around 20 psig. The pressing factor can fluctuate from 20 psig by about $\pm 10\%$ without unfavorably influencing the activity of instruments.

The electronic framework required both electrical and pneumatic ability to work the segments. A transducer or converter is required between the regulator and the valve to change over current (4-20 mama) to pressure (3-15 psig)

The segments for a microchip based framework contains the control calculation dwell as a PC program in the memory of the PC. The administrator speaks with the control framework with a console, a screen, and a printer. The PC can perform a lot a greater number of capacities than execution of the control calculation; the recorder of the pneumatic or electronic framework is supplanted by a screen on which drifters are appeared.

In an advanced regulator both simple and computerized signals are prepared. The simple sign is the sort that addresses a constant variable with shifts over a scope of qualities. The computerized signal is a double sign that can be addressed by two states.

7.3 CONTROL OF CENTRIFUGE

The first framework as worked by the worker for hire would draw centrifuged corrosive through channels by utilization of a mono siphon and siphon the corrosive back to the axis. These channels would obstruct inside the space of minutes causing a lot of postponement. The channels were eliminated and tempered steel projection siphons introduced these would splash through spouts into the axis corrosive not being separated however constrain turns on the lines to stop a siphon if a blockage would happen. This framework functioned admirably for a very long time and was refreshed utilizing radiating pumps. This framework is by and by still in use. The re-plan of the drum channel to eliminate fines from spent corrosive prior to leaving the plant to the tank ranch. the first channel was adjusted and the strainer network size of the drum altered. at first we utilized one of the 2 rotators to eliminate corrosive from the NC, we had two line/siphon frameworks and could utilize either axis. we then fitted our own plan corrosive recuperation framework to one rotator this gave improved corrosive recuperation. we at that point chose to put two rotators in arrangement, first recuperate mass corrosive structure the NC and corrosive recuperation by the corrosive recuperation framework and

afterward to axis water wetted NC again to recuperate more corrosive adding some virus scouring water during this centrifuging step. the fundamental drive to utilize two rotators in arrangement was to improve corrosive recuperation and lessen time before pre-bubbling. the first plan utilized one rotator to eliminate corrosive and do corrosive recuperation. by changing the pipework and centrifuging the NC again from a water medium, we could diminish the washing time in the pre-bubbling units before pressure bubble and run at a more consistent pH. washing in the pre-balancing out vessels isn't effective and tedious.

7.4 CONTROL OF DRYER

7.4.1 Drying parameters measurement

To control the drying interaction and whenever to have the option to record the drying boundaries the establishment incorporate instrumentation and control gear.

A PLC with screen, which is put in a different control room, halfway to keep it dry, yet in addition in light of the fact that the administrators here can be in a spot with diminished clamor level.

7.4.2 Temperature control

The channel temperature naturally constrained by directing either the steam pressure or the measure of gas to the air warmer. The power source temperature consequently controlled to guarantee a powder with a steady lingering dampness content.

On the off chance that the atomization happens by methods for a rotating atomizer the guideline of the power source temperature is finished by changing the insurgency of the feed siphon.

CHAPTER 8

COST ESTIMATION

Cost Estimation is the guess of the expense of a task or activity. The Cost Estimation is the result of the expense assessing measure. The quote has a solitary all out esteem and may have recognizable part esteems.

Table:8.1 Cost of Equipment

EQUIPMENTS	COST
Reactor	₹ 14.25000 lakhs
Dryer	₹ 37.40000 lakhs
Boiler	₹ 8.200000 lakhs
Centrifuge	₹ 48.20000 lakhs
Total	₹ 88.05000 lakhs

8.1 CALCULATE TOTAL DIRECT COST:

Installation cost

=15% of the purchased equipment cost

= ₹13,20,750

Instrumentation and control cost

= 6.5% of the purchased equipment cost

= ₹5,72,325

Piping [installed]

=7% of the purchased equipment cost

= ₹6,16,350

Electrical [installed]

=5% of the purchased equipment cost

=₹ 4,40,250

Building [including services]

=16% of the purchased equipment cost

=₹ 14,08,800

Yard improvement

=12% of the purchased equipment cost

=₹ 10,56,600

Land

=6% of the purchased equipment cost

=₹ 5,28,300

Service facilities

=2.5% of the purchased equipment cost

$$= ₹2,20,125$$

Total Direct Cost= ₹61,63,500

8.2 TO CALCULATE TOTAL INDIRECT COST:

Engineering and supervision cost

= 6% of the total direct cost

$$= ₹3,69,810$$

Construction expenses

=8% of the total direct cost

$$= ₹4,93,080$$

Contractor's fee

=5% of the total direct cost

$$= ₹3,08,175$$

Contingency

=4.5% of the total direct cost

$$= ₹ 2,77,357.5$$

Total Indirect Cost = ₹14,48,422.5

8.3 TO CALCULATE FIXED CAPITAL INVESTMENT (FCI):

Fixed capital Investment= Total Direct cost + Total Indirect cost

$$= 6163500 + 1448422.5$$

$$= ₹76,11,922.5$$

8.4 RAW MATERIAL COST:

CELLULOSE

No. Of kg required = 78 kg

Cost of cellulose per kg = ₹92

$$= 78 \times 92$$

$$= ₹2,15,280$$

NITRIC ACID

No. Of kg required = 114 kg

Cost of nitric acid per kg= ₹25

$$= ₹85,500$$

SULPHURIC ACID

No. Of kg required = 38 kg

Cost of sulphuric acid per kg= ₹25

$$= ₹ 28,500$$

Table: 8.2 Salary chart

S.NO	DESIGNATION	PERSONS FOR1 SHIFT	PERSONS FOR2 SHIFT	SALARY FOR ONE PERSON	SALARY PER MONTH
1	Chemical Engineer	3	6	₹ 15000	₹1,35,000
2	Chemist	2	4	₹ 9000	₹ 54,000
3	Supervisor	2	4	₹ 8000	₹ 48,000
4	Store keeper	2	4	₹ 7000	₹ 42,000
5	Skilled operator	4	8	₹ 5000	₹ 60,000
6	Unskilled	10	20	₹ 2000	₹ 60,000
7	Security	4	8	₹ 2000	₹ 24,000
	TOTAL				₹4,23,000

Total raw material cost = ₹ 3,00,780

8.5 WORKING CAPITAL

Raw material cost	= ₹3,00,780
Wages	= ₹60,156
Utilities	= ₹45,117
Working capital/month	= ₹4,06,053
Working capital per annum	= ₹48,72,636

8.6 ESTIMATION OF TOTAL PRODUCT COST

Depreciation: (15-20% of fixed capital investment)

Consider 17% of FCI

17% (7611922)

= ₹ 12,94,026

Local taxes: (1-4% of fixed capital investment)

Consider 3% of FCI

3% (7611922)

= ₹ 2,28,357

Insurance: (0.4-1% of fixed capital investment)

Consider 0.7% of FCI

0.7% (7611922)

= ₹53,283

Rent: (8-12% of land and building)

Consider 10% (1408800+528300)

= ₹1,93,710

Fixed Charges = ₹17,69,376

8.7 Direct Production Cost (up to 60% of total production cost)

Consider fixed charges = 15% total production cost

Total production cost = fixed charges /15%

= 1769376/15%

= ₹1,17,95,840

8.8 GROSS EARNINGS & INCOME

Selling price of nitrocellulose per kg = 180

Total income= selling price * quantity of product manufactured

= 180 * (2736 kg/ day) * (365 days/ year)

= ₹17,97,55,200

Gross income= Total income – Total production cost

= 17,97,55,200 – 1,17,95,840

= ₹17,85,75,360

Tax= 45% of Gross Income

$$= ₹8,03,58,912$$

Net annual profit= Gross Income – Tax

$$= ₹9,82,16,448$$

Rate of return = $\frac{\text{Net annual profit}}{\text{TCI}} \times 100$

TCI

$$= 11.63 \%$$

Payback period= $\frac{\text{Total capital investment}}{\text{Net profit}}$

Net profit

$$= 2 \text{ years and } 3 \text{ months}$$

CHAPTER 9

PLANT LAYOUT AND LOCATION

PLANT LOCATION AND SITE SELECTION:

A topographical territory of the last plant can have strong impact on the wellsprings of an advanced undertaking. A general understanding in regards to the plant territory should be gotten before an arrangement project shows up at the distinct check plan. The choice of the last site ought to at first be established on a complete survey of the advantages and insults of various topographical domains and in the end on the advantages and downsides of available land. The going with components should be considered in picking a plant site:

9.1 Crude Materials Availability:

The wellspring of crude materials is perhaps the main elements affecting the choice of a plant site. Appropriate consideration on this would allow significant decrease in transportation and capacity charges. Consideration ought to be given to the bought cost of the crude materials, distance from the cause of supply, virtue of the crude materials and capacity prerequisites. The area of business sectors (or) transitional dispersion communities influences the expense of item circulation of the time needed for transportation. Nearness to the significant business sectors is a significant thought in the choice of the plant site, on the grounds that the purchaser for the most part thinks that its invaluable to buy from close by sources.

9.2 Energy Availability:

Force and steam necessities are high in modern plants, and fuel is customarily provided to these utilities. Thus, Power and fuel are usually needed to supply these utilities. Subsequently, Power and fuel can be joined as one main consideration in the decision of plant site

9.3 Transportation Facilities:

Water, rail streets and expressways are the regular methods for transportation utilized by major mechanical concerns. The sort and measure of items and crude materials decide the most appropriate kind of transportation offices. Engine shipping offices are generally utilized and can fill in as a valuable enhancement to rail and water offices. The site ought to approach in any event to two sorts of transportation.

9.4 Garbage Disposal:

In late year, numerous legitimate limitations have been set on the techniques for removal of waste from the cycle ventures. The site chose for a plant ought to have sufficient limit and offices for right garbage removal.

9.5 Work Supply:

The sort and supply of work accessible nearby a proposed plant site should be clarified. Contemplations ought to be given to winning compensation scales, limitations on number of hours worked each week, finishing ventures that can cause disappointment or high turnover rates among the laborers and varieties in the expertise and profitability of the specialists

9.6 Tax collection and Legal Restrictions:

Focal and State charge rates on appropriately pay, and Unemployment protection and comparable things differ starting with one area then onto the next. Additionally, Local guidelines on drafting, construction regulations, disturbance viewpoints and transportation office can impact the monetary decision of a plant site.

9.7 Site Characteristics:

The qualities of the land at a proposed plant site ought to be inspected cautiously. The geology of plot of land and the dirt design should be thought of, since either or both may pronouncedly affect development costs. The expense of the land is significant, just as neighborhood building cost and day to day environment's future changes may make it attractive or important to extend the plant offices.

9.8 Flood and Fire Protection:

Numerous modern plants are situated along waterways or close to huge waterways, and there is danger of flood or tropical storm harm. Prior to choosing a plant division ought to be accessible.

9.9 Local area Factors:

The character and offices of a local area can have a significant impact on the area of the plant. In the event that a specific least number of offices for acceptable living of plant work force don't exist, it frequently turns into a weight for the plant to finance such offices. Social offices of local area are essential to sound development. The proficiency, character-history of both local and state government ought to be assess. The provincial history of common occasions of this sort ought to be inspected and the outcome of such events considered. Security from misfortunes by fire is another significant factor in choosing a plant area. If there should be an occurrence of significant fire, help from outside fire.

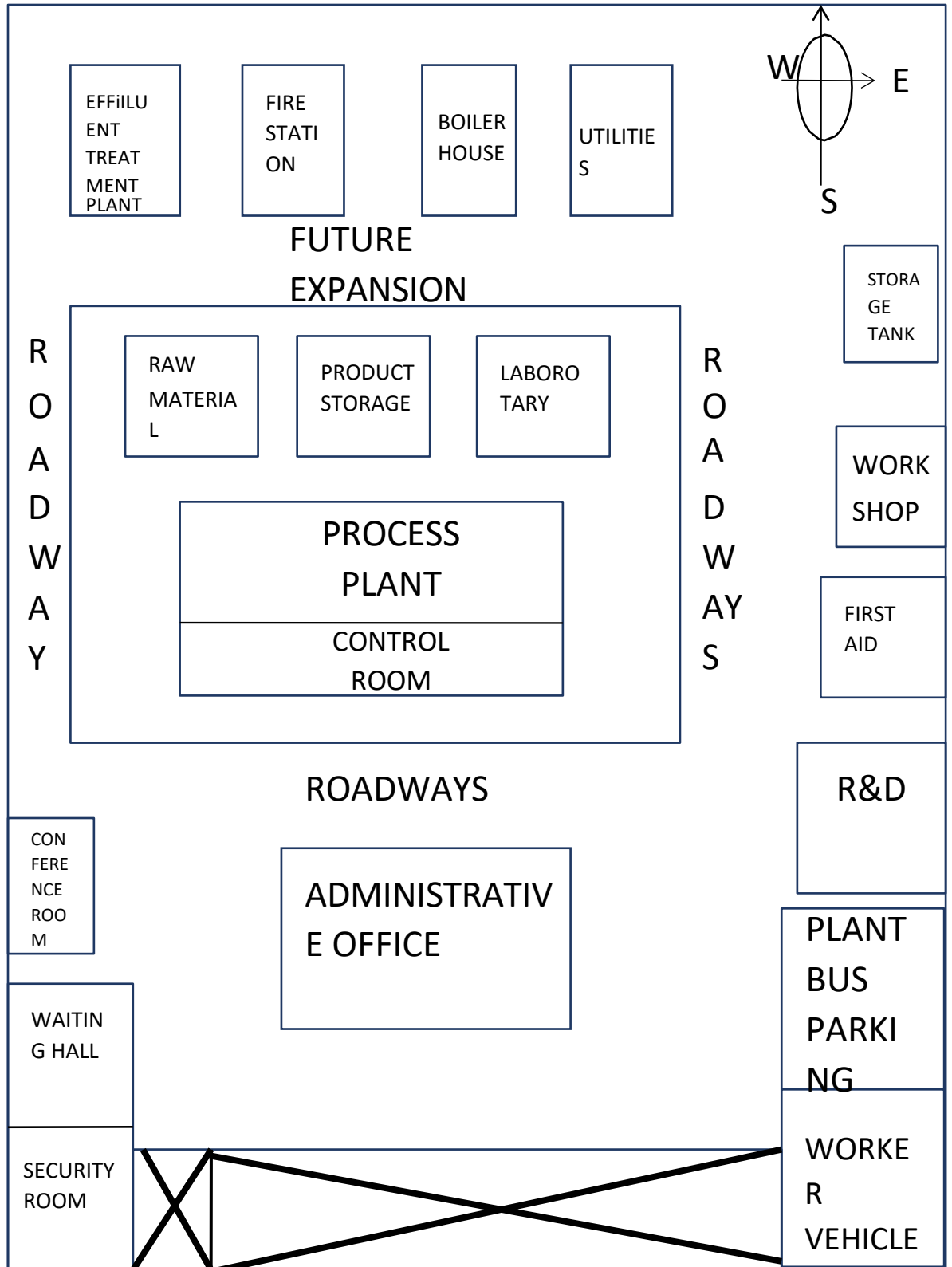


Fig: 9.1 Plant layout

CHAPTER 10

PROCESS SAFETY

10.1 RISKS TO HEALTH

10.1.1 Nearby impacts:

- Inhalation: breathed in liquor fume may influence the predominant ethereal framework, the respiratory framework (discouragement).
- Skin and eye assimilation: may cause slight aggravation, just as gaps and dried skin.
- Ingestion: poisonous because of liquor presence (may cause haemorrhagic gastritis).

10.1.2 Foundational impacts

- Alcohol extended inward breath in high focus, other than the found impacts on the eyes and unrivalled respiratory framework, may cause cerebral pain, laziness, quivers and weariness.

10.1.3 Persistent impacts

- On the off chance that the skin become redness or with rankle, stand out enough to be noticed.

10.2 FIRST- AID PROCEDURES

10.2.1 Crisis systems and first-guides

- Ingestion: never takes care of an oblivious individual. On the off chance that cognizant, give enormous amounts of water (weakening impact). Try not to initiate heaving.
- Inhalation: Remove the casualty to a ventilated territory. If not breathing, give fake breath. Call a doctor.
- Skin contact: promptly take off the tainted garments and wash before reuse.
- Flush the openness territory with a lot of water and impartial cleanser. On the off chance that the skin become redness or with rankle, stand out enough to be noticed right away.
- Eyes contact: don't permit the casualty to keep the eyes shut, cautiously hold the eyelids separated and wash persistently with eye - wash answer for in any event 20 minutes. Stand out enough to be noticed quickly.
- General: subsequent to administrating the principal helps, search for satisfactory clinical help.

10.2.2 Workplace

- It has the right to introduce appropriated weariness situation, in an approach to dodge spread and ensuing liquor fume inward breath.
- The work regions should be furnished appropriately with wellbeing stations.
- Contaminated apparel should be isolated from the typical garments and wash before reuse.
- Keep the Individual Protection Equipment perfect, very much kept up and as needs be hygienized.
- Concentration of dissolvable in the working environment air ought to be checked every now and again.

10.2.3 Respiratory Protection

- Select appropriated breathing as per work conditions and furthermore convergence of the toxin, in an approach to ensure the oxygen important to specialist's security.
- When utilizing the respiratory shield, it's fascinating to have a formal respiratory assurance program including: occasional and affirmation clinical tests, individual actual test, ecological monitory, respirator upkeep, appropriated nearby to capacity the types of gear.

10.2.4 Handling and protection:

- Clothes (shirt and trousers) made by cotton
- Helmet
- Goggle
- Safety shoes with antistatic base

CHAPTER 11

CONCLUSION

The various configuration involved for the production of Nitrocellulose has been designed for the capacity of 1000 TPA. Nitrocellulose is used for the replacement of gun powder and it is used as a blasting agent and rocket propellant. Various aspects of safety such as risks to health, first aid procedures, work environment, respiratory protection, handling and protection, firefighting procedures and applications have been considered. The material balance has been calculated for both individual as well as overall equipment. Material Balance for the reactor is 0.384 Km³/h and for Dryer is 19.6 Kg. The Energy Balance for the drier has been calculated and is 2875.6 KJ/Kg. The cost of the plant has been detailed and the payback period accounts to 2 years. The design of reactor and dryer have been carried out in this project. The project based on production of Nitrocellulose of capacity 1000 tonnes per annum includes material balance and energy balance. Design of equipment is done for Continuous Stirred Tank Reactor and Dryer. Cost estimation for payback period is around 2 years and 3 months. Efficient site selection and safety aspects are studied in this project.

REFERENCES

1. Brownell and Young, "Process Equipment Design", 1st edition, 2009
2. DiranBasmadjian, "Mass transfer and Separation Processes", 2nd edition, 2007
3. Dryden, "Outlines of Chemical Technology, M. Gopala Rao, Marshall SittigAffiliated East-West Press, 1973
4. Max S. Peters and Klaus Timmerhaus, "Process Plant Design and Economics for Chemical Engineers", 4th edition, 1992
5. Max. S. Peter's, "Plant design for Chemical Engineers", 5th edition, 2004
6. Nexant abstract, "Process Technology, Production costs, Capacity, Regional/Supply demand Forecasts", January 2009
7. SeaderJ. D., Warren D. Seider, "Product and Process Design Principles", 3rd edition, Wiley, 2017