

**DESIGN OF A PLANT TO PRODUCE 50 METRIC
TONNES/DAY OF POLYVINYL ACETATE
EMULSIONPAINT**

BY

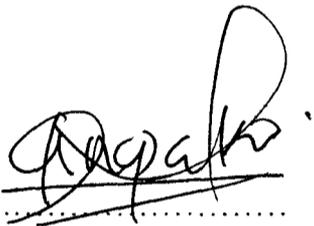
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(2001/11672EH)**

**A project submitted in partial fulfillment of the requirement
of Bachelor of Engineering (B.Eng) in Chemical Engineering
Department in the School of Engineering and Engineering
Technology Federal University of Technology Minna**

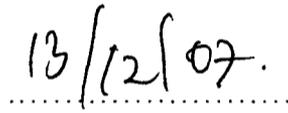
November 2007.

DECLARATION

I VONKUR DAVID N., declares that this design work is originally done by me and presented to department of chemical engineering, for the award of bachelor of engineering has not been presented wholly or partially for any other degree else where



Vonkur David N



Date

CERTIFICATION

This project is the original work undertaken by Vonkur David Nankpark which has been examined and certified under the supervision of Dr M.O Edoga and approved by the same person on behalf of Chemical Engineering Department, School of Engineering and Engineering Technology, Federal University of technology Minna.

Dr M.O. Edoga

Project supervisor

Date

External supervisor

Date

DEDICATION

This project is dedicated to the Almighty God, the lion of the tribe of Judah. And to my humble and persevering parents and my beloved late younger sister Benedicta Nanwor may your soul rest in perfect peace.

ACKNOWLEDGEMENT

It is not of he that willeth, neither of he that runneth, but of the lord that showeth mercy. my sincere thanks to God for his infinite mercy and love showered upon my life in the course of this study, though it was not easy but at last he saw me through. This work would not have been possible without the immense contribution of my parents and siblings; “kudos to you all”

My heart felt appreciation to my supervisor Dr M.O.Edoga whose advice, constructive criticism and encouragement were instrumental to the concept and completion of this project.

To Prof. J.O.Odigire whose humility beats me one on one, Prof. K.R.Onifade whose diligence I emulate, Prof. Aberuagba my mentor in biotechnology, Dr Duncan, Engr M.A.Olutoye, Engr S.O. Azeez

Engr Agbajelola David, Engr U.G.Akpan e.t.c.

I also sincerely appreciate my pastor, S.K.Favour and family alongside with my church elders and members whom might have contributed either in cash or in kind to the success of this struggle, may God enlarge your coast. This acknowledgement will be incomplete if I don't acknowledge my niece Chichi and beloved late younger sister, Benedicta Nanwor, till we meet to part no more.

Abstract

The design of a plant for the production of 50 metric tonnes per day of polyvinyl acetate emulsion paint using vinyl acetate as starting material has been successfully carried out. The process flow sheet shows major items of equipment, their operating condition and material flows. . Based on the design of the paint plant carried out, the total production cost of 2.294448×10^{12} Naira and a net profit of $\text{N}2.492 \times 10^{10}$ revealed that the project is economically viable with a pay back period of 4 yr , return of rate of 24.8% and a return on investment of about 95%.

The sizing of the major process items of equipment were carried out. The economic evaluation of the process shows that it is profitable. .

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CHAPTER ONE

1.0 INTRODUCTION

Polymers constitute more than half of the world's production in petrochemical industry. This term polymer can be defined as the compound formed from the combination of monomeric units called monomers.

Heterogeneous polymerization, free radical polymerization process called "emulsion polymerization" has wide industrial application in the production of polymers such as polyvinyl acetate. These types of polymers have wide range of application mostly in the production of paints, binders, synthetic rubber etc.

Natural resins and unsaturated oils such as (Lin seed oil, tung oil) are used for decoration and protection coatings centuries ago. Synthetic resins (alkyd resins), which really are modified natural oil, became important due to the desire for important quality paints.

The most accepted binders for this present day study on the quality development of emulsion paint is the polyvinyl acetate (P V A), the quality of the binders is improved, the quality of the emulsion paint also increases.

BINDER: a binder is a substance that binds the pigments and gives the paint a hard durable surface on drying, and also correct the defect of chalking, flaking, cracking etc. in this design project, polyvinyl acetate will be polymerized from vinyl acetate monomers in the jacketed batch reactor, cool by the heat exchanger and pumped to the storage tank where it is collected to the mixer for use in the production of emulsion paint. The batch polymerization process is used in this work to produce polyvinyl acetate and other ingredients such as initiator are also added to improve the quality of polyvinyl acetate (P V A).based emulsion paint. The viscosity coverage and protective power of the paint can be increased by using the pigment, extenders and additives. When all this is observed, an improved, viscous emulsion paint is obtained.

1.1 AIMS AND OBJECTIVE

The aim of this design work is to synthesis polyvinyl acetate from vinyl monomers using a batch & semi batch polymerization process and the using it as a binder in the production of emulsion paint with improved quality. Other ingredients were also used to improve the viscosity protective ability and quality of the P V A based emulsion paint obtained.

1.2 SCOPE OF WORK

This design work is for the production of 50 metric tonnes/day of emulsion paint using vinyl acetate as monomers which polymerizes to polyvinyl acetate as the major raw material for the production of polyvinyl acetate emulsion paint. Other ingredients are added to increase the quality and properties of the paint.

CHAPTER TWO

2.0 LITERATURE SURVEY

2.0.1 ORIGIN

The synthesis and patenting of vinyl acetate monomer by Dr Klatte in 1913, in Germany, provided the foundation for many valuable and now essential plastic products. He found that the catalysed reaction of acetylene with acetic acid gave a readily polymerized low boiling liquid (vinyl acetate) to yield a potential range of dense solid materials.

Klatte and others found that polyvinyl acetate (P V A) was compatible with other polymers and plasticizers, which could give valuable adhesives and coating for cellulose and textile products. From 1930 many companies manufactured a range of products, such as P V A for liquid solutions and emulsions, hot melt adhesives and paints.

Hydrolyzed version of P V A gave polyvinyl alcohol as a water-soluble coating and binder. The poly acetal derivatives of these have provided superior binding and electrical insulation with good stability.

Vinyl acetate monomer is a key raw material for the production of polyvinyl acetate (P V A) and polyvinyl alcohol. Approximately 80 percent of all vinyl acetate monomer produce in the world is used to make these two chemicals. Vinyl acetate monomer used to make poly vinyl butyral (P V B), ethylene vinyl acetate (EVA copolymers) and ethylene vinyl alcohol(EVOH) resins (McGreavy, 1994).

Poly vinyl acetate (PVA) resins are vinyl acetates containing thermoplastic copolymers used for making emulsion (latex) products. They are produced in both homopolymer and copolymers types, and are sold in the form of powders, beads or as latex base stock for compounded emulsions. Major application includes interior and exterior paints, adhesives, paper coatings and textile treatments.

All polyvinyl alcohol is manufactured using PVA as a starting material. Polyvinyl alcohol resins are powdered polymers produced by the controlled hydrolysis of PVA.

They are easily dispersed and readily dissolve in water, and are available in both fully hydrolyzed and partially hydrolyzed grades.

Ethylene vinyl acetate (EVA) is a random copolymer of vinyl acetate monomer and ethylene. EVA resins are used in the manufacture of packaging film, heavy duty bags, extrusion coating, wire and cable jacketing, hot melt adhesives, and cross linked foam.

Polyvinyl acetate (PVA), is a synthetic polymer and a member of the vinyl ester family. PVA emulsion adhesives first gained market share by replacing hide glues in the 1940's. Today vinyl acetate adhesives are the most widely used in paints, textile sizing and non woven binders. Vinyl acetate emulsion adhesives can be broadly classified as homo polymer or copolymer. Each of these two types can be further classified as self-cross linked or non-cross linked.

The liquid polyvinyl acetate emulsion is milky white, but it becomes clear when it dries. Although water is used to thin the emulsion, the dried film is water resistant. Heavy impastos

layers of the paint will not crack unless they are grossly over pigmented. In contrast to ordinary egg and gum emulsions, the dried color films are extremely hard and resistant to scratching.

The PVA medium can be stored well in glass or polyethylene containers, but iron or tin will discolor it. The emulsion should not be exposed to extreme cold, because freezing temperature will cause it to solidify permanently. The pigments used in egg tempera techniques can be used with PVA, but titanium is customarily used instead of zinc white.

The early synthetic polymers were all discovered and used before there was any real understanding of the chemistry whereby these materials were produced, before there was any meaningful concept between the molecular structure and properties of the polymers, and long before there was any understanding of the importance of chemical engineering principles for the controlled synthesis of the product on a large scale. Graham discovered in 1860 that a number of substances example gelatin, differed markedly in their emulsion properties in water from that of inorganic salts and sugars. These materials were rightly considered to have high molecular weight, but the high molecular weight was incorrectly ascribed to the fact that many small molecules physically associated to form larger aggregates. These interpretation of the observed phenomenon was not surprising since at that time 'the colloidal state of matter' was in vogue i.e the belief that all substances could, under the right conditions be transformed to a colloidal or aggregated state and conversely, all colloidal substances were aggregates of simpler molecules (Barton, 1990). In 1922 cellulose was still regarded as an aggregated or colloidal cyclic tetrasaccharide.

2.0.2 Purposeful synthesis of polymers

During the last three decades significant strides have been made towards meaningful understanding aspects of polymer science and technology. The chemistry, physics and processing of polymeric materials have been well described in a number of texts. There are less ready access to information concerning polymerization reactors, partly because much of the significant work has been carried out in industry and the information is of propriety nature, and partly because an understanding of the complexities of the polymerization reactor, and the role played by the reactor and the physical condition employed in any given system on the molecular characteristics of the product, has required the development of user friendly computational methods and hardware have only become readily available in recent years. The empiricism which characterized much of the early work involving the synthesis and scale up of polymerization processes have not been removed completely, but there is now a growing awareness of some of the essential principles which have to be understood in order to produce well 'tailored' synthetic polymers i.e polymers that have exactly the right molecular characteristics to match the desired end use for the material.

2.0.3 Molecular structure and physical properties of polymers

The relationship between the molecular characteristics of polymers and their solid state, solution, or melt properties is very complex. Much is now known about commodity or high tonnage materials (example polyethylene, polystyrene, cellulose acetate, etc) as many of these have been known for some time. In general, less is known about specialty or effect polymers (e.g. conducting polymers, photo responsive polymers, biocompatible polymers, liquid

crystalline polymers etc) which might be produced in small quantities for high added value low volume applications. There are numerous molecular features that can have impact on the observed physical behavior of polymers and some of the more important ones will outline below. Usually, it is necessary to reach some form of compromise in the design and synthesis of a polymer for a given end use, as changing the molecular structure or composition in order to achieve one desirable property often causes a loss in some other property.

Many of the desirable features of a polymer (e.g. tenacity or mechanical strength of a fibre) are derived from the fact the molecules have a higher molar mass. One might expect that an ever-increasing tenacity or mechanical strength. To an extent this is true but the relationship between properties and molar mass is not linear. Moreover it becomes increasingly difficult to process polymers which have a very high molar mass and the ease of processing decreases significantly as the size of the polymer chains is increased. The target is usually the optimum molar mass, which gives good physical properties and good processing properties. It is not always easy to decouple all the different variables that can be found in polymers in order to assess the quantitative impact on observed properties, but some of the main structural features that should be taken into account are outlined below.

2.0.4 Homopolymers and copolymers

When only one type of repeat unit is formed in a polymer chain it is describe as a homopolymers. Polymer may be linear, branched, ring or star shape. The length of branches may be the same of different in the branched or star shaped molecules.

When two chemically distinct units are used to construct a polymer, an even greater variety of structure is possible. Chains containing two types of structural unit are described as copolymers or binary copolymers .when all copolymers have exactly the same number of structural units, they all have the same degree of polymerization, the same molar mass, and the same composition. The repeating units can be distributed along linear polymer chains in a manner that obeys some statistical law (statistical copolymers), randomly distributed (random copolymers), arrayed alternately along the chain (alternating copolymers) or combined in two distinct blocks (block copolymer). When two different monomers are used to produce branched or block copolymers a considerable variety of structures and composition distribution is possible.

The statistical nature of polymerization process is such that it is not possible to synthesize homopolymers or copolymers with precisely equal chain length or chains that contain precisely the same number of different repeat units in chain. Hence, polymers will actually have some form of molar mass distribution which will stem directly from the nature of the chemistry used to construct the polymers and the influence of the reactor on the polymerization statistics.

2.0.5 Polymerization reactions

Polymerization is the process of joining together small molecules of covalent bonds.

Around the turn of the century, chemists were reluctant to accept the idea of rubber, starch, and cotton as long, linear chain connected by covalent bonds. A popular alternative was the idea of an “associated colloidal” structure. As a matter of fact, some small molecules do

exhibit such behavior. The extraordinary thickening power of aluminum disoaps in organic solvents is due to the formation of microscopic structure

from small molecules. However, the effective molecular weight of such a structure varies with concentration and temperature, where as the molecular weight of true polymers with molecular links does not.

The reactions by which some complex, naturally occurring macromolecules are formed are not completely understood. Even cis polyisoprene, natural rubber, which can be made in a single step from isoprene in the laboratory, is synthesis by a rather complex series of reactions in rubber tree.

The ultimate starting materials for synthetic polymers are few in number. Petroleum, natural gas, coal tar, and cellulose are the main sources. In recent years ethylene and propylene from natural gas and petroleum refining have been used as a starting point for a variety of monomers.

The process of building up polymers from simple repeating unit monomers can proceed with variations. We can classify some of these as follows:

1. By the number of bonds each monomer can form in the reaction used, the functionality.
2. By the kinetic scheme governing the polymerization reaction, chain vs. stepwise reactions.
3. By the chemical reaction used to produce new bonds, ethic addition, esterification, amidation, ester interchange, etc.
4. By the number of monomers used to give homopolymer, copolymer, terpolymer, etc.
5. By the physical arrangement, bulk, solution, suspension, or emulsion system.

2.0.6 Functionality

Monomer can be converted to polymer by any reaction that creates new bonds. Fundamental to any polymerization scheme is the number of bonds that a given monomer can form. Carothers defines this number of bonds as the functionality of monomer in a given reaction; it should be obvious that functionality of two can lead to linear structure.

2.0.7 Kinetic schemes

We can envision two extremes of simplified behavior in the conversion of monomer to polymer. In typical stepwise polymerization, each polymer formed can react with monomer or other polymers. Each dimer, trimer, etc is just as reactive as monomers. In a typical chain polymerization each polymer is formed in a comparatively short time, and then is "dead" and remains unchanged by the reaction of the remaining monomers. Growing chains can add monomer, but neither monomer itself nor "dead" polymer can add monomer. Monomer, growing polymer, and "dead" are quite different from one another in reactivity. Imagine a system of a hundred monomer units; we carry out a reaction that consumes fifty monomer units, i.e. half the original charge is unchanged while the other half is altered by having formed covalent bonds with other units.

The distribution of molecular weights is quite different for the cases. Further reaction of the stepwise polymer will gradually change the distribution towards higher values of x , the number of monomer units in a polymer. Further reaction in the chain polymer system will diminish the monomer concentration, but will also increase the amount of polymer at high values of x .

While these extremely simplified cases are met in practice, some very important exceptions occur that show the need for caution in making generalizations.

2.0.8 Comparism of polymerization

Bulk polymerization offers real hazards. Thermal conductivities of monomers and polymers are low, and viscosity build up limit its transfer by convection. Removal of unreacted monomer is difficult because of the low surface to volume ratio. On the hand the level of impurities can be held down by use of low initiator levels and diligent monomer removal.

Solution polymerization offers easier temperature control because of (1) added heat capacity of solvent (2) lower viscosity.

Removal of last traces of solvent and untreated monomer can be less difficult if impurity level is very low, since the initiator residue can be washed out.

Temperature control is more convenient in emulsion polymerization, because the viscosity changes very little with conversion. Also, thermal conductivity and specific heat of water are higher than those with organic solvent. Removal of monomer can be accomplished without coagulating the latex. However, impurity levels are usually rather high because surfactant and coagulant residue are hard to remove. The agglomeration processes tend to give porous particles that trap some of the aqueous phase its salt and surfactant.

Suspension polymerization is essentially a bulk polymerization carried out in droplets. Temperature control is complicated by the unstable nature of the suspension. Agitation is critical. Often as the viscosity within the beads rises, the reaction rate increases suddenly (Tronnsdorff effects). This leads to a surge in heat generation, which does not usually occur in solution or emulsion polymerization. On the other hand the viscosity of the continuous phase (water) does not change during the reaction, so that control is easier than in bulk polymerization. Monomer recovery parallels that in emulsion polymerization. Polymer recovery is simple and usually leads to lower impurity levels than with emulsion polymers.

Polymer processing after the reaction step varies with the solubility physical state, and the designed final form of the polymer, as well as with the extent of conversion of monomer to polymer. Most polymers recovered by precipitation separates as slimy, stick masses that are hard to handle. Heating, cooling and pumping viscose melts and solutions require the same attention to power inputs and surface scraping as polymerization design. The high viscosities and low diffusivities characteristics of most polymers complicate final removal of liquids, weather solvents, diluents or unreacted monomer. Vacuum evaporators, latex

strippers, and vented extruders are used, as well as belts, pan, spray, and the rotary kiln type of driers.

2.0.9 The Emulsion polymerization Process

In an emulsion polymerization process vinyl or acrylic monomers are converted into a water-dispersed polymer (latex). The process starts with the help of a free radical initiator. The polymer particles are stabilized with surface-active material (surfactant) to prevent undesired fusion or coagulation. The final product is polymer latex.

The emulsion polymerization process has various advantages compared to bulk or solution polymerization as it proceeds at low viscosity. This allows an adequate removal of the heat of reaction generated during the process and the production of high molar mass polymer in combination with high monomer conversion and short cycle times. The final product is a water-based system with a low viscosity.

The emulsion polymerization process is applied on an industrial scale for the production of lattices used as binders in a variety of products such as emulsion paint, adhesives, primers and sealers.

2.1.0 Different phases of the emulsion polymerization process

At the start of the process, the monomers are dispersed into small droplets stabilized by surfactants. Most of the remaining surfactants molecules are present as clusters (micelles) in the water phase. These micelles are very small (10nm) relative to the monomer droplet (1-10micro meter). Three different stages of emulsion polymerization can be distinguished. During stage one the initial formation of polymer particles take place. In stage two the polymerization proceeds with a constant supply of new monomer, which results in growth of the polymer particles. At the end of stage two, monomer supply ceases and subsequently the rate of polymerization decreases gradually (stage 3).

The emulsion polymerization process normally used to produce PVA based lattices proceeds via the three stages mentioned above. They are semi continuous processes during which the monomers are gradually added to the reactor over a period of a few hours.

To begin with, the reactor is charged with water, surfactant and part of the initiator. The reactor is heated to the reaction temperature. Typically 5- 10 percent of the total amounts of monomers are subsequently added to the reactor to produce so-called in-situ seed latex, which allows better control of the particle formation step. The polymerization is started by the initiator generating free radicals by terminal decomposition in the aqueous phase. The free radicals react with monomers present in the water phase to form oligomer chains (stage one). These oligomers can be absorbed into the micelles or can continue to grow and absorb surfactants molecules. In either case this result in the formation of new polymer particles. This process continues until no micelles are left. In the case of semi continuous process, stage one corresponds with the generation of the seed latex.

The polymer particles start to absorb additional monomer, which migrate from the monomer droplets through the water phase. The polymerization then proceeds mainly in the monomer and swollen polymer particles without the formation of new particles (stage

two). The monomers consumed by the polymer chain growth are replaced by new monomers, which continue to migrate from the monomer droplets. Depletion of monomer droplet is prevented by the continuous addition of new monomers. The growing particles

2.1.2 Origin of paint

Paintings of prehistoric period have been found on walls and caves in Italy, France and Spain and this dates back to about 20,000 years ago. The painters of that time used three colors; yellow, red and black.

Early Greeks developed paintings into an art form. They not only decorated surfaces but painted human figures and illustrated legends on walls, wood panels and vases. Many vivid colors were used to decorate their temples and houses.

Early Christians used color in religious symbols and pictures of saint and martyrs on dark walls of underground catacombs. Later when permitted to worship openly they created colorful mosaic and murals. The bible incidentally mentioned two mineral colors; brown and vermilion.

In spite of the early start with color application, the craft of painters such to a low ebb during the dark ages (400-800) BC. People of that time were indifferent to decorated surroundings. Medieval days that followed brought a slight revival of the arts in England. Citizens began using bright colors on walls of churches, which were painted with visions of hellfire and heaven's angel. Soon the desire for decorating led the rich to encase the inner walls of their homes with wainscotings to imitate woven hangings and paint cloths to imitate fine tapestry like most of the craft workers of medieval Europe.

2.1.3 Definition of emulsion

A two-phased liquid system in which small droplets of one liquid (the internal phase) are immiscible in, and are dispersed uniformly throughout a second continuous liquid phase (the external phase). This contrasts with latex, which consists of solids dispersed in a liquid.

2.1.4 Emulsion paint

A coating comprised of an emulsion of a resin binder in water, which will spread over a solid surface and dry out or harden as an adherent and coherent obscuring film.

Paint as a formulated contains three primaries and one secondary class of ingredient, which include binder, pigment, solvent and additives (secondary class).

2.1.5 Binder

The binder as the name implies 'binds' the pigment particles together and give the paint a hard durable surface on drying. Emulsion paint dries on application by evaporation.

2.1.6 Polyvinyl acetate (PVA) resin

This liquid substance is a clear transparent resin that softens below the boiling point of water. It is sensitive to water and decomposes in acid and bases. Its solubility in a wide variety of organic solvent is good. It has excellent adhesive properties.

PVA resin is marketed either dissolved or suspended in an organic medium like natural resins polymerized and marketed as an aqueous emulsion called latex.

2.1.7 Pigments

Pigment is the universally accepted term for the particular matter dispersed in liquid or solid binder. They are usually present in powder form in suspension vehicle pigments are either inorganic or organic in composition and exist naturally or can be synthesized.

2.1.8 Extender

They are also forms of pigments. They are usually white substances such as calcium carbonate, barium carbonate, kaolin. Although this materials impact little color or opacity to paint, they are usually added to cheapen paints and improve its brushing characteristics and toughness, at the same time reducing gloss.

2.1.9 Solvent

A solvent is a liquid that dissolves a substance and which readily evaporate leaving behind the dissolved substance unaltered. These include various alcoholics and other derivatives of a wide range of organic chemicals. They are liquids, which are added to reduce its viscosity and increase its flowing properties when preparing it for application to a surface. After the paint has been applied, the solvent quickly evaporates. Solvents are selected according to the paint been produced and its compatibility to the resin used.

2.2.1 Additives

These are materials added to paint usually in small quantities to help the medium attain a certain characteristic level such as quick drying time and flow thickening properties e.t.c.

Some additives and properties:

1. **Bodying agent:** these are added to increase the viscosity of the paint and improve its properties e.g. methyl cellulose, hydroxyl ethyl cellulose (Natrosol)
2. **Anti settling agents:** these are added to paints to retard sedimentation of pigments and increase shelf life e.g. sodium metaphosphate (calgon pt)
3. **Light stabilizers:** some paint particularly white and colored ones with ageing turn yellow. This is so because of the exposure to sunlight when the paint is on its substrate. Stabilizers which deal with this problem include dibutyl dilaurate and monoethyl glycol (M.E.G)
4. **Wetting agent:** it is added to paint film especially water base paint to ease dispersion of pigment e.g. symperonic NX (surfactant)
5. **Biocide acid:** it is introduced to kill flies and prevent mould growth e.g. phenol derivatives
6. **Anti-foam/defoamer:** to decrease the foaming ability of paint films e.g. monoethelyn glycol, kerosine
7. **Driers:** these are catalysts introduced to speed up the drying.

2.2.2 Dispersion

Paint production involves bringing pigment particles and vehicle into close contact and achieving a thorough dispersion of the particle throughout the binder. Dispersion is in fact the most important operation in a paint plant.

If the pigment particles are not completely dispersed with all pigment particles wet by the vehicle, they tend to link together in a structure that leads to poor brush-ability, low gloss and the appearance of over sized particles in the film.

2.2.3 Making up and mixing

The dispersion stage is highly pigmented and this can easily result in instability. At this stage resin and solvent are basically added to stabilize the paint under production.

Fungicides and tint (color) bases are added during this process of thinning and the paint is checked against a previously established color standard.

2.2.4 Color matching

Color in paint must be uniform and this tends to be difficult if matched manually. There are automated machines that blend and match colors, and this help make the color adjustments with negligible deviations.

2.2.5 Tests

The paint just produced is tested in the laboratory before it is approved for packaging. Some of the tests are listed below:

1. Ph test
2. Adhesion test
3. Viscosity test
4. Dispersion or particle size test
5. Drying time test
6. Opacity or coverage test
7. Weight per litre test

2.2.6 Tests on emulsion paint

2.2.7 Weight per litre

The paint produced is poured into the specific gravity cup (100ml) or measuring cylinder and filled to the brim and covered with its lid. It is then weighed on the chemical balance. The weight is noted and then divided by 100.

Weight of empty specific gravity cup = a kg

Weight of empty cup plus weight of paint = b kg

Weight of paint = (b-a) kg = c

$$\text{S.G} = (c/100)$$

Weight per litre = (c/100) g/litre

2.2.8 pH test

This is done by taking a small sample of paint and adding one or two drops to the p.H. director, the color then changes. This color is compared with the standard p.H color.

2.2.9 Particle size or dispersion test

This is one of the most important test in the paint factory. The test is carried out during dispersion stage by dipping the palette knife into the paint and checking for the particle size with the naked eye. It like wise then confirmed on the grinding gauge.

2.3.1 Drying time test

This is carried out using a drier. The normal drying time for water based emulsion paint when done mechanically is 30 minutes and for hard drying 24 hours.

2.3.2 Opacity test

This the obliterating power of the pigment used. It's carried out by brushing or applying the paint on the wall and its covering power observed. When covering is is high then opacity is said to be good, but when covering is low opacity is poor.

2.3.3 Viscosity test

The required viscosity for water based emulsion paint is 7.5-10 poise depending on the grade of paint being produced. The test is carried out using a rotho thinner viscometer and the rotho thinner works on the principle Newtonian motion which makes

2.3.4 MIXING

Mixers cut across almost every processing industry, including the chemical process industry; minerals, pulp and paper, waste and water treatment e.t.c. mixing can also involve different materials other than liquid. One concept that differentiates mixing requirements is the difference between physical criteria. Thus various definition can be based on physical descriptions (Perry, *).

The various mixing system are normally categorized according to their principle phase. This extends from single step mixing of fluids to the pure mixing of solids with solids. Very strong shear forces have to be applied if viscosity of the mixture is very high and the mix is shaped plastically.

In the minds of many, agitators and mixers are synonymous. McCabe and Smith, however point out that agitators perform numerous additional functions. The suspend solid particles in fluids, disperse gas, emulsify liquid and promote heat transfer between a fluid and solid surface.

Equipment design itself not so much on the function but on the nature of the fluid or solid being processed as viscosity and / or immiscibility increases, mechanical energy in various forms and at growing intensity is added. Suspension of solid particles requires a degree of agitation of the same order as that required for dispersion of immiscible liquids in extraction or reaction vessels. For mixing of highly viscous liquids, paste, and solid powders, more energy-intensive mechanical mixers are required. The type of device depends on the characteristics of a given feed. (see appendix *).

For any given impeller geometry, speed, and diameter, the impeller draws a certain amount of power. This power is 100 percent converted to heat in low-viscous mixing.

The principle factors which influence mixing equipment choice are:

- Process requirement
- Flow properties of the process fluid
- Equipment cost
- Construction materials required

Mixing occurs through the flow of liquid and on a microscopic scale, by the motion of the turbulent eddies created by the agitator. Bulk flow is the predominant mixing mechanism required for the blending of miscible liquids and for solid suspensions. Turbulent mixing is important in operations involving mass and heat transfer.

2.3.5 Propeller and turbine agitators

These are the type of mixing equipment that is used in the preparation of high viscous materials. They are similar to mechanical mixers and blenders found in laboratories and kitchens. They are by far the most predominant type of agitators employed in chemical process plants: they consist basically of a motorized rotating impeller immersed in the mixture.

Propellers cause fluid to flow parallel with the rotating shaft. Because of the deep vortex they can create, they are often employed to disperse non-wetting solids in liquids. Most common

impeller fall in the category of radial flow or axial flow category, like impellers in centrifugal pumps, they discharge liquid at high velocity in the radial direction. This acts like a jet mixer, entraining surrounding fluid, while setting up two circulatory systems. Axial impellers are similar radial ones, except that blades are pitched, usually at about 45- degree angle. Because of the uniformity and control of circulation, axial flow turbines are superb for suspensions of solids, dispersion of immiscible liquids, heat transfer enhancement and promotion of chemical reactions. (NB: include diagram).

2.3.6 PASTE AND VISCOUS MATERIAL MIXING

This involves the mixing of material of different viscosity and different phases. Because of the high viscosity, Reynolds number (N_{Re}) may be less than 100. Mixing occurs as a consequence of laminar shearing and stretching forces and turbulence plays no part. Relative motion of an agitator stretches and deforms the material between itself and the vessel walls. As a layer of fluid gets stretched into thinner layers, the striations diminish and the shear forces tear solid agglomerates apart until homogeneity is obtained. When solids are present, it may be necessary to reduce the particle size.

Mixers for high viscous materials generally have a smaller high shear zone (to minimize dissipative heat effects) and rely on the impeller to circulate all of the mixer contents past the high shear zone. Equipment for viscous mixing usually has a small clearance between impeller and vessel walls, relatively small volume, high power per unit volume, e.t.c.

2.3.7 DISPERSIVE MIXING

The mixing process can be observed as an overlapping of dispersion and convection. Dispersion is understood to mean the completely random change of place of the individual particles. The frequency with which the particles of an ingredient changes place with those of another is related to the number of particles in other ingredients in the direct vicinity of the particles in the ingredient. Dispersion is therefore a local effect (micro-mixing) taking effect in case of pre-mix system where a number of different ingredient are in proximity and which leads to a fine mix in very small areas.

2.3.8 HOMOGENEITY

For judging the efficiency of a solid blender or of a mixing process in general, the status of mixing has to be qualified, i.e. a degree of mixing has to be defined. This property is a product of a mixing process end goal. There are circumstances where a good mix can be called for in respect of the particle size and composition.

2.3.9 POWER CONSUMPTION IN STIRRED VESSEL

Power consumption in stirred vessel depends on the type of agitator used, which in turn depends on the viscosity of the mixture. Small blade high speed agitators are used to mix low or medium viscosity liquid. The diameter of the agitator is one third that of the vessel. Two of the most common types are the six blade flat turbine and the marine type propeller. Large blade low speed agitator is used for mixtures of high viscosity.

2.4.0 RATE AND TIME OF MIXING

Mixing time is defined as the time required to produce or mix a predetermined quality while rate of mixing is the rate at which the mixing progresses towards the final stage.

For a single phase liquid in a stirred tank to the time when the contents in the vessel reached the required degree of uniformity if the tracer is completely miscible and has the same viscosity and density as liquid in the tank, the tracer concentration may be measured as a

function of time at any point in the vessel, using detector like colorimeter or by electrical conductivity

2.4.1 DENSITY

Density is a measure of the ratio of the weight of a substance to the weight of equal volume of water at the same temperature. The density of liquids and mixture of liquids and solids are calculated using different correlations.

2.4.2 Density of a Mixture of Liquids

$$\rho = M/V_M \quad (1)$$

M= Molecular mass

V_M = Molar volume, $m^3/kmol$

2.4.3 Density of mixture of liquid and solids

The density of a mixture of liquid and solids can be calculated using the following correlation

$$\rho_{\text{mix}} = \frac{1}{C_W/\rho_s + (1-C_W)/\rho_L} \quad (2)$$

C_W = weight of solids/ weight of mixture

ρ_s = density of solid, kg/m^3

2.4.4 Viscosity

Viscosity of a substance is the property of the substance that resists flow. The viscosity is important in the design of mixers in that the impeller dimension will depend on the mixing requirement based on the viscosity and density of the mixture.

2.4.5 Viscosity of liquids

Can be evaluated from sounder's equation

$$\text{Log}(\log_{10} \mu) = [I/M \rho \times 10^{-3}] - 2.9 \quad (3)$$

Where μ = viscosity, mNs/m^2

M = molecular mass

I = sounder's index, estimated from group contribution (see appendix for chart)

ρ = density at the required temperature, kg/m^3

For a binary mixture of liquids

$$\text{Log}(\log_{10}\mu) = \rho_m [x_1 I_1 + x_2 I_2/x_1 M_1 + x_2 M_2] \times 10^{-3} - 2.9 \quad (4)$$

X_1, x_2 = mole fraction of components

M_1, M_2 = molecular mass of components

2.4.6 Viscosity of mixture of solid and liquid

Is given by the equation

$$\mu_M/\mu_0 = [1 + 2.5C_v + 10.05C_v^2 + 0.00273 e^{(16.6 C_v)}] \quad (5)$$

Where μ_M = Viscosity of the mixture

μ_0 = viscosity of the suspend liquid.

$$C_v = C_w \rho_m / \rho_s$$

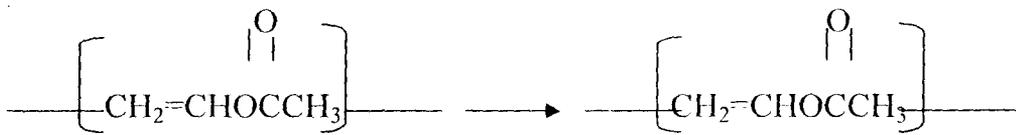
CHAPTER THREE

3.0 MATERIAL BALANCE

3.1 Balance Around the Reactor

To design a plant for the production of 50 metric tons/ day of emulsion paint using polyvinyl acetate.

Reaction taking place



The reaction takes place in an emulsifier. 5% polyvinyl alcohol in 100ml distilled water.

The material balance is as shown below:

Component	Input		Output	
	Moles/batch	Kg/batch	Moles/batch	Kg/batch
Vinyl acetate	0.0249	548.6	-	-
Emulsifier	0.0696	784.65	-	-
Polyvinyl - Acetate emulsion	-	-	0.0636	1400

UNIT 2

Heat exchanger

Material in = 1400 kg of polyvinyl acetate emulsion

Material out = 1400kg of polyvinyl acetate emulsion

UNIT 3

Polyvinyl acetate storage

Material in = 1400kg of PVA

Material out = 1400kg of PVA

Composition to be used

S/No.	Component	Percentage
1.	Polyvinyl Acetate	28
2.	Titanium Dioxide	25
3.	Clay (Extender)	12
4.	Water (Solvent)	30
5.	Aluminum (Additive)	5

Project Specification: 50 tons = 1000 x 50

= 50,000 kg/day

Basis is taken per batch

Equipment specification and selection will be based on

$$\frac{50000\text{kg} / \text{day}}{10\text{batches} / \text{day}} = \mathbf{5000\text{kg}/\text{batch}}$$

Based on formulation, a batch of paint will require

$$\frac{28}{100} \times 5000 = 1400 \text{ kg of polyvinyl acetate/batch}$$

$$\frac{25}{100} \times 5000 = 1250 \text{ kg of pigment/batch}$$

$$\frac{12}{100} \times 5000 = 600 \text{ kg of extenders/batch}$$

$$\frac{30}{100} \times 5000 = 1500 \text{ kg of solvent/batch}$$

$$\frac{5}{100} \times 5000 = 250 \text{ kg of additives/batch}$$

3.2.1 BALANCE AROUND UNIT 4

Material entering consists of

$$30\% \text{ solvent} = 0.3 \times 1500 = 450 \text{ kg of solvent}$$

$$80\% \text{ binder} = 0.8 \times 1400 = 1120 \text{ kg of binder}$$

$$20\% \text{ additives} = 0.2 \times 250 = 50 \text{ kg of additives}$$

$$100\% \text{ pigment} = 1250 \text{ kg of pigment}$$

$$100\% \text{ extenders} = 600 \text{ kg of extender}$$

Assumption: No accumulation nor generation in the unit, therefore input = output

S/No.	Component	Input (kg)	Output (kg)
1.	Binder	1120	1120
2.	Solvent	450	450
3.	Additives	50	50
4.	Pigment	1250	1250
5.	Extender	600	600
6.	Total	3470	3470

3.2.2 BALANCE AROUND UNIT 5

No accumulation or generation

Materials in = Materials out

The material flow is as presented in the table below

S/No.	Component	Input (kg)	Output (kg)
1.	Binder	1120	1120
2.	Solvent	450	450
3.	Additives	50	50
4.	Pigment	1250	1250
5.	Extenders	600	600
6.	Total	3470	3470

3.2.3 BALANCE AROUND UNIT 6

70% solvent was added = $0.7 \times 1500 = 1050$ kg of solvent

20% binder was added = $0.2 \times 1400 = 280$ kg of binder

80% additive was added = $0.8 \times 250 = 200$ kg of additive

Materials out

Solvent = $1050 + 450 = 1500$ kg of solvent

Binder = $280 + 1120 = 1400$ kg of binder

Additives = $200 + 50 = 250$ kg of additives

S/No.	Component	Input (kg)	Output (kg)
1.	Binder	1120	1400
2.	Solvent	450	1500
3.	Additives	50	250
4.	Pigment	1250	1250
5.	Extenders	600	600
6.	Total	3470	5000

3.2.4 BALANCE AROUND HOLDING TANK

No accumulation or generation

Materials in = Materials out

The table is presented below:

S/No.	Component	Input (kg)	Output (kg)
1.	Binder	1400	1400
2.	Solvent	1500	1500
3.	Additives	250	250
4.	Pigment	1250	1250
5.	Extenders	600	600
6.	Total	5000	5000

CHAPTER FOUR

4.0 ENERGY BALANCE

The energy balance involved in the production process is the heat generated as a result of mixing. There is no heat added to aid in the process, and the heat of mixing is not significant to make withdrawal of heat necessary.

4.1 Energy Balance around the Reactor

The energy balance equation is given by

Energy in = Energy out + accumulation

Assuming that there is no accumulation nor generation,

Energy in = Enthalpy of feed + enthalpy of steam

Enthalpy of vinyl acetate at 70°C = 70 + 273 = 343

$$C_p = \int_{298}^{343} C_p dT$$

$$\begin{aligned} H_{1,1} &= 3.6210(343 - 298) + (6.76 \times 10^{-2}) \left[\frac{(343 - 298)^2}{2} \right] + \\ &(-2.103 \times 10^{-5}) \left[\frac{(343 - 298)^3}{3} \right] + (-3.965 \times 10^{-9}) \left[\frac{(343 - 298)^4}{4} \right] \\ &= 162.945 + 68.445 - 0.638 - 0.0041 = 230 \frac{kJ}{kmole} \end{aligned}$$

For the non-reacting specie

Mass of the specie = 784.65

Specific heat capacity = 4.297 $\frac{J}{kg}$

$$Q = 784.65 \times 4297 \times (70 - 35)$$

Heat generated in a system is given by

$$Q = Q_p + Q_s \text{ ----- } 3.1$$

Where

Q_p is the heat added to maintain system temperature

Q_s is the heat generated

For this system, heat added to maintain system temperature is zero.

$$Q_s = mC_p\Delta T \text{ ----- } 3.2$$

m = mass of the mixture

$$C_{p_{\text{mix}}} = x_a C_{p_a} + x_b C_{p_b} + x_c C_{p_c} + \text{-----} x_n C_{p_n}$$

x_a is the mol fraction of the components

C_p is the specific heat capacity at constant temperature.

4.1 BALANCE AROUND UNIT 3

$$\begin{aligned} C_{p_{\text{mix}}} &= (0.130 \times 4.183) + (0.36 \times 0.520) + (0.173 \times 1.382) + (0.323 \times 4.1123) + (0.014 \times 0.897) \\ &= 2.3109 \text{ KJ/KgK} \end{aligned}$$

The temperature is assumed to change from 28°C to 30°C

$$Q = 3470 \times 2.3109 \times (30-28)$$

$$Q = 16,037 \text{ KJ}$$

4.2 BALANCE AROUND UNIT 4

This is the same as that of unit 1. Thus the heat generated is 16,037 KJ.

4.3 BALANCE AROUND UNIT 5

$$\begin{aligned} C_{p_{\text{mix}}} &= (0.28 \times 4.1123) + (0.09 \times 4.183) + (0.01 \times 0.897) + (0.25 \times 0.520) + (0.12 \times 1.382) \\ &= 1.833 \text{ KJ/KgK} \end{aligned}$$

$$Q_s = 5000 \times 1.833 \times (34-32)$$

$$= 18,329.2 \text{ KJ.}$$

CHAPTER SIX

6.0 EQUIPMENT DESIGN

6.1 BATCH REACTOR

$$\text{Density of reaction mixture} = 1120 \frac{\text{kg}}{\text{m}^3}$$

$$\text{Mass of the reaction mixture} = 1333.33 \text{kg}$$

$$\text{Volume of the reactor} = \frac{1333.3}{1120.4} = 1.20 \text{m}^3$$

Volume of the vessel V_R = Volume of the cylindrical section + volume of the hemisphere

$$V_R = \frac{\pi D^2 H_L}{4} + 2\pi D^3 \frac{1}{3}$$

$$V_R = \frac{\pi D_T^3}{3}$$

$$D_T = \sqrt[3]{\frac{3V_R}{\pi}}$$

$$D_T = \sqrt[3]{\frac{3 \times 1.20}{3.142}} = 1.046$$

$$H_T = \frac{3D_T}{4} = \frac{3 \times 1.046}{4} = 0.7845 \text{m}$$

For a stirred tank,

$$\frac{D_i}{D_T} = 0.30$$

$$D_i = D_T \times 0.30 = 0.3 \times 1.046 = 0.3138$$

To calculate impeller height

$$H_i = 0.3 \times D_T = 0.3 \times 1.046 = 0.3138 \text{m}$$

Liquid height to tank diameter

$$H_L = 1.05 D_T = 1.05 \times 1.046 = 1.0983 \text{m}$$

Vessel Thickness

$$\frac{b}{D} = \frac{1}{12}$$

$$b = \frac{D_A}{12} = \frac{0.314}{12} = 0.026m$$

$$\text{Density of the mixture} = 1120.8 \frac{kg}{m^3}$$

$$\text{Specific heat capacity} = 4.17 \frac{J}{kg}$$

$$\text{Thermal conductivity} = 0.435 \frac{W}{m^2 k}$$

$$\text{Viscosity of mixture} = 30.05 \times 10^{-5} \frac{kg}{ms}$$

$$\text{Diameter of the tank} = 1.048m$$

$$\text{Heat transfer area} = \frac{3\pi D_T^3}{4} + \left[\frac{\pi D_T^2}{8} + \frac{2\pi D_T}{3} \sin \frac{3D_T}{8} \right]^{\frac{1}{2}}$$

Substituting,

$$A_w = \frac{3 \times 3.142 (1.048)^3}{4} + \left[\frac{3.142 \times (1.048)^2}{8} + \frac{2 \times 3.142 \times 1.048}{3} \sin \frac{3 \times 1.048}{8} \right]^{\frac{1}{2}}$$

$$A_w = 2.59 + [0.431 + 2.19 \times 0.0069]^{\frac{1}{2}} = 2.59 + 0.668 = 3.62m^2$$

Heat transfer coefficient of the inside vessel h_i

$$= 0.73 (N_{Re})^{0.65} (N_{Pr})^{0.33} \left(\frac{k}{D_T} \right)$$

$$(N_{Re}) = \frac{1120.8 \times 3.33 \times (1.048)^2}{30.05 \times 10^{-5}} = 136,411.33$$

$$N_{Pr} = \frac{C_p \mu}{K} = \frac{4.17 \times 10^3 \times 30.05 \times 10^{-5}}{0.43} = 288.06$$

$$h_i = 0.73(136,411.33)^{0.65} (288.06)^{0.33} \left(\frac{0.435}{1.048} \right) = 0.73 \times 2175 \times 6.48 \times 0.415$$

$$= 4,270 \frac{W}{m^2 k}$$

Overall heat transfer coefficient

$$\frac{1}{U_i} = \frac{1}{h_i} + \frac{X}{k} + \frac{1}{h_o}$$

$$\frac{1}{U_i} = \frac{1}{4270} + \frac{4.0 \times 10^{-3}}{0.435} + \frac{1}{5678.2} = 0.000234 + 0.0092 + 0.000176$$

$$\frac{1}{U_i} = 0.00961$$

$$U_i = 104.06 \frac{W}{m^2 k}$$

6.2 High Speed Disperser

The design of the high speed disperser will be undertaken.

Total materials in the high speed disperser = 3470 kg/batch

Density of the mixture = 1531 kg/m³

To calculate volume of the mixer,

$$V_R = \frac{M}{\rho} \tag{4.1}$$

$$= \frac{3470}{1531} = 2.27 m^3$$

Volume of the vessel V_R = Volume of cylindrical section (V_a) + volume of hemisphere (V_b)

$$V_R = V_a + V_b \tag{4.2}$$

$$V_a = \pi r^2 h = \frac{\pi D_r^2 H_r}{4} \tag{4.3}$$

Taking the ratio

$$\frac{H_l}{D_T} = 1$$

$$H_l = D_T$$

$$V_a = \frac{\pi D_T^3}{4} \quad 4.4$$

$$V_b = \frac{2\pi r^3}{3}$$

$$= \frac{2\pi D_T^3}{3}$$

$$= \frac{\pi D_T^3}{12} \quad 4.5$$

Adding equation 4.4 and 4.5,

$$V_R = \frac{\pi D_T^3}{4} + \frac{\pi D_T^3}{12} \quad 4.6$$

$$V_R = \frac{\pi D_T^3}{3} \quad 4.7$$

$$D_T = \sqrt[3]{\frac{3V_R}{\pi}} \quad 4.8$$

$$V_R = 2.27m^3$$

$$\pi = 3.142$$

$$D_T = \sqrt[3]{\frac{3 \times 2.27}{3.142}}$$

$$D_T = \sqrt[3]{2.167}$$

$$D_T = 1.29$$

Diameter of the tank = 1.29m

To Calculate Impeller Diameter

$$D_A = \frac{D_T}{3}$$

$$= \frac{1.29}{3}$$

$$= 0.43m$$

$$D_r = H_r = 1.29\text{m}$$

Height of the liquid = 60% of the entire height

Height of the reactor = height of liquid / 0.6

$$\frac{1.29}{0.6} = 2.15\text{m}$$

To Calculate Impeller Height

$$H_i = \frac{D_r}{3}$$

$$H_i = \frac{1.29}{3} = 0.43$$

To Calculate Width of Agitator Blade (a)

$$a = \frac{D_i}{5} = 0.086\text{m}$$

To Calculate Impeller Length

$$\frac{S}{D_i} = \frac{1}{4}$$

$$S = \frac{D_i}{4}$$

$$D_i = 0.43$$

$$S = \frac{0.43}{4} = 0.108m$$

To Calculate Thickness of Vessel

$$\frac{b}{D_i} = \frac{1}{12}$$

$$b = \frac{D_i}{12} = \frac{1.29}{12}$$

$$= 0.108m$$

To Calculate Power Requirement

Assuming the speed of the agitator to be 1000rpm, which gives

16.667 rpm

$$P = \frac{P_o N^3 D_A^5 \rho}{g_c} \quad 4.9$$

Where N = Power number obtained from plot of Reynolds number

against power number

g_c = acceleration due to gravity

$$R_c = \frac{\rho N D_A^2}{\mu} \quad 4.10$$

$$\mu = 698.136 \text{ kg / ms}$$

$$\rho = 1531 \text{ kg / m}^3$$

$$R_c = \frac{16.667 \times (0.43)^2 \times 1531}{698.136} = 6.76$$

Using the plot (traced to curve 3), $P_o = 8.32$

$$P = \frac{8.32 \times (16.667)^3 \times (0.43)^5 \times 1531}{9.81}$$

$$P = 88377 \text{ kgs}^3 / \text{m}^3 = 119.88 \text{ Kw}$$

Calculation of residence time

$$\begin{aligned} \theta &= 12000 \left(\frac{\mu V_R}{P} \right)^{(1/2)} \times (V_R)^{(1/5)} \\ &= 12000 \times \left(\frac{698.136 \times 2.27}{119880} \right)^{(1/2)} \times (2.27)^{(1/5)} \\ &= 1,628.4 \text{ sec.} \end{aligned}$$

6.3 Pre-Mixer Design

The dimensions of the pre-mixer and the high-speed impeller.

The following are the specifications

To Calculate Power Requirement

Assumption: Speed of agitation is 250 rpm.

$$N = 4.167 \text{ rps}$$

$$P = \frac{P_0 N^3 D_A^5 \rho}{g_c}$$

$$R_c = \frac{\rho N D_A^2}{\mu}$$

$$R_c = \frac{4.167 \times (0.43)^2 \times 1531}{698.136} = 1.690$$

Using the plot (traced to curve 3).

$$P_0 = 35.08$$

$$(35.08 \times (4.167)^3 \times (0.43)^5 \times 1531) / 9.81$$

$$= 5,823.42$$

$$P = \frac{5823.42}{737.25} = 7.90 \text{ Kw}$$

To calculate residence time

$$\theta = 12000 \left(\frac{\mu V_R}{P} \right)^{(1/2)} \times (V_R)^{(1/5)}$$

$$= 12000 \times \left(\frac{698.136 \times 2.27}{7899} \right)^{(1/2)} \times (2.27)^{(1/5)}$$

$$\theta = 6342 \text{ sec}$$

6.4 Make-up Tank Design

Total material in the make up tank is 5000kg

Density of the mixture 1369.9 kg/m³

$$V = \frac{5000}{1369.9} = 3.65$$

$$D_T = \sqrt[3]{\left(\frac{3V_R}{\pi}\right)}$$

$$V_R = 3.65 \text{ m}^3$$

$$D_T = \sqrt[3]{\frac{3 \times 3.65}{3.142}}$$

$$D_T = \sqrt[3]{3.485} = 1.52 \text{ m}$$

Impeller Diameter (D_a)

$$D_a = \frac{D_T}{3}$$

$$= \frac{1.52}{3} = 0.51 \text{ m}$$

Height of liquid = Height of liquid/0.6

$$D_T = H_L = 1.52 \text{ m}$$

Therefore, height of vessel

$$= \frac{1.52}{0.6} = 2.53 \text{ m}$$

To Calculate Impeller Height

$$H_A = \frac{D_T}{3}$$

$$= \frac{1.52}{3} = 0.51 \text{ m}$$

To Calculate width of agitator (a)

$$a = \frac{D_A}{5}$$

$$= \frac{0.51}{5} = 0.102$$

To Calculate Impeller length (S)

$$\frac{S}{D_d} = \frac{1}{4}$$

$$S = \frac{D_d}{4}$$

$$= \frac{0.51}{4} = 0.128 \text{ m}$$

To Calculate thickness of vessel (b)

$$\frac{b}{D_r} = \frac{1}{12}$$

$$b = \frac{D_r}{12}$$

$$= \frac{1.52}{12} = 0.127 \text{ m}$$

To Calculate Power Requirement

$$Re_m = 5.88$$

$$\mu_m = 323.30 \text{ km / m.s}$$

$$\rho = 1369.9 \text{ kg / m}^3$$

$$g_c = 9.81$$

From the plot of Re vs P_o ,

$$P_o = 9.43$$

$$P = \frac{9.43 \times (7.5)^3 \times (0.51)^5 \times 1369.9}{9.81}$$

$$P = \frac{19167.53}{737.25} = 26 \text{ kw}$$

To Calculate Residence Time

$$\theta = 12000 \left(\frac{\mu V_R}{P} \right)^{(1/2)} \times (V_R)^{(1/5)}$$

$$\theta = 12000 \times \left(\frac{323.30 \times 3.65}{25999} \right)^{(1/2)} \times (3.65)^{(1/5)}$$

$$\theta = 3322.8 \text{ sec}$$

CHAPTER SEVEN

7.0 EQUIPMENT SPECIFICATION AND SELECTION

The equipment used in the chemical process industries can be divided into proprietary and non-proprietary. The proprietary equipment such as pumps, compressors, filters, centrifuges, etc are designed and manufactured by specialist firms. Non-proprietary equipment is designed as special, one-off items for particular processes.

The chemical Engineers part in the design of non-proprietary equipment is usually limited to selecting and sizing the equipment. The information would then be transmitted in the form of sketches and specification sheets, to the specialist mechanical design group, or the fabricators team for detailed design.

7.1 High Speed Dispenser

The data sheet for the Mixer (High Speed Dispenser) designed is as shown below:

Vessel Diameter (D_T)	= 1.29m
Vessel Height (H_L)	= 2.15m
Agitator Diameter (D_A)	= 0.43m
Vessel Volume (V_R)	= 2.27m ³
Impeller Height (H_A)	= 0.43m
Impeller Length (S)	= 0.145m
Width of agitator blades (a)	= 0.086m
Speed of Agitator (N)	= 16.667 rps
Power Requirement (P)	= 119.88 Kw
Pipe Diameter (D)	= 24.4m
Flow Rate of Mixture (M_c)	= 3470 kg/hr
Residence Time (θ)	= 1628.4 sec

Viscosity of mixture (μ)	= 698.136 kg/ms
Density of the mixture (ρ)	= 1531 kg/m ³

7.2 Pre-Mixer

Vessel Diameter (D_T)	= 1.29m
Vessel Height (H_L)	= 2.15m
Agitator Diameter (D_A)	= 0.43m
Vessel Volume (V_R)	= 2.27m ³
Impeller Height (H_A)	= 0.43m
Impeller Length (S)	= 0.145m
Width of agitator blades (a)	= 0.086m
Speed of Agitator (N)	= 4.167 rps
Power Requirement (P)	= 7.90 Kw
Residence Time (θ)	= 6342 sec
Viscosity of mixture (μ)	= 698.136 kg/ms
Density of the mixture (ρ)	= 1531 kg/m ³

7.3 Jacketed Batch Reactor

Volume of the reactor	= 1.20m ²
Vessel diameter	= 1.046m
Impeller diameter	= 0.3138m
Impeller height	= 0.3138m
Liquid height	= 1.05m
Vessel thickness	= 0.026m
Impeller length	= 0.0785m

CHAPTER EIGHT

8.0 SAFETY AND LOSS PREVENTION

8.1 INTRODUCTION

Hazard is commonly defined as exposure to possible danger

or loss (Odigure, 1998). Hazard in chemical process industries refer to exposure of life and properties to possible danger or loss, as a result of accident due to explosion, leakage of dangerous substances to the environment, high dust and noise level etc.

8.2 CAUSES OF HAZARD IN PAINT INDUSTRIES

8.2.1 Chemical Causes

This occurs primarily from emission losses in paint. Major emission sources include:

- Fugitive losses during manufacturing process
- Losses during filling and cleansing
- Losses during mixing of preparations and storage of solvents

Primary factors affecting emissions from paint manufacture are the type of solvents used. Emissions largely in the form of volatile organic compounds depend on the temperature and time, the solvent used, the degree of tank enclosure and the type of air pollution control used.

Water based paints are not defined as dangerous goods by the code for the transportation of dangerous goods by road and rail.

8.2.2 Fire and Explosion Hazards

Water based paint is combustible following evaporation of the aqueous component. Since solvent based paint is a flammable liquid, keep containers cool with water spray. Fire fighters are to wear self-contained breathing apparatus if there is a risk of exposure to vapor or products of combustion.

Fire fighting equipment (trucks, extinguishers, sand buckets, etc) should be provided at strategic points especially close to the working area.

8.2.3 Mechanical and Electrical Causes

Mechanical devices can constitute risk to life when the operating regulations and procedures are not observed. Protective gears should be provided for personnel in this area. Helmets should be provided for those that will hoist or lift. Goggles should be provided for those in the welding section, while safety boots should be worn by all personnel entering the factory to avoid slipping on liquid materials.

Electrical equipment should be handled in their proper manner to avoid the risk of fire emanating from them. Safety rules should be observed and unauthorized persons should not be allowed to operate machinery.

8.2.4 Hazard from Raw Materials

8.2.4.1 Pigment

This is divided into organic and inorganic pigments. The pigment to be used is inorganic (TiO_2). Inhalation is the route by which pigment are hazardous. Process during which pigment could be inhaled includes working with raw powdered pigment. Skin contact with pigment is less hazardous. They are not absorbed in significant amounts by the skin.

Nose masks should be provided for personnel that will be handling the powdered raw materials.

8.2.4.2 Vehicle

Common vehicles include oils, water, egg yolk, polymer emulsions and solvent solution. They also contain additives such as stabilizers, preservatives, etc. Preservatives can be especially hazardous since their purpose is to kill microorganisms. Protective clothing and hand gloves should be provided for those that will handle the vehicle liquids. Eating should be banned in the working area. Adequate materials should be provided for proper cleaning of the hands after handling.

8.2.4.3 Solvent

The solvent to be used is water; hence there is no threat of hazard from this.

8.3 HAZARDS AND POLLUTION PREVENTION

8.3.1 Spills

To reduce emissions of volatile organic compounds from the manufacture, control techniques that should be employed include condensers and/or absorbers on solvent handling operations and scrubbers and after burners on operations.

Paint spills should be contained using sand and earth. Prevent run-off into drains or water-ways. Drums should be provided to collect the spilled paint and properly labeled “drums for disposal”.

8.3.2 Fire and Explosion Hazard

Extinguishing media to be provided include foam, carbon dioxide, and dry chemical powder extinguishers.

8.4 HEALTH EFFECTS

No adverse health effects are expected if paint is handled in accordance with the product label. Symptoms that may arise as a result of mishandling include swallowing, eye contact and skin contact. To prevent swallowing, eating should be banned in working area. A well equipped clinic should be provided to handle matters of accidental swallowing. Eye goggles should be provided for personnel in the filling section.

CHAPTER NINE

9.0 MATERIALS OF CONSTRUCTION

Many factors have to be considered when selecting Engineering materials, but for the chemical process plant, the overriding consideration is usually the ability to resist corrosion. Other factors include mechanical properties, cost of materials, effect of high and low temperatures on the mechanical properties, ease of fabrication and availability in standard size.

The material properties considered include:

- Strength - Tensile Strength
- Stiffness - Elastic Modulus (Young Modulus)
- Toughness - Fracture Resistance
- Hardness - Wear Resistance
- Fatigue Resistance
- Creep Resistance

For this mixer equipment, agitation occurs at a high speed, thus the material should be able to withstand the shear produced as a result of the mixing. The constituents do not pose a major threat to the component parts.

Carbon Steel should be used for the equipment design, because it has excellent ductility and permits cold forming operations. Furthermore, it is cheap, readily available in the wide range of standard forms and sizes and can be easily worked.

Low-Alloy Steel (such as AISI 4340) should be used in the construction of the impeller blades. They have better mechanical and corrosion resistant properties. The greater strength they possess will help the impeller to carry out the function of mixing the viscous material.

The vinyl acetate is not corrosive to the metal inside the reactor, hence carbon steel can also be used for its construction as it has high strength and durability to withstand the shear stress as a result of the mixing.

CHAPTER TEN

10.0 INSTRUMENTATION AND CONTROL

The control of a system is necessary so as to prevent the reaction from going out of hand as a result of disturbances to vital parameters like temperature, pressure, level, composition in the system.

For the plant under consideration, the batch jacketed reactor will handle an endothermic process in which steam will be used as a source of heat. Cascade control will be employed to ensure proper check on the variable disturbance which could be temperature build up in the reactor.

The control scheme is as shown in the following diagrams.

CHAPTER ELEVEN

11.0 PLANT LOCATION/SITE SELECTION/SITE LAYOUT

11.1 PLANT LOCATION

The location of the plant can have a crucial effect on the profitability of the project, and the scope for future expansion. The factors to be considered include:

- Location, with respect to raw material supply
- Location, with respect to marketing area
- Transport facilities
- Availability of labor
- Availability of utilities, e.g. water, fuel, and power
- Availability of suitable land
- Environmental impact and effluent disposal
- Local community considerations
- Climate
- Political and Strategic considerations.

This plant should be sited where the regulation governing the emission of volatile organic matter does not pose a threat to the activities of the organization.

7.1.1 Raw Material Availability

The source of raw materials is one of the most important factors influencing the selection of a plants site. This is particularly true for this plant because large volumes of both raw materials are needed and the closer the source is to the plant, the better, as this will reduce transportation costs.

7.1.2 Market Forces

The location of markets for immediate distribution affects the cost of product distribution and the time required for shipping. Proximity therefore is an important consideration in the selection of a plant. In the case of this plant, the major consumers are the household and construction industries and hence the plant should be located in a central location to serve the customers.

7.1.3 Suitability of Land

The characteristics of the land at the proposed site should be examined carefully. The topography of the tract of land structure must be considered, since either or both may have an

effect on the construction costs. The cost of land is important, as well as local building requirements. Future expansion should be planned for. The land should be ideally flat and have load bearing characteristics. A full site evaluation should be made before it is situated.

11.1.4 Transport

The transport of materials and product to and from the plant will be an overriding factor in site selection. If practicable, a plant should be selected so that is close to at least two major forms of transport. If possible, the plant should have access to all means of transport

11.1.5 Availability of Work Force

Labour will be needed for construction of the plant and its operation. Skilled labour and unskilled labour will be required for the plant construction and operation. Skilled tradesmen will be required for the plants maintenance. Local trade union customs and restrictive practices should be considered.

11.1.6 Availability of utilities

Utilities such a water, electricity, steam and other process services should be within the reach of the plant. The location of the plant should be such that the process requirements are sourced easily. Since water will be required in large quantities, facilities should be available to bet it from source. Also, source of demineralised water should not be too far away.

Electricity of the area that will host the plant should be stable and available all year round.

11.1.7 Effluent Disposal and its Impact on Environment

Facilities should be provided for the disposal of the effluent from the plant. In case of spills, they should be cleaned and disposed off properly. In choosing plant site, the permissible

tolerance levels for various levels of effluent should be considered. As all industrial processes produce waste, consideration should be given to waste disposal.

CHAPTER TWELVE

12.0 ECONOMIC ANALYSIS

Chemical plants are built to make a profit, and an estimate of the investment required and the cost of production are needed before the profitability of a project can be assessed.

For any industrial plant to be put into operation, huge sum of money must have been invested in it to purchase and install the necessary machinery and equipment. Land and service facilities must be obtained and the plant must be erected complete with the piping, controls, and service. In addition to all these cost, it is necessary to have money available for the payment of expenses involved in plant operation. The capital requires to have the necessary manufacturing and plant facilities is called the fixed capital investment. That which is necessary for operation of the plant is termed the working capital. The sum of the fixed investment and the working capital is the total capital investment.

An approximate estimate of the capital cost of a project can be obtained from knowledge of the cost of an earlier project that was carried out using the same production process. The capital cost of a project is related to capacity of the plant by the equation,

$$C_2 = C_1 \left(\frac{S_2}{S_1} \right)^n$$

(Coulson and Richardson's Chemical Engineering, 3rd Ed)

Where C_1 = "capital cost of the project with capacity S_1 "

C_2 = "capital cost of the project with capacity S_2 "

n = "index number"

S_1 = "capacity in year 1"

S_2 = "capacity in year 2"

Calculation of Fixed Capital Investment

It was discovered that the fixed capital investment (FCI) for a plant producing 100000 tonnes/year of Paint was \$6.5M. Based on this, the cost of producing of 18250 tonnes/year of Paint can thus be calculated.

With the relationship given as

$$C_2 = C_1 \left(\frac{S_2}{S_1} \right)^n$$

(Sinnot, 1999)

Where C_1 = "capital cost of the past project"

C_2 = "capital cost of the this project "

n = "index number"

S_1 = "capacity of past project"

S_2 = "capacity of this project"

Now,

Conversion Factor,

1 Dollar = 125 naira

$$C_1 = 6.25 \times 10^6$$

$$N = 0.6 \quad (\text{Sinnot, 1999})$$

$$S_1 = 100000 \text{ tonnes / year}$$

$$S_2 = 18250 \text{ tonnes / year}$$

Substituting into the equation gives

$$C_2 := C_1 \frac{S_2^n}{S_1}$$

$$C_2 = \$ 1.25 \times 10^{10}$$

$$C_2 = 1.5625 \times 10^{12} \text{ Naira}$$

So, the fixed capital investment (FCI) for the production of 18250 tonnes/year of paint is:

$$\text{FCI} = C_2$$

$$\text{FCI} = 1.5625 \times 10^{12} \text{ Naira}$$

Estimation of Total Capital Investment

I. Direct Costs

A.

Equipment + Installation + Instrumentation + Piping + Electrical + Insulation + Painting

1. Purchased equipment cost (PEC), 15-40% of fixed capital investment

Assuming

$$\text{PEC} = 25\% \text{ FCI}$$

$$\text{PEC} = 3.90625 \times 10^{11}$$

2. Installation, including insulation and painting, 25-55% of purchased equipment cost

Assume

$$\text{Installation} = 30\% \text{ PEC}$$

$$\text{Installation} = 1.171875 \times 10^{11}$$

3. Instrumentation and controls, installed, 6-30% of purchased equipment cost

Assuming

$$\text{Instrumentation} = 25\% \text{ PEC}$$

$$\text{Instrumentation} = 9.765625 \times 10^{10} \text{ Naira}$$

4. Piping installed, 10-80% of purchased equipment cost

Assuming

$$\text{Piping} = 40\% \text{ PEC}$$

$$\text{Piping} = 1.5625 \times 10^{11}$$

5. Electrical, installed, 10-40% of purchased equipment cost

Assuming

$$\text{Electrical} = 35\% \text{ PEC}$$

$$\text{Electrical} = 1.3671875 \times 10^{11} \text{ Naira}$$

So, the cost of equipment, installation, instrumentation, piping, electrical, insulation and painting is given as

$$CA = PEC = \text{Instrumentation} + \text{installation} + \text{piping} + \text{electrical}$$

$$CA = 5.078125 \times 10^{11} \text{ Naira}$$

B. Buildings, process and auxiliary, 10-70% of purchased equipment cost

Assuming

$$\text{Building} = 40\% \text{ PEC}$$

$$\text{Building} = 1.953125 \times 10^7 \text{ Naira}$$

C. Service facilities and yard improvements, 40-100% of purchased equipment cost

Assuming

$$\text{Service} = 50\% \text{ PEC}$$

$$\text{Service} = 2.734375 \times 10^{11} \text{ Naira.}$$

D. Land, 1-2% of fixed capital investment or 4-8% of purchased equipment cost)

Assuming

$$\text{Land} = 5\% \text{ PEC}$$

$$\text{Land} = 1.953125 \times 10^{10} \text{ Naira.}$$

Thus, the direct cost is equal to

$$\text{Direct cost} = \text{Building} + \text{Service} + \text{Land}$$

$$\text{Direct cost} = 4.8828125 \times 10^{11} \text{ Naira.}$$

II. Indirect costs: expenses which are not directly involved with material and labour of actual installation of complete facility (15-30% of fixed capital investment)

A. Engineering and supervision, 5-30% of direct cost

Assuming

Engineering = 30% Direct cost

Engineering = $1.46484375 \times 10^{11}$ Naira.

B. Construction expense and contractor's fee, 6-30% of direct cost

Assuming

Construction = 45% Direct cost

Construction = $2.197265625 \times 10^{11}$ Naira

C. Contingency, 5-15% of direct cost

Assuming

Contingency = 12% Direct cost

Contingency = 5.859375×10^{10} Naira.

Thus, indirect cost is equal to

Indirect cost = Engineering + Construction + Contingency

Indirect cost = $4.248046875 \times 10^{11}$ Naira.

III. Fixed Capital Investment:

Fixed capital investment to be Direct cost + Indirect cost

Fixed Capital Investment = Direct cost + Indirect cost

Fixed Capital Investment = $9.130859375 \times 10^{11}$ Naira.

IV. Working Capital, 11-20% of fixed capital investment

Assuming

Working Capital = 10% Fixed Capital Investment

Fixed Capital Investment = $9.13085937 \times 10^{10}$ Naira.

V. Total Capital Investment (TCI):

Total capital investment to be fixed capital investment + Working capital

Assuming

. Total Capital Investment = Fixed capital investment + Working capital

Total Capital Investment = $1.004394531 \times 10^{12}$ Naira

Estimation of Total Product Cost:

I. Manufacturing Cost : direct production + fixed charges + Plant overhead cost

A. Fixed Charges, 10-20% of total product cost)

i. Depreciation, This depends on life period, salvage value and method of calculation.

About 13% of FCI for machinery and equipment and 2-3% of building value for buildings

Assuming

Depreciation = 13% Fixed capital + 3% Building

Depreciation = 1.24560×10^{11} Naira.

ii. Local Taxes, 1-4% of fixed capital investment

Assuming

Tax = 3.9% Fixed Capital Investment

Tax = $3.65234375 \times 10^{10}$ Naira

iii. Insurance, 0.4-1% of fixed capital investment)

Assuming

Insurance = 0.8% Fixed Capital Investment

Insurance = 7304687500 Naira

iv. Rent, 8-12% of value of fixed capital investment

Assuming

Rent = 10% Fixed Capital Investment

Rent = $9.130859375 \times 10^{10}$ Naira

Thus, fixed charges is given as

Fixed Charges = Depreciation + Rent + Tax + Insurance

Fixed Charges = $2.596972657 \times 10^{11}$ Naira.

Assuming

Fixed Charge = 15% TPC

Making total product cost, TPC, the subject of the formula,

$$\text{TPC} = \frac{\text{FC}}{15\%}$$

TPC = $1.731315105 \times 10^{12}$ Naira

B. Direct Production Cost:

i. Raw materials, 10-50% of total product cost)

Assuming

Raw materials = 45% TPC

Raw materials = $7.790917971 \times 10^{11}$ Naira.

ii. Operating Labour (OL), 10-20% of total product cost

Assuming

. Operating Labour = 15 % TPC

Operating Labour = $2.596972658 \times 10^{11}$ Naira.

iii. Direct Supervisory and Clerical Labour (DS & CL), 10-25% of OL

Assuming

Direct Supervisory = 15 % of Operating Labour

Direct Supervisory = $3.89545986 \times 10^{10}$ Naira

iv. Utilities, 10-20% of total product cost

Assuming

Utilities = 15% TPC

Utilities = $2.596972658 \times 10^{11}$ Naira

v. Maintenance and repairs (M & R), 2-10% of fixed capital investment

Assuming

Maintenance = 3.7% Fixed Capital Investment

Maintenance = $3.381279688 \times 10^{10}$ Naira

vi. Operating Supplies, 10-20% of M & R or 0.5-1% of FCI

Assuming

Operating Supplies = 15% Maintenance

Operating Supplies = 5.0719×10^9 Naira

vii. Laboratory Charges, 10-20% of OL

Assuming

Laboratory Charges = 16 % Operating Supplies

Laboratory Charges = 8.1157×10^8 Naira

viii. Patent and Royalties, 0-6% of total product cost

Assuming

Patent and Royalties = 5% TPC

Patent and Royalties = 8.65658×10^{10} Naira

Thus, direct production cost is

DPC = Raw material + Operating labour+ Direct service + Utility + Maintenance
+ Operating service + Laboratory + patent.

$$DPC = 1.47100647 \times 10^{12} \text{ Naira}$$

C. Plant Overhead Costs, 50-70% of operating labour, supervision, and maintenance or 5-15% of total product cost); includes for the following: general plant upkeep and overhead, payroll overhead, packaging, medical services, safety and protection, restaurants, salvage, laboratories, and storage facilities.

Considering the plant overhead cost to be 55% of OL, DS & CL and M & R

Therefore,

Plant Overhead Costs = 55% (Maintenance + Operating labour + Direct service)

$$\text{Plant Overhead Costs} = 1.828555628 \times 10^{11} \text{ Naira}$$

Manufacture cost = Direct production cost + Fixed charges + Plant overhead cost

$$\text{Manufacture cost} = 1.913559299 \times 10^{12} \text{ Naira}$$

II. General Expenses = Administrative costs + distribution and selling costs + research and development costs

A. Administrative costs, 2-6% of total product cost

Assuming

Administrative costs = 4 % TPC

$$\text{Administrative costs} = 6.92523 \times 10^{10} \text{ Naira}$$

B. Distribution and Selling Costs, 2-20% of total product cost; includes costs for sales offices, salesmen, shipping, and advertising.

Assuming

Distribution and Selling Costs = 15% TPC

Distribution and Selling Costs = 2.59698×10^{11} Naira

C. Research and Development Costs, about 3% of total product cost

Assuming

Research and Development Costs = 3% TPC

Research and Development Costs = 5.19395×10^{10} Naira.

Thus, general expenses,

General Expenses = Administrative cost + Distribution and Selling Costs +
Research Costs

General Expenses = 3.80889×10^{11} Naira.

IV. Total Production Cost = Manufacture Cost + General Expenses

Total Production Cost = $\text{N}2.29445 \times 10^{12}$.

V. Gross Earnings/Income:

The selling price of Paint is equal to

Selling price of paint / 20 litre = $\text{N}2000$

Quantity Produced = 12773000 litre.

Total income = Selling price x quantity of product manufactured

Total income = $\text{N}2000 \times 12773000 = \text{N}2.6015 \times 10^{12}$.

Total income = $\text{N}2.6015 \times 10^{12}$.

Gross income = Total income - Total Product Cost

That is,

Gross income = $\text{N}2.6015 \times 10^{12} - \text{N}2.29445 \times 10^{12}$

Gross income = $\text{N}3.115 \times 10^{12}$.

Assuming the tax rate to be 20% (common).

Net profit = Gross income - Taxes

Taxes = 20% of gross income

$$\text{Taxes} = \text{₹} 6.3 \times 10^9$$

Net Profit = Gross Income - Taxes

$$\begin{aligned}\text{Net Profit} &= \text{₹} 3.115 \times 10^{12} - \text{₹} 6230000000 \\ &= \text{₹} 2.492 \times 10^{10}.\end{aligned}$$

Rate of Return:

$$\text{Rate of return} = \frac{\text{Net profit}}{\text{Total CI}} 100\%$$

Therefore,

$$\text{ROR} := \frac{\text{Net profit}}{\text{Total CI}} 100\%$$

$$\begin{aligned}\text{ROR} &= \text{₹} 2.492 \times 10^{12} / \text{₹} 1.004394531 \times 10^{12} \\ &= 24.8\%\end{aligned}$$

Pay-Back Period:

The pay-back period is calculated as the reciprocal of the rate of return.

Therefore,

$$\text{PBP} := \frac{1}{\text{ROR}}$$

$$\text{PBP} = 4 \text{ Years}$$

Return on Investment

This is calculated as given thus.

Return on investment (ROI) is given by the expression,

$$\text{ROI} = \frac{\text{Total profit - depreciation}}{\text{Total investment}}$$

That is,

$$\text{ROI} := \frac{\text{Total_income} - \text{Depre}}{\text{Total_income}} 100\%$$

$$\text{ROI} = 95.2\%$$

CHAPTER THIRTEEN

13.0 CONCLUSION AND RECOMMENDATION

13.1 CONCLUSION

Based on the design of the paint plant carried out, the total production cost of 2.294448×10^{12} Naira and a net profit of $\text{N}2.492 \times 10^{10}$ have

revealed that the project is economically viable with a pay back period of 4 yr . Also the design showed that the plant is environmental friendly and hence worth investing in. Paint can also have adverse effects on health if not used properly. If used in closed areas, its chemical components can irritate eyes, skin, and lungs and cause headaches and nausea. It can also contribute to respiratory problems, muscle weakness, and liver and kidney damage.

13.2 RECOMMENDATIONS TO THE INDUSTRIALIST

Having carried out the design of paint plant, the following recommendations are made to the industrialists to be noted during the construction, start-up and operating phases of the work:

The safety of workers, equipments and infrastructures should be highly evaluated during the design implementation stage of the design.

Adequate data and technological parameters should be at the possession of the plant operations at all time to forestall any unwanted accident.

Routine turn around plant maintenance should be of paramount importance in the design. An articulate and organised maintenance team should safeguard quick plant shut down and ensure equipment salvage value. This will also take care of schedule, slippage, cost over-run and possible re-work.

Personnel should undergo routine training about new work ethic and equipments to improve their knowledge of the plant operation and increase overall plant productivity.

Procurement of raw materials and equipments should be based on strict regulation of specification and maximum quality.

Plant should not be operated above the design specification to avoid abnormal conditions and explosions.

The implementation of this design work must be adequately supervised by the experts.

The plant should be sited close to the source of raw materials.

The water and air around the plant should be monitored regularly to ensure compliance with the Environmental Protection Agency Standards.

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