DESIGN OF AN AGITATION SYSTEM FOR THE PRODUCTION A LUBRICANT FROM BLENDING OF BASE OIL AND AN ADDITIVE

BY

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93/4090

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A PROJECT SUBMITTED IN PARTIAL
FULFILLMENT OF THE REQUIREMENT FOR THE
AWARD OF BACHELOR OF ENGINEERING
(B.ENG.)

MARCH, 2000.

CERTIFICATION

I hereby certify that I have supervised, read and approved this project carried out by Ajala A. Oluseyi of the Department of Chemical Engineering, in the School of Engineering and Engineering Technology, Minna and hence found it adequate in scope and quality for the partial fulfillment of the award of Bachelor Degree in Chemical Engineering.

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DEDICATION

This project is dedicated to my dearest mother and above all, to Almighty God who has ensured my survival throughout my study and also made everything a reality.

ACKNOWLEDGEMENT

I want to express my profound and unreserved gratitude to the creator himself for a continually encouraging and ensuring my safety even in the midst of so much despair.

My acknowledgment also goes to my mother Mrs. C.A Durosaro and every member of my family.

Dr. Odigure, you 've been great, another supervisor couldn't been better. You have contributed immensely to what I am proud of today. Your children and family as a whole will never run out of God's favour. Amen. To all the lecturers in the chemical engineering department and others I say a big thank you.

To my true friends in need and indeed, I appreciate Biodun Ojerinde, Felix Oloriebi, Aluta E.O and so on, I want to say thank you for been there.

The entire members of my class, vultures and family of greatness, I say thank you all.

Lastly I want to say a big thank you to every member of my family and to God Almighty for his care and mercy on me.

ABSTRACT

The design of an agitation system for the production of 20, 000 tones / year of lubricant from blending of a base oil and an additive has been carried out. The area covered included material balance as well as energy balance over the mixer.

A technological flow diagram which shows major items of equipment and material flow was provided. The plant layout also shows the location of different departments. All these were produced and included in the work. A sectional view of the mixer, drawn to scale, has also been provided. The sizing of the mixer as well as impeller were carried out. A cost estimate of the equipment show that ₦1,915104.403 is needed as an investment capital.

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CHAPTER ONE

1.0 INTRODUCTION

Since engineers are concerned with the application of technology to satisfy human needs, the essence of engineering is characterised by the design power in which resources are transformed in the best way possible into needed devices or system.

Mixing can be therefore defined as the intermingling of two or more dissimilar portions of a material, resulting in attainment of a desired level of uniformity either physical or chemical in the final product [F.A Holland]. Mixing can be classified base on the phase of the mixing substances as liquid, liquid-solid, Gas-liquid, solid and so on. In mixing two possible types of problem are encountered which are ; How to design and select mixing equipment for a given system and how to assess whether a mixer is suitable for a particular application.

In finding the solution to these problems, the following parameters are considered. Mechanism of mixing, power consumption, flow pattern of substance to be mixed and the equipment available and cost. In general, agitator (mixer) can be classified into two groups, viz: (1) Agitator with a small blade area which rotates at high speed e.g. Marine and turbine type propeller, (ii) Agitator with a large blade area which rotates at a low speed, this includes anchors, paddles and helical screws. Mixing equipment is designed to achieve a pre-determined level of homogeneity and also to improve heat transfer. Here, the rotational speed of an impeller in a mixing vessel is selected so as to achieve a required rate of heat transfer. Excessive mixing should also be avoided to avoid wasteful of energy and destruction of the product quality.

1.1 AIMS AND OBJECTIVES

The objectives of the design work are to;

(1) Prepare a material balance over the mixer

(2) Prepare an energy balance over the mixer

(3) Prepare a material flow diagram of the process

(4) Prepare a technological flow diagram of the process

(5) Draw out a layout of the plant

(6) Carry out a detailed chemical engineering design of the agitation system

(7) Provide a sectional diagram of the designed equipment

(8) Estimate the investment cost of the equipment

(9) Undertaken safety consideration of the process

(10) Prepare a control diagram of the equipment.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 BACKGROUND

Mixing is one of the most common operation in chemical and industrial processes. It involves a process of reducing the degree of non-uniformity or gradient of property in a system such as viscosity, concentration, temperature and so on. Here single phase is involved known as liquid-liquid phase. Therefore with the help of an agitator. There will be increase in transfer of the material from the surface or bottom to the bulk of solution. Mixing also prevent sedimentation and effective use of the interfacial surface.

2.2 MIXING MECHANISM

For mixing to be carried out successfully, it is very important to know the flow pattern of the liquids involve and density of solid material to be blend. In solid-liquid mixing devices, it is advantageous to prevent stagnant zone and to create intensive mixing zone. In mixing mechanism, fluid properties most especially viscosity and in solid properties most especially density used to be taken to consideration for appropriate mixing. The flow of mixing vessels may be laminar or turbulent.

2.2.1 IMPELLER REYNOLD NUMBER

Reynolds number is one of the factor used to determine whether the flow in the impeller stirred tank is turbulent or laminar.

When NR0 > 10,000 flow in the tank is turbulent. Between NR0 of 10,000 and 10 is a transition range in which flow is turbulent at the impeller and laminar in the remote parts of the vessel. When NR0 > 10, flow is laminar. Reynolds is defined as

$$N_{Re} = \frac{Da^2 N\rho}{N}$$

Where N = rotational speed (rev/s)

Da = impeller diameter cm

ρ = fluid density (kg/m^3)

μ = viscosity (kg/ms)

2.2.2 LAMINAR & TURBULENT MIXING

Laminar mixing occurs in a high viscosity liquid in excess of 10NS/m^2 which may be either Newtonian or Non-Newtonian. The inertia forces therefore tend to die as quickly as the impeller of the mixer cover sufficient proportion of the cross section of the vessel to impact sufficient bulk motion. Turbulent mixing occurs in low viscosity liquids (less than 10Ns/m^2) where the bulk flow pattern in mixing vessels with rotation impeller is turbulent. The inertia imparted to the liquid by the rotating impeller is sufficient to cause the liquid to circulate throughout the vessel and return to the impeller.

2.3 POWER CONSUMPTION IN STIRRED TANK

Power consumption which can be viewed in two ways due to different flow pattern and mixing mechanism is the most important parameter in the design of stirred vessel.

2.3.1 LOW VISCOSITY SYSTEM

Typically equipment for low viscosity liquid consist of a vertical cylindrical tank with a height to diameter ratio of 1.5 to 2 fitted with an agitator. Also high-speed propeller of diameter of about one third of that of the vessel are suitable.

Therefore, considering a stirred tank in which Newtonian liquid of viscosity (μ) of density (ρ), is agitated by an impeller diameter D, rotating at a speed N the tank diameter D_T and the other dimensions mentioned above then the functional dependence of the power input to the liquid P, on the independent variable (μ, ρ, N, D, D_T, g) may be expressed as:

$P = F(\mu, \rho, N, g, D, D_T)$ ------------------------------*

In equation *, p is the impeller power that is the energy per unit time dissipated within the liquid.

It is readily acknowledged that the functional relationship in equation * cannot be established from the first principle. However, by using dimensional analysis the number of variable can be reduced to give:

$$\frac{P}{\rho N^3 D^5} = F(\frac{\rho N D^2}{\mu}, \frac{N^2 D}{g}, \frac{D_T}{D}, \frac{w}{D}, \frac{H}{D}) \text{ ------------------------------*ii}$$

Where the dimensional group on the left hand side is called power number N_P, $\rho ND/N$ is the Reynolds number (Re). N^2D/g is the froude number (Fr). Other dimensionless length ratios such as $\frac{D_T}{D}, {}^{w}\!/_{D}$, etc relate to specific impeller /vessel arrangement for geometrically similar systems these ratio must be equal and functional relationship between the power number and the other dimensionless group reduces to Np = F (Re Fr) --------------------*iii.

The simple of the function in equation iii is the power law given by $Np = K^1 Re^b Fr^c$ ------------* iv .

Where k1, b, c must be determined from experimental measurement and are dependant on impeller per vessel configuration.

2.3.2 HIGH VISCOSITY SYSTEM

High viscosity liquid is slow both at the molecular scale on account of the low values of diffusivity as well as the macroscopic scale due to poor bulk flow. While in low viscosity liquids momentum can be transferred from a rotating impeller through a relatively large body of fluid in high viscous liquid only the fluid immediate vicinity of the impeller is influenced by the agitator and the flow is normally laminar.

The proportionality constant (k) in equation *iv is a friction of the type of rotating member and the geometrical configuration of the system. There is relationship between data on power consumption with time independent non - Newtonian liquid and Newtonian liquids in laminar region. This relationship depend in the fact that its connect average angular shear rate δ_{ang}. For a mixer which is characterize with power consumption which is directly proportional to the rotational speed of impeller can be represent mathematically as

$$\delta_{\mathrm{ang}} = KsN$$

where Ks is a function of the type of impeller and the vessel configuration under consideration.

2.4 CLASSIFICATION OF AGITATOR (MIXERS)

In general, agitators can be classified into following two groups

2.4.1 SMALL BLADE HIGH SPEED AGITATORS

This type of agitator can be used to mix low to medium viscosity liquids. Two of the most common types are the six blade flat turbine and the marine type propeller. Flat blade turbines used to mix liquid in a baffled tanks produce radial flow patterns primarily perpendicular to the vessel wall. In contrast marine type propellers used to mix liquids in baffled tanks produce axial flow patterns primarily parallel to the vessel wall. Marine type propellers and flat blade turbines are suitable to mix liquids with dynamic viscosity up to 10 and 50 pas respectively. A typical turbine mixing system is the standard configuration defined by the following geometric relationships:

(i) a six-blade flat blade turbine agitator

(ii) $D_A = D_T/3$ (iii) $H_A = D_T/3$ (iv) $a = D_T/5$ (v) $r = D_T/4$ (vi) $H_L = D_T$

(vii) 4 symmetrical baffles and (viii) $b = D_T/10$

Here, agitator tip speeds U_T can be given as $U_T = \Pi D_A N$, this is used to determine the degree of agitation in a mixing process. For this work, small blade with high speed was selected for conversion process.

2.4.2 LARGE BLADE LOW SPEED AGITATORS

Large blade low speed agitators include anchors, gates paddles, helical ribbons and helical screws. They are used to mix relatively high viscosity liquids and depend on a large blade area to produce liquid movement throughout a tank. They are low shed agitators they are useful for mixing clear thickening liquids. Anchor agitators operate within close proximity to the tank wall. Helical screws normally function by pumping liquid from the bottom of a tank to the liquid surface. The liquid then returns to the bottom of the tank to fill the void created when fresh liquid is pumped to the surface. Where this liquid velocity decreases towards the tank wall, the liquid at the wall of an unbaffled tank is nearly motionless. Therefore, Baffles set away from the tank wall create turbulence and facilitate the entrainment of liquid in contact with the tank wall.

Gray (1963) investigated the mixing times of helical ribbon agitators and found the following equation to hold: $N_t = 30$; where N is the rotational speed of the helical ribbon agitator and t is the batch mixing time (F.A Holland 1998).

2.5 MIXING EQUIPMENT

The choice of mixer type and its design is govern by experience because there is no standardization of equipment and design codes available.

2.5.1 VESSELS

There are usually vertical cylindrical tank up to 10m in diameter which typically are filled to a depth equal to about one diameter.

2.5.2 BAFFLES

Baffles are often filled to the walls of the tank to prevent gross vortexing which is detrimental to mixing especially for the viscosity systems. Thus take the form of thin strips of about one tenth of the tank diameter width and typically four equal spaced baffles may be used. In some cases, the baffles are mounted flush with the wall, although occasionally a small clearance is left between the wall and the baffles are however not required for high viscosity liquid because the viscous shear is sufficiently great to damp out the rotary motion.

2.5.3 IMPELLERS

There are two types of impellers namely:

2.5.3.1 AXIAL FLOW IMPELLER

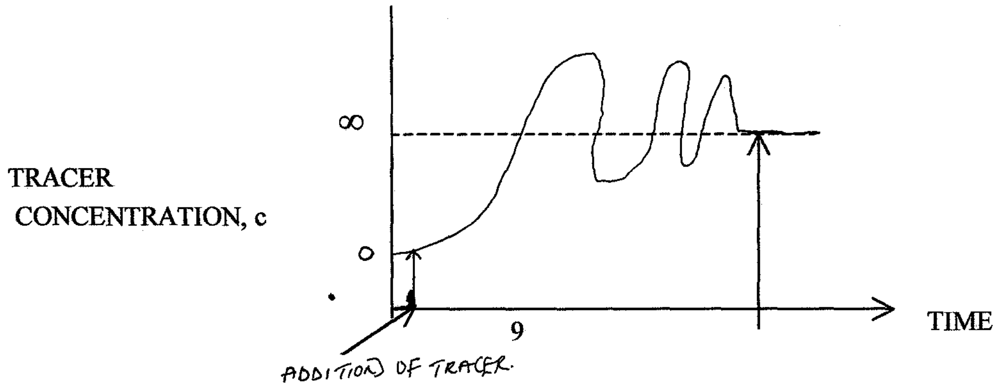
These impellers which the blades make an angle of less than 90^0 with the plane rotation. Propellers and paddles are example of axial flow impeller. Propeller mixer may be clamped on the side of an open vessel in the angular off centre position of plate on top of the closed vessel or mounted near the bottom of the cylindrical wall of a vessel especially to blend low viscosity fluids.

2.5.3.2 RADIAL FLOW IMPELLER

These systems have blades, which are parallel to the axis of the drive shaft. The smaller multi-blade ones are known as turbine, larger shower – speed impeller with two or four blades are called paddles. The other type of radial flow impeller is called anchor which is used for some pseudo plastic fluid systems where stagnant fluid may be found next to the vessel impeller. The fluid flow is principally circular in the direction of rotation of the anchor.

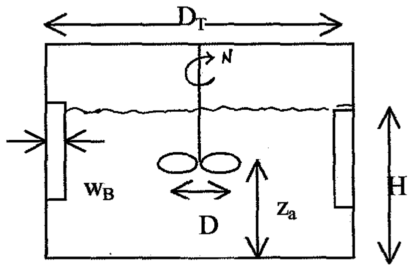
2.6 RATE AND TIME OF MIXING

Mixing time can be defined as the time required to produce a mixture or a product of predetermined quality. The rate of mixing on the other hand is the rate at which the mixing progresses towards the final state. For a single phase liquid in a stirred tank to which a volume of tracer material is added the mixing time is measured from instant the tracer is added to the time when the content of the vessel have reached the required degree of uniformity. If the tracer is completely miscible and has the same viscosity and density as the liquid in the tank the tracer concentration may be measured as a function of time at any point in the vessel by means of detector such as colour meter or by electrical conductivity, for a given amount of tracer the equilibrium concentration C, may be calculated and can be plotted against time to give a curve shown in fig a below.



2.7 SCALE UP OF STIRRED VESSEL

During the design of a mixing equipment the designer always faced with the problem of choosing the satisfactory arrangement for a large units in order to achieve the same kind of flow pattern in two units. These are the conditions that need to be maintained when choosing the type of mixer (I) geometrical kinematic dynamic similarities and identical boundary conditions power of the agitator can be related easily with the geometrical and mechanical arrangement of the mixer, hence a direct medication of the change in power rising from the alteration of any of the factor relations to the mixer. A typical mixer arrangement is as shown in fig b below.



Where D = Diameter of agitator, D_T = Diameter of tank

Z_A - Height of agitator from the base of the tank

H = Depth of liquid, R = No of baffles, NB = width of baffles

N = speed of agitator, p = pitch of agitator

W = width of blades of agitator

2.8 SELECTION OF EQUIPMENT

The principal factors which influence mixing equipment choice are (I) The process requirements (ii) The flow properties of the process fluids (iii) equipment costs and (iv) Construction material required. (Perry).

Ideally, the equipment chosen should be that of the lowest total cost which meets all process requirements. The total cost includes depreciation on investment operating cost such as power and maintenance costs. Actually, there are no satisfactory specific guides for selecting mixing equipment because the ranges of application of the various types of equipment overlap and the effects of flow properties on process performance have not been adequately defined.

2.9 CHOICE OF MIXER TANK

The choice of mixer tank depends on the flow properties of containing mixtures like incase of solid –liquid mixture (heterogeneous) the sped of agitator and viscosity need to be looked into, here, impeller stirred tank (vessel) is considered, because batch mixing times have been studied and for mixing to obtain uniformity, the impeller should be located at one third of the mixture depth above the vessel bottom unless rapidly settling material or a need to stir a nearly empty vessel required a lower impeller location.

CHAPTER THREE

3.0 PROBLEM STATEMENT OF THE DESIGN

The aim of the design is to design a process for blending base oil additive from the storage point for raw materials to the filling point.

A stainless steel mixer (reactor) incorporated with impeller and baffles is to be designed in which 7.78m^3 of base oil and 1.69 m^3 additives are uniformly blended together.

The scope for a 20,000 tonnes per year of lubricant plant using the blending process.

Operating Hour

A shift of 8 hours per day is available

360 days is the total operating time per year

The number of operating hour per year will be

360 x 8 = 2880 hours.

Base oil storage / Additive storage.

The base oil will be obtained from refineries in Nigeria while the additive are imported. For the base oil and additive, assuming no loss in processing (in delivery), the amount of base oil needed per hour is:

$$\frac{20{,}000{,}000(kg/hr)x0.775}{2880(hr/hr)} = 5{,}381.94\text{kg/hr}$$

$$= 5{,}382\text{Kg/hr} \qquad = 0.01929\underline{m}^3s$$

The amount of additive needed per hour is

$$\frac{20{,}000{,}00(kg/hr)x0.485}{2880(hr/hr)} = 3{,}368\text{Kg/hr}$$

$$\text{or } 3{,}368\ \frac{kg}{hr}\ \Bigg|\ \frac{1hr}{360\ s}\ \Bigg|\ \frac{m^3}{485kg} = 0.01929\ m^3/s.$$

3.1 RAW MATERIALS:

The main raw materials required for the blending process are oil and additive

3.2 UTILITIES AND SERVICES:

The services provided is the electricity at 440v, 50Hz, 3 - phase.

3.3 PRODUCT SPECIFICATION.

The desired product is a blended oil. The viscosity of which should be 887.75cp and Density of 572.9Kg/ m^3

3.4 FLOW SHEETING

The entire flow sheet of the process is based on the step - by - step operation carried out to get the desired product. It involves pumping of base oil and additive from the storage tanks to the blender followed by mixing. The blending which is carried out in a stainless steel incorporated with impellers and baffles for agitation at 60^0c. After the attainment of the required viscosity and Density, the mixing is discontinued. The flow sheet is illustrated in the figure below:-

3.5 ON STREAM TIME

The on stream time for the process is about 8 hours, that is 8 hour per batch. However the process is carried out as the need for new flux of raw materials arises.

3.6 DESIGN DATA:

i Base oil:

density at 25°c (77°F) is 0.775g/cm^3 (775Kg/ m^3)

Viscosity at 25°c (77oF) is 280cp

ii Additive, mixture for the purpose of :

a Viscosity index improval

b Pour point dispersal

c Antiwear promotion

d Extreme pressure

e Dispersant promotion

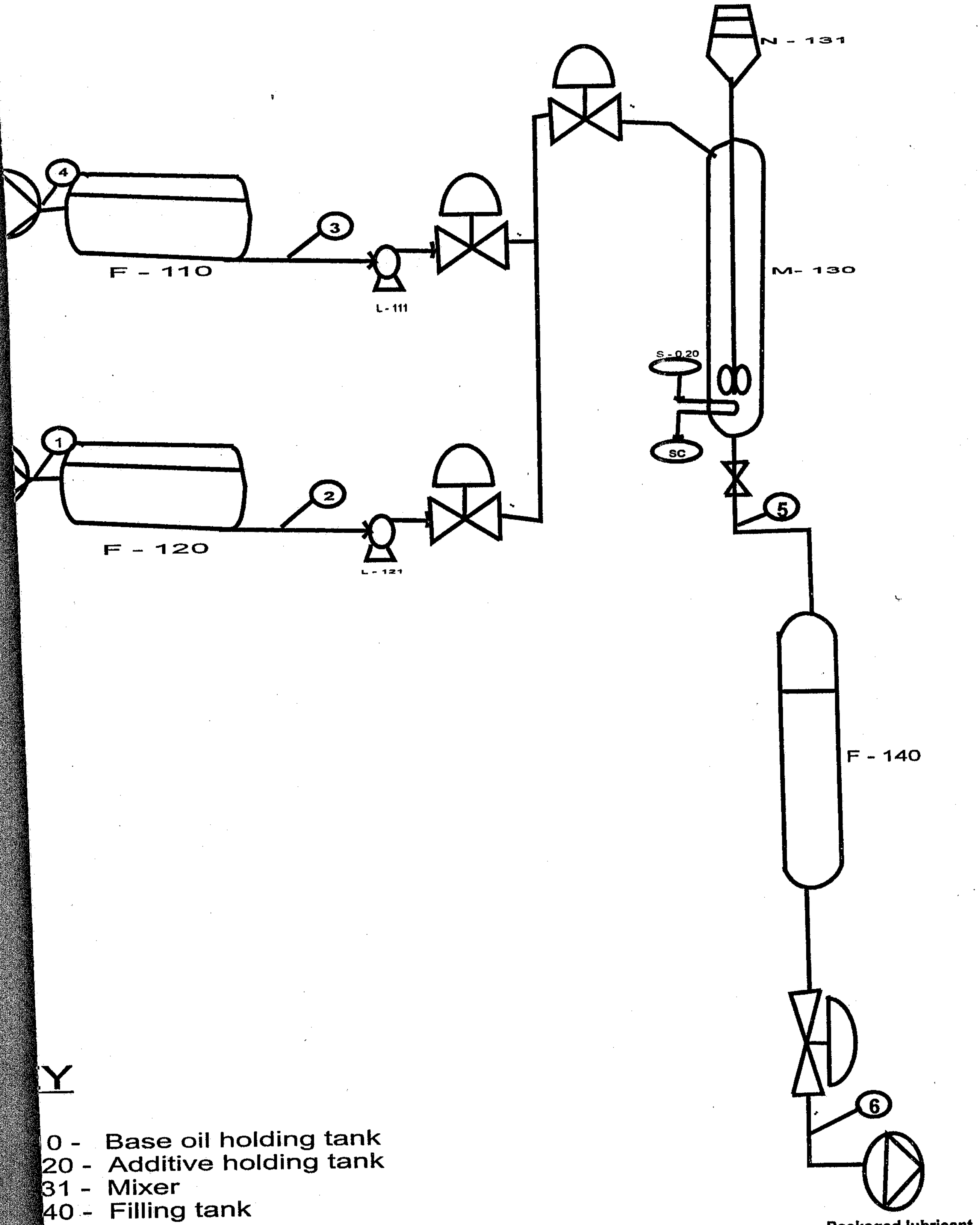
Average density at 25°c (77°F) is 0.485g/cm^3 (485kg/cm^3)

Average viscosity at 25°c (77°F) is 15,000 cp.

iii Final batch volume 8500gal (32.2m^3)

iv Mixing to talk place in loft (3.05m) diameter round bottom tank

FLOW CHART FOR THE PRODUCTION OF BLENDED LUBRICATING OIL FROM BASE OIL AND ADDITIVE



Y

0 - Base oil holding tank
20 - Additive holding tank
31 - Mixer
40 - Filling tank

3.7 MATERIAL AND ENERGY BALANCE:

The material and energy balance for the entire process is given in this section with the fact that, the blender (reactor) is done in the detailed design section.

3.7.1 MATERIAL BALANCE.

From the data gathered from evaluation of an existing plant situated at Ilorin, Kwara State, Nigeria. The optimum time of mixing is about 8 minutes. Hence the material balance is proceeded as follow.

3.7.1.1 BASE OIL STORAGE TANK/ADDITIVES STORAGE TANK

To calculate the volume of the storage tanks whose angle of repose is 40° four literature:

Volume of storage tank $V = \frac{\Pi L D^2}{12}$

where $L = \frac{\theta x D}{100}$ and D = Diameter of the tank

D = 10m

$$\therefore L = \frac{40x10}{100} = 4m$$

$$\therefore V = \frac{\Pi x 4 x (10)^2}{12} = 104.72m^3$$

3.7.1.2 FILLING TANK

From the principle of material balance,

Material in = material out

(5) = (6)

6944.4kg/hr = 6944.4kg/hr.

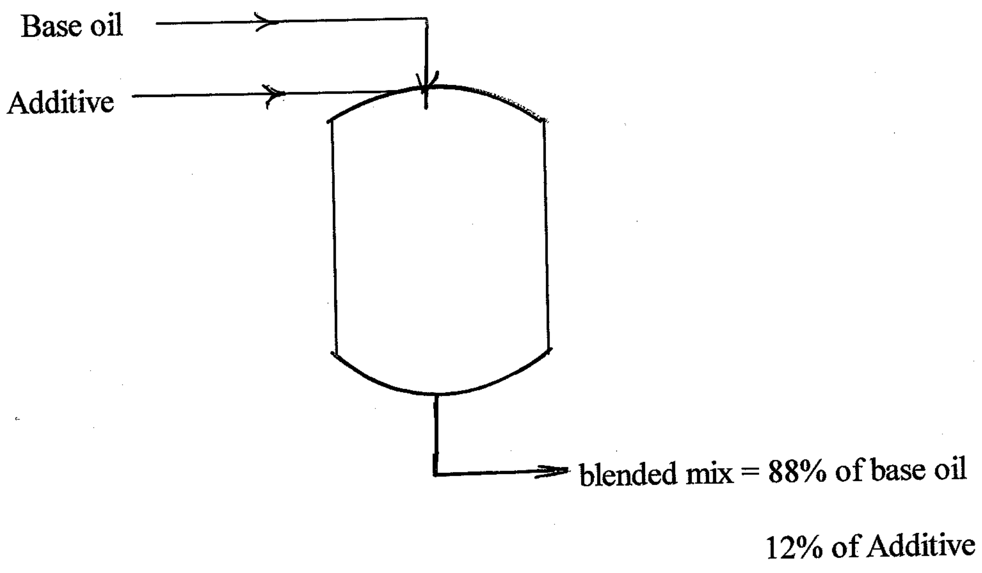
3.7.1.3 BLENDING TANK:

This involve a material balance over the blending tank

Taking a basis of 6944.4 kg/hr of the blended mix,

material in = material out.

(2) + (3) = (5)



For base oil;

Since we have 88% of base oil in the final mix and going by the law of conservation of mass

Material in = material out + Accumulation

But for this particular process accumulation = 0

∴ material in = material out

88% of 6944.4kg/hr = material is (for base oil)

∴ mass of base oil fed into the blender

= 6111.072 kg/hr = mass of base oil from holding tank.

Similarly,

mass of additive in blended mixture,

= 12% of 6944.4kg/hr

= o.12 x 6944.4

= 833.328kg/hr

∴ mass of additive form holding tank = 833.328kg/hr

The summary of the material balance is presented in the table below:

MATERIAL BALANCE TABLE

Stream/composition	Additive from delivery (1)	Additive to blender (2)	Base oil to blender(3)	Base oil from delivery (4)	Product from blender(5)	Product from filler (6)
Base oil	-	-	6111.072	6111.072	6111.072	6111.072
Additive	833.328	833.328	-	-	833.328	833.328
Total	833.328	833.328	6111.072	6111.072	6944.4	6944.4

3.7.2 ENERGY BALANCE

An energy balance is carried out around the blender as follows:

From the literature;

c_p (cal/ g^0 c) = specific heat capacity of a oil mixture is given as

$$c_p\ (\text{cal}/\ g^0c) = \frac{A}{\sqrt{d_4^{15}}} + B(t-15) \quad = A + B\ (t-15) \text{ and } d\ =1$$

(a) petroleum oil (base oil) A= 0.415 and B= 0.009

(b) castor (Additive) A = 0.500 and B= 0.007

For base oil c_p = 0.415 + 0.009 (60.15)

= 0.820 cal/g^0c

Additive c_y = 0.500 + 0.007(60-15)

= 0.815 cal/g^0 c

To calculate the specific heat capacity of the mixture.

$$\frac{Cp_O x W_o + Cp_A x W_A}{W_A + W_o}$$

where $cp_{\underline{o}}$ = S.H.C of base oil

cp_A = S.H.C of additive

$W_{\underline{o}}$ = mass of base oil

W_A = Mass of additive

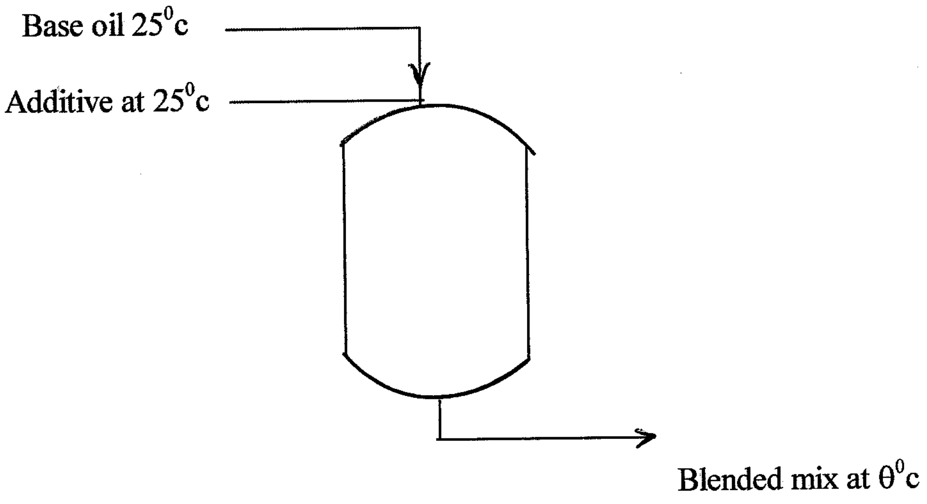
S.H.C of the mixture $\dfrac{0.820x6111.072 + 0.815x833.328}{6944.4}$

$$= \frac{5690.24}{6944.4}$$

$= 0.8194\ cal/g^{0}c$

$= 0.8194x4186.8 = 3430.75/kg^{0c}$

3.7.2.1 ENERGY BALANCE AROUND THE BLENDER:



From the law of heat conservation;

Heat loss = Heat gain

provided there is no heat loss to the surrounding

HEAT GAIN:

For the mixture

Q = $MC\Delta\theta = mc\ (\theta-\theta m)$

where M = mass of the mixture

C = S.H.C of the mixture

$\Delta\theta$ = temperature change

θ = final temperature

θm =temperature of the mixture

Hence , Heat gain

$=6944.4\ x3430.7\ \ x\ \ (\theta m- 25)$

$=\ 23824153.8\ (\theta m\ -\ 25)$

HEAT Loss

Heat loss by steam at 100^0c

$= m\lambda$

where m = mass of the steam and it is assumed to be 100kg/hr

and λ = specific latent heat of vapourization

λ for steam at 100% = 2412.031kJ/kg

$= 100 \times 2412.031$

$= 241203.1$kJ/kg

Heat loss by condensed steam when its temperature goes from 100 $\longrightarrow \theta$

$= mc\ \theta$

$= 100 \times 4.2 \times (100 - \theta)$

Total heat loss

$= 241203.1 + 42000 - 420\theta$

And since heat loss = Heat gain

$241203.1 + 42000 - 420\theta m = 23824153.08\theta m - 595603827$

$\longrightarrow 595887030.1 = 23824573.08\theta m$

$\Rightarrow \theta m = 59.01^0$c

hence the operating temperature = 59.01^0c

3.7.2.2 POWER REQUIREMENT OF THE PUMP

L –111: The power required for pumping the base oil is given by:

$\frac{\Delta p Q p}{\eta p} x 100$ (from standard literature)

where Δ_p = pressure differential across the pump, N/m^2

Q_p = flowrate , m^2/s

η_p = pump efficiency, percent

from standard,

$\eta_p = 80\% = 0.80$

Q_p = 0.0192 m3/s

$\underline{\Delta_p}$ = 1.5 bar = 1.5 x 10^5 N/m2

$$\text{Power} = \frac{1.5 \times 10^5 \text{ N/m2} \times 0.01929 \text{ m}^3\text{/s} \times 100}{80}$$

= 3616.8 Nm/s (watt)

= 3617 watt

L-121 : The standard equation gives us,

$\underline{\Delta_p}$ = 1.5 bar = 1.5 x 10^5 N/m2

$$\text{Power} = \frac{1.5 \times 10^5 \text{ N/m2} \times 0.01929 \text{ m}^3\text{/s} \times 100}{80}$$

= 3616.8 Nm/s (watt)

= 3617 watt

L-121 : The standard equation gives us,

Power = $\underline{\Delta_p}$ $\underline{Q_p}$ / ηp x 100

where $\underline{\Delta_p}$ = 1.5 x 105 N/m2

Q_p = 0.01929 m^3/s

ηp = 82

$$\text{power} = \frac{1.5\times 10^5 \text{ N/m2} \times 0.01929 \text{ m}^3 \times 100}{82}$$

= 3529 watt

CHAPTER FOUR

4.0 DETAILED DESIGN OF THE EQUIPMENT

4.1 CALCULATION PROCEDURE

1. Step 1: Determination of final solution density and viscosity;

The required equations are; ρ_e, mix $= \sum_{1=1}^{n} xi\rho ei$

$$Tc, mix = \sum_{1=1}^{n} xiTci$$

$$Z_{RA}, mix = \sum_{1=1}^{n} xiZ_{RAi}$$

Density

	Base oil	Additive
x_i	0.88	0.12
p_c,atm	27.35	81.03
T_c, ^{0}k	540.1	512.7
Z_{RA}	0.2651	0.3524

P_c,mix = (0.55x27.35) + (0.12x81.03) = <u>33.7916atn</u>

T_c,mix = (0.55x540.1) + (0.12x512.7) = <u>536.812 K</u>

_Z_{RA} = (0.85x0.2651)+ (0.12x0.3524) = <u>0.2756</u>

$$T_r, mix = \frac{T}{Tc, mix} = \frac{298.15}{536.812} = 0.5554$$

R = 82.05606 (atn.cm^3)/(mol.K)

$$\text{Density of mixture } \rho^{Bp} = \frac{Pc, mix}{RTc, mixZ_{RA,mix}^{[1+(1-Tr,mix)^{2/7}}}$$

$$\rho^{Bp} = \frac{33.7916}{82.05606 \text{x} 536.812 \text{x} 0.2756^{[1+(1-0.5554)2/7]}}$$

$$\therefore \rho^{Bp} = 0.0077$$

Using molecular weights of base oil = 78.123 and additives = 44.0962

: - Average molecular weight = (0.88x78.123)+(0.12x44.0962)

= <u>74.0398</u>

Thus, ρ^{Bp} = 0.0077x74.0398 = <u>0.5729g/cm^3</u> = <u>572.9kg/m^3</u>

<u>Viscosity of the mixture</u>

$$\ln \mu_{mix} = \Sigma_{wj\ln\mu j}$$

$$= (0.58 \text{x} \ln 250)+(0.12 \text{x} \ln 15,000)$$

$$= 5.6348+1.11539$$

$$\ln \mu_{mix} = 6.7887$$

$$\mu_{mix} = e^{6.7887} = \underline{887.75 \text{cp}}$$

4.1.1 Step 2: **DETERMINATION OF THE REQUIRED AGITATION INTENSITY**

Density difference of the two liquids = 0.775-0.485 = 0.29

$$\text{Viscosity ratio} = \frac{15,000}{250} = 53.57$$

:- On the basis of the process capabilities associated with bulk velocity of 0.2 ad 0.6ftls. From literature, a bulk velocity of 0.30 ftls should be adequate for this process.

4.1.2 COMPUTATION OF THE REQUIRED IMPELLER PUMPING INTENSITY

3 Step 3:

Since "a square batch" is usually assumed for the design basis of bulk velocity, an equivalent tank diameter T_{eq} is computed.

$$\therefore \frac{\Pi}{4}Teq^3 = V \Rightarrow Teq = \left(\frac{4v}{\Pi}\right)^{1/3}$$

$$T_{eq} = \left[8500gal\frac{231in^3}{gal}x\frac{4}{\Pi}\right]^{1/3} = 135.72\text{in} = 3.447\text{m}$$

Therefore, a 135.72in diameter tank has a cross sectional area of:

$$\text{C.S.A} = \frac{\Pi Teq^2}{4} = \frac{\Pi}{4}x135.72in^2 = 14{,}467.18\text{in}^2 = 9.33\text{m}^2$$

$$\text{but} \quad \begin{array}{c|c} \underline{14.467.18\text{in}^2} & \underline{1\text{ft}^2} \\ 1 & 144\text{In}^2 \end{array} = \underline{100.47\text{ft}^2} = 9.33\text{m}^2$$

:- The impeller pumping capacity = bulk velocity x cross-sectional area

$$= 0.3\text{ftls} \times 100.47\text{ft}^2$$

$$Q = \begin{array}{c|c} 30.14\ \underline{\text{ft}^3} & \underline{60\text{S}} \\ \text{S} & 1\text{min} \end{array}$$

$$= 1808.46\text{ft}^3/\text{min}$$

$$\begin{array}{c|c|c} \underline{1808.46\text{ft}^3} & \underline{1\text{min}} & \underline{0.02832\text{m}^3} \\ \text{min} & 60\text{s} & 1\text{ft}^3 \end{array} = 0.8535\text{m}^3/\text{s}$$

4.1.3 SELECTION OF IMPELLER DIAMETER AND DETERMINATION OF REQUIRED AGITATION SPEED

Using the correlation for pumping number as a function of impeller Reynolds number we could determine the impeller diameter.

Also, the impeller diameter is usually a fraction of the tank diameter:

$$\Rightarrow \left(\frac{D}{Teq}\right) = 0.25 \quad \text{but} \quad D = \text{impeller diameter}$$

D = 0.25x135.72in = 33.93in/0.86in will be used

but the blade width (w) is calculated from the correlation

$$\frac{W}{D} = \frac{1}{5} \Longrightarrow W = \frac{D}{5} = \frac{33.93}{5}in = 6.79\text{in} = 0.172\text{m}$$

Pumping number $= \text{NQ} = \left(\frac{Q}{ND^3}\right)$

Reynolds number $= 10.7\left(\frac{D^2 N\rho}{\mu}\right)$

Using the final batch date (assumed N = 100 r/min)

$$= \Rightarrow \text{Re} = \frac{10.7\text{x}(33.93)^2\,\text{x}100\text{x}0.5729}{887.75} = \underline{794.95}$$

From the correlation for pumping number, literature value, at a

Re $= 794.95$ and $\frac{D}{T} = 0.25$, the pumping no

$$\text{NQ} = 0.71 = \frac{Q}{ND^3} \quad \Rightarrow \text{N} = \frac{Q}{NQD^3}$$

:- The speed for the required pumping capacity

Q $= 1808.46\text{ft}^3/\text{min}$ and impeller diameter $D = \frac{33.93\text{in}}{1}\left|\frac{\text{ft}}{12\text{in}}\right.$

$= 2.825\text{ft} = 0.86\text{m}$

$$= \Rightarrow \text{N} = \frac{1808.46 ft^3/\text{min}}{0.71x(2.828)^3} = 112.619\text{r/min} = 1.877\text{r/s}$$

Since N calculated does not match N assumed, Hence, an iterative solution is sought for the pumping speed.

Iterative	Reynolds no	Pumping no	Speed, r/min
2	895	0.72	111.06
3	883	0.72	111

This speed of 111r/min is necessary to provide the pumping capacity of $1808.46\text{ft}^3/\text{min}$ when using a 33.93in diameter impeller.

4.1.4 SELECTION OF STANDARD SPEED AND MOTOR HORSE POWER

Step 5:

Viscosity correction factor = 1.35 (N_P) = 1.35x1.37 = 1.55 for the design conditions.

$$\Rightarrow \text{impeller power} = P = \frac{1.85\rho_{mix} \text{ X } N^3 x D^5}{1.524x10^{13}} \text{ hp}$$

$$P = \frac{1.85x0.5729x(111)^3 x (33.93)^5}{1.524x10^{13}} = 3.19KW = 4.277hp$$

Therefore, with an 85 percent loading for the motor, a minimum motor

horse power would be = 4.277hp = 5.032 hp⇒ 3.75KW

So a 5.2hp (3.951kw) motor would be required.

4.1.5 SPECIFICATION OF THE NUMBER AND LOCATION OF IMPELLER

The design procedure is such that 5.2hp at 111r/min will provide the desired agitation if the number and location of impellers are suitable for the batch height, as related by the ratio of the liquid level to tank diameter Z/T.

From the literature, 10ft-diameter tank holds 48.9 gal/in of liquid level.

:- 8500gal will fill the tank to $8500 \text{ gal} \left| \frac{in}{48.9gal} \right. = Z = 173.83in$

173.83in ⇒ (14.5ft) = 4.42m

The resulting liquid -level -to-tank-diameter ratio is

$$\frac{Z}{T} = \frac{173.83in}{120in} = 1.45$$

From literature:

Since the liquid viscosity is 57.75cp, (< 25,000cp) and the liquid level gives a $\frac{Z}{T}$ of 1.45, two impellers should be used to provide liquid motion throughout the tank.

To properly load the 5.2hp motor with a dual impeller system, each impeller should be sized for $\frac{5.2hp}{2} =$ 2.60hp

:- at 85 percent loading = 0.85x2.6 = 2.21hp

Thus the initial estimate for power number = Np = 1.37 (1.35) = 1.85 and the impeller diameter D

D = [1.524x1013xpµNp pN3]$^{1/5}$

$$\left[\frac{1.524x10^{13}x2.21}{1.85x0.5729x(111)^3}\right]^{1/5} = 29.73\text{in} = 0.755\text{m}$$

∴ R_e = 10.7x(29.73)2x111x0.5729

557.75 = 677.58

:- for R_e of 677.55 the viscosity correction factor is 1

:- N_p = 1.37x1 = 1.37

$$D = \left[\frac{1.524x10^{13}x2.21}{1.37x0.5729x(111)^3}\right]^{1/5} = 31.57\text{in} = 0.80\text{m}$$

:- Two 31.57-in - diameter impeller (with 6.31- in- blade width)

are equivalent to 33.93 - in- diameter impeller.

Thus, the lower impeller should be located T/3 = 120 = 40in

3 = 1.016m

bottom and the upper impeller (2/3)Z = 2/3x173.73in = 115.09in

= 116in off = 2.95m

4.16 TIME REQUIRED FOR UNIFORM BLENDING

Step 7:

Since a batch volume of 8500gal is being blended horse power requirement of the tank = 5.2hp

Rotational speed = 111r/min

Two pitch blade impeller of diameter = 31.57in = 0.80m

3.048m/10ft diameter tank being used.

$$\Rightarrow R_e = \frac{10.7x\,(31.57)^2\;x\;0.5729x111}{887.75} = 763.91$$

:- A dimensional blend time $t_bN\ (D/T)^{2.3}$ is to be found

:- At Re = 763.91, form literature, $t_bN\ (D/T)^{2.3} = 28$

$$\Rightarrow \frac{D}{T} = \frac{31.57in}{120in} = 0.263$$

$$t_b = \frac{28}{N(D/T)^{2.3}} = \frac{28}{111(0.263)^{2.3}} = 5.440\text{min}$$

$\Rightarrow t_b$ =326.416 secs.

t_b = 330secs. (5.50mins)

4.2 EQUIPMENT COSTING

Costing is an essential part of design. It gives a knowledge in terms of investment capital, of what a particular production process entails.

A cost index given by

$Ce = Cs^n$

is used to determine the cost of the equipment.

Where Ce = purchased equipment cost, ¢

S = characteristic size parameter, in the unit given in table 6.2 of (R&C vol. 6 third edition page 225)

C = cost constant from table 6.2

n = index for the type of equipment

The mixer employs basically the same principle as an agitator.

Cost of impeller stirrer

Ce = ?

C = ¢1000

n = 0.5

S = 3.752kw

Ce = ∉1000x$3.752^{0.5}$

= ∉1937

Cost of mixing tank

C = 1250

n = 0.60

S = $32.173m^3$

Ce = 1250x$32.173^{0.6}$

= ∉10032.40

Hence, the total cost for the equipment

= 1937+10032.40

= ∉11969.40

Using a conversion rate of =N=160 to ∉1

∉11969.40 = 11969.40x160

= =N= 1,915104.402

4.3 SAFETY

The security of the unit as well as personnel working around, it is a vital factor to be considered along side with the plant design. For smooth operation of the mixer and the entire plant in general. The special precaution considered necessary, includes thus;

4.3.1 (1) PERSONNEL SAFETY

For the safety of the workers, the following items should be made available for their uses.

i safety book

ii safety heat resistant gloves

iii safety head helmet

iv ear and nose protector

v overalls and boiler suits

4.2.3 (2) FIRE AND SAFETY DEPARTMENT

The function of this department would be:

i To fight and quench all fire outbreak in the plant

ii To ensure that the personnel are well protected and follow all safety guide lines and rules.

iii Organise safety training for all the staff

iv Provision of all necessary safety signboard, posters, carton signs etc.

v Checking for leakages along all pipe network periodically.

4.3.3 (3) INBUILT SAFETY GADGETS

In-built safety gadgets are safety precautions installed in all equipment and around all buildings at strategic points in the plant especially, areas demarcated as high risk areas.

In addition, escape routes, fire extinguishers, hoses etc., should be made available, overflow alarms and efficient process control mechanism should be installed on the equipment.

The plant environment should be protected by sanitation as this will provide clean, healthy and safe working condition. Some areas of sanitation include clearing of spilled oil, clearing of unwanted materials and so on.

4.4 SIZING AND SPECIFICATION

The volume of mixed solution inside the blender equals $32.2m^3$

The base of the reactor is hemi-shperical

The following relationship apply to the specification of the reactor

i Liquid height to tank diameter

ii Tank diameter to impeller diameter

iii Agitation intensity at 60^0c ⇒ 0.09144m

iv Impeller pumping velocity ⇒ 1.55rev/s

v Cross-sectional area of the mixer ⇒ 9.33m2

vi Tank diameter = 3.045m

vii Height of the reactor = 90ft + clearance factor (0.260ft)=12ft=

3.6576m

viii Two 31.52in diameter (0.8m) impeller with 6.3in-blade width

(0.16m) are equivalent to 33.93-in-diameter (0.86m) impeller.

ix A 5.2hp (3.95kw) motor is required for the process. Other specification are given in

detailed design calculation.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

An agitated mixing tank for the production of 6944.4/g/hr of lubricant has been successfully designed, the major work performed covered material and energy balance, sizing, chemical and mechanical engineering design and costing of the equipment.

The total investment cost from calculation is =N= 1,915104.402.

5.2 RECOMMENDATION

In view of the high viscosity of the oil, an appropriate control measure must be taken by employing air agitation. This is because air agitation creates a kind of forced conversion and while the stirrer creates a vortex.

Therefore, a uniformly blended oil is achieved at the end of the process.

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