DESIGN OF AN AGITATED BATCH-LEACHING VESSEL FOR THE PRODUCTION OF INSECTICIDAL EXTRACT FROM SWEET BASIL PLANT

BY

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DECLARATION

I Olusanya Tayo Bolaji, of the Department of Chemical Engineering in the School of Engineering and Engineering Technology, Federal University of Technology Minna, declare that this design project is my work and is submitted in partial fulfillment for the award of Bachelor of Engineering from the Federal University of Technology Minna. Every detail as well as information obtained from published and unpublished work have been duely acknowledged.

....

Signature Date

CERTIFICATION

I hereby certify that I have supervised, read and approved this project carried out by Olusanya Tayo Bolaji 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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Project Supervisor Date

Engr Olutoye

....

Head of Department Date

Dr. J.O. Odigure

....

External Examiner Date

DEDICATION

This project is dedicated solely and absolutely to the one who stood by me and ensured my survival throughout my study and also made everything a reality. Some know him as the wonderful counselor, some the Everlasting father, yet another group refer to him as the prince of peace, but I call him the only and final hope in life the I AM.

He brought me from an humble beginning to an undeserved and exalted end, making it possible and also granting me the privilege to be counted among the academic intelligence of my time.

Since you don't share your glory with any man, all glory, honour and appreciation I return to you. Thank you Jesus.

ACKNOWLEDGEMENT

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

My acknowledgement also goes to my parents Mr. and Mrs. Olusanya and every member of my family.

Uncle Segun, I want to say you've been wonderful, never stop the good work and God in his mercy will bountifully reward you.

Engr Olutoye, you've been great another supervisor couldn't have 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, H.O.D, Dr Odigure, Engr Akinbode, Engr Abdulrahim, Engr Akpan, Engr Mrs. Eterigho, Engr Duncan and others I say a big thank you.

To my true friends in need and indeed, I appreciate, Rasheed Akinbami, Enahinor Queen, Adeola Mudashiru, Isamot Omowumi and Akintola Abdulwaheed. Seye Omotayo, Abiodun Oyeyemi, Jinadu Babatunde, and Jolaiya Kunle (a.k.a Kekule) I want to say thank you for been their.

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

Dr. Onimole, you've affected my life with every single sermon you preached. Please do not stop transforming lives through your message. Thank you very much.

Lastly I want to say a big thank you to every F.C.S member and the 97/98 and 98/99 past executives.

ABSTRACT

The design of an agitated batch leaching vessel for the production of 1000kg/batch of insecticide from Ocimum Basilicum plant has been carried out. The area covered included material balances as well as energy balance over the extractor.

A technological flow diagram which shows major items of equipment and material flow was provided. The plan layout also shows the location of different departments. All these were produced and included in the work.

A sectional view of the extractor, drawn to scale, has also been provided.

The sizing of the extractor as well as impellers were carried out. A cost estimation of the equipment show that N2,780,558.55 is needed as an investment capital.

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CHAPTER ONE

1.0 INTRODUCTION

The goal of a plant design is to develop and present a complete plant that can operate on an effective industrial basis. To achieve this goal, the chemical engineer must be able to combine many separate units or pieces of equipment into one smoothly operating plant. If the final plant is to be successful, each piece of equipment must be capable of performing its necessary function. The design of equipment, therefore, is an essential part of a plant design.

The engineer developing a process design must accept the responsibility of preparing the specifications for individual pieces of equipment and should be acquainted with methods for fabricating different types of equipment. The importance of choosing appropriate materials of construction in this fabrication must be recognized. Design data must be developed, giving sizes, operating conditions, number and location of openings, types of flanges and heads, codes, variation allowances, and other information. Many of the machine design details are handed by the fabricators, but the chemical engineer must supply the basic information.

The design of an agitated batch leaching vessel that can be employed for the production of extract from Ocimum basicicum plant (sweet basil) is the basic concept of this work. The equipment is design to produce 1000kg of extract per batch. An appropriate solvent-ether is used for the leaching process. The solvent and grounded form of the plant are charged into the vessel and extract removed via drain valve. The extract is sent to a distillation column where it can be concentrated and the solvent produced thus, is reused.

Availability of the equipment tools, operationability of the process, the cost of equipment, efficiency, durability, capacity, maintenability low energy consumption and safety of equipment necessitated its choice.

1.1 Problem Statement

An agitated batch leaching vessel is to be design to produce 1000kg of extract per batch of 6hours. The extract has a viscosity of 1.97×10^{-1} Pas, density of 870kg /m^3 and leaves the extractor at a temperature of 52^0C and the solvent (ether) enters at 25^0C.

1.2 Aims and Objectives

The objectives of the design work are to:

1. prepare a material balance over the entire plant
2. prepare an energy balance over the extractor
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. carryout a detailed chemical engineering design of the agitation equipment (extractor)
7. produce a sectional diagram of the designed equipment
8. Estimate the investment cost of equipment as well as pipe.
9. Undertake safety consideration of the process
10. Prepare a control diagram of the equipment.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 HISTORICAL BACKGROUND

Sweet basil is probably a native of India and Africa. It has been used in the former country for centuries as a condiment, and has long been popular in England.

The family name of sweet basil is Lamiaceae. It is a very useful crop in Nigeria particularly in southern Nigeria. It vernacular names are Efirin-ata, Efirin-wewe, Efirin-aaja, Efirin-mamugba; Sanya, Efiri (owo); Efiri ata and Manigbosanya.

Sweet basil is planted for its invaluable medicinal component and as food. It is a annual 1-3ft high crop found in the tropical and mediterranean climate. The plant type is herbaceous and it is in the class of flowering plants.

It is propagated mainly by seeds, commonly cultivated and reproduced freely. The whole plant is used for extraction of the active ingredeient.

2.2 IMPORTANCE AND USES OF SWEET BASIL

Apart from serving as an effective insecticides, Sweet basil can also come in handy as a repellant. Repellants are materials that affect insects and other organisms and disrupt their natural behaviour. For blood sucking insects {mosquitoes} the desired result is to interrupt host seeking and especially to interrupt biting of humans and animals to prevent the spread of the disease.

Sweet basil contains essentials minerals required by humans for healthy growth hence it is used as a food supplement in many homes. An infusion of the leaves is used by natives as cooling drinks.

2.3 PROCESS DESIGN PHILOSOPHY

The general term plant design includes all engineering aspects involved in the development of either a new, modified, or expanded industrial plant. The economic evaluation and general economic analysis of process is called process engineering, while process design refers to the actual design of the equipment and facilities necessary for carrying out the process.

The design itself requires the use of engineering principles and theories combined with a practical realization of the limits imposed by industrial conditions.

A plant design-project moves to completion through a series of stages such as

(i) Inception
(ii) Preliminary evaluation of economics and market
(iii) Development of data necessary for final design
(iv) Final economic evaluation
(v) Detailed engineering design
(vi) Procurement
(vii) Erection
(viii) Start up and trials
(ix) Production

Equipment design project involves a wide variety of skills. Among these are research, market analysis cost estimation and plant location surveys.

The general approach in any plant design involves a carefully balanced combination of theory, practice, originality, and common sense.

2.4 **Agitated Vessels**

Channeling of the solvent in percolation or filter-press leaching of fixed beds with its consequent slow and incomplete leaching, can be avoided by stirring the liquid and solid in leaching vessels. For coarse solids, many types of special stirred or agitated vessels have be devised. In such cases, closed cylindrical vessels are arranged vertically and are fitted with power-driven paddles or stirrers on vertical shafts, as well as false bottoms for drainage of the leach solution at the end of the operation. In others, the vessels are horizontal with stirrer arranged on a horizontal shaft. In some cases a horizontal drum is the extraction vessel, and the solid and liquid are tumbled about inside by rotation of the drum on rollers. These devices are operated in batch wise fashion and provide a single stage leaching. They can be used singly but frequently are also used in batteries arranged for countercurrent leaching. They have been used extensively in the older European and South American installations for leaching vegetable oils from seeds.

Batch (pot) extractors and rotating extractors are used in batch extraction. They serve both for the actual extraction process and for distillation of the solvent from the extraction residue.

In processing by the enrichment method, the feed material rest on a perforated tray fitted into the vessel.

2.4.1 Effects of Agitation

Agitation has two important effects:

1) The suspension and dispersion of solid particles in the solvent and
2) The promotion of efficient mass transfer between the solid and liquid phases.

2.5 Uses of the Impeller Stirrer

The impeller stirrer is used in conjunction with small clearances from the bottom with a ratio D/d = 1.5 either with or without baffles.

It can also operate with strongly fluctuating fill levels (e.g during vessel discharging) because it mixes even small amounts of liquid very well.

2.6 PROCESS DESIGN OPTIONS

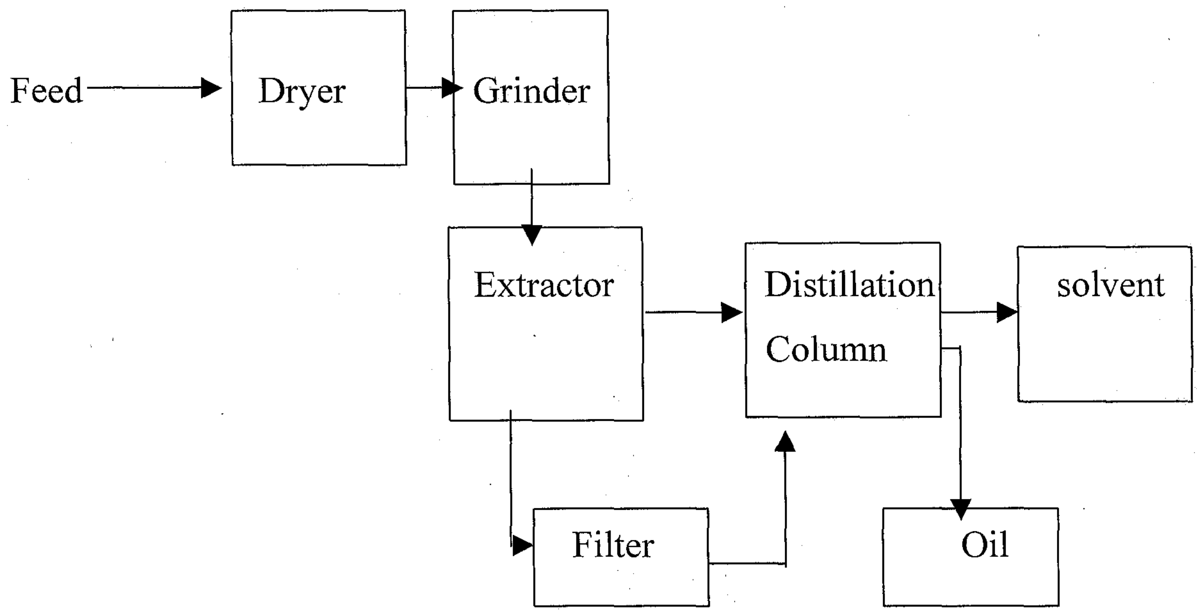
The chemical engineer has many tools to choose from in the development of a profitable plant design. The most useful tool in terms of optimization of the design is the use of high speed computers. Many problems which usually arise in the process development and design can easily be handled with a higher degree of completeness with computer. Other design and safety factors can be reduced with substantial savings in capital investment.

In original design work, the engineer must deal with many differences types of experimental and empirical data. Some data can be obtained from literature such as physical and chemical properties. Many approximations also must be made in carrying out theoretical design calculations.

In the approach to design, it is necessary to make many assumption. Another important factor is cost. Consideration must be given to cost and probable projects throughout the work. This obviously leads to consideration of customer needs and demands and they are determined through market survey.

2.7 CHOICE OF PROCESS ROUTE AND SELECTION OF BATCH EXTRACTOR

The process route employed for the production of the insecticide is given below



FLOW PROCESS DIAGRAM

The choice of the process is predicated on the following

- Controllability and convertibility of the process flow
- Feasibility of the techniques of the process line
- Quality of the unit in terms of cost, efficiency, durability, capacity and energy consumption

2.8 JUSTIFICATION OF NEED

Although there are numerous active insecticides available in the market, however most of these are imported synthetic insecticide with appreciable level of toxicity to human health. Apart from the dangers these insecticides may pose to human life, the huge amount of foreign exchange is also lost from importation of the commodity.

The production of an effective botanical insecticide from plant that is sourced locally would not only reduce the epidemic resulting from mosquito scourge, but also reduce unemployment rate and save the government the annual colossal loss from insecticide importation.The environment is also protected.

CHAPTER THREE

3.0 PROCESS DESIGN

3.1 PROCESS DESCRIPTION

The process involved in the production of Ocimum Basilicum (Sweet basil) extract is given or depicted in the flow sheet attached in the appendix.

The first stage of processing involves washing of the plant with water in a washer. This serves to remove any contaminant or impurities associated with the plant. The material is then dried to remove about 80% of moisture before grinding.

After grinding, the product is fed into the extractor together with the appropriate solvent- diethyl-ether. Extraction time is six hours per batch, and liquid solution obtained is passed through a filter to remove suspended solid particles.

The distillation unit serves to enrich the solute and also to produce solvent which can be reused for subsequent extraction. The solvent leaves the distillation column at about 52^0C (in the vapour state) and the enrich extract leaving goes to a storage tank. The amount of extract is 1000kg product.

3.2 DETAILED MATERIAL BALANCE CALCULATION OVER THE PLANT

3.2.1 BASIC ASSUMPTIONS

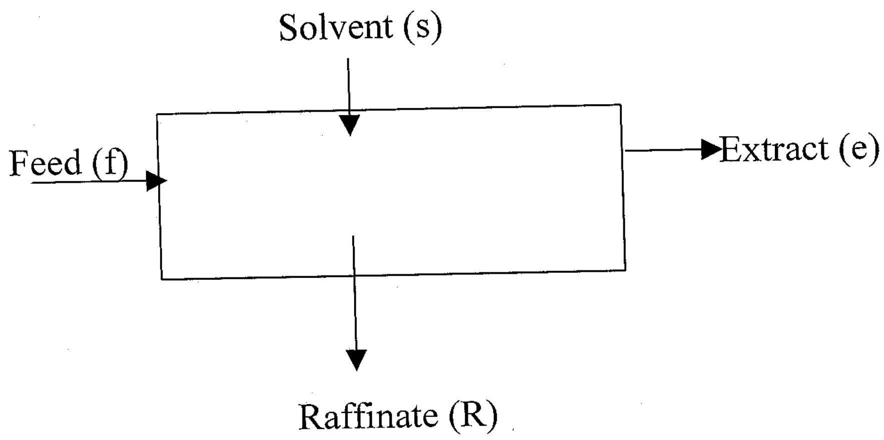
1. There is no reaction between solvent and solute
2. 98% of product (extract) is solute and remain percentage is solvent
3. Distillate contains 95% solvent
4. There is no spillage of material.

BASIS : 1000kg of product extract

According to the law of conservation of mass;

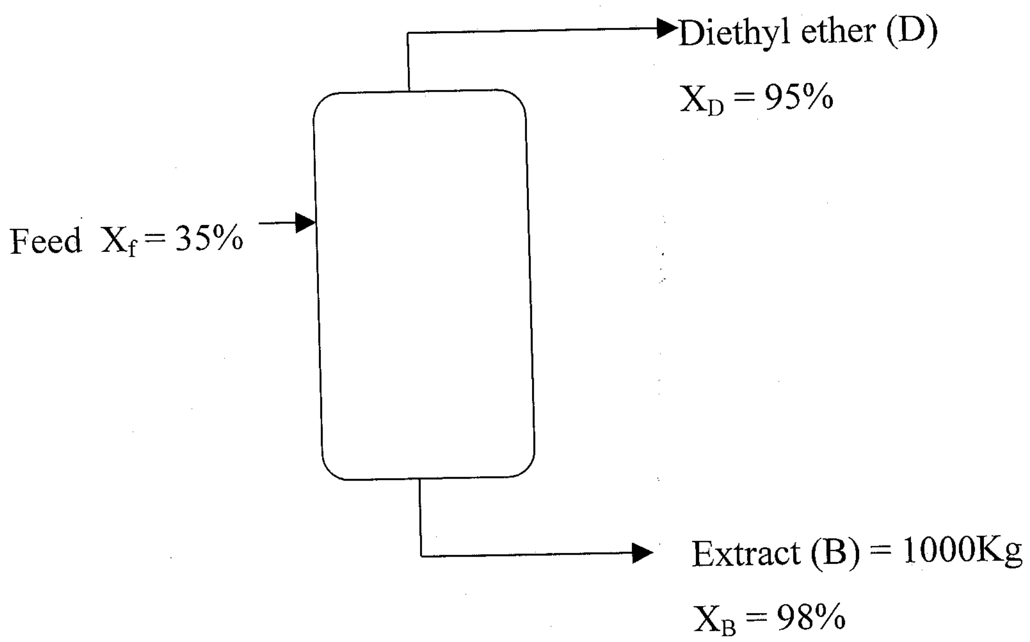
Material in = Material out + accumulation

For the entire process



i.e F+S = R+E

<u>Balance Over Distillation column</u>



An overall balance gives

F=D+B

Inserting values we have

F=D+1000 (1)

A component balance gives (for product)

$FX_f = DX_D + BX_B$

Putting the values;

0.35F = 0.05D + 0.98 x 1000

0.35f = 0.05D + 980 (2)

put (1) in (2)

0.35 (D+1000) = 0.05D+980

0.35D + 350 = 0.5D + 980

= (0.35-0.05)D = 980 – 3550

0.3D = 630

$D = \frac{630}{0.3}$

= 2100kg

Substituting the value of D in (1) we have

F = 2100 + 1000

= 31000kg

Hence: D = 2100kg and F=3100kg

Mass of extract in Feed

= FX_F = 3100 x 35/100

= 1085kg

Mass of solvent = 3100-1085 = 2015kg.

Mass of extract in Bottom product

= BX_B

= 1000 x 0.98

= 980kg

M: mass of solvent = 1000 –980

= 20kg

Mass of extract in Distillate

= 2100x0.05

= 105kg

Mass of solvent

=2100-105

=1995kg

Total mass of extract feed

=1085kg

& Mass of extract product

=980 + 105

= 1085kg

Mass of extract in = mass of extract out

Like wise,

Total mass of solvent in

= 2015kg

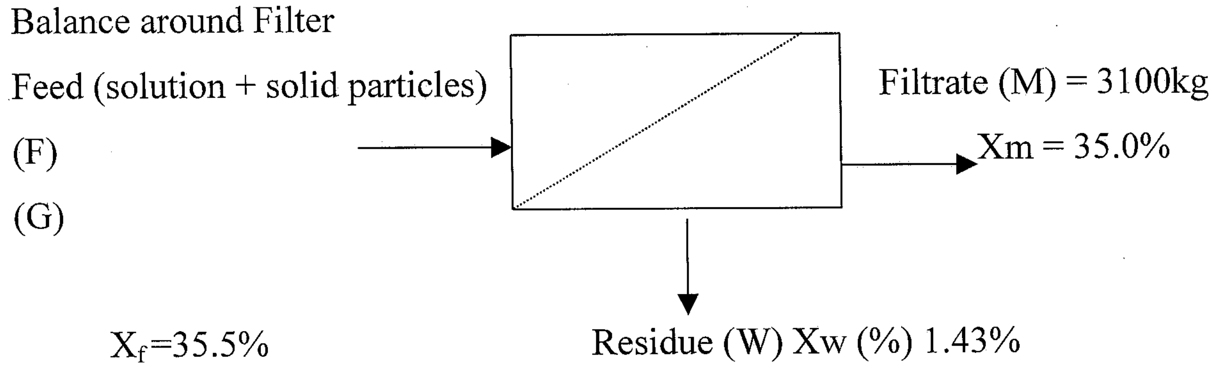
Total mass of solvent out

=1995 + 20

= 2015kg

Then mass of solvent in = Mass of solvent out

Balance around Filter



An overall balance gives

F = M + W

Based on the assumption that 1.43% of solute was lost,

Mass of solute in filtrate = 1085kg

Mass of solute present in feed

= 1.0143 x 1085

= 1100.5kg

Hence mass of liquid product

= 2015 + 1100.5

= 3115.5kg

There fore percentage of extract loss

$$= \frac{1100.5 - 1085}{3115.5} \times 1000$$

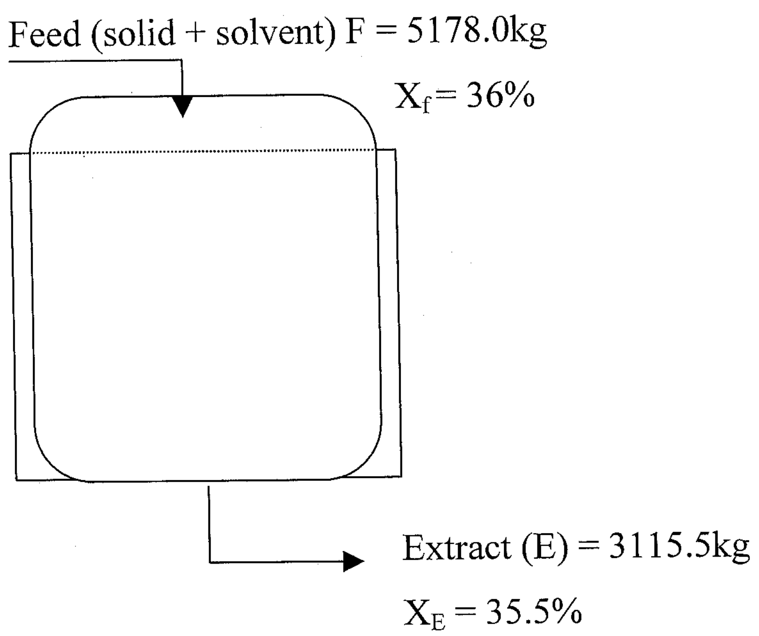
$$= \frac{15.5 \times 100}{3115.5} = 0.498$$

$$= 0.5\ \%$$

This conform with the difference from the figure

35.5 –35 = 0.5%

Balance around Extractor



Mass of solute in feed = 1100.5kg

Hence mass of insoluble + solute

$$= \frac{1100.5}{0.36} = 3057 \text{ kg}$$

mass of insoluble $= \frac{64 \times 3057}{100}$

= 1956.5 kg

Mass of solvent present in extract

= 31155-1100.5

= 2015kg

Let 95% of solvent feed be recovered in the extract then; mass of solvent feed

$$= \frac{2015}{0.95} = 2121\text{kg}$$

Amount of soheent lost to raffinate

= 2121.00 – 2015

= 106kg

Mass of solvent in feed = 2121kg

Mass of feed = 3057kg

Mass of extract = 3115.5kg

Mass of solvent in extract = 1956.5kg

Mass of solvent in raffinate = 106kg

Hence total mass of material in

= 3057 + 2121

= 5178kg

Total mass out

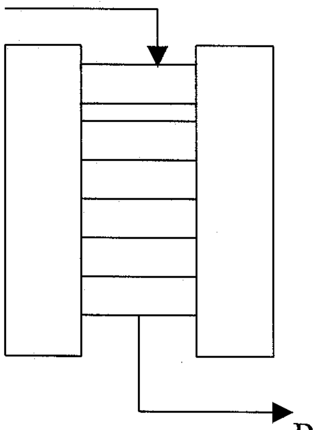
= 3115.5 + 1956.5 + 106

= 5178 kg

mass in = mass out

Balance around grinder

Feed (F)



Product P. = 3057kg

Let 3% of material be lost in grinder, then 97% is recovered

: Mass of feed f = (3057 x 100)/97 = 3152kg

3.3 DETAILED ENEGRY BALANCE

Balance around extractor

We make use of the parameters

M= Mass of material

C_p = Specific heat capacity

ΔT = Temperature change

Calculating heat gain

Feed (sweet Basil)

M_F = 3152kg

C_{pt} = 2.83kJ/kg'k

ΔT = (0-25)

For solvent (Diethyl ether)

$M_s = 2121kg$

$C_{pf} = 0.118kJ/kg$ "k

$\Delta T = (Q - 25)$

Total Heat gain

$3152 \times 2.83 (\theta - 25)$

calculating heat loss

steam at 100^0C

$Q = ml$

l =specific latent heat of vaporization = $2.26x10^6 J/kg$ for steam

$= 2.26x10^3 KJ/kg$

Heat lost by condensed steam when its temperature goes from

100^0C to $\theta^0C = MC\theta$

$= 100 x4 2 x (100-\theta)$

$= 420 (100-\theta)$

Total Heat loss

$= 100 \times 2.26x10^3 + 420 (100-\theta)$

Assuming heat loss to the environment is negligible then

Heat loss = Heat gain

$= 2.26 \times 10^5 + 420 (100-\theta) = 3152x2.83x (\theta -25) + 2121 \times 0\ 118x (\theta -25)$

$2.26x105 + 42000-420\theta = 8920.16\theta\ 223004+250.280 - 6.256.95$

$2.26x10^5 + 42000 + 6256.95 + 223004 = (8920.16+20+20+250.28) \theta$

$497260.95 = 9590.44\theta$

$= \theta \cong 52^0C$

3.4 SUMMARY OF MATERIAL AND ENERGY BALANCE

SUMMARY OF MATERIAL BALANCE

Feed Stream	In stream (kg)	Out stream (kg)	Composition %
Sweet Basil (solid)	3152	1000	98
Solvent	2121	1000	95
Steam	100	-	-

ENERGY BALANCE

Feed stream	Initial (^{0}C) Temperature	Final (^{0}C) Temperature	Specific Heat capacity kJ/kg ^{o}k
Sweet Basil	25	52	2.83
- Solvent	25	52	0.1118
Steam	100	52	4.2

CHAPTER FOUR

4.0 DETAILED DESIGN OF EXTRACTOR

4.1 EQUIPMENT SIZING/SPECIFICATIONS

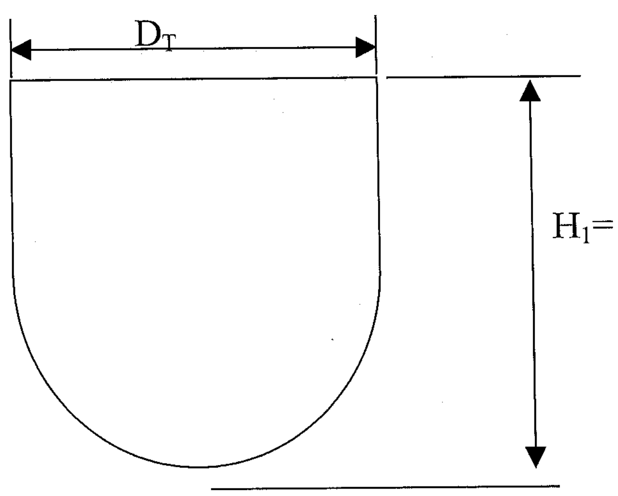
Equipment specification is an integral part of a complete plant design. It shows the general engineering principle, principal size of major items of equipment, based on operating conditions, power rating, material of construction and services requirement.

The equipment used in chemical process industries can be distinguished as propriety and non – propriety. The formal are equipment as pumps, compressors and steam ejectors and vacuum pumps. While the later are design as special units e.g extractors.

Equipment size involve the determination of the geometric charac teristics of the equipment. The job of a chemical engineer is to select and specify the equipment needed for particular duties. The sizing carried out in this section are thus based on this premise.

Determination of the geometrical parameters

Extractors (agitator} with spherical head.



Note that Height of Cylindrical part = Diameter of Extractor

Volume of extractor

Batch extractors generally comprises of 2 to $10m^3$ capacity

{ULLMANN'S ENC OF IND. CHEM VOL B3,Unit operation B3, Unit operation B1}.

The volume of the extractor is given by

Volume of cylindrical part + volume of hemispherical part

i.e $V_T = V_C + V_S$

Where V_E= Total volume or volume of extractor.

$$V_C = \pi r^2 h \quad \text{or} \quad \frac{\pi D^2 h}{4}$$

but D = h

$$:- V_c = \frac{\pi D^3}{4}$$

$$\text{Also } V_s = \frac{4 \pi r^3}{3} = \frac{4 \pi D^3}{3 \times 8} = \frac{\pi D^3}{6} = \frac{\pi D^3}{12} \text{ for hemisphere}$$

$$\text{Taking a volume of } 5m^3 \quad .: 5 = \frac{\pi D^3}{4} + \frac{\pi D^3}{12}$$

$$5 = D^3 + [\pi/4 + \pi/12]$$

$$\frac{D^3[3\pi + \pi]}{12}$$

$$12x5 = D^3(4\pi)$$

$$D^3 = 60/4\pi = 4.775$$

D = 1.68m

Hence the diameter of the vessel = 1.68m.

Cross - Sectional Area of Extractor

Area of Vessel (extractor) A_E = Area of Cylindrical part +Area of hemispherical bottom

i.e $A_E = A_C + A$

Alternatively

Volume of extractor = Area of extractor x Length of extractor

$\therefore$ Area of extractor = $\frac{\text{Volume of extractor}}{\text{Length of extractor}}$

$A_E = \frac{V_E}{L_E}$

V_E $5m^3$

L_E = Height of Cylindrical part + Height of hemisphere

= D + D/2

= 3D/2

$L_E = \frac{3x1.68}{2}$

= 2.52

$A_E = \frac{5}{2.52}$

$=1.98m^2$

Agitation Intensity

One measure of the amount of motion in an agitated tank is velocity. Due to difficulty in measuring the actual velocity and the fact that it depends on location in the tank, an artificial, define velocity called Bulk velocity is used as a more practical measure of agitation intensity.

Bulk velocity is defined as the impeller pumping capacity (rheumatic flow rate) divided by the cross – section area of the tank.

For this process a bulk velocity of 0.12m/s will be adequate

(Hand book of chemical engineering calculation, Table 12-1, page 12-6)

Impeller Pumping Capacity

Using a bulk velocity of 0.12m/s

Area of tank = $1.98m^2$

Impeller pumping Capacity = Bulk velocity x Cross section area

= 0.12 x 1.98

= $0.24m^3/s$

Agitator speed

The impeller diameter is some fraction of the tank diameter typically between 0.06 and 0.18 (Hand book of chemical engineering calculation page 12-7)

Using a impeller diameter (d) to tank diameter (D) ratio of 0.4

i.e $d/D = 0.4$

.: $d/1.68 = 0.4$

.: $d = 1.68 \times 0.4$

$= 0.672m$

For a pitched blade impeller with four blade

Width/impeller $= 1/5$

.: $W/d = 1/5$

or $W = d/5$

$= 0.672/5$

$= 0.1344m$

Impeller Reynolds's Number N_{RE}

$$N_{RE} = \frac{d^2 \; N_p \; P}{\mu}$$

Where d = impeller diameter (m) P= Density of fluid kg/m^3

N = Rotational speed r/s

μ = viscosity Kg/ms

Calculation involves an iterative process in which an initial estimate of rotational speed must be made.

Using an initial value of $N = 1.80$ r/s and fluid properties for the final batch ie, density = $870kg/m^3$ and viscosity = 1.97×10^{-1} Pas the initial estimate of Reynolds No becomes

$$N_{RE} = 0.672^2 \times 1.8 \times 870 = \frac{1994.3 \times 1.8}{1.97 \times 10^{-1}}$$

$= 3589.7$

From the graph of pumping number N_Q Versus N_{RE} at d/D = 0.4, (Hand book of Chemical Engineering calculation by Nicholas Choppy page 12-7), We obtain

$N_Q = 0.65 = Q/Nd^3$

ie $0.65 = Q/Nd^3$

Where Q pumping Capacity = $0.24m^3/s$

$$0.65 = \frac{0.24}{N \times 0.672^3}$$

$$\therefore \quad N = \frac{0.24}{0.65 \times 0.672^3} = 0.7909 \times 0.65^{-1}$$

$= 1.22$ r/s

The estimate and calculated speeds do not match ie, N estimate = 1.80 r/s and N calculated = 1.22 r/s, and the pumping number N_Q is not constant for this N_{Re} range, hence we iterate

With N = 1.22r/s

N_{RE} 1.994.3 x1.2

= 2433.046

From which we obtain

$N_Q = 0.46$

$N = 0.7909 \times 0.64^{-1}$

$= 1.236$ r/s

This gives $N_{RE} = 1994.3 \times 1.236$

$= 2464.42$

From which we obtain

$N_Q = \cong 0.64$

$\therefore \quad N = 0.7909 \times 0.64^{-1}$

$= 1.236$ r/s

or $\cong 1.24$ r/s

Power Required to Rotate the Agitator Impeller

For a pitched – blade impeller that is 0.672m diameter and has four 0.1344m- wide blade mounted at a 45^0 angle.

Power number for impeller geometry

This is given by the formula

$N_P. = P/\rho N^3 d^5$ (Hand book of chemical engineering calculation, page 12-2)

Where P= impeller power

D= impeller diameter

N= agitator of rational speed

ρ = density of fluid

N_P= power number (dimensionless)

The pitched blade impeller has the ratio

W/D = 0.2

Which gives Np = 1.37 (From standard value)

{Hand book of chemical Engineering Calculation, pg 12-1 fig 12-1}

Power number at process is given by the above formula

Hence ; $p = Np \times P \times N^3 \times d^5$

$P = 1.37 \times 870 \times 1.24^3 \times 0.672^5$

= 0.311kW

With an 85% loading for the motor, a minimum motor power would be 0.31142/0.85 = 0.366kW.

The power number provides important design information about the correct motor size necessary to operate an impeller at a given speed.

Hence 0.36kW agitator operating at 134r/s will provide the sufficient desired agitation to solve the problem by creating a bulk velocity of 0.12m/s.

Number and Location of Impellers

0.366kW agitator operation at 1.24r/s will provided the desired agitation if the number and location of impeller is suitable for the batch height as related by the ratio of liquid level Z to tank diameter D

i.e. Z/D

where Z = liquid level or height in the extractor

D = Extractor diameter.

(From TABLE 12-2, Capacity Data for Cylindrical vessel, page 12-9, Handbook of Chemical Engineering Calculation by Nicholas Choppey) We have that

1.68m-diameter tank with spherical head will put $0.255m^3$ in the 0.226m head.

Therefore the remaining volume i.e.

$$5-0.265 = 4.735m^3$$

This volume ($4.735m^3$) will full the vertical wall portion of the tank at a rate of $2.205m^3$ /m for a total liquid depth of

$$(4.735m^3/2.205m^3/m) + 0.226m$$

$$= 2.37m$$

Thus, the depth of liquid in the extractor vessel = 2.37m

∴ Liquid level to tank diameter ratio

$$Z/D = 2.37m/1.68m$$

$$= 1.72$$

IMPELLER LOCATION

From table (Handbook of Chemical Engineering Calculation page 12-9)

For viscosity < 25Pa.s and maximum liquid level to tank diameter ratio

$Z / T = 2.1$, two impellers are required.

Lower Impeller Location

$$= D / 3$$

$$= 1.68 / 3 = 0.56m$$

Upper Impeller Location

$$= 2Z / 3$$

$$= 2 / 3 \times 2.37 = 1.58m$$

BAFFLE LENGHT AND HEIGHT

The baffle height extend the full height of the vertical wall (i.e., the straight side) of the tank.

Since the vertical wall is taken as equal to the diameter

⇒ Baffle length = 1.68m

Four equally spaced plate type baffle (at 90^0) are required.

The width of the baffles is given by the ratio

$W_b / D = 1/10$

$\Rightarrow \quad W_b = D/10 = 1.68/10$

$= 0.168m$

where W_b = baffle width.

HEAT TRANSFER CALCULATION

Inside heat transfer coefficient

Correlation for the agitated heat transfer Nusselt number ($N_{Nu} = h_i$ T/K) of a jacketed tank is expressed as

$$N_{Nu} = 0.85 N_{Re}^{0.66} N_{pr}^{0.33} (Z/D)^{-0.56} (d/D)^{0.13} (\mu_b/\mu_w)^{0.14}$$

(Page 12-13 Handbook of Chemical Engineering Calculation)

Where N_{Nu} = Nusselt number

N_{Re} = Reynold's number

N_{pr} = Prandtl number

Z = Liquid height in tank

D = Tank diameter

d = Impeller diameter

μ_b = Viscosity at bulk fluid temperature

μ_w = Viscosity at surface temperature

$$N_{Re} = d^2 N\rho/\mu$$

$$= \frac{0.672^2 \times 1.24 \times 870}{1.97 \times 10^{-1}}$$

$$= 2472.94$$

$$N_{Pr} = Cp_{mix}\mu / K_{mix}$$

Where Cp_{mix} = specific heat capacity of mixture

K_{mix} = Thermal conductivity of mixture

Let Cps = Heat capacity of solvent = $2.2KJ/kg^0K$

Cp_f = Heat capacity of feed = 2.468 kJ/kg^{0}K

Ws = mass of feed = 3057kg

W_f = mass of solvent = 2121kg

$$\therefore Cp_{mix} = \frac{Cps\,Ws + Cp_f W_f}{Ws + W_f}$$

$$= \frac{2.2 \times 2121 + 3057 \times 2.468}{3057 + 2121}$$

$$= 12120.876 / 5178 = 2.36 kJ/ kg^0k$$

$$\text{Also, } Kmix = \frac{Ws\,Ks + W_f K_f}{Ws + W_f}$$

$$Ks = 1.49 \times 10^{-4}\ KW/m^0C$$

$$K_f = 2.8 \times 10^{-4}\ KW/m\ ^0C$$

$$\therefore K_{mix} = \frac{2121 \times 1.49 \times 10^{-4} + 3057 \times 2.8 \times 10^{-4}}{2121 + 3057}$$

$$= 11719.89 / 5178$$

$$= 2.26 \times 10^{-4}\ KW/m^0C$$

$$\therefore Npr = \frac{2.36 \times 1.97 \times 10^{-1}}{2.26 \times 10^{-4}}$$

$$= 2057.2$$

μ_b/μ_w is taken to be = 1. This is as a result of lack of data and the very small exponent on the term.

$$N_{Nu} = 0.85 \times 2472.94^{0.66} \times 2057.2^{0.33} \times (1.72)^{-0.56} \times (0.672/1.68)^{0.13} \times 1$$

$$= 0.85 \times 173.588 \times 12.4 \times 0.738 \times 0.888$$

$$= 1199.03$$

Hence, inside heat-transfer coefficient (h_i)

$$h_i = N_{Nu}K_{mix} / D = \frac{1199.03 \times 2.26 \times 10^{-4}}{}$$

1.68

$= 161.3 W/m^{2\,0}C$

Overall Heat transfer coefficient

This is calculated from the formula

$HD / K_{mix} = aN_{Nu}$

Where h = Overall heat transfer coefficient

a = 0.36 For a jacketed vessel with paddle agitator .

$\therefore\ h = 0.36 \times 217.75$

$= 58 W/m^2K$

Time Required to Heat the Tank Content

The available heat transfer area A is the jacketed wall in contact with the liquid,

i.e. Area of cylindrical part + Area of Spherical head

= $1.98m^2$ from previous calculation

Using the formular

$In\ \{(T_1-t_1)/(T_1-t_2)\} = (hA/MC)\theta$

(Page 7-28, Handbook of Chemical Engineering calculation).

Where T_1 = heating-medium temperature (steam) = 373^0K

t_1 = Initial batch temperature = 298^0K

t_2 = Final batch temperature = 325^0K

h = Overall heat transfer coefficient = $58W/m^2K$

A = heat transfer area = $1.98m^2$

C = specific heat of batch = 2.36KJ/KgK

θ = time

M = mass of batch

$$\therefore \quad In\{(373 - 298)/(373 - 325)\} = \{(58 \times 1.98)/(5178 \times 2.36 \times 10^3)\}\theta$$

$$In\ 1.5625 = 9.368 \times 10^{-6}\theta$$

$$\therefore \quad \theta = 0.443/9.368 \times 10^{-6}$$

$$= 47600s$$

$$\theta = 13.22hr$$

Flow Rate of Solvent Vapour

This is obtained as follows

$$q = UoA(Ti\text{-}To) = UoA\Delta T$$

where $q = ml$

m = mass flow rate (Kg/s)

l = specific latent heat of vaporization of ether

$= 2.671 \times 10^4$ kJ/Kg

ΔT = temperature change

$= 52 - 25 = 27^0$ C

$A = 1.98m^2$

$$m \times 2.671 \times 10^4 = 58 \times 1.98 \times 27$$

$$\therefore \quad m = \frac{58 \times 1.98 \times 27}{2.671 \times 10^4}$$

$$m = 0.12 Kg/s$$

Power in the Condenser

We have that,

$$q = m(Hi - Ho)$$

Ho = enthalpy at outlet temperature

Hi = enthalpy at inlet temperature

$$H = Cp\Delta t$$

$$\Rightarrow \quad Ho = 2.2 \times (52 - 25)$$

$$= 2.2 \times 27$$

$$= 59.4 KJ/kgK$$

$$q = 0.12 \times 59.4$$

$$= 7.13 KW$$

Flow rate of heating medium(st eam)

This is given by,

$$Ms\, \lambda s = UA\Delta T$$

Ms = flow rate of steam

U = heat transfer coefficient = $58 W/m^2K$

A = heat transfer area = $1.98m^2$

ΔT = (100 - 52) = 48^0C

λs = enthalpy of vaporization of steam = 2412.031KJ/Kg

2412.03 x Ms = 58 x 1.98 x 48

$$Ms = \frac{58 \times 1.98 \times 48}{2412.03 \times 10^3}$$

$$= 2.29 \times 10^{-3} Kg/s$$

Pressure inside the Extractor

P = ρhg + atmospheric pressure

Where ρ = $870 Kg/m^3$

h = batch height = 2.37m

g = $9.81m/s^2$

atmospheric pressure = $1.0132 \times 10^5 N/m^2$

$= 870 \times 2.37 \times 9.81 + 1.0132 \times 10^5$

$= 12.1547 \times 10^4 N/m^2$

Pipe Size And Selection

Economic pipe diameter for carbon steel pipe is obtained from the formula

$D = 293 \times G^{0.53} \times \rho^{-0.37}$

(page 192, Chemical Engineering Design, volume 6, Richardson and Coulson)

Where G = mass flow rate of stream in Kg/s

ρ = density Kg/m^3

d = diameter in mm

Assuming a liquid mixture flow rate of 11Kg/s

$$d = 293 \times 11^{0.53} \times 870^{-0.37}$$

$$= 293 \times 3.56 \times 0.082mm$$

$$= 85.53mm$$

Friction loss from Genereaux's formula

$$\Delta p = 4.07x10^{10} x G^{184} x M^{0.16} x p^{-1} x d^{-4.84}$$

where

Δp = pressure drop

G= flow rate kg/s

P = density kg/m^3

μ = viscosity Pa.s

d = pipe id, mm

$$\Delta p = 4.07x10^{10} \times 11^{1.84} \times (1.97x10^{-1})^{0.16} \times 870^{-1} \times 85.53^{-4.84}$$

$$= 1.42kPa/m.$$

Hence pressure drop in the pipe with optimum diameter of 85.53mm is 1.42kPa/m.

$$\text{Cross-sectional area of pipe} = \frac{\Pi d^2}{4}$$

$$= \Pi \times (85.53)^2/4$$

$$= 0.0057m^2$$

fluid velocity = volumetric flow rate

cross sectional area

but volumetric flowrate = mass flow rate/Density of liquid mixture

i.e G/ρ

$= 11/870 = 0.0126 m^3/s$

fluid velocity = 0.0126/0.0057

= 2.22m/s

4.2 EQUIPMENT COSTING

Most cost data which are available for immediate use in a preliminary or predesign estimate are based on conditions at some time in the past. Because prices may change considerably with time due to changes in economic conditions, some method must be used for updating cost data applicable at a past date to cost that are representative of conditions at a later time.

This can be done by the use of cost indexes given by

$C_e = C\ S^n$ (page 159, plant design and economics for chemical engineers)

C_e = purchased equipment cost £

S = characteristic size parameter in SI unit

C = cost constant from Table (Table 6.2, Chemical Engineering Design volume 6 page 225)

n = index for that type of equipment

The base date is mid-1992, and prices are thought to be accurate within ± 25 percent.

Cost of Extractor

Volume used = $5m^3$

$C = £\ 8{,}000$

$S = 5m^3$

$n = 0.4$

$Ce = 8000x5^{0.4}$

$= £\ 15{,}229.23$

Cost of Agitator

Power required = 0.366kW

$Ce = 0.366^{0.5}\ x1000$

$= 0.605x\ 1000$

$= £\ 605$

Cost of Pipe

This is given by the formula

$27d^{0.55}\ £\ /m$

$= 27x85.53^{0.66}$

$= £\ 508.82/m$

hence for 2m pipe

$508.82x2 = £\ 1017.64$

SUMMARY OF COST

Materials	Quantity	Unit cost E/m	Cost E
Jacketed vessel	1		15229.23
Agitator	1		605
Pipe	15-350mm	508.82	
Pipe Mixture	2m		1017.64
TOTAL COST			16851.87

Using a conversion rate of

1£ to N165

= £ 16851.87x105

= N2,780558.55

4.4 SAFETY CONSIDERATIONS

The preparation and undertaking of safety measures is part and percel of any engineering design. With an added important for chemical process plants which have special hazard attached to the chemical need and process condition.

The security of the plant or unit as well as personnel working in the plant is a vital factor to be considered along side with the plant design.

4.4.1 PRINCIPAL SAFETY PROBLEM

1. Toxic chemical

The major components of the insecticide produced are ether and extract from Sweet basil. The extract contains a wide variety of chemicals ranging from ketones, aldehydes, thymol, terpenes to alcohols and esters as well as phenols.

The association of these compounds is of every little toxicity to man (if there is any). Although the compounds or their association is human friendly, it should be handled with care due to the volatility of the constituent. Deliberate exposure should also be avoided.

2. Flammability

The principal flammable component of the insectide is ether. Though highly volatile, ether is moderately flammable and cannot be said to pose a potential fire risk. Chemically ethers are quite inert, especially as compared to alcohols. They may however be split by appropriate reaction with acid. In general ethers behave somewhat like hydrocarbons and their physical, chemical, and perhaps, even physiological properties may be favourably compared to hydrocarbons in which a-CH_2-group is replaced by an oxygen atom. Ethers slowly undergo peroxidation on prolonged contact with air, in a molecule in which there is also a double bond, a primary, or a secondary alcohol group, oxidation takes place with greater difficulty. This explanation is based on the premise that the determination of the flammability of any chemical or compound is based on the evaluation of its physico-chemical properties.

3. Corrosion

Neither the whole insecticide nor its chemical constituent is corrosive. Nevertheless appropriate storage vessel and flow pipes should be chosen or selected.

4.4.2. SAFETY PRECAUTIONS

1. Personnel safety

Every attempt should be made to incorporate facilities for health and safety protection of plant personnel in the original design. This includes, but is not limited to, protected walkways, plat forms, stairs and ergonomics. Physical hazards, if avoidable should be clearly defined. In such areas means for egress must be unmistakable. All machinery must be guarded with protective devices. In all cases, medical services and first aid must be readily available for all workers.

For safety of the workers, the following items should be provided for their use

i) Safety boots

ii) Safety heat resistant gloves

iii) Ear and nose protectors

iv) Safety head helmets.

v) Overalls and boiler suits.

a) Fire prevention Department

The function of this department include

i) Fight and put out all fire out break in the plant

ii) Ensure that the personnels are well protected and follow all safety guide lines

iii) Organize safety training for all the staffs

iv) Provision of all necessary safety sign boards, poster e.t.c

v) Periodic checking for leakages along all pipe net works.

3) Inbuilt safety Gadgets

Inbuilt 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 extinguisher, 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 provides clean, healthy and safe working conditions. Some area of sanitation includes, elimination of rodents, microorganisms, cleaning of the plant surroundings, provision of facilities such as "rest room" "changing rooms".

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

An agitated batch-leaching vessel for the production of 1000kg of insecticide has been successfully designed the major work done covered material and energy balances, sizing, chemical and mechanical engineering design and costing of the equipment and pipe.

The total investment cost from calculation is N2,780,558.55,.

5.2 RECOMMENDATION

In view of the volatility of ether, appropriate control measure should be taken to avoid carrying out the operation at high temperature. This also applies to the extract which is a composition of volatile oils.

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