Model potash plant design

Business

PRODUCTION OF POTASSIUM CARBONATE FROM COCOA HUSK ASH A Process Engineering Project Report Presented to the Department of Chemical Engineering Faculty of Chemical and Materials Engineering College of Engineering Kwame Nkrumah University of Science and Technology, Kumasi By AMANING OSEI EMMANUEL ATTIPOE EDEM KODZO BOAKYE KWAME JUWAH CHUKWUJINDU AWELE OMENOGOR ANWULI ROSEMARY in Partial Fulfillment of the Requirements for the course Process Engineering Project April 2013. TABLE OF CONTENTS

CHAPTER ONE – INTRODUCTION This project deals with the design of unit processes involved in the production of potassium carbonate from organic sources. The specific organic source that has been chosen for use in our process is cocoa husk ash. This is due to the quantity and quality of its potassium carbonate and the ready availability of cocoa in our environment. We are looking to design a continuously running system for this production process, the project follows the cocoa ash from input to a leaching unit through a clarifier to an evaporator, to a crystallizer and finally to a calciner which delivers the fine white crystals.

MAIN OBJECTIVE The main objective of this project is to design a bench scale plant for the processing of 1. 44 tons of cocoa pod ash per day.

SPECIFIC OBJECTIVES The specific objectives of this project are as follows: * To collate literature on the project, * To select and describe a process for obtaining potassium carbonate, * To carry out material and energy balances of the process, * To specify all equipment, CHAPTER TWO -LITERATURE REVIEW PRODUCTION OF POTASSIUM CARBONATE Potassium carbonate can be produced using mined potassium chloride or wood ash as raw material

PRODUCTION FROM POTASSIUM CHLORIDE Potassium carbonate is produced commercially from potassium hydroxide’s reaction with carbon dioxide. The hydroxide is obtained from the electrolysis of potassium chloride and the chloride is mined as rock salt. 2KOH + CO2> K2CO3 + H2O PRODUCTION FROM WOOD ASH (COCOA POD ASH) Potassium carbonate has been produced locally from wood ash for centuries and the ashes of cocoa pods have been discovered to have an interestingly large amount of this potassium carbonate. The cocoa pods are first dried under the sun after which they are burnt and the ash collected.

The ash is then put in water and the leached solution decanted and heated to dryness to obtain the potassium carbonate crystals.

STORAGE AND HANDLING Potassium Carbonate is stored in a cool, dry, dark and well ventilated location in tightly sealed containers or cylinders DANGERS Potassium carbonate may be irritating to the skin, eyes, gastrointestinal and respiratory tracts. It may cause permanent eye damage and is harmful if swallowed. It may also be corrosive to metals. CAUTIONS Potassium carbonate causes severe irritations to the skin and eye upon contact.

Inhaling the substance causes irritation of the mucous membranes, coughing and dyspnea.

Ingestion may also cause irritation and burns from the mouth to the stomach. Ingesting massive amounts may cause ulcerations, vomiting and death from shock USES OF POTASSIUM CARBONATE The demand for potassium carbonate is diverse and this makes the chemical one of very great importance. INDUSTRIAL USES According to Anamika Swami (2012), one of the most important uses of potash includes its application in the production of fertilizers. In addition to phosphorous and nitrogen, plants require potash for its healthy growth.

More than 95% of the potash produced is used for fertilizing plants.

Potassium carbonate is also used as a major component in the manufacture of soaps. These soaps produced are milder than the soaps containing sodium carbonate. Another significant industrial use of potash is its use in the manufacture of specialty glass, from optical lens to television screens and cathode ray tubes. Apart from these major uses, potash is also used for a large variety of purposes which include: * Manufacturing of printing inks and pigments * Dying and bleaching of textiles * Ceramic glazing * Welding flux for metals in the industry Pharmaceuticals With such a huge number of uses for potash, it is widely manufactured and marketed all over the world. Today potash is widely available in different forms in many of the online stores at affordable price rates (Swami, 2012).

USES IN FOOD PROCESSING Potassium carbonate is used as an ingredient in the production of various foods like grass jelly (consumed in Chinese and Southeast Asia) and German pastry(Baker J. T. 2005). It is sometimes used as a buffering agent in the production of mead or wines. CHEMISTRY OF POTASSIUM CARBONATE PHYSICALPROPERTIES Potassium carbonate is a white odourless, crystalline material.

It does not have a measured boiling point or range because it decomposes quickly after melting when heated.

The compound has a melting point of 891°C. It has a density of 2. 290 g/cm and a molecular weight of 138. 2 g/mol (Scholar chemistry, 2009) CHEMICAL PROPERTIES Potassium carbonate is an inorganic compound of chemical formula K2CO3. It is soluble in water and has a solubility of 112 g per 100g of water at 200C. It is hygroscopic in nature and insoluble in ethanol.

It is strongly alkaline and should be keptaway from alkaline metal in powder form. CHAPTER THREE – PROCESS SELECTION AND DESCRIPTION INTRODUCTION

Potassium carbonate is typically obtained from cocoa pod husk by the pyrolysis of the already dried husks followed by the leaching of the ash produced with water. The soluble potassium carbonate dissolves while the insoluble silica and calcium carbonates do not. The potassium carbonate can then be obtained by either heating to dryness or crystallization. In our process, the dried cocoa pods are to be burned at 6000C to obtain an optimum yield of leachable potassium carbonate (M. Y.

K. Woode) LEACHER Here, the cocoa pod ash and water are introduced at the top of the vessel and then mixed thoroughly by the rotating blades.

The average residence time for the content of this vessel is 20 minutes. The water used in leaching is at room temperature so as to avoid the tea effect, a situation where unwanted and otherwise insoluble components of the ash are dissolved. The slurry of potassium carbonate solution and sludge containing the insoluble silica and calcium carbonates leave the bottom of the leacher at room temperature.

CLARIFIER The slurry from the leaching vessel enters the clarifier and is separated into the denser sludge at the bottom and the less dense clear solution at the top.

The sludge leaves through the opening at the bottom of the clarifier where there are rake arms continually rotating, slow enough to prevent blockage but not so fast as to cause a disturbance in the clear solution-sludge profile. The sludge is washed in an adjoining filter with water and the filtrate added to the water to be used for leaching. The cake can be disposed of in landfills.

The clear solution leaves the clarifier through an opening at the top of the vessel.

EVAPORATOR The clear solution from the clarifier enters the rising film calandria type evaporator at the bottom and is concentrated from 27. 8 to 50 weight percent.

This type of evaporator is chosen because firstly, the potassium carbonate salt is not heat sensitive and secondly, because the natural convection which occurs in the tubes due to density differences causes upward fluid movement and thus reduces pump work needed. Steam at 4 bar is used as the source of heating for this operation. CRYSTALLIZER The concentrated solution enters the crystallizer through the feed end of the shell and tube heat exchanger. The heated solution from the exchanger enters the crystallizer proper at the vaporizing chamber where vapor flashes out forcing potassium carbonate crystals out of solution.

There is a clear liquor recycle from the top of the settling chamber while a mixture of crystals and mother liquor is continually withdrawn from the bottom of the crystallizer. The mother liquor is separated from the crystals and then recycled to the feed end of the heat exchanger. An evaporative Oslo-Krystal crystallizer is used for this operation due to the low solubility differences of potassium carbonate over relatively large temperature differences, thus making a cooling crystallizer uneconomical. * CALCINER Potassium carbonate crystallizes at 1240C as sequester hydrate K2CO3. .

5H2O and so to obtain the anhydrous salt, the crystals have to be calcined at a temperature of 750oC. This changes the crystals from the damp wets solids to fine white crystals. Figure 3. 1Plant Design for the Daily Production of 935kg of Potassium Carbonate CHAPTER FOUR – MATERIALAND ENERGY BALANCES MATERIAL BALANCE The bench scale plant has the capacity to process 1. 44 tons of cocoa pod ash per day which comes down to 60kg of the ash every hour LEACHER CLARIFIER EVAPORATOR HEAT EXCHANGER CRYSTALLIZER CALCINER ENERGY BALANCES EVAPORATOR * * * HEAT EXCHANGER

CRYSTALLIZER CALCINER CHAPTER FIVE – EQUIPMENT SPECIFICATION AND PIPING PIPELINE SPECIFICATIONS Sizing of pipes for fluid flow in a given plant does not only depend on the fluid’s physical properties, but also to some extent, on the sound economic factors.

In most engineering practices under this heading, the criterion used is the optimum diameter which is the diameter of the pipe that gives the least total cost for annual pumping charges. The design parameters considered are: * The nominal size * Schedule number * Material of construction * Wall thickness

The optimum diameter is first of all estimated based on the fluid density, capacity and viscosity depending on the nature of the fluid Sample calculation Pipeline 1 Location: from leacher to clarifier. Assuming turbulent flow, Dopt= 3. 9q0. 36? 0. 13 Where Dopt = optimum pipe diameter, in q= volumetric flow rate of fluid = 1803600 x 1178m3/s x35.

31= 0. 001499 ft3/s ? = fluid density = 1178 kg/m3 = 73. 55 lb/ft3 Dopt= 3. 90. 0014650.

3673. 550. 13= 0. 6562 in= 16. 66mm From steel pipe size table, (Geankopolis, 1993) Inside diameter = 0.

742 in = 18. 85 mm Outside diameter = 1. 050 in = 26. 67 mm

Nominal pipe size = ? in Inside cross-sectional area = 2. 79 x10-4 m2 Schedule number = 80 S Wall thickness = 3. 912 mm Pipeline 2 Location: from clarifier to filter Dopt= 3.

9q0. 36? 0. 13 Where q = fluid volumetric flow rate = 403600 x 1205 m3/s x 35. 31= 0. 000326 ft3/s ? = density of sludge = 1205 kg/m3 = 75. 24lb/ft3 Dopt= 3.

90. 0003260. 3675. 240. 13= 0.

3798 in= 9. 65 mm From steel pipe size table, Inside diameter = 0. 423 in = 10. 74 mm Outside diameter = 0. 675 in = 17. 15 mm Nominal pipe size = 3/8 in Inside cross-sectional area = 9.

1 x 10-5 m2 Schedule number = 80 S Wall thickness = 3. mm (Geankoplis, 1993) Table 5. 1Summary of Pipeline Specifications Pipeline Location| Fluid transported| Mass flow rate, kg/h| Nominal pipe size, in| Schedule number| Material of construction| Leacher to Clarifier| Leached Slurry solution| 180| ? | 80| Stainless steel| Clarifier to Filter| Sludge| 40| 3/8 | 80| Stainless steel| Clarifier to Evaporator| Potassium Carbonate Solution| 140| ? | 40| Stainless steel| Evaporator to Heat Exchanger | Conc. Potassium Carbonate Solution| 77. 84| 3/8| 40| Stainless steel| Heat Exchanger toCrystallizer | Conc. Potassium Carbonate Solution| 251.

9| ? | 80| Stainless steel| Crystallizer to Heat Exchanger| Conc. Potassium Carbonate recycle| 173. 55| ? | 40| Stainless steel| Crystallizer to Calciner| Hydrated Crystals| 46. 51| ? | 40| Stainless steel| CHAPTER SIX – DESIGN OF A LEACHING VESSEL PROBLEM STATEMENT A leaching vessel is required to extract the potassium carbonate from the cocoa pod ash. The water to be used is at room temperature and is fed in at twice the feed rate of the cocoa pod ash.

INTRODUCTION Leaching is also known as solid extraction; it is used to obtain soluble matter from its mixture with an insoluble solid.

In leaching, the amount of soluble material removed is often greater than in ordinary filtration washing and the properties of the solids may change during the operation. When the solids to be leached are permeable or able to disintegrate during the process, the solids are dispersed into the solvent and are later separated from it. Dispersed-solid leaching: solids that form impermeable beds, either before or during leaching, are treated by dispersing them in the solvent by mechanical agitation in a tank or flow mixer. The leached residue is then separated from the strong solution by settling or filtration.

Small quantities can be leached batch wise in this way in an agitated vessel with a bottom draw off for settled residue. Continuous counter current leaching is obtained with several gravity thickeners connected in series. DESCRIPTION OF EQUIPMENT The Leaching vessel used operates a co-currently manner with water as the leaching fluid. The ash enters the leacher at 60 kg/h and the water enters at 120 kg/hr. The vessel description is as follows: * Dished bottom – this requires less power than a flat one and eliminates sharp corners or regions into which fluid currents can penetrate. Height of liquid is approximately equal to the tank diameter.

* An impeller is mounted on an overhung shaft * The shaft is driven by a motor, sometimes connected directly to it but more often connected to it through a speed-reducing gearbox. * Baffles are installed in the sides of the vessel to prevent vortexing and rotation of the liquid mass as a whole. A typical agitation process vessel is as shown in Fig. 6. 1.

Fig 6. 1 Typical Agitation Process Vessel JUSTIFICATION This method of extraction is chosen mainly because of high extraction efficiency that can be achieved.

The design will cover the chemical engineering aspect as well as the mechanical engineering aspect. (A) (B) Chemical engineering design * Slurry properties * Vessel details * Baffle details * Impeller details (C) Mechanical engineering design * Material of construction * Design pressure * Weight of vessel * Weight of vessel content * Design load * Dead weight stress * Bending stress * Vessel support * Shaft details * Support details CHEMICAL ENGINEERING DESIGN VISCOSITY AND DENSITY OF THE MIXTURE VISCOSITY OF MIXTURE Using a model proposed by Thomas, (1965) ? m? L= 1+2. 5? +10. 05? 2+AeB? Where, ? = volume fraction of solid particles 0.

25 A = 0. 00273 B = 16. 6 ? L= 3. 7480? 10-3kg/ms By substitution, ? m3. 7480? 10-3= 2. 4263 DENSITY OF SLURRY ? slurry = 1178 kg/m3(Appendix E) DETERMINATION OF LEACHER DIMENSIONS Fig 6.

2 Turbine Dimension Specifications (McCabe and Smith, 2009) Typical proportions are: DaDt= 1 3HDt= 1 JDt= 112 WDa= 15LDa= 14EDt= 13 The number of baffles is usually 4; the number of impeller blades ranges from 4 to 16 but is generally 6 or 8. DIMENSIONS OF THE LEACHING VESSEL A cylindrical vessel with an ellipsoidal bottom would be used because dished bottoms (example ellipsoidal) require less power than the flat ones.

Equating the volume of the mixture to the volume of a cylindrical vessel with an ellipsoidal base gives; V = (? Dt24) (H-a3) (Geankopolis, 1993) As V= 0. 07923 From shape factors; Ht = 1. 5 DtDt= 0. 40 mHt= 0.

6 m (McCabe and Smith, 2009) CHOICE AND DESIGN OF IMPELLER The selected impeller is the pitched blade turbine 450 because of the following reasons * Provide strong axial flow for suspension of solids * Efficient turbulence flow impeller for blending immiscible liquids. * Combined axial and radial flows are achieved. * It can operate at reasonable speed. * Low cost. Da/Dt= 1/3 Da= 0.

1333 m

H/Dt = 1 H = 0. 5000 m J/Dt= 1/12 J = 0. 03330 m E/Dt = 1/3 E = 0. 1333 m W/Da = 1/5 W = 0. 0267 m L/Da = 1/4 L = 0.

3333m Where: Da = Diameter of impeller Dt = Tank diameter H = Depth of liquid in tank E = Height of impeller above vessel floor W = impeller width L = length of impeller blade J = Width of Baffles (McCabe and Smith, 2009) Impeller Thickness (Iw) Iw = Da/8 (McCabe and Smith, 2009) Iw = 0. 0166m Height of Impeller from Liquid Level, hihi =(2 ? Ht)/3 (McCabe and Smith, 2009)hi = 0. 333 m| Number of Baffles (NB) Four baffles at equal spacing are used. Width of Baffle, JJ = Dt/12J = 0. 03330 m| BAFFLES Height of baffle from the vessel’s bottom, hbhb= Da/2hb= 0. 0444mLength of Baffle (LB)LB= h -hbLB= 0.

3556m| Offset of Baffle from wall (Ow) OW = J /16 = 2. 78? 10-3m Offset of baffle from the tangent line at bottom, OB OB = Da2 = 0. 0667m (Sinnott, 2005) POWER AND SPEED OF IMPELLER REQUIRED IMPELLER SHAFT SPEED (Nr) Nr= NRe?? mDa2?? m Da= diameter of impeller NRe= reynold’s number According to Walas (2010) since NRe> 104, the fluid flow in the mixer tank is turbulent.

Although the NRe> 104, Froude’s number is not taken into account because the vessel would be fully baffled. The variation of the Reynolds number with increasing shaft speed is as shown in Table 6.

1 Reynolds Number| Impeller Shaft Speed (Rps)| 10000| 2. 8687| 11000| 3. 1556| 12000| 3. 4425| 13000| 3. 7294| 14000| 4. 0162| 15000| 4.

3031| Table 6. 1Reynolds Number With Corresponding Impeller Shaft Speed. IMPELLER DISCHARGE RATE (Q) Q= NQ? Nr? Da3 NQ = is the discharge co-efficient For a pitched turbine impeller, NQ = 0. 6 Q = 0. 6? 0.

416? (0. 5311)3 = 4. 0769? 10-3m3/s VELOCITY HEAD(HV)HV= Np? Nr2?

Da2NQ? gWhere: Np= is the power numberNpfor a pitched turbine impeller is 1. 3g is gravity due to acceleration= 9. 81m/s2HV= (1. 3? 2.

86872? 0. 13332)/ (0. 6? 9. 81)HV = 0. 0323 m| POWER (P)P = Np? N3D5? 10-3 = 7. 7935? 10-4 kWDissipation in mechanical losses is accounted for by multiplying by 1.

25 = 9. 7419? 10-4 kW = 0. 0013 hpIMPELLER TIP SPEED (IS)Is = ?? Nr? d(Sinnott, 2005)Is = 3. 142? 2. 8687? 0. 1333Is = 1.

2013 m/s| Table 6. 2 Summary of Chemical Engineering Design Parameters Parameters| Value| Unit| Design Volume| 0. 0723| m3| Residence or blending time| 2400| s| Vessel Height| 0. | m| Dished height (Ellipsoid height for bottom and top dish ends)| 0. 1| m| Total height| 0. 7| m| Diameter of Tank| 0.

4| m| Height of Impeller from the bottom of the vessel| 0. 1333| M| Impeller Diameter| 0. 1333| M| Impeller Thickness| 0. 0166| M| Height of Impeller from Liquid Level| 0. 0267| M| Number of Baffles| 4| -| Width of Baffle| 0.

0333| | Height of Baffle from Vessel’s Bottom| 0. 0444| m| Length of Baffle| 0. 3556| | Offset of Baffle from wall| 2. 78? 10-3| m| Rotational Speed| 2. 8687| rps| Impeller Discharge Rate| 4.

0769? 10-3| m3/s| Velocity Head| 0. 0323| m| Power| 0. 013| hp| Impeller Tip Speed| 1. 2013| m/s| MECHANICAL ENGINEERING DESIGN MATERIAL OF CONSTRUCTION The mixer will be made from a standard AISI 304 stainless steel (18Cr/8Ni) material that is austenitic grade. Austenitic grade steels are non-magnetic and provide excellent corrosion and heat resistance with good mechanical properties over a wide range of temperatures, respond very well to forming operations, and are readily welded. It is also considerably cheap.

Property| Value| Unit| Density| 8, 000| Kgm3| Poisson ratio| 0. 27- 0. 30| | Elastic modulus| 193- 200| Gpa| Shear modulus| 86| Gpa|

Tensile strength| 515| Mpa| Yield strength| 205| Mpa| Elongation| 40| %| Reduction| 50| %| Hardness| 201| Brinell| Allowable tensile stress| 68. 9| Mpa| Allowable shear stress| 41. 4| Mpa| Table 6. 3Mechanical Properties of AISI 304 Stainless Steel (18Cr/8Ni) Source, Celalettin, (2002) SHAFT DESIGN SHAFT DIAMETER Continuous torque for shaft ? c= Pmotor2? N (Celalettin, 2002) From calculation, ? c= 0.

1040 Nm Design torque input? in=? c? service factor(Celalettin, 2002) According Celaletin (2002) using a service factor of 1, Implying,? in=? c= 0. 1040 Nm Maximum force on shaft FM=? in2. 2d(Celalettin, 2002)

From calculation FM = 0. 3546 N Length of shaft Ls= HT-E (Celalettin, 2002) From calculation, Ls = 0. 4667 m Maximum bending moment M= Fm? Ls(Celalettin, 2002) From calculation M = 0. 1655 Nm Equivalent blending moment Meq= M2+? C2(Celalettin, 2002) From calculation, Meq = 0.

1955 Nm Minimum shaft diameter for shear stress ds= 316Meq?? s(Celalettin, 2002) From Celaletin (2002) allowable shear stress, ? s= 41. 4? 106Nm2 From calculation, ds = 0. 003m = 3. 0 mm Minimum shaft diameter for tensile stress dt= 316M+Meq?? t(Celalettin, 2002) According to Celaletin (2002) allowable tensile stress, ? t= 68. 9? 06Nm2 From calculation, dt = 0. 0030 m = 3.

0 mm The required shaft diameter dsh= larger shaft diameter = 3. 0 mm PURE TORQUE LOAD For safe operation of the shaft, three stresses are accounted for: bending stress, direct stress due to the mass of the impeller and direct stress due to the mass of the shaft. That is the addition of the direct stress due to mass of impeller, the direct stress due mass of shaft and

the maximum bending stress. Using the relation (combined stresses; yield stress of material for construction); 32Mmax? dsh3+4mimg? dsh2+lsh? g;? y(Celalettin, 2002) Mass of impeller, mim= 4? s? Vim Density of stainless steel 304, ? ss= 8000 kgm3 Volume of impeller, Vim= wLB From calculation Vim = 1. 185? 10-4 m3 From calculation mim = 3.

792 kg Putting all the calculated parameters in to the left side of equation 10. 41 gives 69. 21 MPa According Celaletin (2002) ? y= 205 MPa Implying, 67. 74 MPa; 205 MPa Therefore a shaft diameter of 3 mm can be used. DESIGN PRESSURE Internal pressure, Pi= hydrostatic head +atmospheric pressure (sinnot, 2005) Pi=? gh+atmospheric pressure where,? = density of slurry h= height of tank g= acceleration due to gravity= 9.

81 ms2 Atmospheric pressure= 101, 325 Nm2

From calculation, Pi = 101, 681. 1 N/m2 = 0. 102 N/mm2 Design pressure, Pd= internal pressure + (10% of internal pressure) Design pressure Pd= Pi+0. 1Pi(Sinnot, 2005) Putting Pi= 101, 681. 1 N/mm2 in the above equation yields Pd = 111849.

21 N/m2 = 0. 111 N/mm2 DETERMINATION OF VESSEL THICKNESS Shell Thickness (es) For cylindrical tanks, wall thickness is by; According to Sinnot (2005) S = 165 N/mm2 = 165? 106 N/m2 for AISI 304 stainless steel (18Cr/8Ni) Minimum thickness, C = 2 mm for a vessel diameter less than 1 m. (Sinnot 2005), Welding efficiency for initial work, E = 0. 85 (Sinnot 2005)

S = maximum allowable working stress = 165, 000 kPa ri = internal radius = 0. 2 m P = internal pressure = 1. 01325 kPa From calculation es = 1.

60 ? 10-4 m = 0. 16 mm According to the formula, the wall thickness is as given above, however the wall thickness recommended for the design of the cylindrical section of the mixer vessel is 2 mm. Then outer diameter of shell is given by Do = Di + 2es Using a steel plate of wall thickness 2 mm, the outer diameter is given by Do = 0. 4 +(2 ? 0. 002) Do = 0. 404 m DEADWEIGHTAND CONTENT WEIGHT WEIGHT LOADS The major sources of dead weight loads are: * The vessel shell The vessel ? ttings * Internal ? ttings: plates (plus the ? uid on the plates); heating and cooling c oils.

* External ? ttings: piping. * Auxiliary equipment which is not self-supported * The weight of liquid to ? ll the vessel. The vessel will be ? lled with water for thehydraulic pressure test Note: for vessels on a skirt support, the weight of the liquid to ? llthe vessel will be transferred directly to the skirt. The weight of the vessel and ? ttings can be calculated from the preliminary designsketches. For a steel vessel, the dead weight is estimated using the equation below: Wv= 240?

Cv? Dm (H+0.

8Dm)t(Sinnot, 2005) whereWv = total weight of the shell, excluding internal ? ttings, such as plates, N, Cv = a factor to account for the weight of nozzles, 1. 08 for vessels with only a few internal ? ttings, H = height of the vessel = 0. 60m = 600 mm t = wall thickness = 2. 00167 mm Dm = mean diameter of vessel = (Dt+ (0. 001? t)) = 0. 40200 m = 402.

00 mm Wv = 129. 5954 N = 135 N WEIGHT OF VESSEL CONTENT (WS) The vessel content weight is given by the correlation below: Weight of slurry,

WS= ms? g(Sinnot, 2005) Where ms = mass of slurry From calculation, Ws = 842. 2 N = 0. 8422 KN

Total weight of vessel WT= Wv+Ws ……(Sinnot, 2005) From computation, WT = 977 N = 0. 977 KN According to Ray (1976) making allowance for loads that have not been accounted for; motor, gear box and bearing weight, shaft weight and ladder, the design load (weight) is taken as 5 % above the total weight of the leacher.

This implies that the design load (weight) is equal to; WDS= 100+5100? WT From computation WDS = 1025. 85 N = 1. 0259 KN DESIGN OF SUPPORT In designing support of vessels, the following must be considered: * Size and shape of vessel * Weight of vessel including its contents Vessel location and orientation * Accessibility to the vessel and fittings for inspection and maintenance. The bracket support (isolated support) is employed in this design BRACKET SUPPORT The main load carried by the support (bracket support on three legs) is the weight of vessel (mixer) and its contents. The main sources of load to consider are: * Dead weight of vessel and contents * Wind * External loads imposed by piping and attached equipment For a bracket support, the relation gives the design load (for a single-gusset plate): Fb= 60Lctc(Sinnot, 2005) where Fb = maximum design load per bracket, N

Lc = characteristic dimension of bracket (depth), mm tc = thickness of support plate, mm Since three support legs would be required, the maximum design load on each leg is given by Fb= WDS3(Sinnot, 2005) From calculation, Fb = 341. 95 N The height of legs is given by; HL= 14?

HT(Brownell et al, 1959) Where, HL = height of leg HT = Overall height of mixer From calculation, HL = 0.

15 m The characteristic dimension is also given by the equation Lc= 10. 7? tc(Brownell et al, 1959) Solving for tc gives, tc= 0. 7Lc Putting tc = 0. 7LC into the initial equation and making Lc the subject gives; From calculation, Lc = 2. 5 mm and tc = 2. 00 mm Height of bracket hb= 1.

5? Lc(Sinott, 2005) From calculation, hb = 4. 275 mm Height of legs HL= 20? dl(Sinott, 2005) Solving for dl = diameter of leg gives dl= HL20 From calculation, diameter of leg dl = 0. 0075m = 7. 5 mm STRESS ANALYSIS OF VESSEL The primary stresses are longitudinal and circumferential stresses due to pressure, Longitudinal stress (? L) and circumferential or hoop stress (? h) due to internal pressure is givenby the equation below: ? L= Pi? DT4tv(Sinott, 2005) Pi = internal pressure, Pa From calculation, ? L= 2, 796, 230 N/m2 = 27. 96 N/mm2 ? h= Pi? DT2tv(Sinott, 2005)

From calculation, ? h= 5, 592, 461.

45 N/m2 = 55. 92 N/mm2 The direct stress ? w is due to the weight of the vessel, its contents, and any attachments. The stress will be tensile (positive) for points below the plane of the vessel supports, and compressive (negative) for points above the supports. Direct stress ? w due to weight of vessel, its content and any attachment is given by, ? w= WT? tvDT+tv(Sinott, 2005) DT = internal diameter of vessel, m tv = thickness of vessel, m From calculation, ? w= 202, 065N/m2 = 20. 20 N/mm2 FLANGE DESIGN AND SELECTION Several different types of flange are used for various applications.

The principal types used in the process industries are: * Welding-neck flanges. * Slip-on flanges hub and plate types. * Lap-joint flanges. * Screwed flanges. * Blank, or blind, flanges. Welding-neck flanges, have a long tapered hub between the flange ring and the welded joint.

This gradual transition of the section reduces the discontinuity stresses between the flange and branch, and increases the strength of the flange assembly. Welding-neck flanges are suitable for extreme service conditions; where the flange is likely to be subjected to temperature, shear and vibration loads.

They will normally be specified for the connections and nozzles on process vessels and process equipment. So the selected flange is welding neck flange. GASKET DESIGN AND SELECTION The gasket factor m is the ratio of the gasket stress (pressure) under the operating conditions to the internal pressure in the vessel or pipe.

The gasket factor gives the minimum pressure that must be maintained on the gasket to ensure a satisfactory seal. The following factors must be considered when selecting a gasket material: * The process conditions: pressure, temperature, corrosive nature of the process fluid. Whether repeated assembly and disassembly of the joint is required. * The type of flange and flange face. Selected Gasket: Corrugated metal, asbestos inserted (soft steel) Gasket factor m = 3. 25 Minimum design seating stress y = 37.

9 N/mm2 (Sinnott, 2005) Table 6. 4 Summary of the Mechanical Engineering Design Parameter | Value| Unit | Shaft details| Continuous torque for shaft| 0.

1040 | Nm| Maximum force on shaft| 0. 3546 | N| Length of shaft| 0. 4667| m| Maximum bending moment | 0.

1655 | Nm| Equivalent bending moment | 0. 1955 | Nm| required shaft diameter | 0. 0030 | m| Vessel details|

Design pressure| 111849. 21| N/m2| Vessel thickness| 0. 002m| m| Weight of vessel| 129.

5954| N| Weight of vessel content| 842. 2 | N| Design load (weight)| 1025. 85 | N| Support details| Maximum design load per bracket| 341. 95 | N| Height of legs| 0. 15 | m| bracket depth| 2.

85 | mm| Thickness of support plate| 2. 00 | mm| diameter of leg | 0. 0075| m| Height of bracket | 4. 275 | mm| Longitudinal stress| 27. 96 | N/mm2| Hoop stress| 55. 92 | N/mm2| Direct stress| 20.

20 | N/mm2| Flange details| Thickness of flange| 24| mm| Bolting type| M24| | Flange details| Number of bolts| 20| |

Gasket (Corrugated metal, asbestos inserted (soft steel))| Minimum design seating stress| 37. 9| N/mm2| Minimum gasket width| 10| mm| Safety factor| 3. 25| | CHAPTER SEVEN – DESIGN OF A CLARIFIER PROBLEM STATEMENT The clarifier is required to separate the clear potassium carbonate solution from the insoluble sludge material. The clear solution to be obtained is 27. 8 wt% potash. INTRODUCTION The term clarification is applied to the removal of solids from liquids or reduction of the solid concentration in a liquid.

The particle size may vary widely, from large particles that settle quickly to those in colloidal range (Purchas, 1967).

The clarifier is a vessel in which solid concentration of a solid-liquid suspension is increased at the bottom purely by sedimentation, and decreased at the top with the formation of a clear liquid. Gravitational force is mainly used in this unit process to enhance settling of the solid particles due to its natural occurrence, thereby reducing clarifying costs. (Osborne, 1981) TYPES OF CLARIFIER PARALLEL PLATE CLARIFIER The Parallel Plate Clarifier is designed to remove solids from process liquids. The liquid is fed from a leaching tank into the clarifier through the inlet pipe, which directs flow into the separation section.

Figure 7.

1 Parallel Plate Clarifier The liquid then enters the lower area of the laminar plates through side slots which distributes the slurry across the entire width of the plates. Particles settle onto the face of the plates and slide down to the bottom. The clarified liquid exits the plate section through weirs at the top of the unit which are designed to develop and control adequate pressure drop, thereby maintaining laminar flow. The clarified liquid then flows into the effluent chamber and out of the clarifier. Settled solids collect at the bottom of the pyramid sludge hopper and are removed from the clarifier.

The unique, modular design of the Parallel Plate Vertical Clarifier allows for easy removal of individual plates from the clarifier for inspection (Svarovsky, 2000). CIRCULAR CLARIFIER As written by Osborne (1981) and Foust et al (1980), the circular clarifier is made up of a cylindrical tank with a conical base. They are large diameter, shallow depth tanks with slowly revolving rakes which remove the settled sludge. In the circular clarifier, feed slurry is introduced into a central feed well; it passes through the feed well into the tank where sedimentation begins.

The main separation is kept continuous by accommodating the solids coming in so that it is equal to the rate at which solids settle through every zone, and it is developed by density difference of settling zone of the suspension.

Figure 7. 2 Circular Clarifier In circular basin clarifiers, the feed usually goes through a centrally located feedwell and the overflow is into a trough around the periphery of the basin. The bottom slopes gently to the solids discharge point in the centre and the solids are pushed down the slope by a number of motor driven scraper blades which revolve slowly around a vertical center shaft.

This design is frequently used in the purification of sewage, wine, and other products (Svarovsky, 2000). JUSTIFICATION In the processing of slurries, several methods of mechanical separation may be suitable. All of which can be classified under settling or filtration.

Settling does not always give complete separation; however, it is often the best way to process very large volumes of a dilute suspension as it separates most of the liquid from the solids. Most filters are not suitable because the cake washing and bed washing makes them expensive to run.

A clarifier would suit the process generally because, they are employed with dilute suspensions and their primary purpose is to produce a clear overflow. The choice of the desired equipment is based primarily on its ability to execute and accomplish (to obtain a clear potassium carbonate solution) the separation at a minimum cost. Hence, settling equipment was chosen over filtering equipment. (Purchas, 1967) According to Wills (2006), clarifiers can be classified based on the drive mechanisms used; * bridge support, * centre column supported and * Traction drive.

The bridge-supported clarifiers offer the following advantages over a center column-supported design: * The ability to transfer loads to the tank periphery * A less complicated lifting device. * Access to the drive from both ends of the bridge. PROCESS DESCRIPTION In the operation of the clarifier, feed which is slurry enters the vessel through a feed pipe into a feed well designed to dissipate the velocity and stabilize the density currents of the incoming stream. (Wilson et al, 2005) The feed is directed down into the tank where separation is done. Separation is as a result of heavy particles settling to the bottom of the tank.

The clarified liquid flows into an overflow launder outside the main tank. The underflow solids are withdrawn from the underflow. When the particle settling velocity is less than the upward fluid velocity, particles will be entrained out in the overflow resulting in poor clarification. (Purchas, 1967) EQUIPMENT DESCRIPTION TANK Tanks are constructed of such materials as steel, concrete, wood, compacted earth, plastic sheeting and soil cement. The selection of the materials of construction is based on cost, availability, topography, ground conditions, climate, operating temperature, and chemical corrosion resistance.

The material to be used is steel since it does not react with aqueous potassium carbonate. (Chapman, Hazen and Camp, 1945) OVERFLOW LAUNDER For circular tanks, outlets may be placed at the wall or cantilevered or suspended in-board. The launder placed in-board about 30%

of tank radius leads to better tank performance in large clarifiers. This counters the wall effect caused by density currents moving toward thewall of the clarifier and thereby making overflow liquid impure by increasing solid concentration. The unit will have an out-board launder for effluent clear aqueous liquid. Ekama et al, 1999) FEED WELL Center feed tanks can also be fed with horizontal pipes or vertical pipes that discharge freely at their end. Some of these pipes can also be equipped with a bell-mouth outlet that reduces the release velocity into the tank center. Basically, there are many entrance mechanisms into the feedwell. There is the side feed and vertical pipe feed mechanism of feed flow into the thefeedwell. The main aim of these mechanisms is to reduce velocity of the influent feed and thereby reduce agitation such that will enhance settling. Figure 7. Feed Well Entry Mechanisms (Wilson Et Al, 2005) SLUDGE REMOVAL MECHANISMS Settled sludge is typically collected and removed from the tank floor by mechanical scrapers or hydraulic suction. These mechanisms should collect solids quickly to prevent floating while maintaining a concentrated sludge. The needs of design to select a sludge removal mechanism include relative costs, knowledge of how quickly the mechanism can remove solids from the tank, and what effect the mechanism may have on effluent quality and return sludge concentration. (De Clercq et al, 2000) RAKING ARM DESIGN

The construction must be strong enough so that the required torque to rake the settled solids to discharge point can be applied. The necessary design also depends upon the nature of compressed solids. There are many different types of construction varying from single rigid member blades bolted directly on to many truss-type arm designs in larger tanks. In most conventional clarifiers, the rake arms are connected to the central shaft. They have plates joined to it with which it rakes settled solids towards the center. They rotate at very low speeds of about 0. 167 – 0. 5 rpm. Albertson, 1995) The conventional design (raking inward) is used in most units. Rake-speed requirements depend on the type of solids entering the thickener. (Perry, 1997) There are several basic rake or scraper designs used. The figure below shows four different types of scrapers. The multi-blade plows, using straight scraper blades, have been used most extensively. The designs using curved blades are commonly referred to as spiral plowsand have been used for decades in Europe. Based on encouragement from Albertson and Okey (1992) and others, engineers are now choosing spirals in an increasing percentage of clarifier designs.

Figure 7. 4 Scraper Configurations (Guenthert, 1984) Form C is simple and easy to design and hence, it is mostly used in the making of the clarifier. DRIVE ASSEMBLIES The drive assembly is the key component of a sedimentation unit. The drive assembly provides * The force to move the rakes through the thickened slurry and to move settled solids to the point of discharge, * The support for the mechanism which permits it to rotate, * A reliable control which protects the mechanism from damage when a major overload occurs.

The drive motors should have a steel main spur gears mounted on bearings, alloy-steel pinions and an iron planetary gear system. The drive typically includes a torque-measuring system with torque indicated on the mechanism and often transmitted to a remote indicator. If the torque becomes excessive, it may possess capacity to automatically activate a safeguard against structural damage as raising the rakes, and stopping the drive. (Tekippe, Bender, 1987) INLET PIPE AND PORTS According to Wilson et al (2005), Circular clarifiers can be fed by several different inlet configurations.

Most plants are fed from the center; however, there are two basic peripheral feed alternatives. Mid-radius feeding devices have been developed and even patented; however, their use is so rare that the subject is not discussed further in this text. The location of the feed point determines the internal hydraulic regime of the tank. Center feeding causes the flow to move radially outward toward the weir, and, in many tanks, there is a doughnut-shaped roll pattern formed, which results in some surface flow back towards the center. The opposite pattern is formed by peripheral feed devices.

From a treatment and hydraulic standpoint, the influent pipe should be sized to keep material in suspension, but keep velocities low enough to avoid floc breakup and excessive head loss. CLARIFIER DESIGN The design will cover the chemical engineering aspects as well as the mechanical engineering aspects; Chemical engineering design: I. Flow rates II. Volume of the clarifier III. Settling Velocity IV. Residence time V. Clarification zones Mechanical engineering design: I. Material of construction II. Rake and drive unit specifications III. Weight of vessel IV. Weight of vessel content

V. Design load VI. Vessel support VII. Vessel thickness VIII. Stresses CHEMICAL ENGINEERING DESIGN SPECIFICATION FEED FLOW RATE Mass flow rate of feed into clarifier was specified as 180 kg/hr of slurry which is made by dissolving 60 kg/hr of cocoa pod ash in 180 kg/hr of water and leaching it. Mass flow rate in, G = 180 kg/hr= 3 kg/min= 0. 05 kg/s Density of the slurry was determined experimentally to be 1178 kg/m3; hence the volumetric flow rate is given by v = m/ ? Volumetric flow rate, Q = 0. 153 m3/h = 4. 244 x 10-5 m3/s The overflow rate is 43% of the feed flow rate, hence;

Overflow rate = 140 kg/hr For the underflow rate; taking the total mass balance, Flow rate in = Flow rate out Feed flow rate = Underflow rate + Overflow rate 180 kg/h = Underflow rate + 0. 43(180) Underflow rate = 180 – 140 = 40 kg/h DEPTH AND DIAMETER OF CLARIFIER The clarifier is made up of a cylindrical section joined to a conical section. The volume of the clarifier is then given by the equation below, for which the diameter to height ratio of about 25: 16 (Wilson 2005). Hence, V= ? D2h4+ 0. 04? D212 Where V is Volume, hc is height of conical section, D is Diameter.

For a residence time of 20 minutes, 60 kg of cocoa pod ash solution will be in the clarifier. Hence, with a flow rate of 60 kg/20 min, the equivalent volume will be given by Therefore, 50933. 79 cm3/20 min will be entering the clarifier. The clarifier capacity should then be 50933. 79 cm3. Hence, Solving the equation, D = 0. 5 m = 50 cm h = 0. 32 m = 32 cm The height of the conical section is 4 cm and will be inclined at 10. 1o. SETTLING VELOCITY Void fraction, Vf= liquid volume = 0. 12 m3 Vp= particle volume = 0. 075 m3 Sludge is thick since void fraction, ? ; 0. 7

The actual settling velocity, U is given by; where up is the free fall velocity of ash given as 0. 0004 m/s. The velocity of ash settling in water is 2. 972 x 10-5 m/s. RESIDENCE TIME The clarifier is designed to operate with a residence time of 20 minutes (Appendix C) CLARIFICATION ZONE This is the zone in the clarifier which contains the clear effluent before discharge. In order to achieve the required clarity, the settling rate of the finest particle must be higher than the effective up-flow of clear liquid. Figure 7. 5Settling Zones In The Clarifier MECHANICAL DESIGN SPECIFICATIONS MATERIAL

The primary material for construction of circular clarifier mechanisms has been coated carbon steel. Galvanized steel can also be used. A disadvantage of this coating is that it can be scratched or damaged in transport and in installation. However, if adequately protected and installed, it does offer good resistance to corrosion. The use of stainless steel has increased in recent years to provide additional corrosion protection for circular clarifier mechanisms. Either stainless steel 304 or 316 can be used for this purpose. (Wilson et al, 2005) The latter is more expensive but offers better corrosion protection in some installations.

Stainless Steel is preferred because it does not react with potassium carbonate. It is also rust and corrosion resistant at atmospheric conditions. FEED WELL The Fitch feed well is developed with fluid flow velocity reduction as its main function. The feed is split into two equal tangentially fed streams and the impingement of these opposing streams upon each other destroys random feed stream velocities and simultaneously promotes mixing of the solids in solution and improves settling rate and detention efficiency. But considering the sizing of the design, the normal feedwell design is favourable due to its simplicity.

It allows entering feed directly into the clarifier’s settling zone thereby allowing efficient solid-liquid separation. (Osbourne, 1981) RAKE SPECIFICATIONS The rakes or scrapers are of the form as chosen in the scraper configuration diagram. They are aligned parallel to each other and are inclined to blade angles of between 15 and 45 degrees, but 30 degrees has become popular in the United States and Europe. (Wilson et al, 2005) It is suitable for slow settling mixtures to avoid remixing of settled solids; hence they are to revolve at a very slow velocity. Rake speed, x = 0. 463 rpm. Rake tip speed, n = x?

D n = (0. 463 rpm) (0. 5?) = 0. 2315 m/min DRIVE UNIT According to Wilson et al (2005), The drive units for circular tanks typically consist of three sets of reducers that transition speeds from the motor to the rotating mechanism. Worm gears, cycloidal speed reducers, and cogged gears have been used by the different manufacturers. Bearings are extremely important components of the drive mechanisms. The principal types include one in which steel balls run on hardened strip liners set in cast iron, and the second involve forged steel raceways. The latter are commonly called precision drives.

Generally, there are two common forms of clarifier drives: bridge supported styles and center pier (column) supported styles. Bridge supported drives are used in full span bridge clarifiers, typically less than 15 m (50 ft) in diameter. The access bridge supports the center drive. The output flange of the drive attaches to the rotating torque tube (drive shaft), which rotates the collector mechanism. Figure 7. 6 BridgeSupported Style Worm Gear Drive, With Replacement Strip Liners. Selection of the drive size and operating torque and rotational speed are dependent on the application.

Center pier supported styles are used on half span bridge, center column support clarifiers, typically larger than 15 m (50 ft) in diameter. The center column supports the center drive, and the rotating spur gear attaches to the drive cage, which rotates the collector mechanism. Typical drive configurations include a primary, intermediate, and final gear reduction unit.

Selection of the drive size, operating torque, and rotational speed is dependent on the application. Figure 7. 7Pier Supported Style Fabricated Steel Drive, With Precision Bearing Another type of drive used more commonly is the rim-drive mechanism.

It features a motor, gear-box, and drive wheel that runs on the top of a circular tank. The bridge supported worm gear drive system would be used to turn the rake shaft that holds the rakes that direct settled sludge toward the central underflow outlet in the design of the clarifier. TORQUE The torque, is T = FR2, for circular clarifiers that have two arms. Where T is the maximum operating torque. F is magnitude of force. (it is given as 2. 5 N for low duty work) (MIP, 2009) R is radius. T = (2. 5 N)(0. 223 m)2 = 0. 124 Nm POWER (MIP, 2009) RAKE SHAFT DIAMETER

Shaft size is dictated by torque, not horsepower. However, changes in horsepower and speed affect the torque. To calculate the minimum shaft size; Dsd= 23. 6 mmPx (Yung and Nyberg, 2008); but P is in horsepower and Dsd is shaft diameter of rake. ? P= 0. 003 kW= 0. 003 kW x 1. 36 = 0. 00408 hp Dsd= 23. 6 mm0. 004080. 463= 6. 988 mm ~ 1 cm This is the minimum shaft diameter. The shaft diameter is considered as 1 cm as approximated from 0. 7 cm. Hence, the diameter of the rake shaft is 1 cm. Stainless steel rods of diameter 1 cm shall be used to make the rake shaft. SURFACE AREA

To know the amount of 1mm thick stainless steel sheets required to be able to design the whole unit, the surface area of the whole unit should be determined. So the surface area is thereby calculated as follows, Variable definitions, h : height of cylindrical part of tankl : length of scraper r : radius of the wide tankS : length of side of conical section h0 : height of overflow launder sider0 : radius of overflow launder b : breadth of scraper r1 = 7. 5 cm h1= 10 cm h2 = 4 cm r2 = 2 cm Figure 7. 8 Representationsof Variables on Side View of Feed Well The surface area of the tank is given by

A1= 2? r1h+? rS+? r02-? r12+ 2? r0h0 A1= 2? (25)(10) + ? (25)v(252+42) + ? (28-252) + 2? (28)(3) = 4586. 57 cm2 The surface area of the feed well is also given by A2= ? r12+? r12-? r22+ 2? r2h2 + 2? r1h1 A2= ? (7. 52) + ? (7. 52-22) + 2? (7. 5)(10) + 2? (2)(4) = 862. 37 cm2 The surface area of the cross over plate is given by A3= D2r1= 5015= 750 cm2 The surface area of a scraper is given by A4= lb=(10)(2. 5) = 25 cm2 But 6 will be needed, hence; 25 cm2 x 6 = 150 cm2 Total surface area = A1 + A2 + A3 + 6A4 = (4586. 57 + 862. 37 + 750 + 150) cm2 = 6348. 94 cm2

Therefore, the volume of a 1 mm thick sheet of stainless steel of that total surface area will be given as Vt = (6348. 94 cm2)(0. 1 cm) = 634. 894 cm3 MASS OF WHOLE VESSEL The total length of the shaft is (40 + 22 + 22 + 22. 3) cm = 106. 3 cm The cross sectional area of the shaft is ? x (1cm)2/4 = 0. 785 cm2 The total volume of the shaft is then given by 106. 3 cm x 0. 785 cm2 = 83. 49 cm3 Density of stainless steel is 7. 85 g/cm3 Therefore, the mass of the whole shaft is Ms= 7. 85 g/cm3 x 83. 49 cm3 = 655. 4 g = 0. 6554 kg The mass of the empty vessel will then be given by M = ? Vt, where ? s density of stainless steel and Vt is volume as calculated above. M = 7. 85 g/cm3 x 634. 894 cm3 = 4983. 9179 g = 4. 983 kg ~ 5kg Hence, the total mass of the whole vessel is 5 kg + 0. 6554 kg = 5. 6554 kg ~ 5. 7 kg The weight is then given as 5. 7 kg x 9. 81 m/s2 = 55. 917 N The mass of the full clarifier is 5. 7 kg + 60 kg = 65. 7 kg The weight of the full clarifier is 65. 7 kg x 9. 81 m/s2 = 644. 517 N DESIGN PRESSURE Internal pressure =

Hydrostatic Head + Atmospheric Pressure = ? gh + atmospheric pressure Where, ? = density of slurry = 1178 kg/m3 h = overall height of the tank = 0. 4 m = acceleration due to gravity = 9. 81m/s2 Atmospheric pressure = 101325 N/m2 Internal Pressure, Po = (1178 x 0. 4 x 9. 81) + 101325 = 4622. 472 + 101325 = 105947. 472 N/m2 But Design pressure, Pd = 1. 1Po(Silla, 2003) Therefore, the Design Pressure is given by Pd = 1. 1Po = 1. 1(105947. 472) = 116542. 219 N/m2 VESSEL THICKNESS Stainless steel is ductile, tough, and hard. A thickness of about 1 – 2 mm should be used for the design. (Azom articles, 2011) (Barton, 1974) Where ri = Internal radius = 0. 25 m Tv = thickness of vessel required S = design stress = 165 N/mm2 at 25oC for Austenitic stainless steel 165 x 106 N/m2 (Sinnott, 2005) Pd = design pressure = 116542. 219 N/m2 C = Corrosion allowance = 0. 2mm (Sinnott, 2005) E = welding efficiency, 0. 85 for initial work. (Barton, 1974) Hence, the thickness of the sheet is 2 mm. PRESSURE STRESSES Hoop stress, (Gere and Timoshenko, 1998) D = diameter of clarifier t = thickness of vessel Longitudinal stress, WEIGHT STRESS Dead weight stress, (Sinnott, 2005) Ww = Weight supported by whole vessel, that is the weight of substance in container when full. D = diameter of clarifier t = thickness of vessel Hence, RADIAL STRESS Radial stress

Where Pd= design pressure = 116542. 219 N/m2 Hence, SUPPORTS The weight of the full clarifier is 65. 7 kg x 9. 81 m/s2 = 644. 517 N Hence, the overall weight on the support is 644. 517 N. The support stand would be made up of three standing structures on the outer perimeter of the bottom 120o to each other. The height of the support leg is supposed to be 60 cm from the base of the clarifier to the floor. 7. 10. 3 Summary of Specifications

PARAMETER| SPECIFICS| Feed Mass flow rate| 180 kg/h = 0. 05 kg/s| Feed Volumetric flow rate| 0. 153 m3/h = 4. 244 x 10-5 m3/s| Underflow rate| 102. 6 kg/h|

Overflow rate| 77. 4 kg/h| Tank diameter| 50 cm| Tank depth| 36 cm| Total Height| 40 cm| Settling velocity| 2. 972 x 10-5 m/s| Residence time| 20 min| Material| Stainless steel| Rake speed| 0. 463 rpm| Rake tip speed| 0. 2315 m/min| Torque| 0. 5575 Nm| Power| 0. 003 W = 0. 00408 hp| Overall Surface area| 6348. 94 cm2| Volume of steel required| 634. 894 cm3| Mass of whole vessel| 65. 7 kg| Design Pressure| 116542. 219 N/m2| Wall thickness| 2 mm| Pressure stress| 1. 8209 MPa| Weight stress| 15. 606 kPa| Radial stress| 58. 2711 kPa| Weight on support| 644. 517 N| CHAPTER EIGHT – DESIGN OF AN EVAPORATOR

PROBLEM STATEMENT Clear potassium carbonate solution obtained from the clarifier (27. 8wt%) is to be concentrated to 50wt% using saturated steam at 4bar. The feed is coming in at 250C with a flow rate of 140kg/h INTRODUCTION Evaporation is an operation used to concentrate a solution of non-volatile solute and a volatile solvent (commonly water) and is done by vaporizing a portion of the solvent. An evaporator is a typical application of heat exchangers in which heat is transferred from a heating medium (usually steam) to a solution by conduction through a solid surface(the tube walls).

As the solution boils, mass and heat are simultaneously transferred into the vapor phase (McCabe, 1993) TYPES OF EVAPORATORS BATCH This is the simplest and one of the oldest designs in the batch evaporator it consist of a jacketed vessel that is heated with a vapor or liquid medium . the product is metered into a tank to a specific level heat is applied and the batch is allowed to heat to its boiling point, vapors are removed until desired concentration is reached. HORIZONTAL TUBE This is the only type of chemical evaporator in which the heating medium is inside the tubes its principal advantage is the small head room it requires

VERTICAL SHORT TUBE It consist of tube sheets extending across the body and a central downspout, the liquid is in the tubes and the heating medium is outside the tubes. as the liquid boils up, it rises through the tubes and returns through the central down take and condensate is removed from any convenient place at the bottom of the tubesheet. in this type of evaporator circulation and heat transfer are strongly dependent on liquid level, a common use of this type of evaporator is concentration of sugar cane juice.

LONG-TUBE VERTICAL EVAPORATORS The long tube vertical or rising film evaporator is one of the most widely used tubular evaporators, it is basically a shell and tube heat exchanger mounted to a vapor/liquid separator here dilute feed enters at the bottom of the tube sheets and flows upward through the tubes, at some distance further up, bubbles form and the liquid begins to boil, the bubbles rise rapidly through the tubes and are discharged at high velocity from the top where they impinge on a vapor/liquid separator.

RISING/FALLING FILM Here the rising and the falling film evaporators are combined in order to incorporate the advantages of both, the feed enters at the bottom of the tube sheet of the rising film portion. Boiling starts as the liquid rises through the tubes, a mixture of liquid and vapor is discharged and redistributed over the tubes for the falling film FALLING FILM

It is a variation of the long tube rising-film evaporator, in which the equipment is turned upside down so that the tubular heat exchanger is on top of the vapor liquid separator section, here distributors are required as feed is fed from top and as such distribution is critical, this type of evaporator has the advantage of gravity pulling the film which results in higher heat transfer coefficients and shorter residence time FORCED CIRCULATION

This primarily refers to the use of pumps in the evaporator, in the design of forced-circulation tubular evaporators, although the addition of a pump would result in additional installation, operating and maintenance costs recirculation of part of the concentrate back to the feed stream may increase the heat transfer to allow a sizeable reduction in the evaporator size. In most cases where feed contains solids forced circulation should be used PLATE TYPE

The gasketed plate and frame evaporator is constructed by mounting embossed plates with corner openings between a top carrying bar and bottom guide bar. the plates are gasketed and arranged to form narrow flow passages when a series of plates are clamped together in the frame. Fluids are directed through the adjacent layers between the plates either in series or parallel, the gasket confine the fluids and prevent them from escaping into the atmosphere while the heating medium flows through every other plate. late evaporators are often operated under reduced pressure. AGITATED THIN FILM It is a very useful type of evaporator for difficult to handle materials, problems facing other tubular evaporators like heat sensitive materials, viscous materials, high-boiling liquids, degradation due to long residence time, fouling of the heat transfer surfaces, plugging of tubes, low heat transfer, pressure drops due to high viscosities. his type of evaporators are designed in a way that the volatile materials are quickly separated from the less-volatile materials using indirect heat transfer and mechanical agitation of the flowing product under controlled conditions, the separation is done under vacuum in other to maximize temperature difference. The combination of short residence time, narrow residence time distribution, high turbulence and rapid surface renewal permits the agitated thin-film evaporator successfully handle viscous and fouling materials and hard to handle heat-sensitive materials too. McCabe, 1993) JUSTIFICATION A single effect tubular exchanger similar to a typical long-tube vertical, or film rising evaporator is used to carry out the evaporation process of the potassium carbonate solution. A single effect evaporation process is applicable because of the relatively small evaporation duty required, and the separation of the heat exchanger from the vapor liquid separator helps in achieving little floor space, potassium carbonate solution is not temperature sensitive and as such the large temperature difference does not damage the solution.

EQUIPMENT DESCRIPTION AND MODE OF OPERATION br /> The evaporator consists of a vapor liquid separator on top of a shell and tube heat exchanger, the heat exchanger comprises of a number of vertical tubes arranged in parallel, heat is provided by supplied steam at 4bar on shell side condensing on tubes containing the potassium carbonate solution

Aonce-through mode of operation is used, all the evaporation is done in a single pass; it consists of two essential parts and a steam trap to ensure profitable use of supplied steam * Tubular heat exchanger with steam contained in shell side and potassium carbonate solution in tube side * Vapor liquid separator for removing entrained vapor from concentrate * Pre-heater to reduce heat transfer area of the evaporator The tubular