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North Lebanon Alternative Power
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Heavy Metals Recycling Unit for NLAP-IPP Demonstration Plant

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بسم الله الرحمن الرحيم

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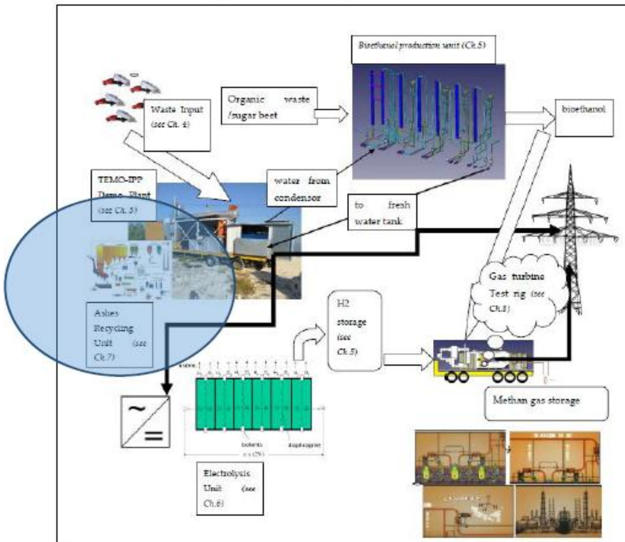
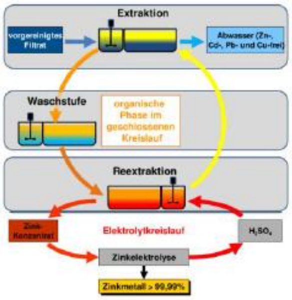
Tripoli, 11. April 2018

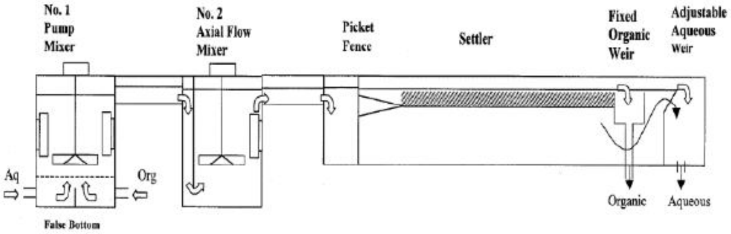
PhD thesis: Optimal heavy metals recovery from waste bottom and fly ashes from waste incineration



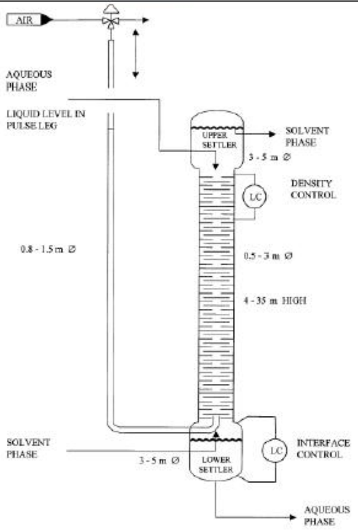


The most commonly encountered toxic heavy metals in wastewater:

- Arsenic, Lead, Mercury, Cadmium, Chromium, Copper, Nickel, Zinc.
- **Sources:** Industrial sources: e.g. Printed board manufacturing, metal finishing and plating, semiconductor manufacturing, textile dyes, Street runoffs, Landfills
- **Effects:** Many heavy metals are essential trace elements for humans, animals and plants in small amounts. In larger amounts cause acute and chronic toxicity.



Conventional Mixer Settler



BATEMAN PULSED COLUMN

Working packages:

1. Development of a basic liquid-liquid extractor for Ni, Cu, CO, Zn, Cd, Pb, Hg.
2. Optimization of process in pulsed column or similar column with different diluent pairs

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Contents

1. BASICS

Solvent extraction, or liquid-liquid extraction is a separation technique isothermal in a heterogeneous liquid medium.

The method is based on the existence of a difference in the solubility of a substance in two immiscible liquids. The process has three steps, as shown in Figure 1:

- Mixture of the two immiscible liquids, one of them containing the solute,
- Obtaining physico-chemical equilibrium, leading to demixing,
- Separation of the two new liquid phases obtained based on the difference of densities.

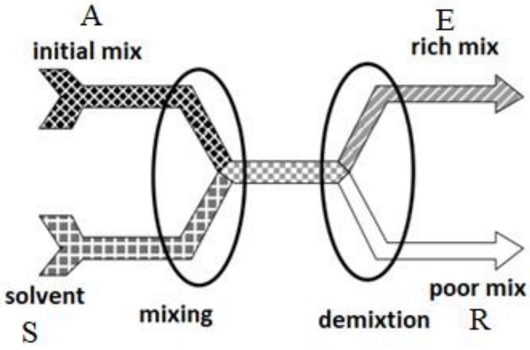


Figure 1 ***: principle of a separation stage by obtaining a balance***

Practically, solute B dissolved in the diluent A is contacted with the solvent S. The solute B, generally more soluble in the solvent than in the diluent, passes from the solution in the solvent, the solvent enriched in solute is the extract E while the diluent depleted solute is the residue (or raffinate) R. The passage of solute B from diluent A in solvent S takes place as long as the equilibrium physico-chemical is not reached. So that the driving force of transfer remains almost constant, the two liquids feeding the column flow against the current.

In order to transport the material as quickly as possible, the area of the transfer surface is increased by various artifices. These objectives can be obtained in a column.

1.1 THE PHASE EQUILIBRIUM OF TERNARY MIXTURES

1.1.1. THE PARTITION COEFFICIENT

A substance B placed in contact with two partially miscible solvents or immiscible S and A is distributed unequally between the two phases that are formed when the physicochemical balance is reached. The ratio of B concentrations in these two phases is the partition coefficient m.

1.1.2. THE TERNARY DIAGRAM

At equilibrium, these biphasic systems are trivariant. At pressure and temperature constants, they can be represented in a system of triangular axes. The equilateral triangle has the advantage of allowing an equivalent representation for all the constituents. The right triangle has the advantage of being able to expand the scale of one of the axes. It is often interesting to limit the plot to the "useful" part. Each vertex of the triangle represents a pure component. The solute content B, in solvent S and diluent A is expressed in mol%, mass, volume, etc ... and is obtained by a suitable projection on the axis chosen as shown in Figure 2.

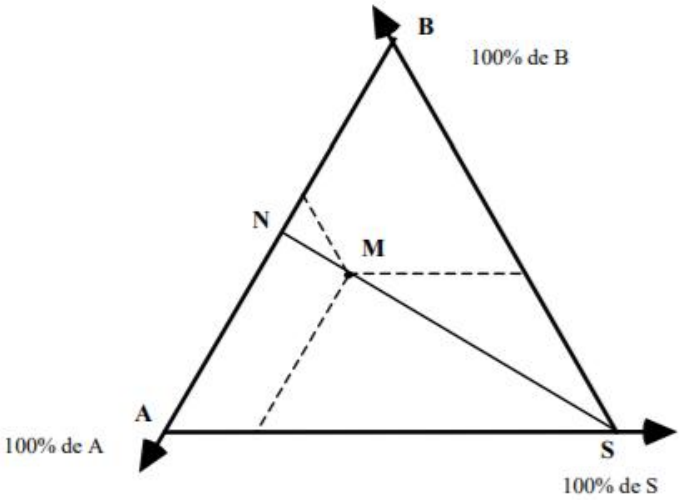


Figure 2 : ternary diagram

It is easy to demonstrate that the quantity of S and the quantity of the mixture N are in a ratio of the lengths of the MN and MS segments (rule of the lever arm) and that the quantities of two components are in the ratio of projections of the segments on the binary axis corresponding.

Conversely, if the mixture N is added a mass of solvent S, the ternary mixture result is represented by the point M on the line NS such that:

$$\frac{mass\ of\ N}{mass\ of\ S} = \frac{MS}{MN}$$

1.1.3. THE DEMIXTION

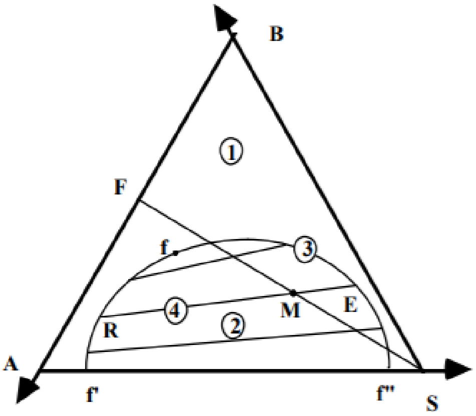


Figure 3 : Isothermal and isobaric demixing curve.

In a ternary system with limited mutual solubility zone (1) stable states, characterized by a complete miscibility, is separated from the zone (2) unstable states constituting the miscibility gap or diphasic zone, by the solubility isotherm (3) or line "Critical" or demixing curve or equilibrium curve or saturation curve.

Within the miscibility gap, no mixture can exist indefinitely:

any system whose overall composition is represented by point M is divided into two composition phases R and E, points at the intersection of the equilibrium line (4) or conodal RME and the demixing curve f'ff ". At the critical point f the two phases in balance have the same composition.

1.1.4. SOLVENT SEPARATION

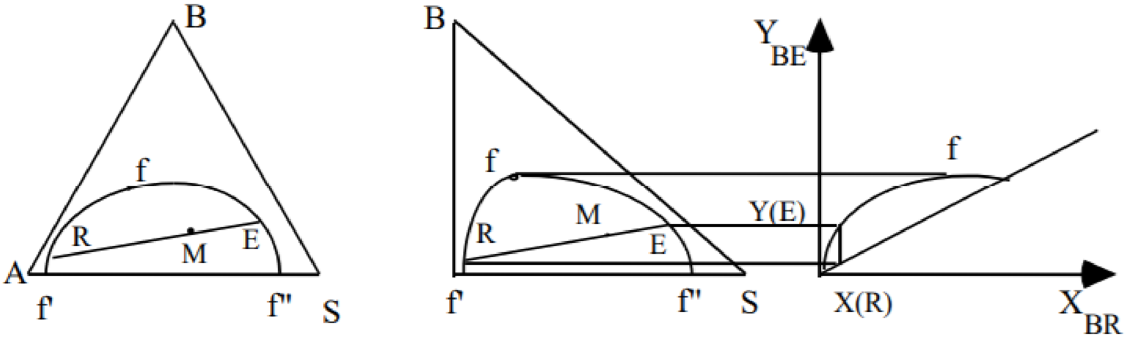


Figure 4 : Representation of a ternary system with limited miscibility

In the zone of total miscibility no separation can take place. However, if starting from an initial mixture F, by the addition of the solvent S, a system whose composition is global M lies within the miscibility gap, which separates into two phases R and E. Phase R, rich in diluent A is the raffinate, while phase E, rich in solvent S, constitutes the extract.

In general, the concentration of solute B in the raffinate is designated by x and in the extract by y. It is then possible to draw the distribution curve or equilibrium curve which represents y in terms of x.

1.2 COUNTERCURRENT EXTRACTION

1.1.5. THE PRINCIPLE

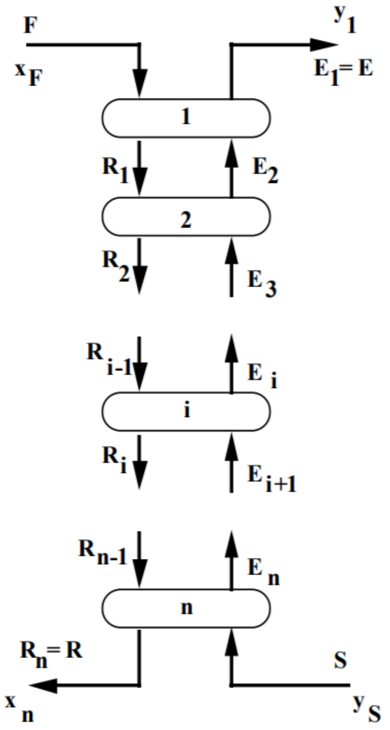


Figure 5 : diagram of countercurrent column

1.1.6. THE MATERIAL BALANCE

The writing of the material balance makes it possible to know the composition of the global system and of each of the subsystems (stages).

Balance sheet on the column:

Global: mF + mS = mE + mR = mM

Solute B: mF xF + mS yS = mE y1 + mR xn = mM xM

This system of two equations with eight unknowns can be solved if six variables are otherwise known. In practice mF, mS, xF and yS (= 0) are imposed. By fixing two other variables, for example xn and mR, this system of equations can be solved.

Moreover, the combination of these relationships makes it possible to determine the position of the point M in the ternary diagram. Graphically, F and S determine M. The point M is both on the FS and ER lines. R (Rn)being known, E (E1) is obtained by the intersection of RM and the demixing curve. At point E1 the conodal matches R1.

Balance sheet on the stage i:

Global: $m_{R_{i-1}} + m_{E_{i+1}} = m_{E_i} + m_{R_i}$

Solute: $m_{R_{i-1}} x_{i-1} + m_{E_{i+1}} y_{i+1} = m_{E_i} y_i + m_{R_i} x_i$

1.1.7.THE EXISTENCE OF A POLE P

The writing of the overall balance successively for the column and for each of the floors allows to show the existence of a pole P through which all RiEi + 1 lines pass.

Column: mR - mS = mF - mE = Cte = mP

The PRS and PFE points are aligned.

The FERS points being known, P is determined graphically.

Stage 1 : $m_{R_1} - m_{E_2} = m_F - m_E = m_P$

PR1E2 points are aligned. R1 being known, point E2 is in turn.

Step by step, it is possible to write:

Floor i: $m_{R_i} - m_{E_{i+1}} = m_F - m_E = m_P$

The points PRiEi$_{+ 1}$ are aligned and the point Ri is known by the graphic construction

previous point, the point Ei$_{+ 1}$ is determined.

Gradually, all the points Ri and Ei are determined.

The construction stops when the right PRnS goes through R or "exceeds" R.

Each line RiEi constitutes a theoretical stage.

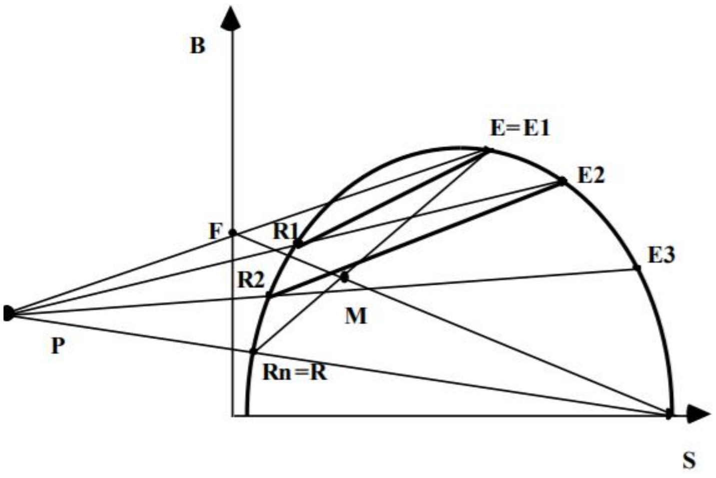


Figure 6 : Graphical construction of theoretical floors

1.1.8.REMARKS

The previous graphical construction is easier if on the same graph the demixing curve and the operating curve.

If an operating line passing through P was confused with an equilibrium line EiRi it then an infinite number of theoretical stages would be required. The ratio of the mass of solvent to that the power supply would then be the minimum usable to effect the separation. In practice we consider the equilibrium line passing through F as confused with the straight line passing through P. The intersection of the lines FS and E1minRn gives the point Mmin hence the value of the ratio (mS / mF) min.

The choice of the value of the solvent rate p = mS / mF is done by taking:

a) a value of mS / mF greater than (mS / mF) min,

b) a value of the extraction factor

$$\varepsilon = m\,p = m\,\frac{m_E}{m_R} = \text{partition coefficient}\,\frac{\textit{mass flow of extract}}{\textit{mass flow of raffinate}}$$

between 1,2 & 2.

1.3 EXTRACTANTS OF METALS

- Copper extractants for acid leach solutions are exclusively oximes. For extraction from ammoniacal solutions beta diketones may be used. The chemistry of oxime extraction of copper is relatively simple:

$$2RH_{(org)} + Cu^{+2} + SO_4^{-2} \rightleftharpoons R2Cu_{(org)} + 2H^{+} + SO_4^{-2}$$

Note the following points about this equation:

When M(2+) is extracted two hydrogen atoms are released.

Extraction of 1.0 gpl Cu produces 1.5 gpl H_2 SO_4 . There are other reactions which take place in copper extraction which can influence extraction and stripping.

- Buffering of the aqueous

Dissociation of H_2 SO_4 :

$$H_2SO_4 \rightleftharpoons H^{+} + HSO_4^{-}$$

$$HSO_4^{-} \rightleftharpoons H^{+} + SO_4^{-2}$$

This dissociation depends on the SO4

2- concentration and salts such as aluminium sulphate or magnesium sulphate can drive this reaction to the left and reduce the H+ concentration which enhances copper extraction. For this reason highly buffered solutions will yield better copper extraction than non buffered solutions.

- Dimerisation of the oxime

Oximes can form dimers in the organic phase and this can influence the extraction.

- Equilibrium Modifiers

These are used in all commercial extractants based on aldoximes and play a most significant role in the extraction of copper influencing not only the equilibrium but also the physical properties of the organic.

Oxime based extractants for copper are largely based on salicyaldoximes which have been modified with one of three modifier types. Examples of the three main extractant types currently in use are:

1. LIX® 984N

A mixture of 2-hydroxy-5-nonylacetophenone oxime and 5-nonylsalicylaldoxime in a high flash diluent. The acetophenone oxime modifies the aldoxime and also performs as an extractant in its own right. Molecular Weight:262.393 g/mol

2. Acorga® M5640

5-Nonylsalicylaldoxime modified with an ester, 2,2,4-Trimethyl-1,3-pentanediol Diisobutyrate (TXIB) in a high flash diluent.

3. LIX® 622N

5-Nonylsalicylaldoxime modified with tridecyl alcohol in a high flash diluent.

Each of the extractants marketed by the major chemical suppliers has been designed for a specific type of PLS with regard to pH and copper tenor. Used under the conditions for which they were designed they all deliver very similar copper net transfer values. The physical properties of the various types of extractant do show some differences with the aldoxime/ketoxime mixtures such as

LIX984N showing lower entrainments and greater tolerance to crud than the other reagents when treating some types of PLS. The vol% concentration of the commercially available extractants is limited by organic viscosity constraints to about 30-33% and this means that the maximum net transfer of copper will be about 10g/l. For leach solutions containing significantly higher copper tenors than this the throughput O/A ratio will have to be increased above 1.0. Typical copper and acid concentrations for an SX plant treating a dump leach solution of 3.0g/l and pH1.8 are shown in Figure 4.

Copper solvent extraction plant configurations

A variety of circuit configurations are used.

- **2E X 1S**

The usual circuit for heap leach plants

- **2E X 2S**

Used where the copper tenor is above about 7-10 g/l or the PLS pH is less than about 1.2. The decision to use a second strip stage is influenced by the life of the project and the sensitivity of the circuit to the copper tenor of the raffinate. Agitation leach plants for example are sensitive to the loss of copper in a raffinate bleed or in the wash liquor used in the solid liquid separation stages.

- **3E X 2S**

These can be justified when the PLS has a very high copper tenor, say above 20-25g/l and a high 93% plus copper recovery is desired. It is possible to use a 2EX2S circuit under these conditions but the throughput O/A ratios will be high, in excess of 2.5:1 and the capital cost of the 2EX2S plant may be higher than that of the 3EX2S plant. The 3EX2S plant will also be much more flexible in operation.

- **2E X 1W X 1S**

The wash stage is used to remove entrained impurities, usually chloride, and entrained and chemically loaded iron.

- **2E X 1P X 1S**

Series parallel circuits are used to treat high volumes of low tenor leach solutions. The parallel stage is often retrofitted to maintain copper production when the copper tenor of the PLS falls below project design and there is also the possibility to increase the volume of the PLS flow. Extractant concentrations are higher and copper recoveries are lower in series parallel circuits than in series circuits. Examples of these circuit configurations are shown in Figure 5.

Computer modeling of copper extraction circuits

Copper SX circuits have been modeled using a number of techniques. One such model is Henkel's IsocalcTM TM programme which applies the stability constants for the equilibrium reactions involved in copper extraction to calculate the extraction isotherm for a given leach solution and circuit organic and then applies the McCabe Thiele construction to predict circuit operation. A typical Isocalc print out is shown in Figure 6. Isocalc can be used in many ways by both project design and plant operating personnel.

- Copper recovery may be predicted for a given PLS, circuit configuration and vol%

extractant concentration.

- The reagent inventory cost and copper recovery may be predicted for a variety of

circuit configurations.

- A wide range of “what if?” situations may be examined, eg. what if the PLS pH

changes from 1.8 to 1.5?

- Operating circuit profiles may be compared with Isocalc predictions. This comparison

may indicate the presence of errors in the assumed or measured parameters of the

plant, eg. the vol % extractant analysis may be in error.

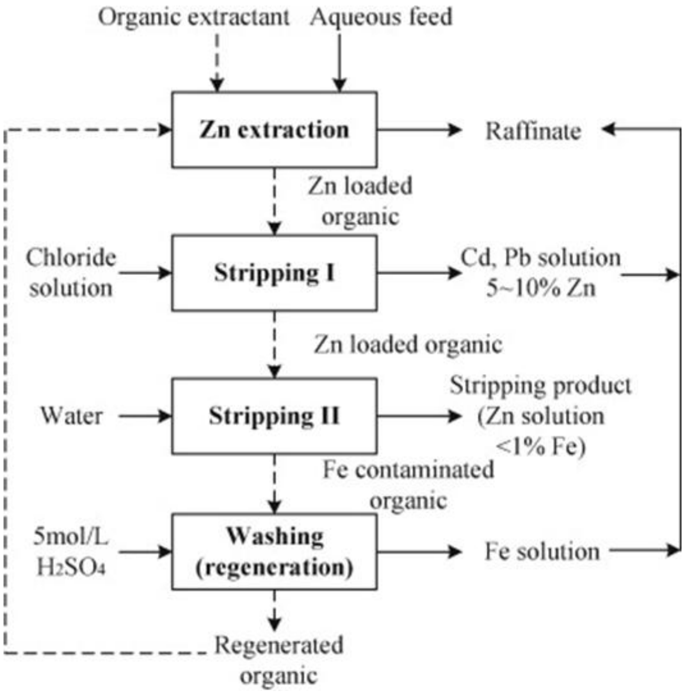
Extractant stability

The oxime based extractants used to recover copper exhibit high chemical stability under normal operating conditions. Chemical attack can take place in the high acid concentrations in strip. Under normal operating temperatures this is not excessive however the degradation rate doubles for every 10°C increase in temperature. At 30°C the half-life of most copper extractants exceeds 150 days and it is only above 50°C that chemical degradation may become an issue. Manganese contamination of the tankhouse may, if the iron level of the tankhouse electrolyte is low, result in permanganate formation and this species can severely degrade both the extractant and the diluent. Bacterial oxidation of the diluent to form carboxylates is relatively common and these ay have a negative effect on the physical and iron transfer characteristics of the organic.

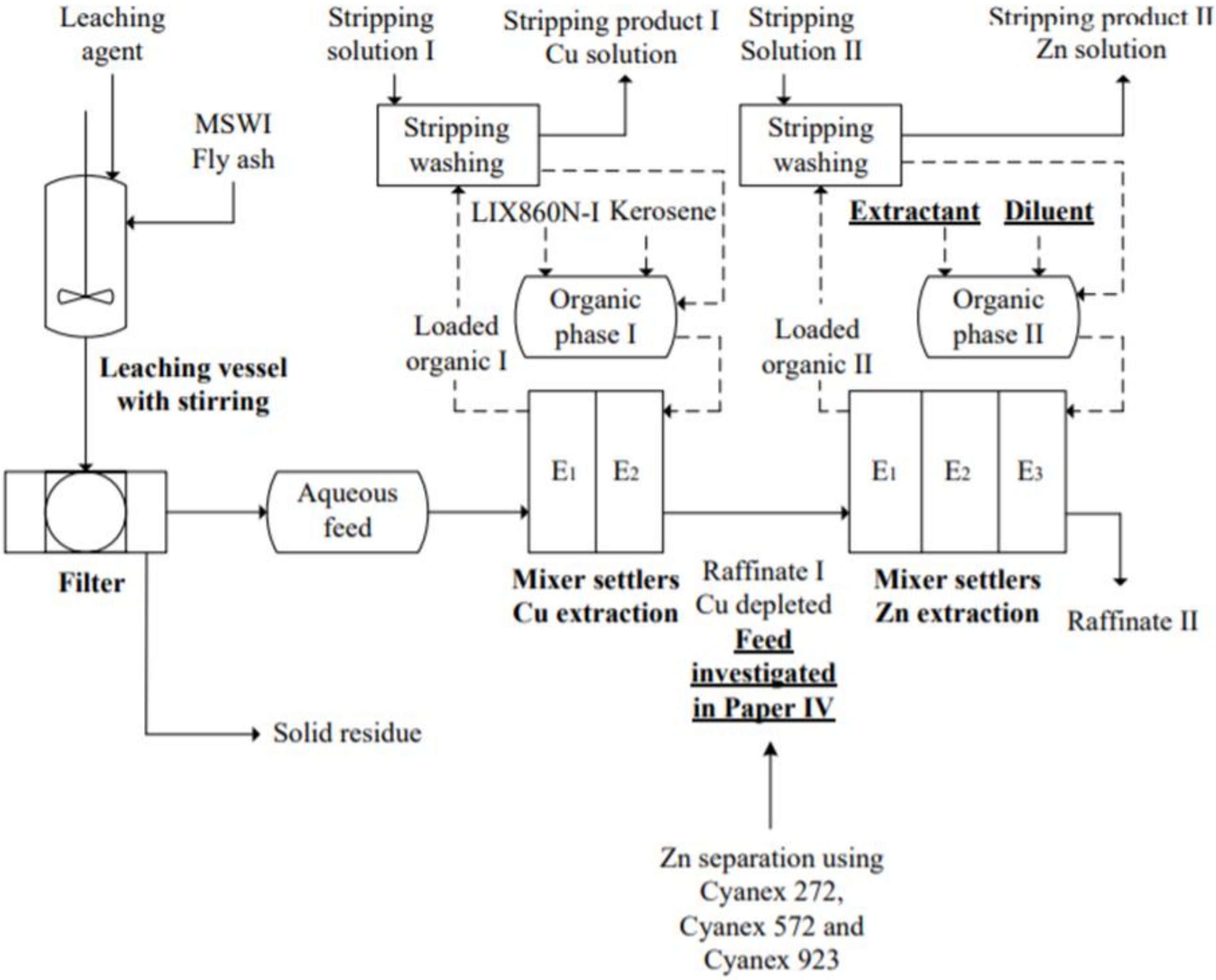
1.1.9. NICKEL EXTRACTANTS

Copper extraction where one type of extractant and circuit predominates there is a number of potential nickel extractants and circuit configurations. Sulphide nickel is usually treated using pyrometallurgical routes but in recent years there has been intensive activity in the development of hydrometallurgical routes for both sulphide concentrates and laterites. Nickel deposits can contain valuable quantities of cobalt and copper and these must also be recovered by SX if they are present in sufficient quantity.Direct solvent extraction of copper, cobalt and nickel from acid leach solutions using oximes, phosphinic acids and versatic acids to extract copper, cobalt and nickel in sequence. While this circuit may function on leach solutions derived from sulphide concentrates, laterite leach solutions contain significant manganese and magnesium, both of which are extracted by phosphinic acid extractants. In addition the aqueous solubility of versatic acid at the pH used for extraction necessitates the inclusion of a versatic acid recovery stage.

1.1.10. ZINC, CADMIUM, LEAD EXTRACTION



1.1.11. OVERVIEW OF METALS RECOVERY SYSTEM



2. CONTRIBUTION

1.4 SOME OPERATIONAL AND EQUIPMENT ISSUES

1.1.12. MIXER SETTLERS

- Well established with literally hundreds of operating units.
- Design parameters are well established and very large units treating over 1000 cubic metres per hour of PLS can be designed from bench scale tests.
- Excellent mixing characteristics with control of the optimum droplet size claimed to be possible with modern turbine designs.
- Prediction of capital and operating costs is accurate.
- The phases are readily accessible for sampling and examination in situ.
- Several design varieties are available such as the Bateman Reverse Flow Settler, the Krebs unit and the Outokumpu VSF mixer settler. The Bateman and Krebs units offer the advantage of installing all of the mixers in a row avoiding the extra piping, walkways and civils involved in the typical head to toe mixer arrangement for conventional mixer settlers. The Outokumpu unit uses a special design of mixer, the vertical smooth flow spiral mixer and pumps the phases from adjacent stages using a dispersion overflow pump. Low power requirements and low entrainments are claimed for the Outokumpu unit.

EQUIPMENT DESIGN AND SELECTION

UNIVERSITY OF LEEDS

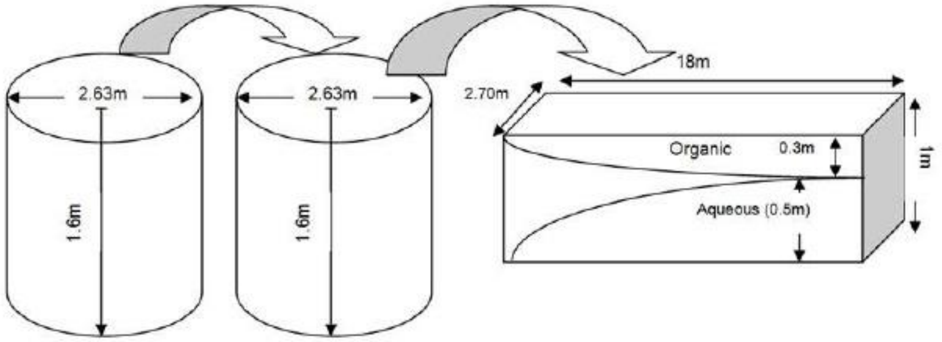
Conventional Mixer settler

Meet the requirements of copper solvent extraction plant

Low power consumption and low organic air entrainments

Process optimisation and control are simple

Easy crud removal



EQUIPMENT DESIGN AND SELECTION

UNIVERSITY OF LEEDS

Mixer settler designs

Four units designs: krebs, outokumpu vf, reverse flow and conventional mixer settler.

Mixer

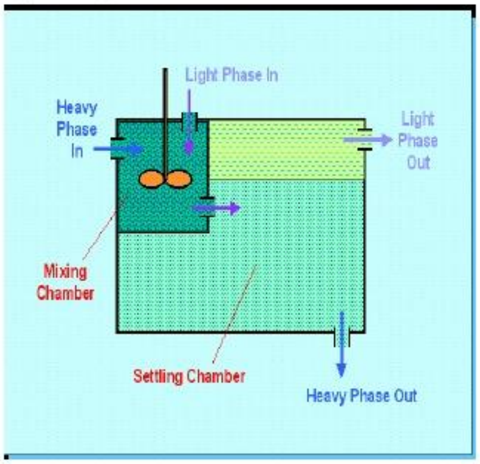
2 cylindrical mixing tanks per stage

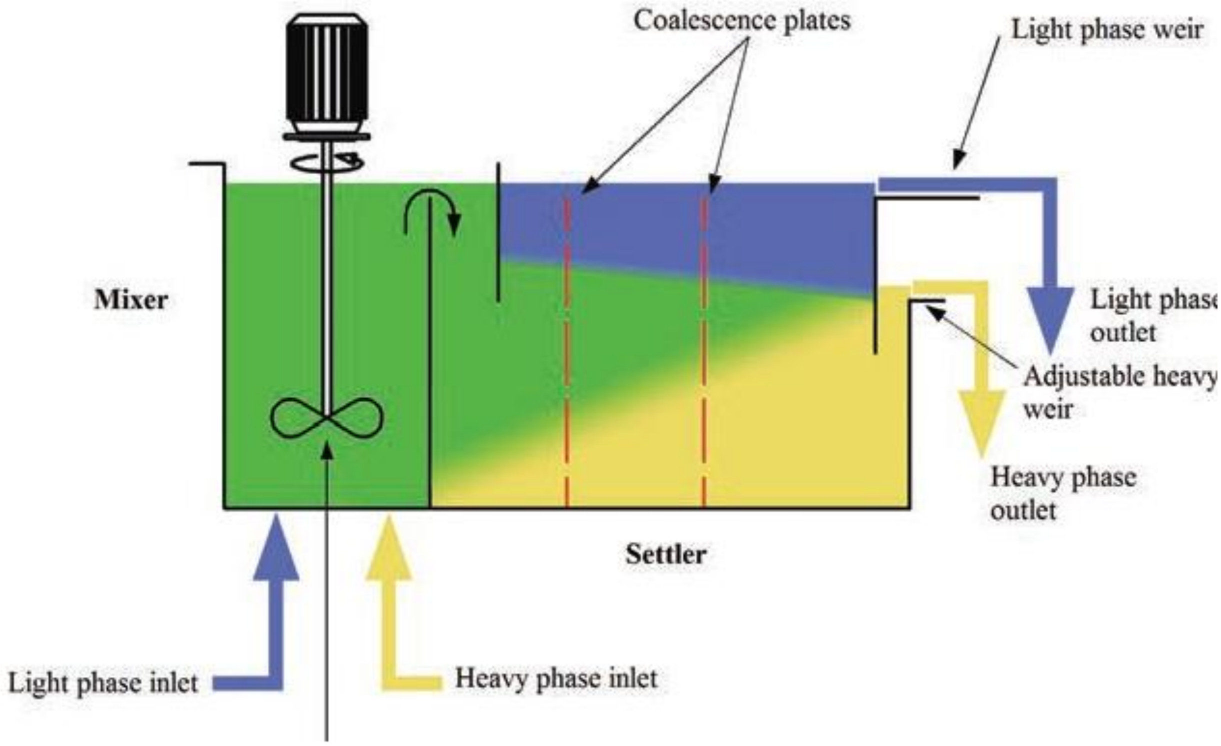
Residence time : 3 minutes.

Tank volume = (solution flow rate x residence time)/effective volume

Tank volume: 6.62m^3

Diameter=: 2.63m





1.1.13. COLUMN CONTACTORS

Advantages claimed for the column contactor include:

- Low area requirements
- Multiple stages within one unit
- Few moving parts
- Low entrainment
- Good vapor conservation

Column installations require piloting for each installation and the flooding conditions for the column must be determined. Recently Olympic Dam Corporation in South Australia has installed a large column plant for extraction.

The long residence times in a column compared to a mixer settler can influence the selectivity of the extraction if contaminants have slow extraction kinetics. The main features of conventional mixer – settlers and pulsed columns are shown in next Figure.

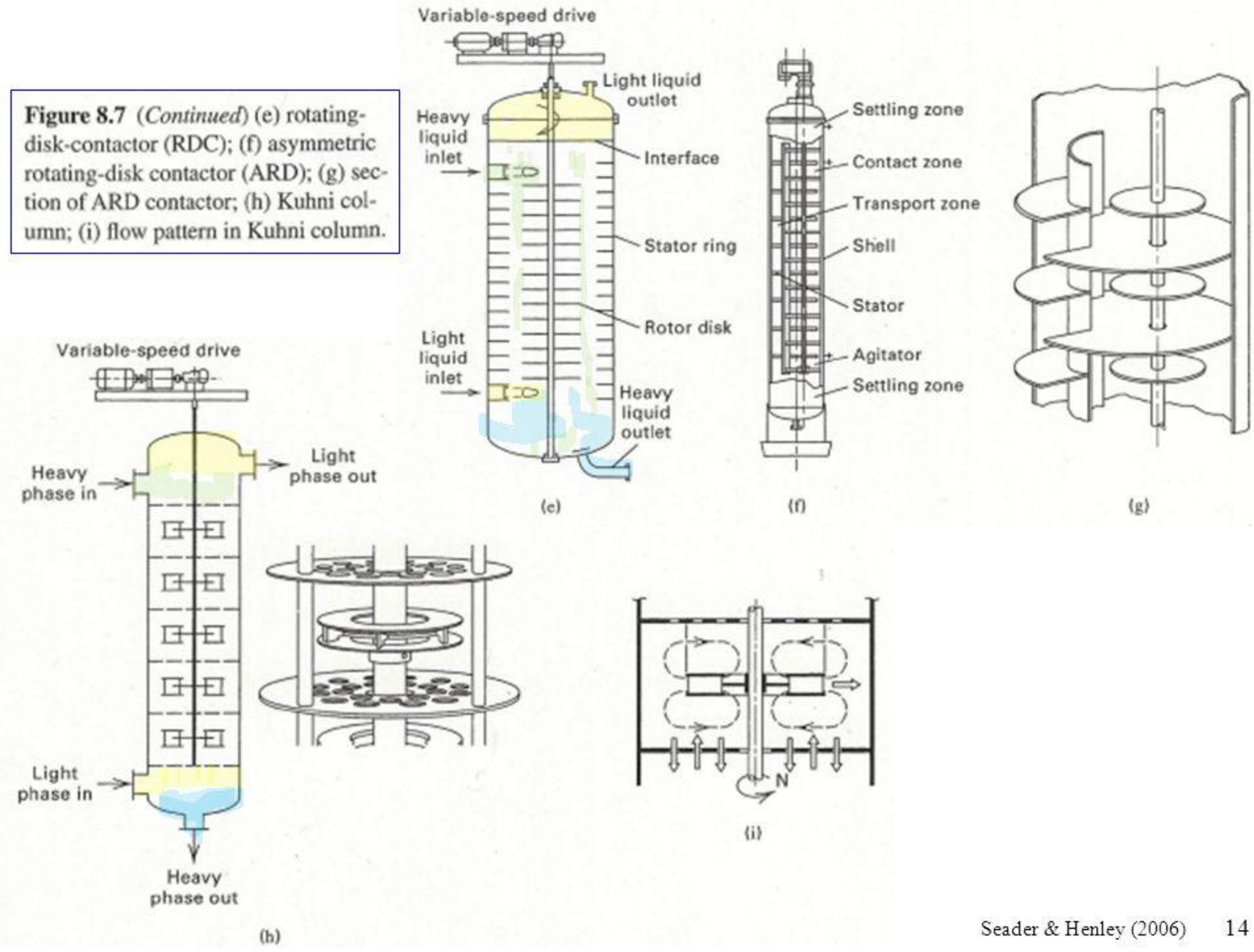


Figure 8.7 (*Continued*) (e) rotating-disk-contactor (RDC); (f) asymmetric rotating-disk contactor (ARD); (g) section of ARD contactor; (h) Kuhni column; (i) flow pattern in Kuhni column.

Seader & Henley (2006) 14

Figure 7 : OVERVIEW OF KIND OF COLUMNS

the figure shows a pulse column stripping the desired component from an organic phase consist of a vertical riser, **poppet valves,** v1which admits air pressure to the pulse leg and v2 which exhausts air from the pulse leg, the rotating cam and drive mechanism which alternately close and opens v1 and v2, the air reservoir which smooths out fluctuations in air pressure supplied in v1 and the pressure regulating valve which permits adjustment of air pressure in air reservoir

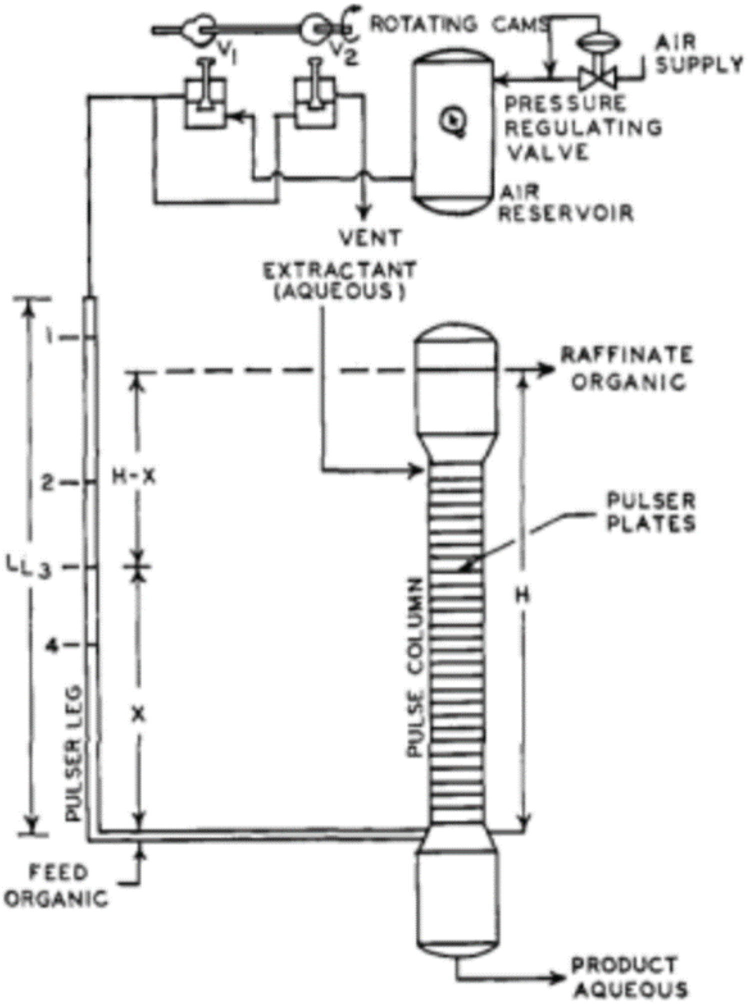


Figure 8 :pulsed column

if the fluid in the column and pulse leg are permitted to reach hydraulic equilibrium (valve 2 open), the fluid level will have reached position 1 in the leg with the fluid level maintained at the overflow point in the column. air pressure is now set and the cam started rotating. When v1 is open, v2 is closed which alternately admits and released air into and from the pulse leg. After equilibrium is reached in the system, the fluid in the leg will reach an average position 3 and will oscillate between points 2 and 4. air pressure forces the fluid down from 2 to 4 while the hydraulic head differences between the column overflow and fluid in the leg force the fluid in the leg back from 4 to 2.This interchange of fluid between the pulse leg and column provides the pulse action required in the column .Operating ranges usually encountered in amplitude area from 0.4 to 1.25 inches in the plate section of the column at frequencies from 40 to 100 cycles in minute . the poppet valve and motor are arranged with flange disconnects and electrical plugs-in for ease in replacement of unit needing maintenance. This pulsers are fitted with rotary and liquid sensing devices which close a safety in the event either sensor signals.

1.1.14. COMPARISON BETWEEN BATEMAN COLUMN AND MIXER SETTLER

flux rates of 30 to 50 m3/m2h, resulting in very small footprint requirements;

- no evaporation losses or air ingress as the units are sealed;
- improved safety of operation and lower fire risk;
- replacement of several mixer settlers by a single column for the equivalent performance;
- operation in either aqueous- or organic-phase continuity (including the possibility of

dispersing the major phase in the minor phase);

- inclusion of washing or scrubbing operations in the extraction or stripping columns;
- improved phase separation in the settlers, lower entrainment losses, and reduced crud

formation since mixing and mass transfer occur in a very low-shear environment;

- high tolerance of solids or crud in suspension;
- lower maintenance downtime due to few moving parts;

- reduced reagent losses, maintenance costs, and operating costs.

Since columns are particularly appropriate for systems that have rapid kinetics and do not require interstage pH control, the extraction of zinc by di(2-ethylhexyl)phosphoric acid (D2EHPA) is ideally suited to this application. The objectives of this study were (i) to determine whether data comparable to the previously optimised results for this system obtained using mixer settlers could be achieved for similar process conditions using a column configuration, and (ii) to validate the claimed advantages of BPCs.

Pilot-plant comparison of Bateman pulsed... (PDF Download Available). Available from: https://www.researchgate.net/publication/292139827_Pilot-plant_comparison_of_Bateman_pulsed_columns_and_mixer_settlers_for_the_extraction_and_stripping_of_zinc_in_the_di2-ethylhexylphosphoric_acid_system [accessed Apr 27 2018].

3. DIMENSIONS

1.5 1.7 TYPE OF METAL TO CONSTRUCTION

the construction of the column requires a metal that is resistant to corrosion and consequently the destruction. We can have mentioned some metals such as stainless steel that is the best un this case

1.6 MIXER –SETTLER

Materials	Height(m)	Radius (m)
Mixer 1	1	0.75
Inlet 1	0.2	0.1
inlet 2	0.2	0.1
Outlet 1	0.6	0.05
Mixer 2	1	0.75
Inlet 1	0.2	0.1
inlet 2	0.2	0.1
Outlet 1	0.6	0.05

Materials	Length (m)	width (m)	Height (m)
settler	2	0.3	1
Barrier to scroll	2	0.3	2

Table 1 :dimensions of mixer-settler

- Total surface needed to mixer=21.2 m²
- Total surface needed to settler=6.3 m²

Then, total surface = 27.45 m² (13 sheet 1m×2 m)

1.7 BATEMAN PULSED COLUMN

materials	radius (m)	Height (m)	number
Stator ring	0.245	0.01	19
rotor disk	0.125	0.02	19
Main tube	0.25	4	1
Tube (driver)	0.05	8.5	1
Inlet & outlet	0.15	0.5	2

Table 2 :dimensions of pulsed column

- Total surface needed to Bateman pulsed column =20.4 m² (11 sheet 1×2 m)

1.8 DIMENSION OF THE EXTRACTION COLUMN (WITH ROTATING DISCS RDC)

The amount of feed solution that considered as aqueous solution at 90°C (3h) is about 300L(waste +nitric acid ,volume of nitric acid=150 l).

A column of 40 cm radius is suitable in this case.

in most cases found limited to operations where:

• the density differences between the carriers is higher than 50 kg/m³

- the volumetric phase ratio between dispersed drop phase and continuous phase is in the magnitude of 0.5 < < 5
- the number of theoretical stages NTS 10

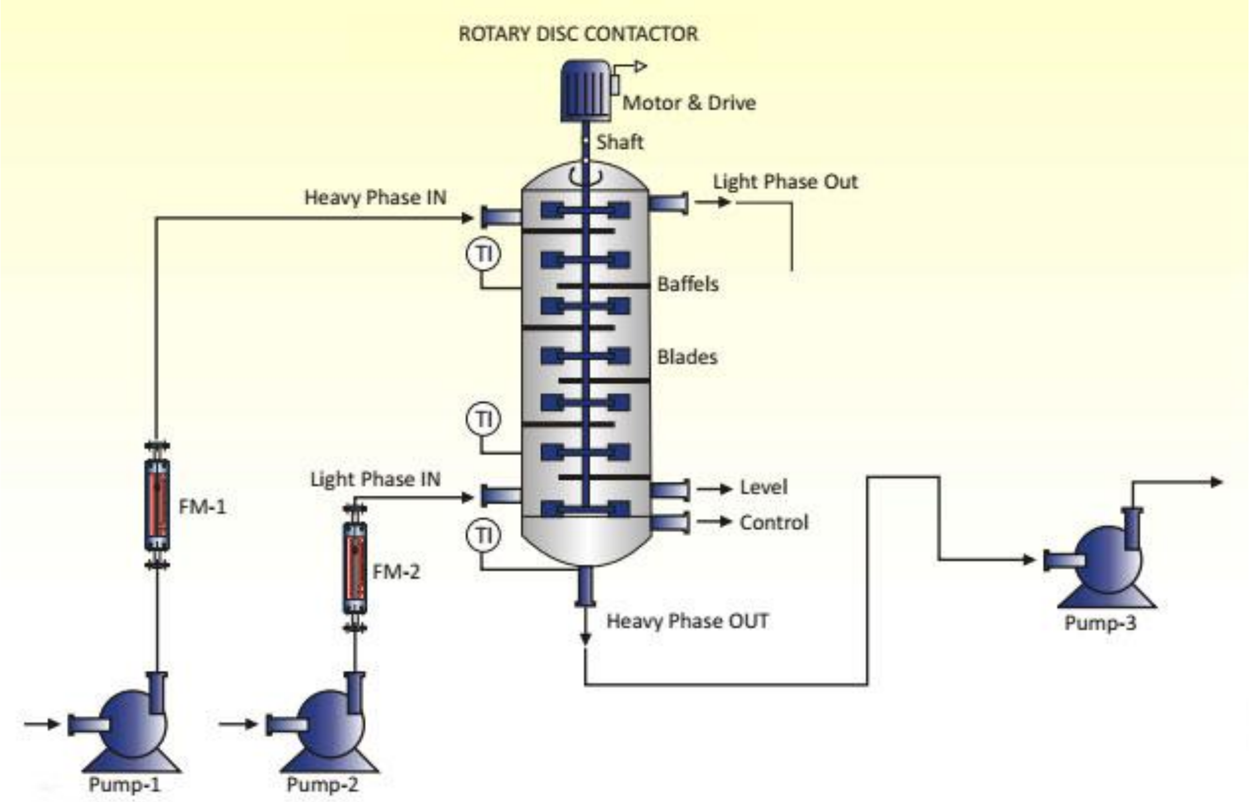


Figure 9 : rotating disc contactor

Equilibrium condition on extraction step is in the range of 8-32%extractant volume percent.

Column	Length (cm)
Height	250
Radius	40
Sheet of stainless steel	2500×125

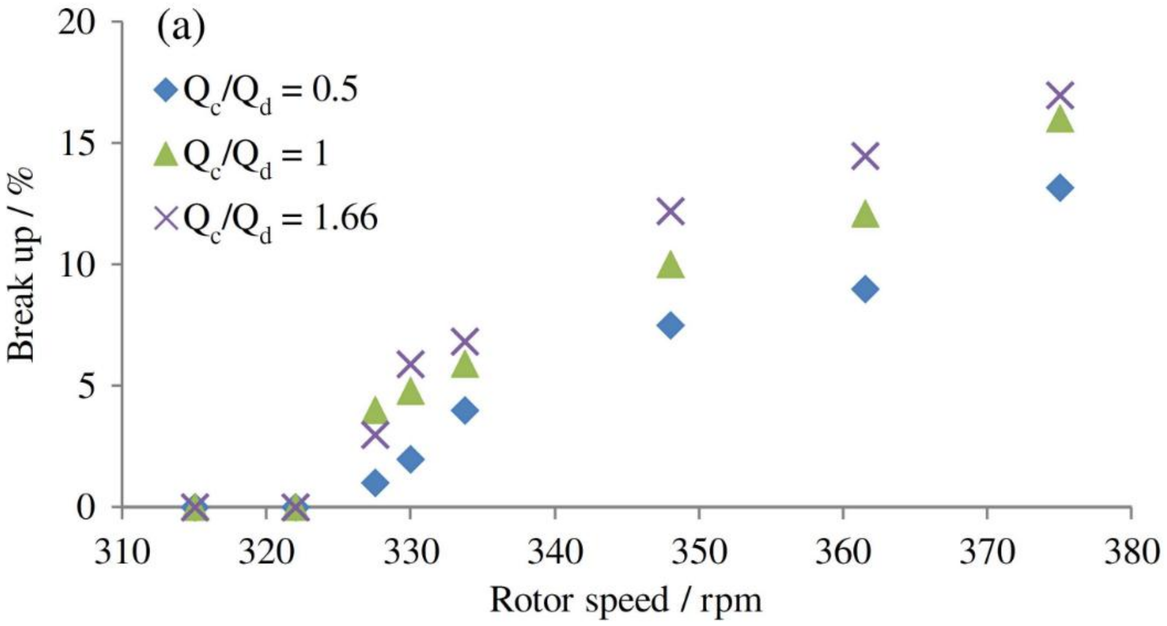
Column height / cm	Column active height / cm	Inner column diameter / cm	Inner stator diameter / cm	Outer rotor diameter / cm	Compartment height / cm	Number of compartment in active region
150	60	9.1	6.1	4.55	3.2	21

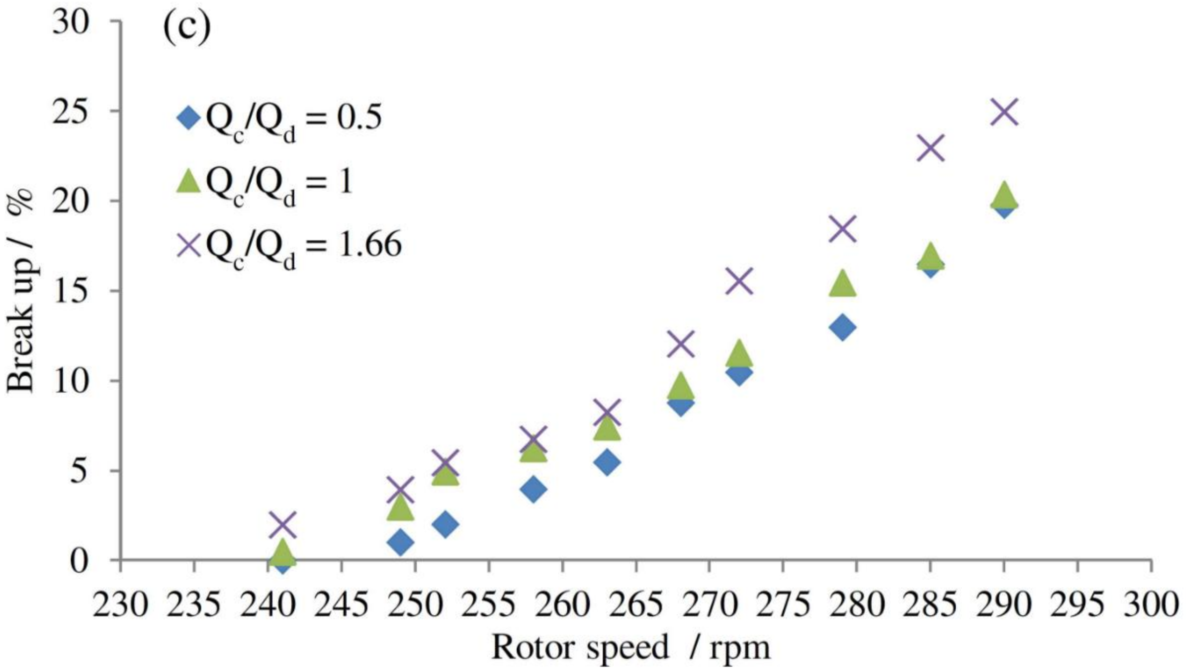
Table 3: Characteristics of the RDC column

1.9 IDENTIFICATION OF ROTOR SPEED

The first and second critical rotor speeds could also be defined based on breakage probability: the first critical rotor speed for a drop with particular size defines as the rotor speed at which the drop breakage starts. In fact, before the first critical rotor speed, the probability of break up for a drop with specific size is zero. Moreover, the second critical rotor speed (for a drop with a particular size) is a rotor speed at which the probability of breaking that drop is equal to 1

The breakage probabilities versus rotor speed for mentioned chemical systems using glassy nozzles with different inner diameters (1.2 and 2.5 mm) to form various drop sizes by adjusting the Q_c/Q_d ratios and continuous phase heights are presented in next figure regarding to these graphs, the drop breakage increases by increasing the volumetric phase ratio that leads to decrease of the first critical rotor speed. It could be justified with increasing this ratio, the drag forces between the continuous phase and dispersed drops increase results to enhance the probability of drop break up due to collision with the rotors. Mother drop diameter is effective on first critical rotor speed such that the nozzle with larger internal diameter produces larger mother drops with an increase in the probability of break up results to decrement of first critical rotor speed. Increasing the height of continuous phase led to increase of resistance against to upward motion of drops thereupon increment of the break up probability and decrement of the first critical rotor speed. Based on experimental results, the first critical rotor speed for considered chemical system should be 230 rpm.





1.1.15. CHARACTERISTICS OF LIX® 984N

Typical properties Physical and performance specifications

Specific gravity	(25 °/25 °C) 0.935 – 0.955 g/cm³
Flash point	Greater than 170 °F=76 °C
Copper complex solubility	> 30 g/l Cu at 25 °
Maximum copper loading	≥ 5.1 g/l Cu
Extraction isotherm point	≥ 4.40 g/l Cu
Extraction kinetics	≥ 95 % (30 seconds)
Extraction Cu/Fe selectivity	≥ 2000
Extraction phase separation	≤ 70 seconds
Strip isotherm point	≤ 1.8 g/l Cu
Net copper transfer	≥ 2.70 g/l Cu
Strip kinetics	≥ 95 % (30 seconds)
Strip phase separation	≤ 80 seconds

Table 4: Typical properties physical and performance specifications

Materials	Density (kg/m^3)
Copper	999
Nitric acid	1510
Oxime LIX	806

Table 5 :Density of solutions

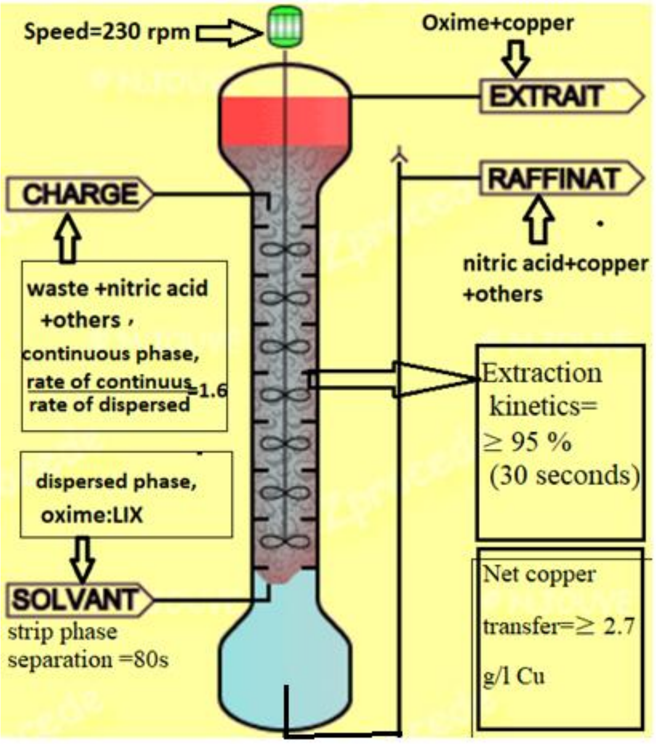


Figure 10 :input and output of column;

Solvent = light phase (feed at bottom), Solvent = dispersed phase (top interface)

To complete 95% of the extraction process ,it takes 30 seconds ,in others words of the solute (copper) passes from solution A(waste + nitric acid) to solvent . the stripping of copper takes 80 seconds.

Parts	**Dimension**
Covering column	Internal diameter:212 mm Outside diameter:220mm
Columns that carry stators	Number:3 Diameter:4 mm Height 2500 mm
Stator	Number:10 Internal diameter:120 mm outside diameter:204 mm Height:15 mm Spaced:150 mm
Decanter (cylinder+cone)	Number :2 Radius 1:110 mm Radius 2:200 mm Height: 100 mm -Cylinder: Height :300 mm, Diameter:400 mm
Rotation axis	Diameter :40 mm, height:3500 mm
Rotor perforated(20 punch ,D=8 mm)	Number :10 Internal diameter:40 mm Outside diameter:100 mm Height:15 mm Spaced :150 mm

Table 6: dimensions of parts of columns

4. DESIGN

1.1.16. BATEMAN PULSED COLUMN

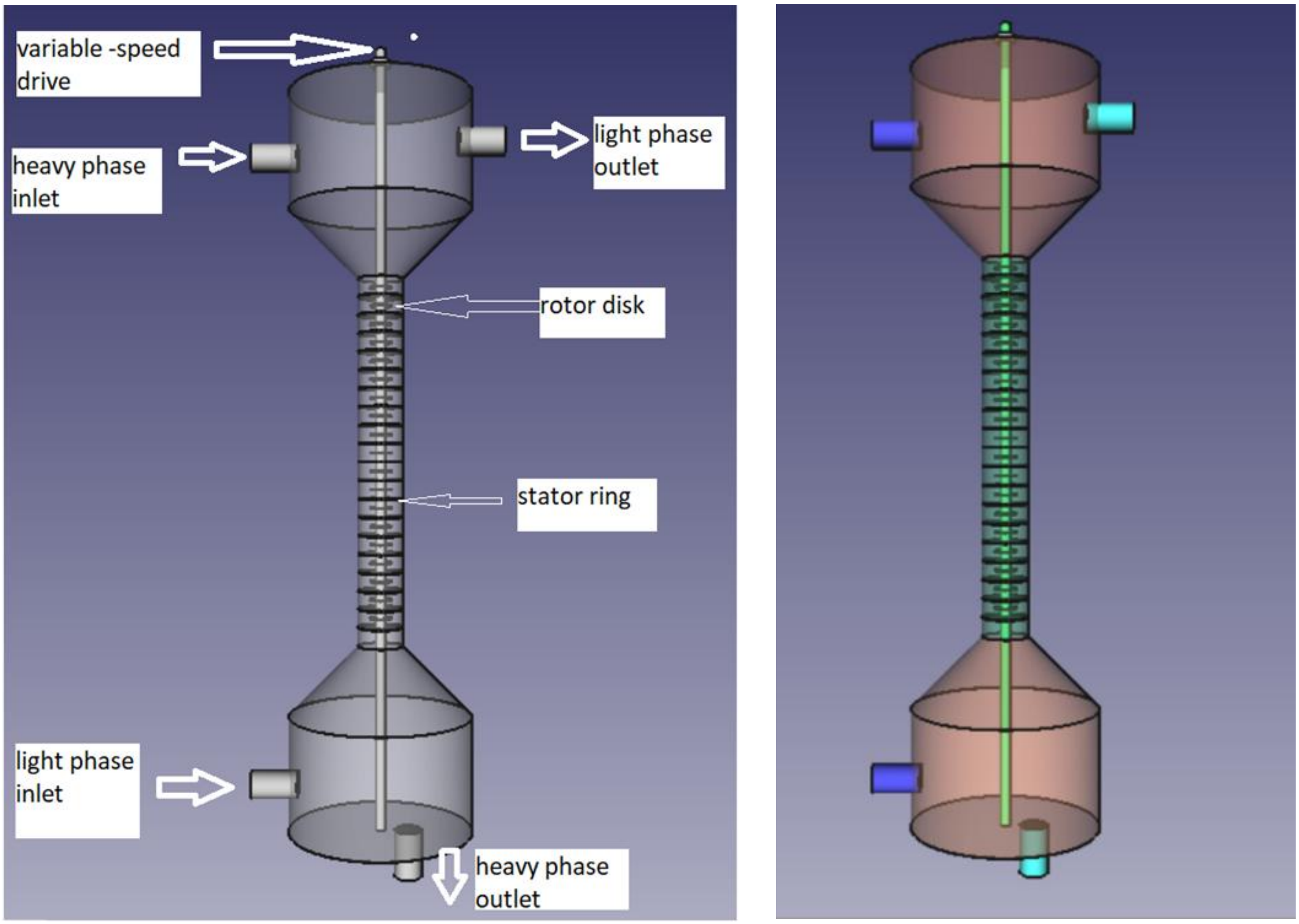


Figure 11 :Bateman pulsed column

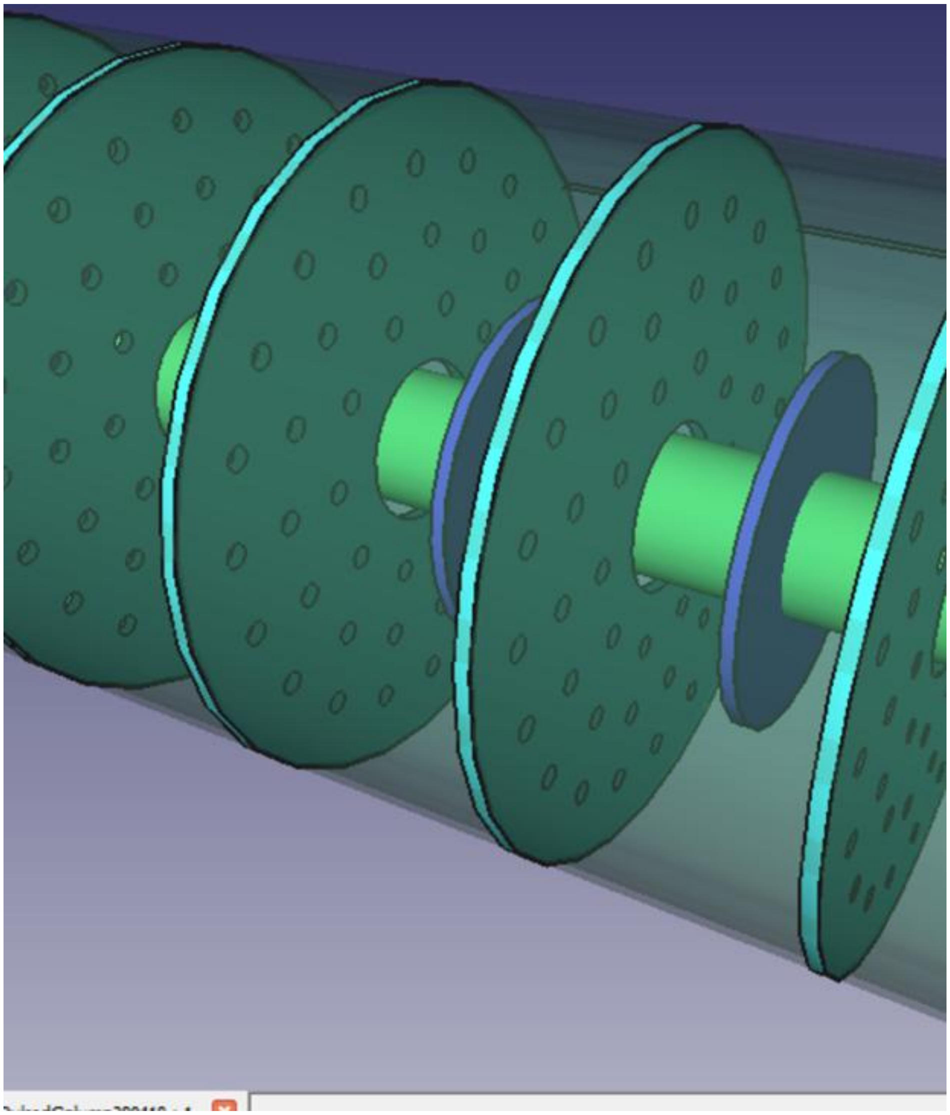


Figure 12 :rotor and stator of Bateman column

1.1.17. MIXER SETTLER

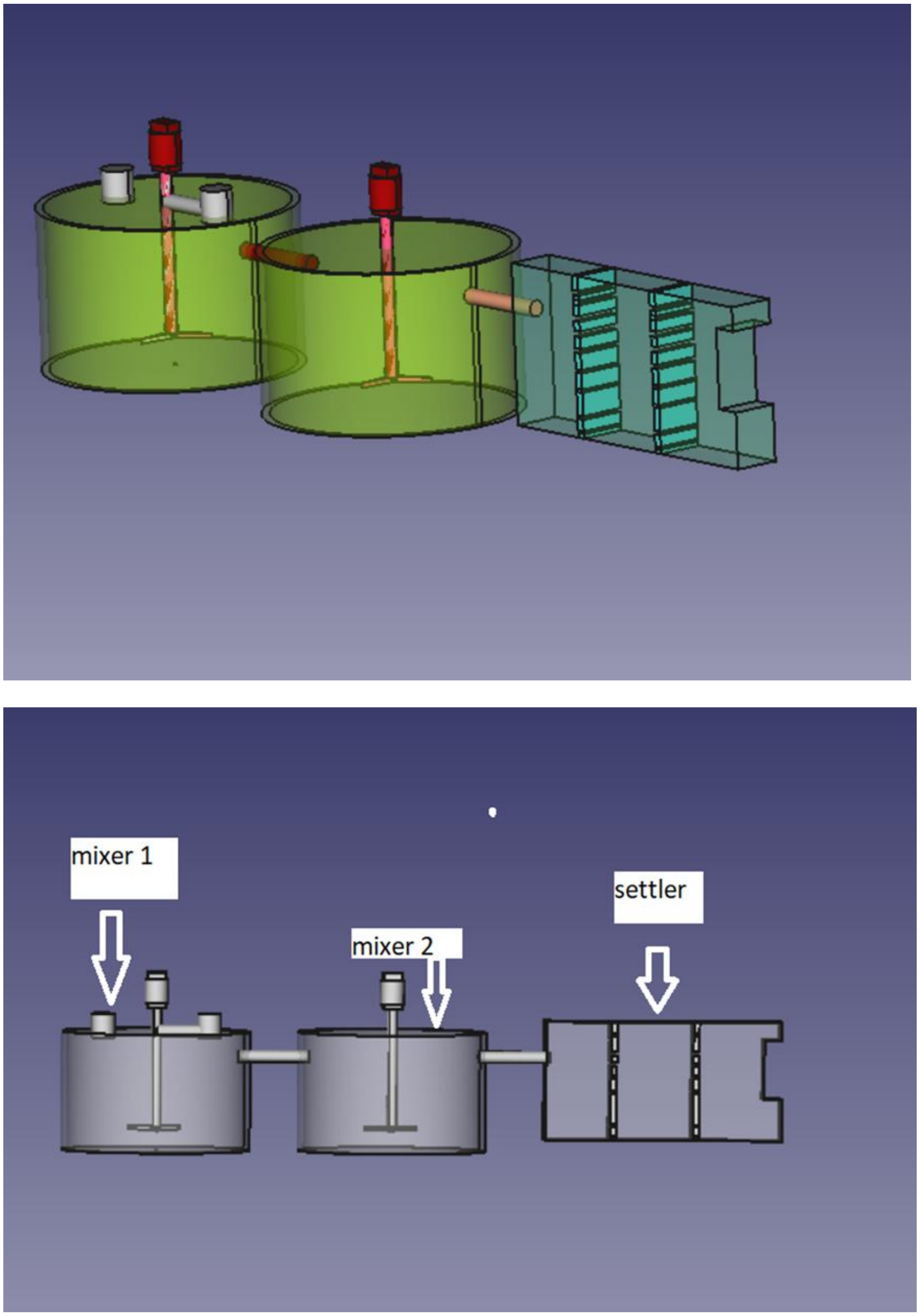


Figure 13 :mixer-settler

1.1.18. RDC COLUMN

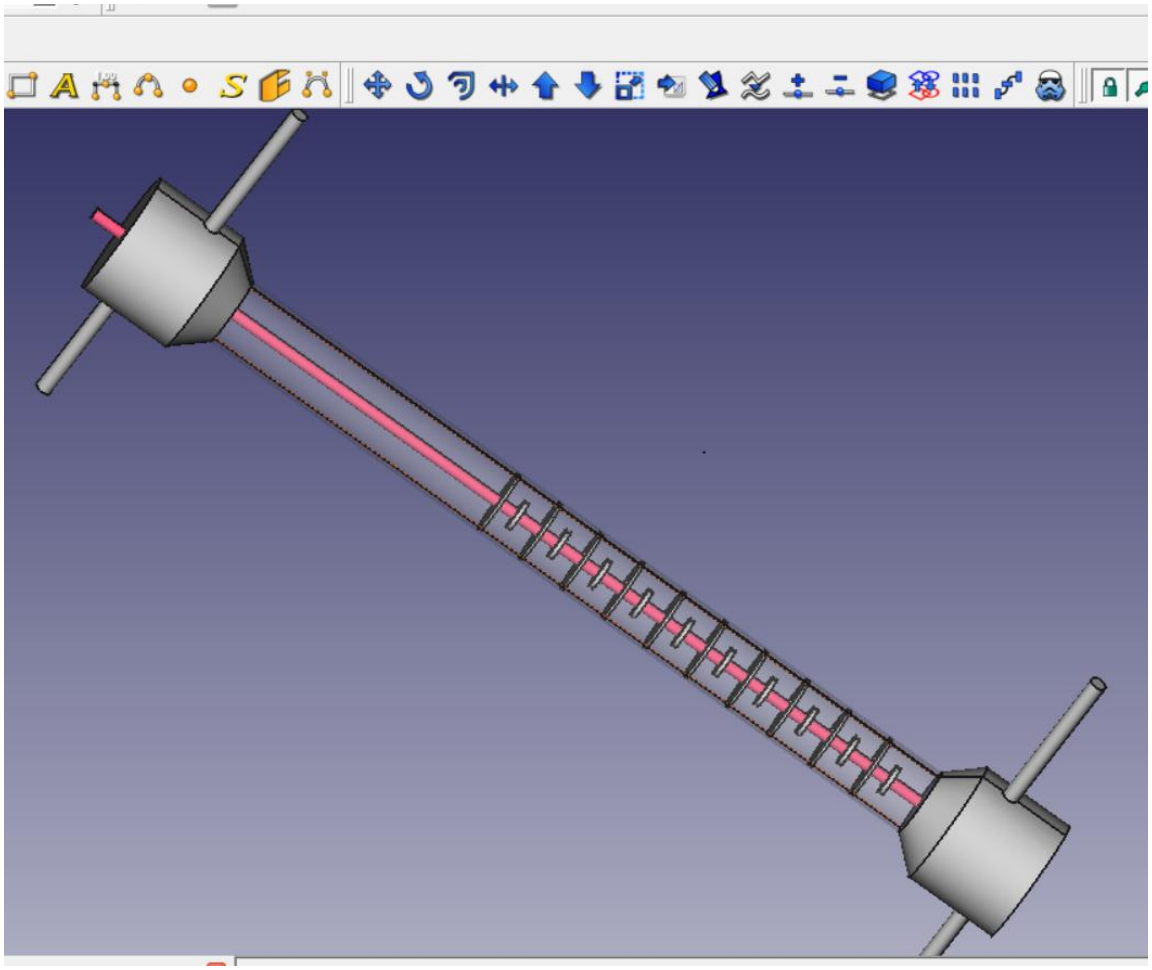


Figure 14 : overview of RDC column

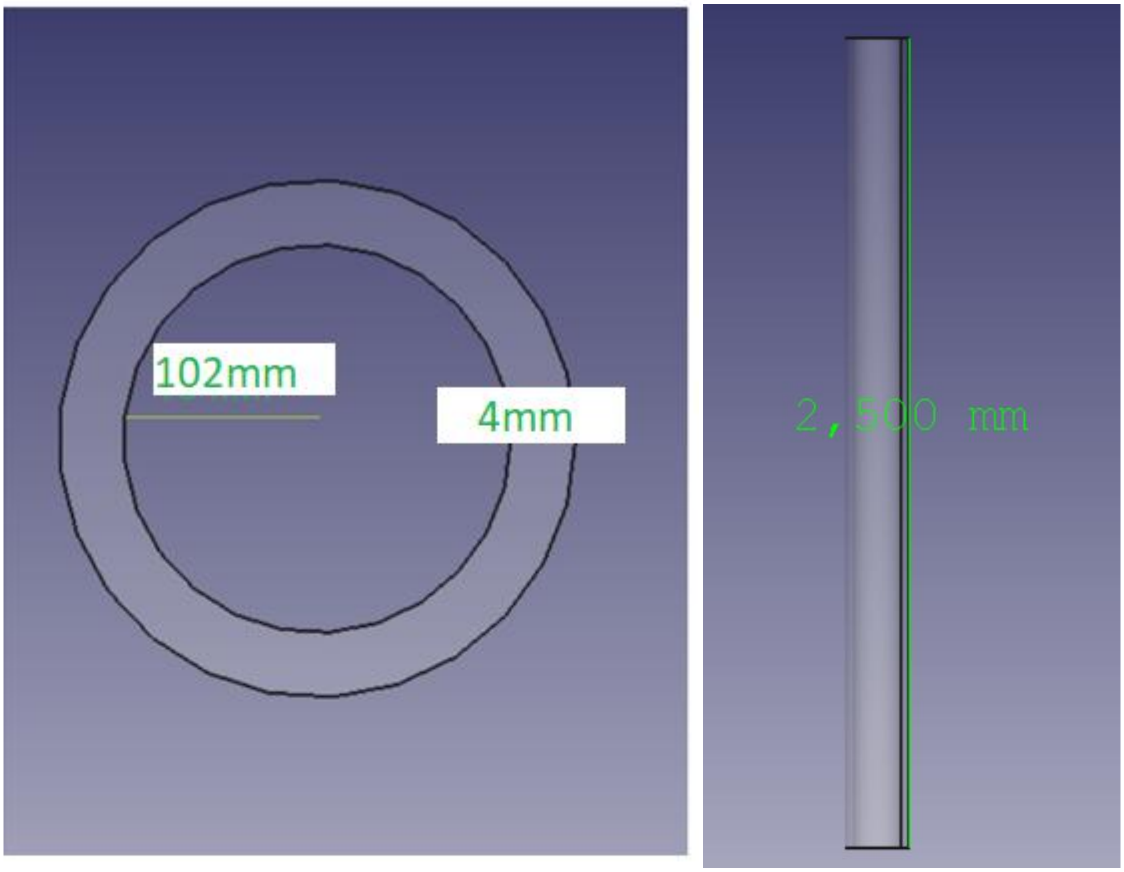


Figure 15 : top and side face of column

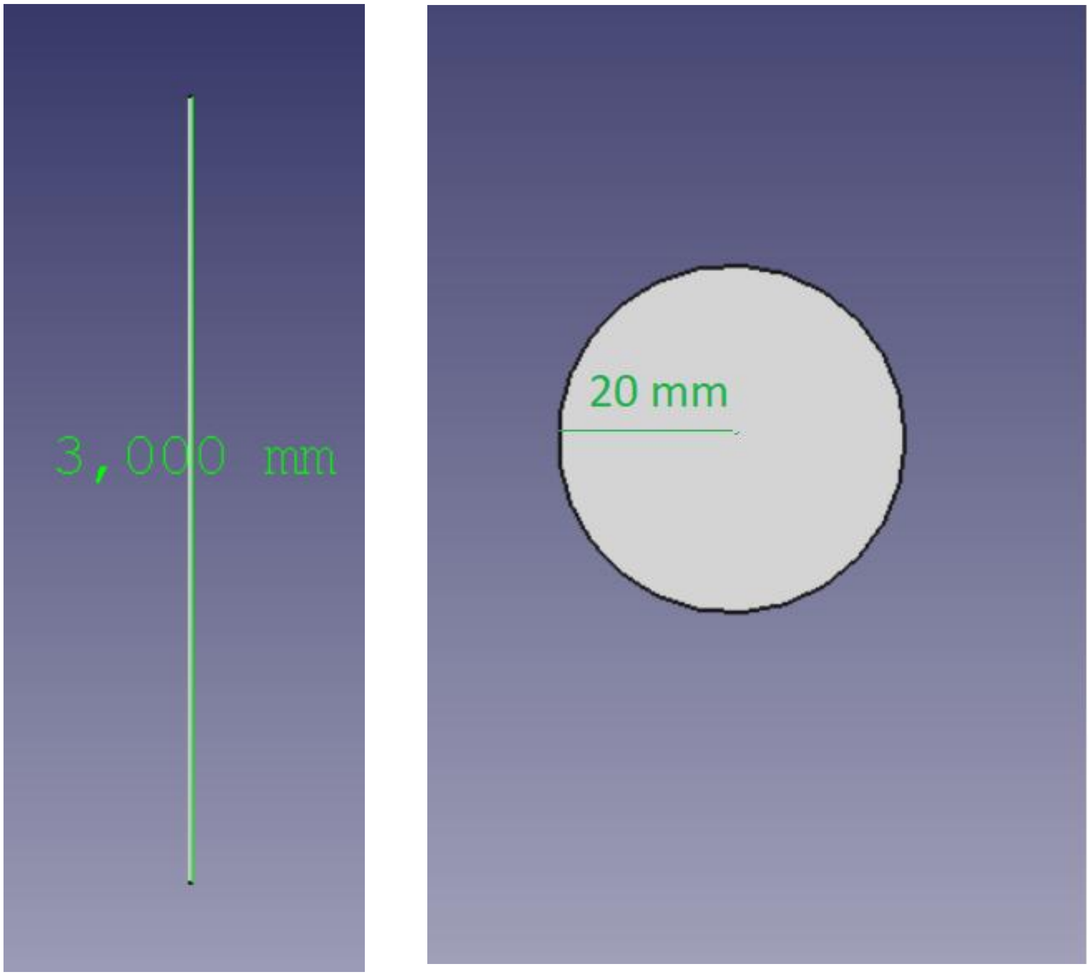


Figure 16 : rotation axis

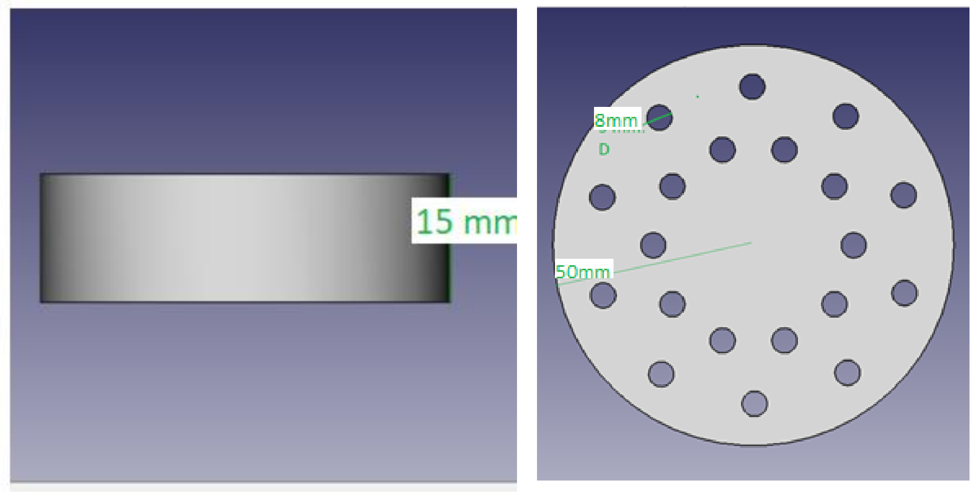


Figure 17 : rotor perforted (20 perforation,)

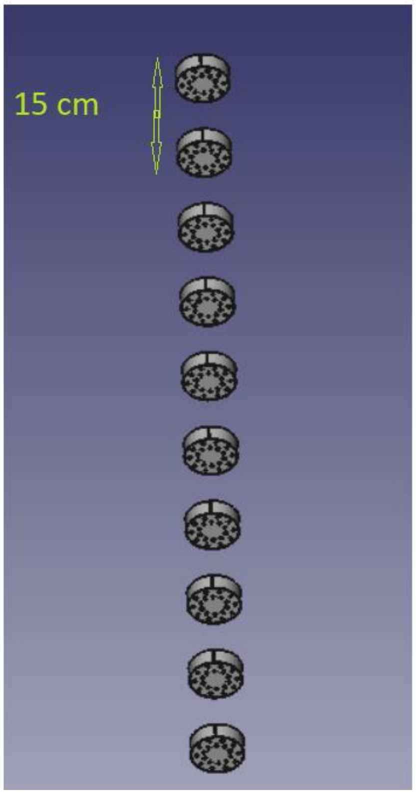


Figure 18 : 10 rotor spaced 15 cm

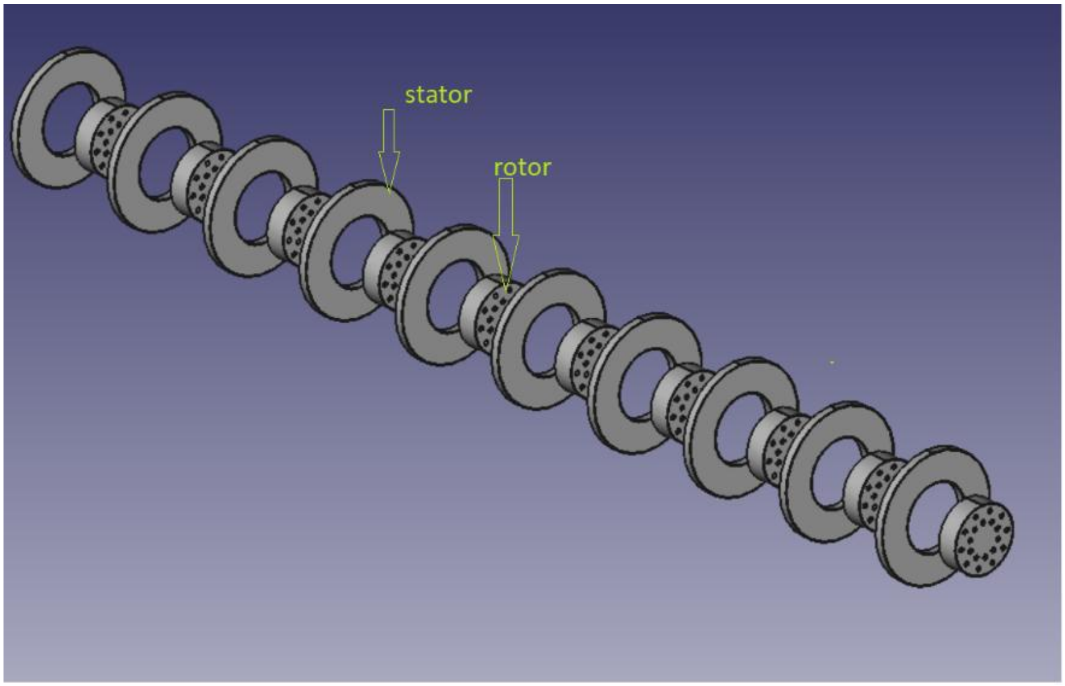


Figure 19 : stator (10 pieces) with rotor

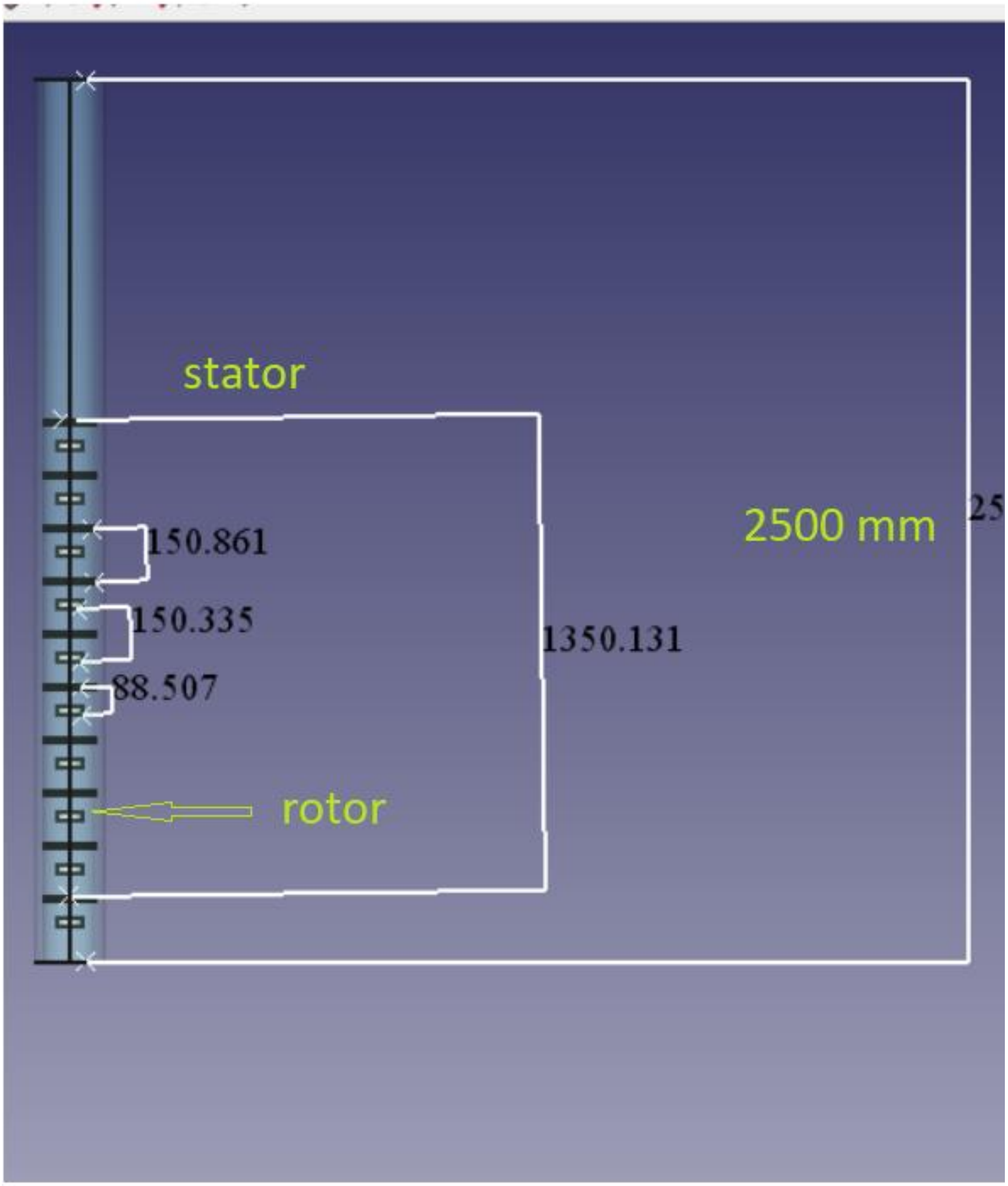
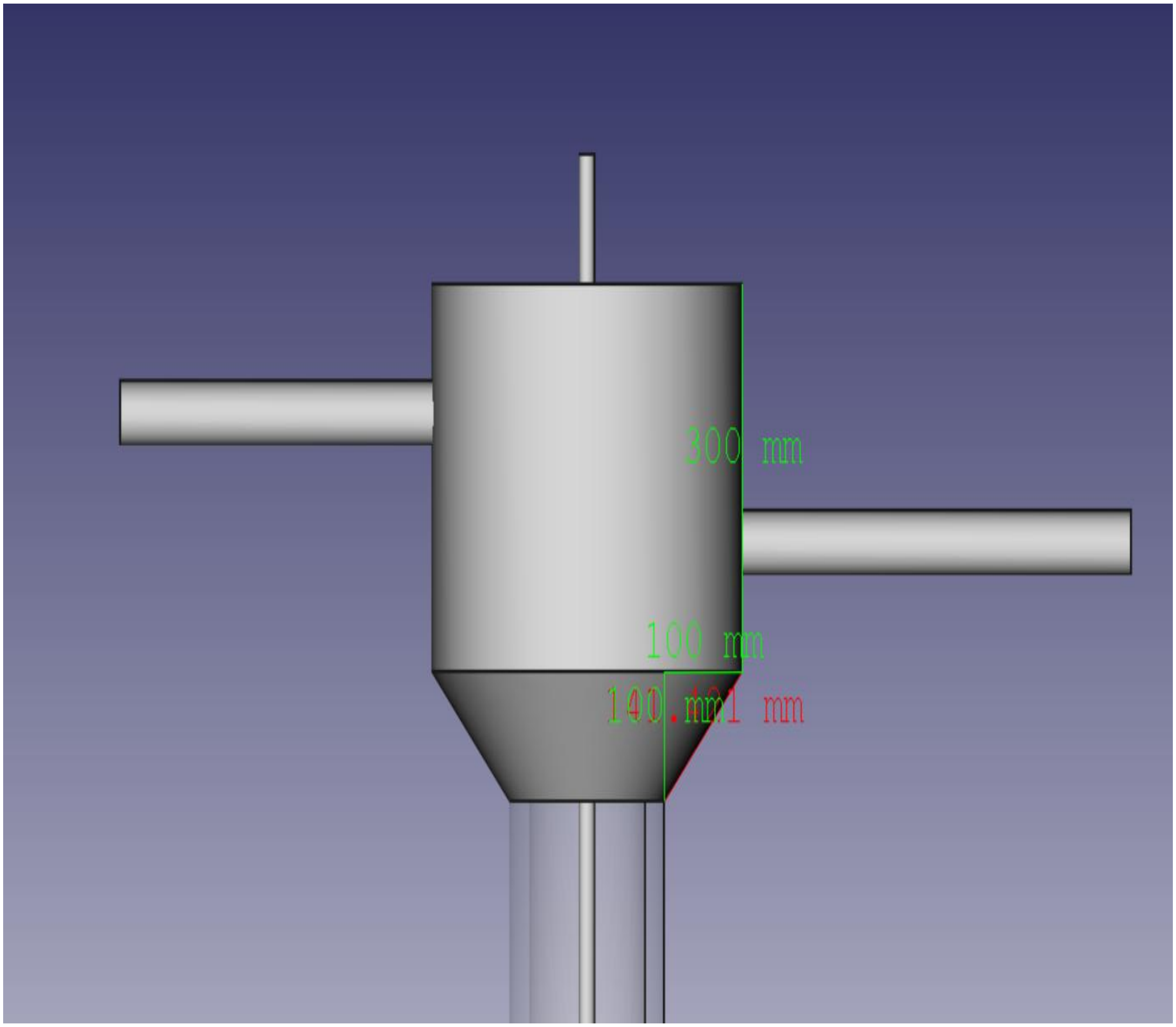


Figure 20 :Distribution of rotors and stators


300 mm
100 mm
140 mm
140.401 mm

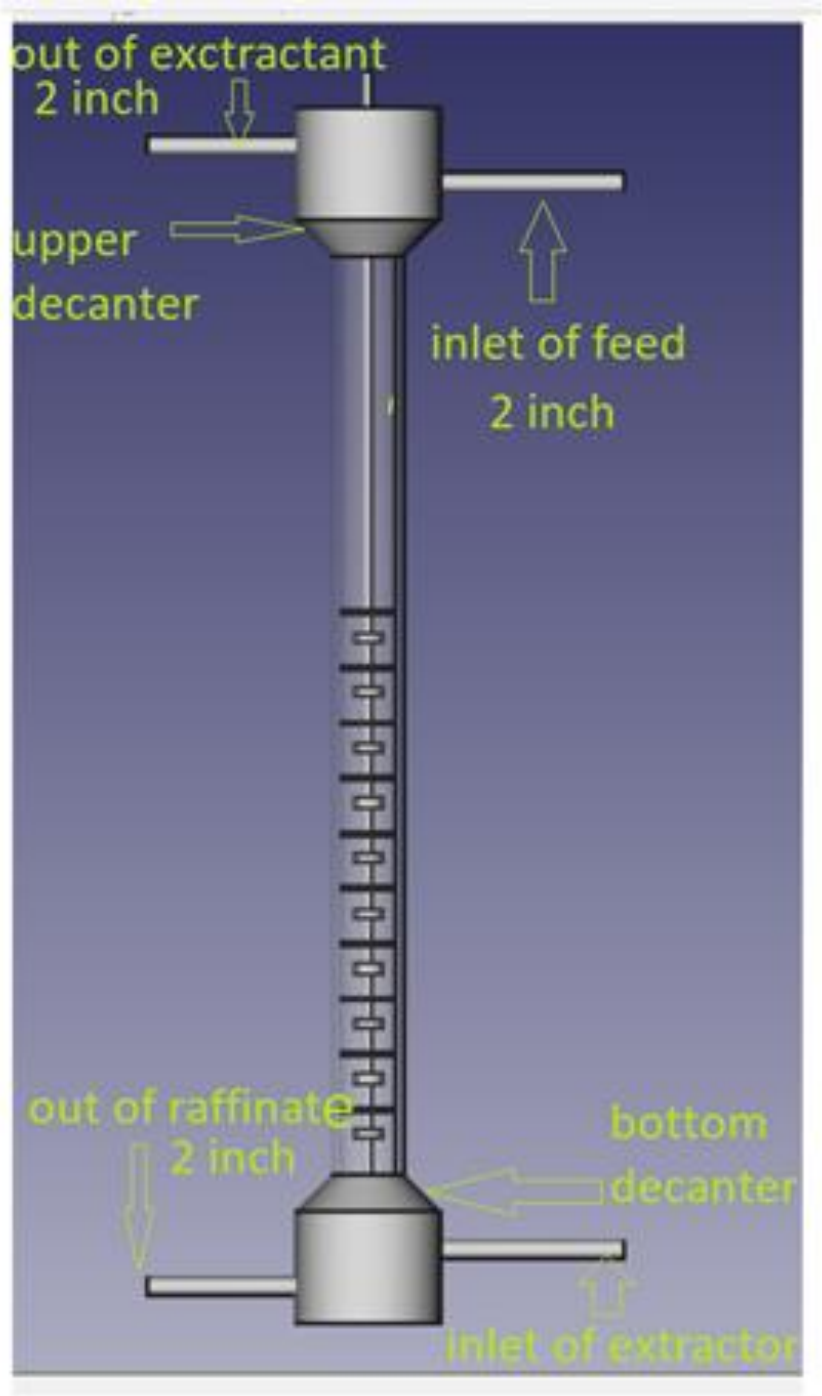


Figure 21 :upper and bottom decanter (200 mm of radius, height 300 mm Cone r1=200mm, height 100 mm)

parts	Freecad files
Column	column06082018.FCStd
Rotation axis	column wih rotation axis140818.FCStd
Stator	stator 06082018.FCStd
rotor	rotor 06082018.FCStd
System	FINAL DESIGN OF COLUMN140818.FCStd

Table 7 :list of parts that formed a system of extraction