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EFFICIENCY OF EVAPORATOR USING STEADY STATE SIMULATION IN ASPEN PLUS TO REDUCE ACID SOLUTION DISPOSAL COST

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யாதும் ஊரேயாவரும் கேளிர்

- கணியன்பூங்குன்றனார்

Per noi tutte le citta sono nostre, tutti i nostri parenti

- *Kaniyan Poongunranar*

(Tamil poet)

I am a world citizen, every citizen is my own kith and kin

- *Kaniyan Poongunranar*

Ringraziamenti

First, I would like to thank my parents for their support and blessing. I would like to extend my regards to my friends and teachers for their strong support and guidance, which made me complete. I would like to specially thank Mr.Marc saulnier, Mr. Emanuele saiu and Mr. Alberto gualandris and Erica ziglioli my project leader who gave me an opportunity to do my thesis work in TDK FOIL(Italy) and guided me for a 6 months in my professional platform, In which I have gained an immense amount of practical knowledge and these work platform has molded me as a chemical engineer by which I could handle the tasks assigned to me in a smarter way.

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I feel blessed to get Caring Parents, Loving Friends and Supporting Mentor & Guide.

Milano, July 2020

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Abstract

Simulation of evaporator unit process by using electrolyte solution is gaining importance and so the process needs to be studied and better ideas suggested such that the disposal cost of the acid solution is reduced. With the advent of computers and simulating software's like "ASPEN PLUS" it is possible to design and optimize a process. Proper study of the process helps to improve plant efficiency and reduce disposal cost of acid solution. The material, unit operation and processes involved are been identified. Steady state simulation is done. Each unit is taken into consideration and the variables are being optimized. Studied using gap analysis, FMEA to continuous monitoring of process.

Keyword: steady state simulation, evaporator, aspen plus software

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Chapter 1

1. Introduction

TDK, la 電気化学工業(Tōkyō Denki Kagaku Kōgyō), Is a Japanese company , founded in 1935 and initially active in the field of ferrite . After the end of the Second World War , TDK became one of the largest producers of magnetic media and electronic components, both for domestic and industrial use.

EUROPE	ASIA	AMERICA	JAPAN
<ul style="list-style-type: none">•Passive components•Power supplies•Hall Sensors & Embedded Controllers•High Performance MEMS Inertial Sensors•ASIC Development & Supply, Custom IC Design	<ul style="list-style-type: none">•Passive components•Power supplies•Magnetic applictaion products•Energy device	<ul style="list-style-type: none">•Passive components•Power supplies•Magnetic applictaion products•Sensors	<ul style="list-style-type: none">•Head quaters•Power supplies

Manufacture of aluminum electrolytic capacitor

(1) Etching

To obtain higher capacitance, surface area of aluminum foil for electrolytic capacitor increases through etching process. In etching process, aluminum foil is applied with DC or AC current in a chloride solution to preferentially dissolve the surface. Surface area is increased by 60-150 times for low voltage foils and 10-30 times for high voltage

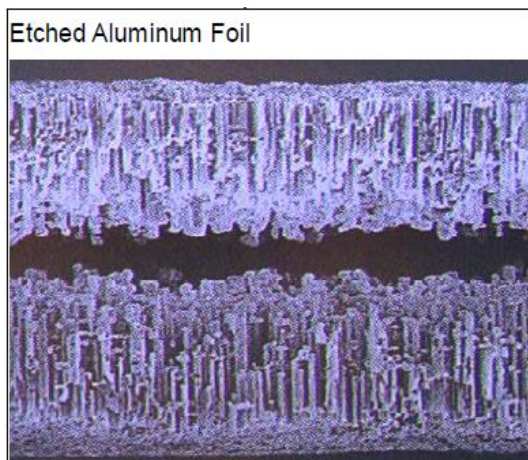


Figure 1.1. Etched Aluminum Foil

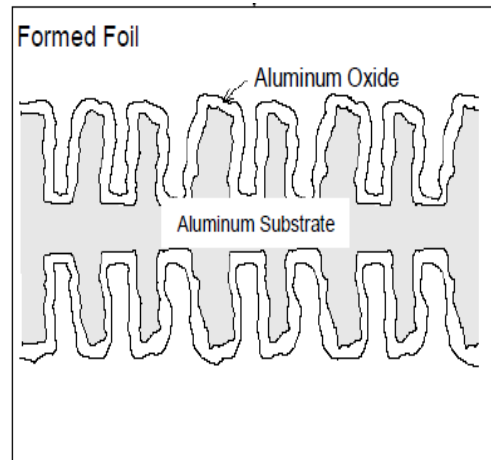


Figure 1.2. Formed Foil

(2) Anodization (Formation of Dielectric Layer)

Aluminum foil for electrolytic capacitor is further formed with anodic oxide film (Al_2O_3) on the surface as dielectric layer. Etched aluminum foil is immersed into a solution including ammonium salt of boric acid or phosphoric acid and applied with DC voltage so that the foil becomes positive and the solution becomes negative. Then aluminum oxide film is formed on the surface in proportion to the applied voltage. The anodic oxide film, having the thickness of 13-15 angstrom/V (1.3-1.5 nm/V), is extremely thin, compact and highly insulating.

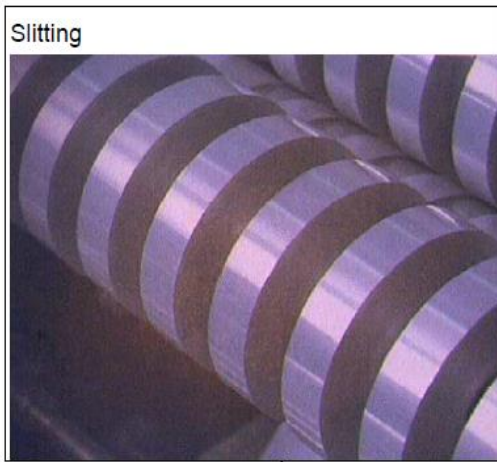


Figure 1.3 Slitting process



Figure 1.4 Stitching and Winding

(3) Slitting Process

Etching and Forming are processed with wide roll of master foil. Then the master roll is slitted into individual rolls with specified width as per the specification.

(4) Stitching and Winding

Slit anode and cathode foils after slitting process are stitched with lead tabs and wound into cylindrical element together with spacer paper. Spacer paper is to contain liquid electrolyte that works as real cathode and restores damaged dielectric film, as well as maintaining the distance between anode and cathode foils constant to prevent short circuit.

(5) Impregnation

Wound element is immersed into electrolyte bath under either low air pressure condition or normal pressure to impregnate. Electrolyte contains one or more polyhydric alcohols such as ethylene glycol as the major solvents and one or more ammonium salts as solutes to restore the damaged oxide film (dielectric) and significantly improve the performance and life of the capacitor.

(6) Assembling

Rubber seal, rubber-lined terminal plate or molded terminal plate is attached to impregnated element.

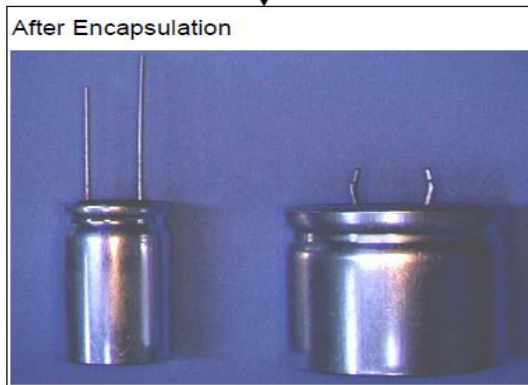


Figure 1.5. After encapsulation

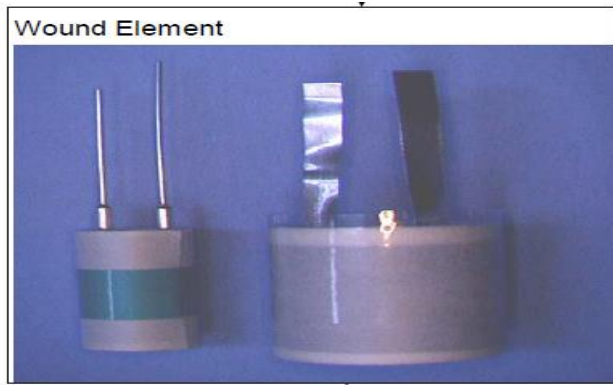


Figure 1.6 Wound element

(7) Encapsulation

Capacitor element is put into aluminum case and sealed together with rubber seal or terminal plate. Materials to seal up capacitor are EPT or IIR, which is selected depending on the capacitor series.

(8) Sleeve

Sealed capacitor is covered with sleeve made of heat shrinkable PVC or PET. The purpose of sleeve is to indicate information of the capacitor. When electric insulation of inner element or aluminum case is required, proper materials shall be selected.

(9) Aging (Reforming)

As described above, the oxide film as the dielectric is formed in Anodization (Forming) Process, but aluminum substrate is exposed during slitting process and stitching process. Oxide film layer is possibly damaged or cracked during winding. Restoring oxide film is necessary for capacitor to fully function. In this process, capacitors are applied with DC voltage in high temperature atmosphere to repair damaged oxide film. Aging makes leakage current of capacitor stable and debugs initial failure.

(10) Process Inspection & Packaging

Capacitors finished with aging are packaged through electrical screening and appearance inspection.

(11) Outgoing Inspection

Outgoing inspection is conducted based on our own sampling plan and criteria

Chapter 2

2. TDK foil Italy & Iceland

TDK Foil produces anodized aluminum foil for electrolytic capacitors. An electronic component used to store an electric charge, consisting of one or more pairs of conductors separated by an insulator. An aluminum electrolytic capacitor is made by winding the conductors (anode and cathode), separated by an insulator (paper). The anode must be oxidized to allow the capacitor to work

Plant Milan, Italy

- Aluminum high voltage etched foil for electrolytic capacitors (anode foil)
- Cathode foil for electrolytic capacitors
- Tab foil for electrolytic capacitors

Plant Akureyri, Iceland

- Aluminum high voltage formed foil for electrolytic capacitors

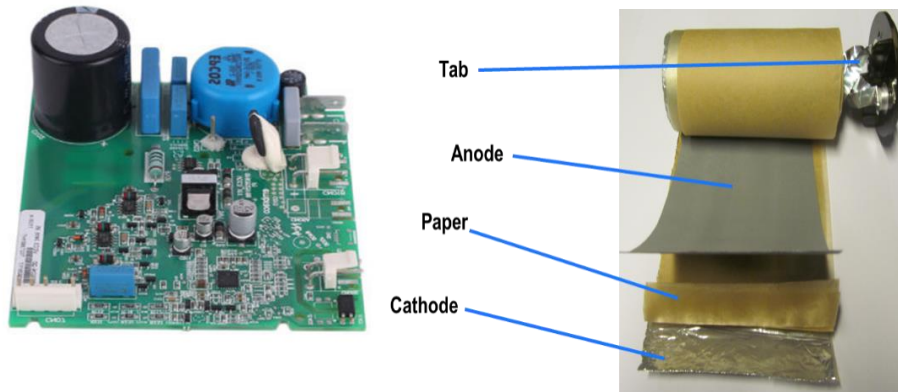


Figure2.1. Aluminium electrolytic capacitor with cathode and anode foil

The production process happens in a microscopic world with two main steps. *Etching* (in Milano – Italy Plant) and *Forming* (in Akureyri – Iceland plant) In etching, several

electrochemical processes are used in order to enlarge the surface area of an aluminum foil and obtain high specific capacitance. At the most advanced high gain foils we create 26 Mio tunnels per cm^2 with ca. 30% of Aluminum is dissolved generating Al salts. In forming the dielectric layer of aluminum oxide is created by anodization.

A thicker oxide layer means a higher insulation of the anode foil => higher final voltage at which the capacitor can work.

The forming process is energy intensive: to build an oxide layer at 600 V more than 70 kWh per sqm are consumed.

*A family in Milano area has a **yearly** consumption of 2.000 kWh of energy (Istat 2011)
Our forming process takes **1h 40min** to use the same amount of energy*

Figure 2.1 shows how the aluminum electrolytic capacitor wound and attached to the electric circuit board.

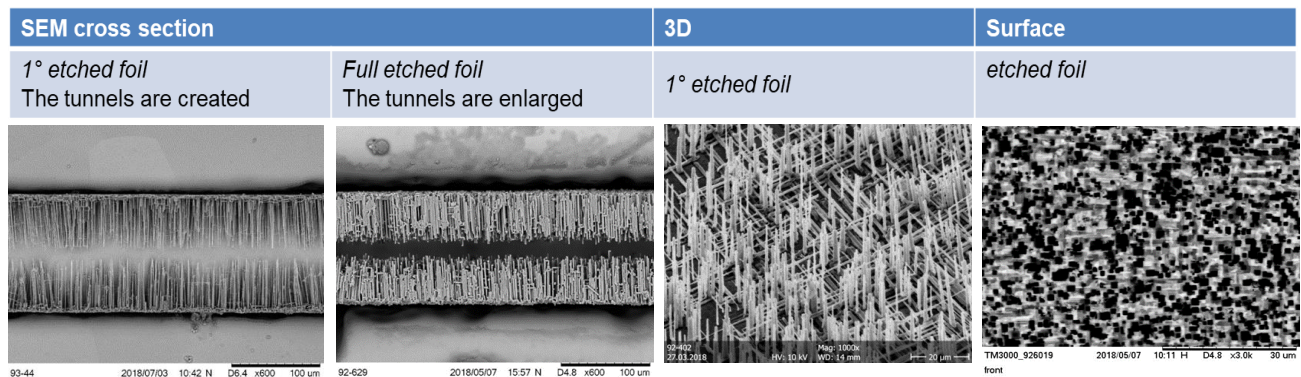


Figure2.2. SEM cross section of foil

Fig 2.2 shows how tunnels formed during different etching process used in electrolytic capacitor.

2.1.General process flow

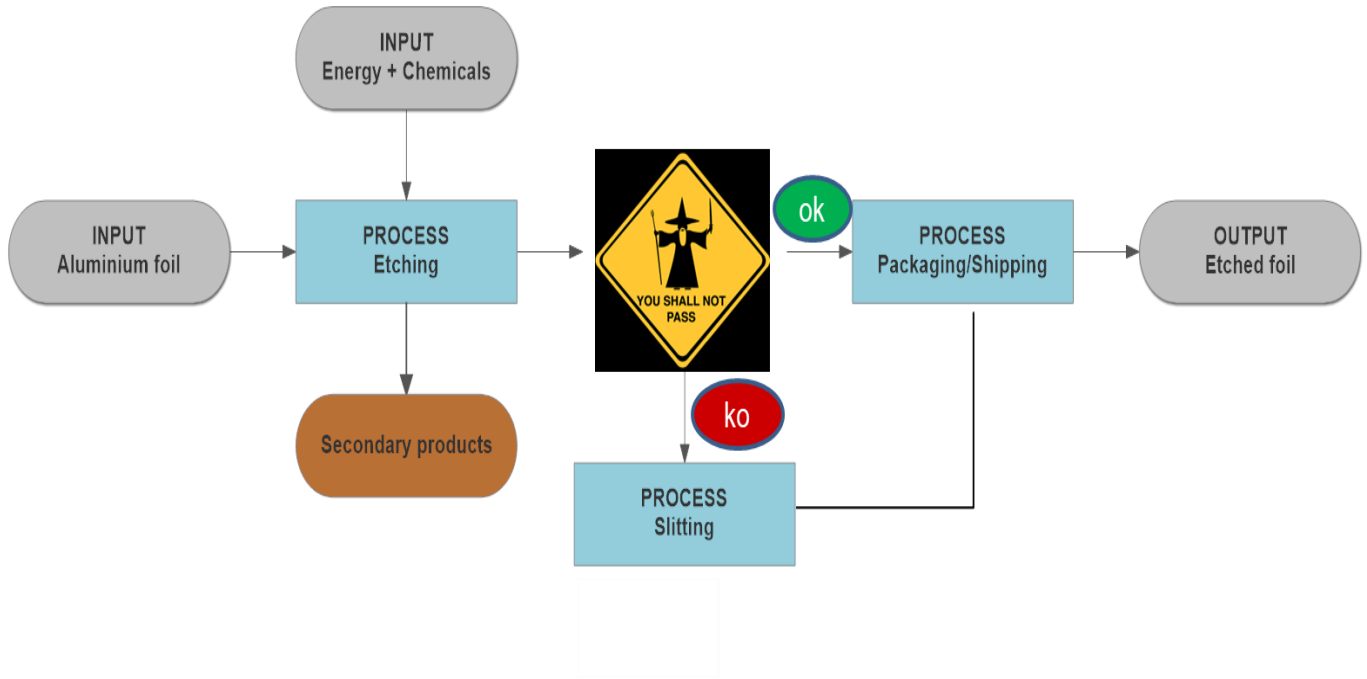


Figure 2.1.1. Block flow diagram of etching process

Block flow diagram shown in the fig 2.1.1. explains us about etching process to till slitting and wounding.

Aluminum electrolytic capacitors are made by layering the electrolytic paper between the anode and cathode foils, and then coiling the result. The process of preparing an electrode facing the etched anode foil surface is extremely difficult. Therefore, the opposing electrode is created by filling the structure with an electrolyte. Due to this process, the electrolyte essentially functions as the cathode. The basic functional requirements for the electrolyte are as follows:

- Chemically stable when it meets materials used in the anode, cathode, and electrolytic paper.
- Easily wets the surfaces of the electrode.
- Electrically conductive.
- Has the chemical ability to protect the anode oxide thin film and compensate for any weaknesses therein.
- Low volatility even at high temperatures.
- Long-term stability and characteristics that take into consideration such things as toxicity.

The grown oxide layer, resulting from the solute and the solvent (electrolyte), greatly controls the performance of the aluminum electrolytic capacitor.

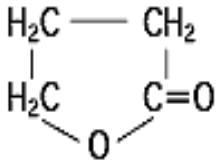
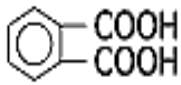
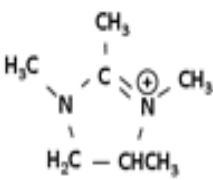
	Type	Typical Compound	Chemical Formula	Structural Formula	
Solvent	Glycol	Ethylene glycol	C ₂ H ₆ O ₂	$\begin{array}{c} \text{CH}_2\text{OH} \\ \\ \text{CH}_2\text{OH} \end{array}$	
	Lactone	γ -Butyrolactone	C ₄ H ₆ O ₂		
Solute	Acid	Aliphatic carboxylic acid	Adipic acid	C ₆ H ₁₀ O ₄	HOOC(CH ₂) ₄ COOH
		Aromatic carboxylic acid	Phthalic acid	C ₈ H ₆ O ₂	
	Base	Ammonia	Ammonia	NH ₃	NH ₃
		Amine	Triethylamine	C ₆ H ₁₅ N	N(C ₂ H ₅) ₃
		Amidine	Tetramethylimidazolium	C ₇ H ₁₅ N ₂	

Table 2.1.1. Composition of the Electrolyte

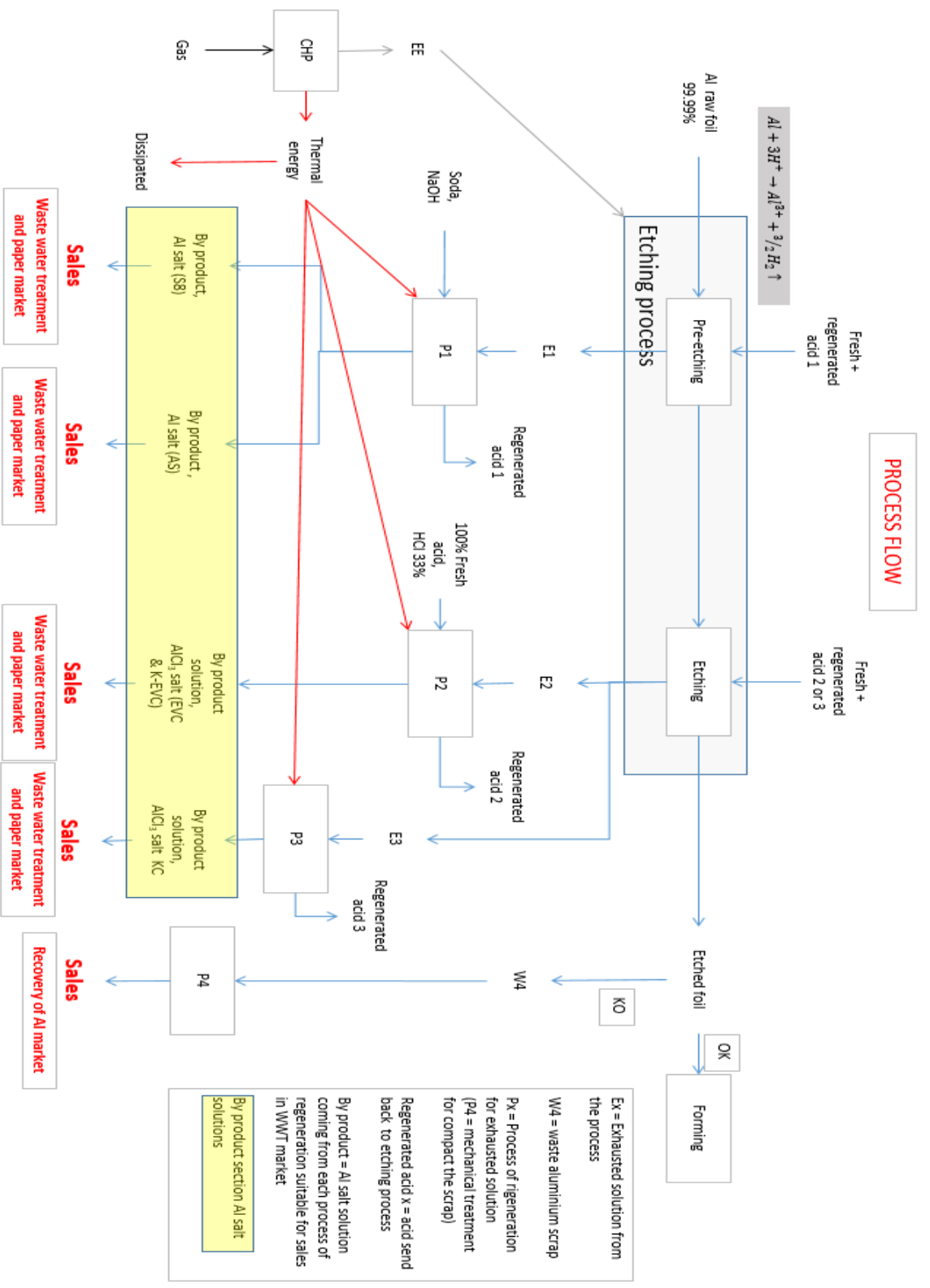


Figure 2.1.2. Schematic flow diagram of pre-etching and etching process

Chapter 3

3. Process explanation

An aluminum foil is used as a raw material for all the process in the company, the main process involved in anode foil and cathode foil production is pre-etching and etching. A production of foil mainly depends on the acid solution and their pH level of the solution. Solution used in all the process are recycled.

3.1 Anode foil production

Anode foil are produced by four process steps pre-etching and chemical etching, nitric etching and nitric washing for pre-etching process we use H_2SO_4 and HCL solution and a solution is recycled by becropour unit and finally gives secondary products as AS, AA, S8, Aluminum hydroxide and product foil

Chemical etching process we use HCL and Nickel phosphorous solution to give TK1 byproduct and product foil and in nitric etching we use HNO_3 and H_2PO_4 solution to get EVC byproduct and anode foil for aluminum electrolytic capacitors.

Tk1(aqueous solution of aluminum chloride in hydrochloric acid) is a byproduct solution obtained from chemical etching process that solution is concentrated using evaporators CL1, CL2 to give final product as KC (aqueous solution of aluminum chloride in hydrochloric acid)

EVC (aqueous solution of aluminum chloride in hydrochloric acid) is a byproduct solution obtained from nitric etching process that solution is concentrated using evaporators CL3, to give a final product K-EVC which we can sale in the market. The solution which is untreated are remains as waste disposal cost for these secondary products. With nitric washing process we get AN as a byproduct solution.

3.2 Cathode foil production

A cathode foil is produced by using a sodium hydroxide and hydrochloric acid, phosphoric acid, ammonium phosphate to give byproduct of KT solution and cathode foil for aluminum electrolytic capacitors.

Chapter 4

4. Chemical plants

All the chemicals are ordered according to the usage with etching machine and maintain with good storage tanks. An acid supplied to the process with correct checking of pH level to maintain good quality of product foil.

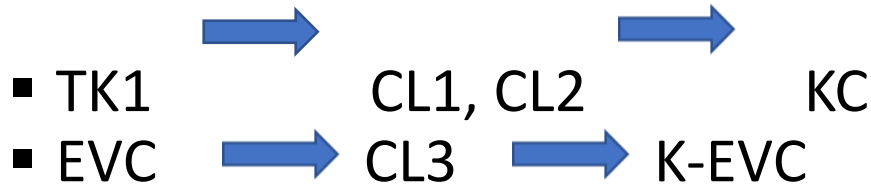
4.1 List of secondary products

The list of secondary products that are produced during the pre-etching and etching process of anode and cathode foil production.

Code name for product	production	Components contain
KC	Chemical etching	Al_2O_3 , H^+ , Ni, PO_4^{3-} , NH_4^+
AN	Nitric washing	Al_2O_3 , H^+ , Ni, NH_4^+
S8	Pre-etching	Al_2O_3 , H^+ , Ni, PO_4^{3-} , NH_4^+ , Cl^- , Na
EVC	Nitric solution regeneration	Al_2O_3 , H^+ , Ni, PO_4^{3-} , NH_4^+
AS	Pre-etching	Sulphuric acid diluted
KT	Cathode foil solution	Al_2O_3 , H^+
AAH	Combination of secondary products	Amorphous aluminum hydroxide
K-EVC	Concentrating EVC	Al_2O_3 , H^+ , Ni, PO_4^{3-} , NH_4^+
TK1	Chemical etching	Al_2O_3 , H^+ , Ni, PO_4^{3-} , NH_4^+
AA	Anode foil pre-etching process	Sulphuric acid diluted

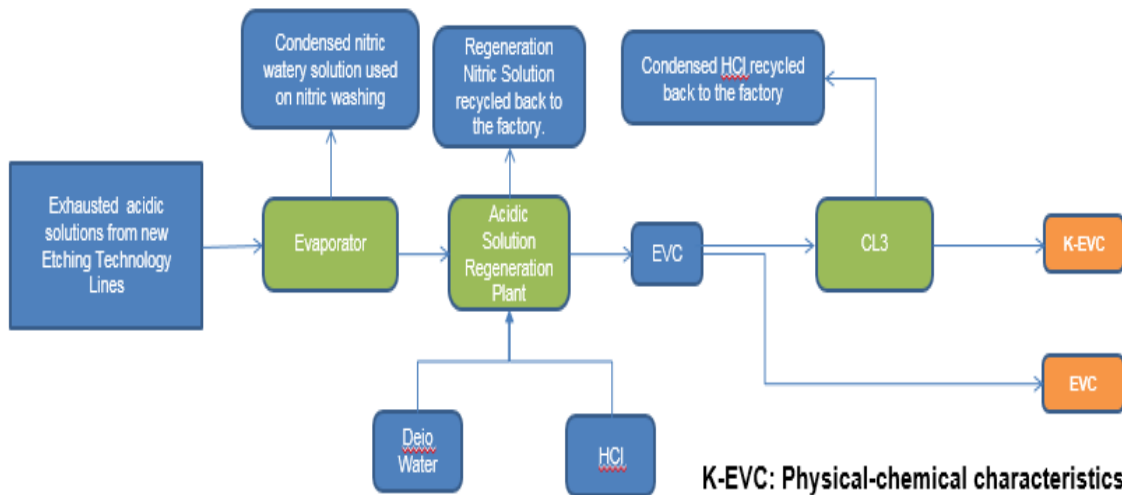
Table 4.4.1. List of secondary products from different etching process

All the secondary products are sold to other chemical companies except EVC and TK1 consider as disposal waste which company must pay disposal cost. Usually EVC solution is produced from nitric solution regeneration column and TK1 solution is produced from chemical etching process. Production quantity of both solutions depends upon the number of etching machines under manufacturing anode foil.



TK1 solution is concentrated using evaporator CL1, CL2 to give a product KC and EVC solution is concentrated using evaporator CL3 to give product K-EVC. The concentrated products are sold out. So due to the overflow of the tank and feed solution remains untreated are considered as a disposal waste.

EVC & K-EVC: Aqueous Solution of Aluminum Chloride in Hydrochloric Acid



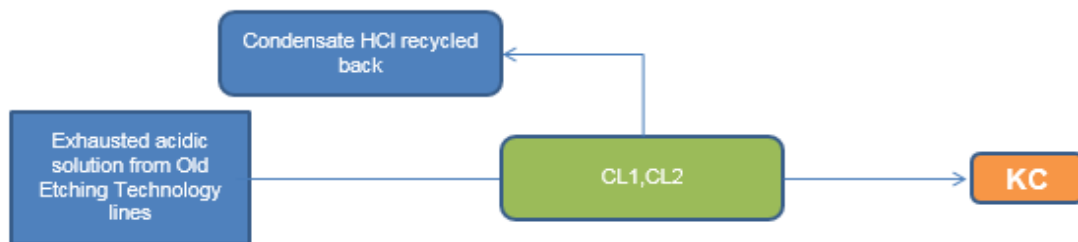
EVC: Physical-chemical characteristics

Concentration in Al₂O₃ (%): 2,5 ± 0,3
 Concentration free HCl (%): 5,0 ± 1,0
 pH: < 1
 Relative Density at 20 °C (g/cm³): 1,06 ± 0,02

K-EVC: Physical-chemical characteristics

Concentration in Al₂O₃ (%): 2,5 ± 0,3
 Concentration free HCl (%): 2,0 - 4,0
 Ammonium: <6000 ppm
 Phosphor: <400 ppm
 pH: < 1
 Relative Density at 20 °C (g/cm³): 1,06 ± 0,02

KC: Aqueous Solution of Aluminum Chloride in Hydrochloric acid



KC: Physical-chemical characteristics

Aluminum content (Al₂O₃) (%): 9,0 ± 0,5
pH < 1
Relative Density at 20°C (kg/l): 1,23 ± 0,02
Freezing Point (°C) < -10
Heavy Metals < 1ppm Nickel: 140 ± 20 ppm

Chapter 5

5. Current installation and performance

The evaporator plants in the Becromal (TDK FOIL) allow concentrating different acid solutions by exploiting the degree of vacuum (low pressure) that occurs in the evaporation chamber present in these plants. Based on their operating principle, we avoid heating the solutions at very high temperatures (thus saving on the supply of thermal energy to be supplied to the system),

Taking advantage of the thermodynamic principle whereby a lowering of the pressure on a constant volume favours the evaporation of the aqueous part of the solution (since the boiling temperatures of the acids in use are always higher than the boiling temperatures of the water)

The system as a whole consists of a preheater (plate and frame heat exchanger) inside which the acid solution is heated by heat transfer rate with "hot" decalcified water; a concentrator (evaporation chamber) consisting of a tank in which a degree of vacuum is achieved by means of a liquid ring pump in which the solution to be concentrated is fed; a condenser, consisting of a graphite block heat exchanger, which allows to condense the vapors that move away from

the concentrator (and conveyed to the condenser) by means of cooled decalcified water, fed in counter-current. The vacuum pump is located downstream of the condenser.

The acid solution to be concentrated is kept in continuous recirculation between the concentrator and the preheater, by means of a circulation pump, and the entire plant is adjusted to the density of the solution to be concentrated. On the bottom of the concentrator, in fact, a density meter is installed which activates the opening of the solution discharge valve, when the density of the acid solution has reached the desired set-point value (corresponding to a higher concentration in terms of acidity) and simultaneously with the discharge of the concentrated solution, the opening of a supply valve of the diluted solution coming from the production departments is activated and suitably stored in a storage tank.

The simultaneous opening of the two valves (loading and unloading) serves to keep constant both the flow rate circulating in the system and the level of liquid head inside the concentrator in order to ensure correct operation of the entire system.

The concentrated solution is collected in a special tank and reused in the plant thus saving on fresh acid consumption. The condensates are sent to the WWT plant, where their low residual acidity is broken down by chemical neutralization.

The hot water for heating the circulating solution is convenient because the heat recovered from the cogeneration plants is reused; as well as the use of decalcified water cooled by closed circuit cooling towers in order to condense the generated vapors.

As an alternative to cooling tower water, cooling water generated by a lithium bromide absorber, installed on the second cogeneration plant, can also be used.

The condensation rate is generally depending on the temperature of the cooling water used in condenser and vacuum maintained in the system.

Performance of CL 1 (Evaporator 1) year 2018-2019

Diluted feed solution	32.393 L/day
Concentrated solution	5255 L/day
Ratio between dilution/concentration	6.16 L/day

Performance of CL 2 (Evaporator 2) year 2018-2019

Diluted feed solution	30.496 L/day
Concentrated solution	4000 L/day
Ratio between dilution/concentration	7.62 L/day

Performance of CL 3 (Evaporator 3) year 2018-2019

Diluted feed solution	36.000 L/day
Concentrated solution	7500 L/day
Ratio between dilution/concentration	4.27 L/day

Table 5.1. performance of evaporators

Above tables explain us how system works currently and to improve efficiency of our system need to detect missing measure, information, data, errors in measure, non-conventional behavior of the system.

Gross errors in the system is detected and eliminated using data reconciliation and plant performance is monitoring to improve its efficiency and then simulation is performed to understand the deep process knowledge.

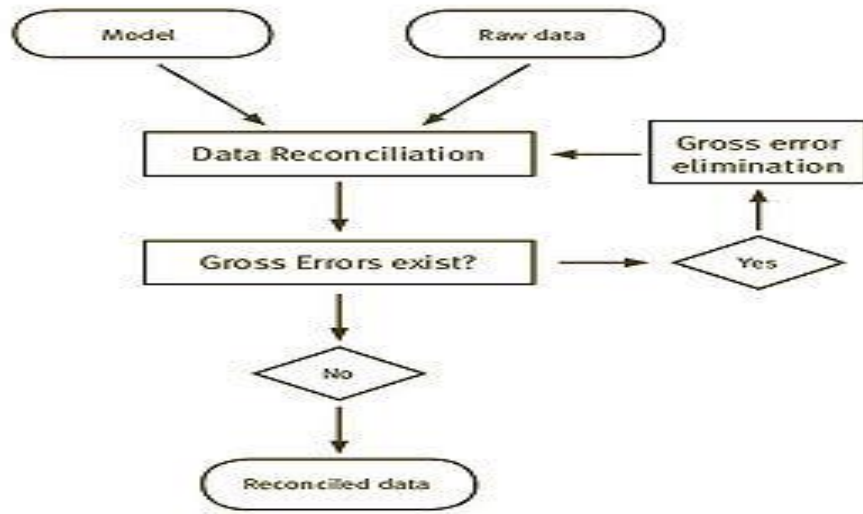


Figure 5.1. Data reconciliation

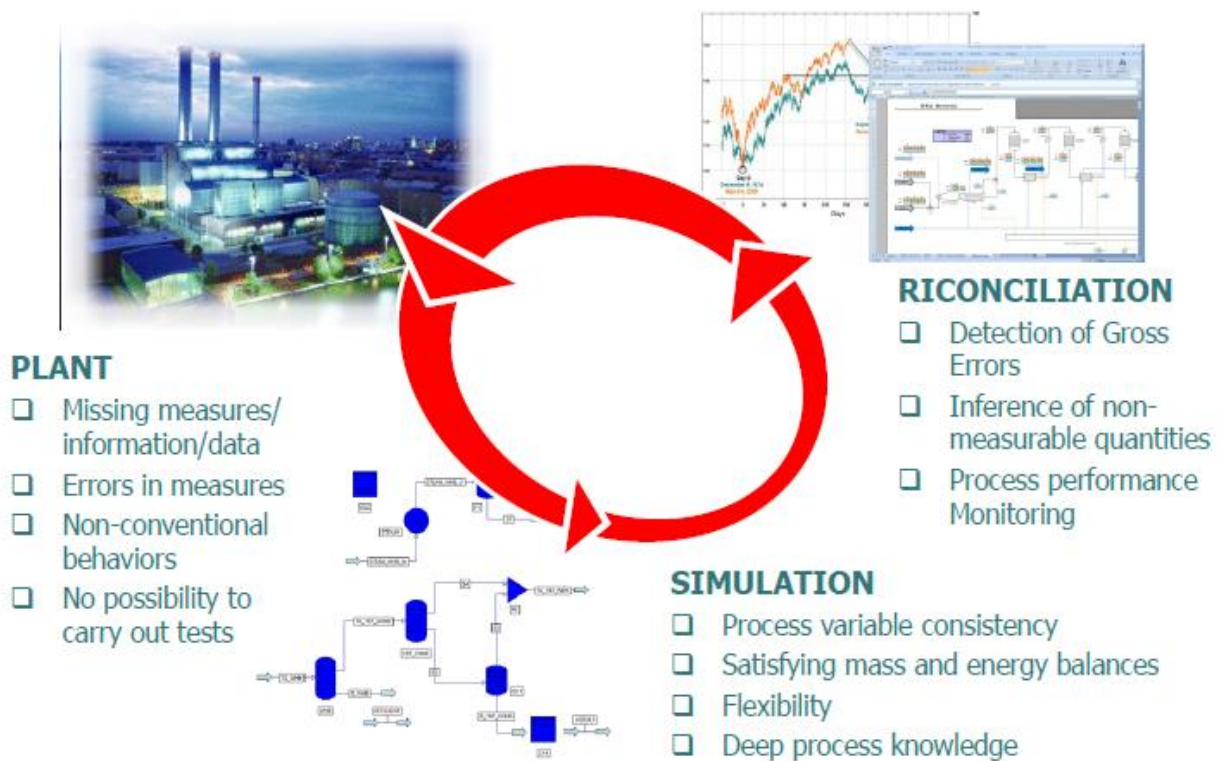


Figure 5.2. Schematic flow diagram of the project

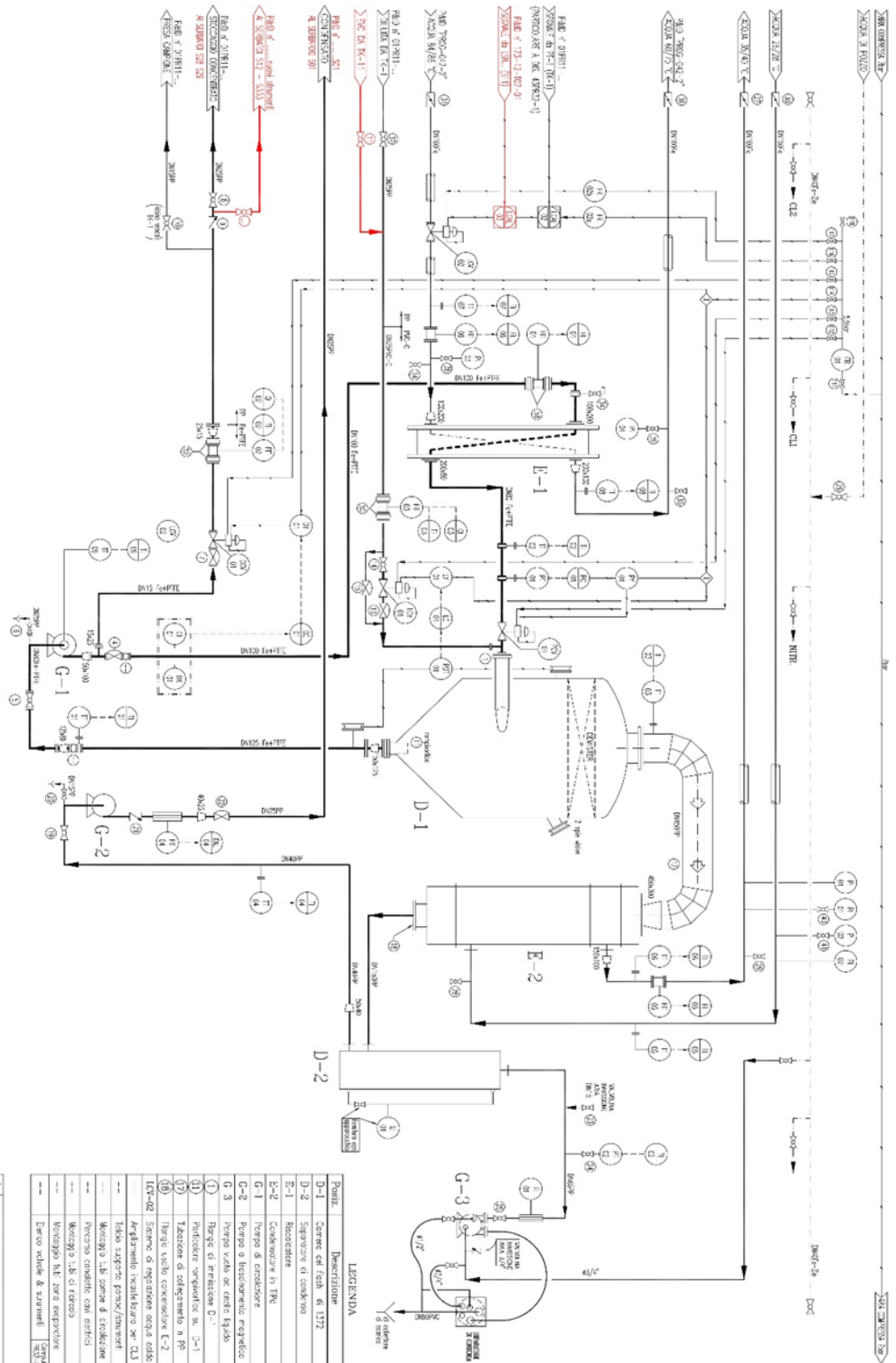


Figure 5.3. Evaporator P&ID

Posiz.	Descrizione	Ref. Disegno
D-1	Corrente del fusto n. 1372	323PR32-1
D-2	Scappatoie di condensa	317PR32-0
E-1	Riscaldatore	381PR32-0
E-2	Condensatore in FRV	391PR32-0
C-1	Imposta di circolazione	---
C-2	Ripresa o trascinamento refrigerante	---
C-3	Ripresa vuoto or cede liquido	331PR32-0
(1)	Purgatore di refrigerante su D-1	341PR32-0
(2)	Talcozona di collegamento in PE	361PR32-0
(3)	Imposta vuoto condensatore E-2	351PR32-0
ICV-02	Scambio di impugnone acqua calda	441PR32-1
---	Intero sistema pompaggio/acquari	451PR32-0
---	Macchine L&L zona di circolazione	461PR32-0
---	Processo condensa con estrazione	471PR32-0
---	Macchine L&L di recupero	481PR32-0
---	Macchine L&L zone evaporatore	491PR32-0
---	Macchine L&L zone condenser	501PR32-0
---	Macchine L&L zone di recupero	511PR32-0
---	Macchine L&L zone di recupero	521PR32-0
---	Macchine L&L zone di recupero	531PR32-0
---	Macchine L&L zone di recupero	541PR32-0
---	Macchine L&L zone di recupero	551PR32-0
---	Macchine L&L zone di recupero	561PR32-0
---	Macchine L&L zone di recupero	571PR32-0
---	Macchine L&L zone di recupero	581PR32-0
---	Macchine L&L zone di recupero	591PR32-0
---	Macchine L&L zone di recupero	601PR32-0

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REVISIONI

Rev.	Descrizione	Data
1	Disegno	15/01/2000
2	Revisione	15/01/2000
3	Revisione	15/01/2000
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5	Revisione	15/01/2000
6	Revisione	15/01/2000
7	Revisione	15/01/2000
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9	Revisione	15/01/2000
10	Revisione	15/01/2000

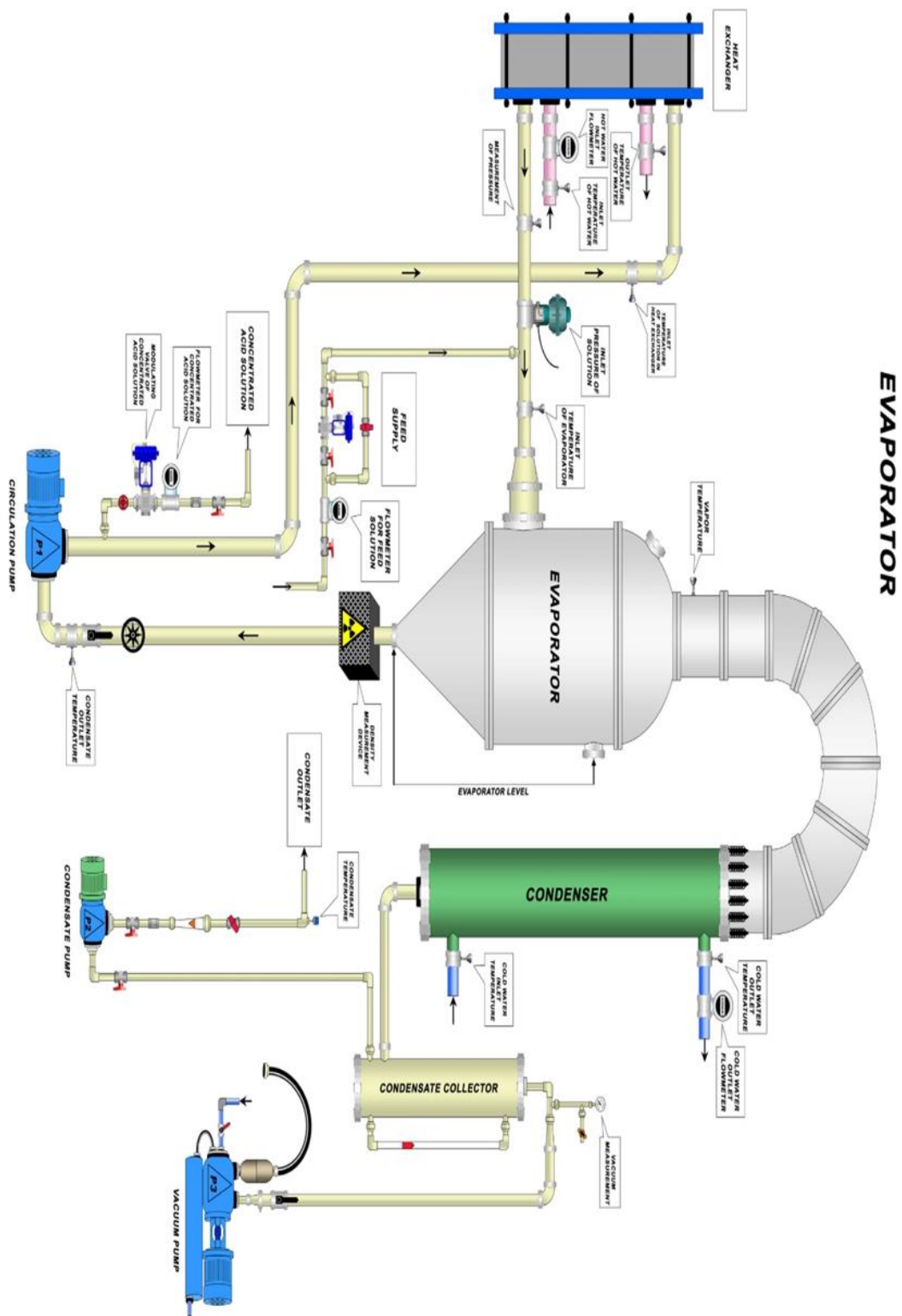


Figure 5.4. Evaporator PFD

Chapter 6

6. Gap analysis of evaporators (CL 1, CL 2, CL 3)

Gap analysis is the process that compares actual performance or results with what was expected or desired. The method provides way to identify the process knowledge. Gap analysis is performed by the team to detect instrumentation failure, PLC failure, indicators, transmitter, all three evaporators PLC audit and understanding better knowledge of the process to get efficiency of the evaporator.

Instrumentation error has been detected according to the priority scale 1 to 4, scale 4 has more priority then scale 1. And a list should be checked by maintenance team for the maintenance of instrumentation error and failure to monitor the efficiency of the process.

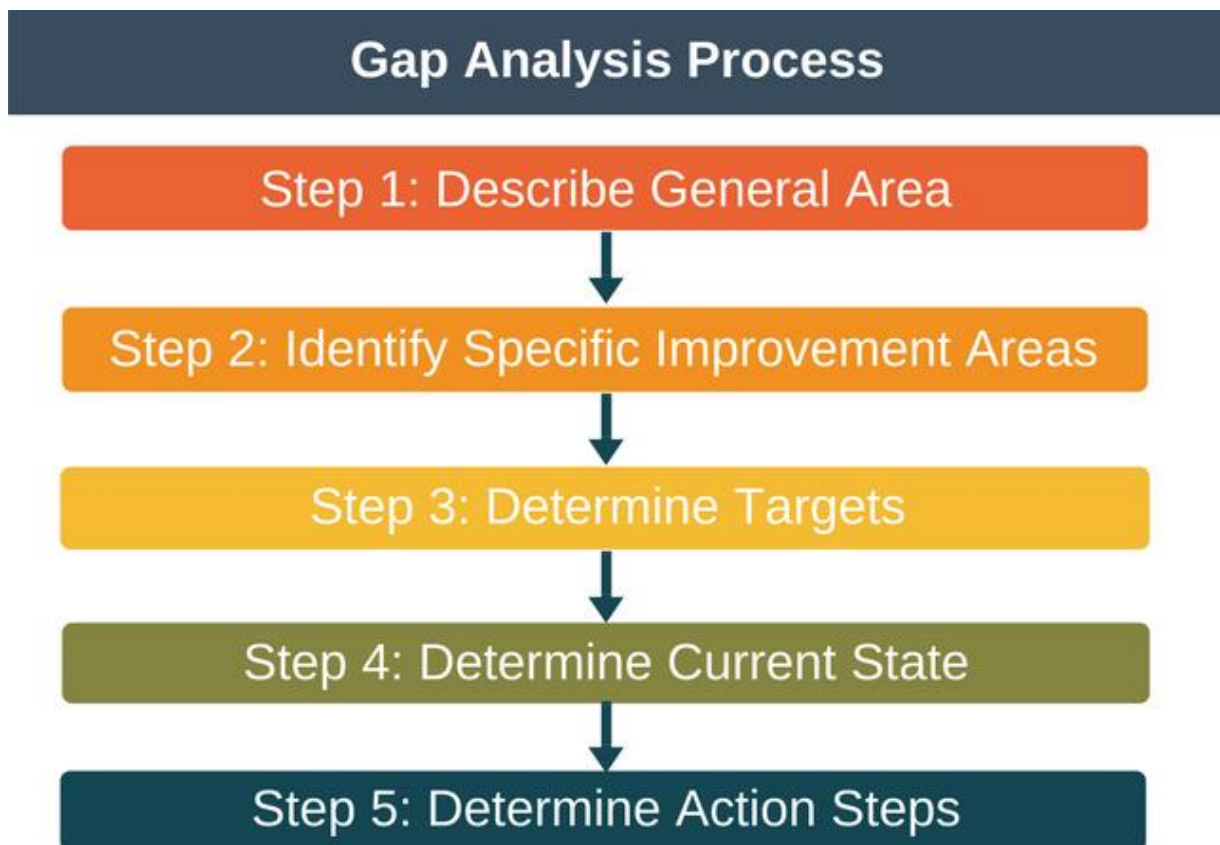


Figure 6.1 Steps involved in gap analysis

Step 1- Describe General Area

In this step we describe the general area that we want to analyse and improve. This may seem like an unnecessary step, but by performing it, we not only highlight what general area is under investigation, but also what areas are not under investigation.

This helps to avoid scope creep and keeps the rest of the analysis very focused. For example, we might decide to analyse our online marketing efforts. This then implies that we are not investigating our offline advertising such as print and TV. By being very clear about what we are, and what we are not investigating, we keep everyone involved on the same page.

Step 2- Identify Specific Improvement Areas

In this step we identify specific areas for improvement within the general area described in step 1. For example, if the general area we are investigating is our online marketing, then we may identify content creation and paid advertising as specific areas we'd like to improve.

Step 3-Determine Targets

Now that we have identified our specific improvement areas, the next step is to set targets for each area.

A common input to this step (and the next step) is benchmarking whereby a company will benchmark its performance in an area against its competitor's performance in that same area. The results of this exercise will show areas of underperformance and these areas are then commonly chosen as the improvement areas for this step. Another commonly used input for this step is to analyse industry best practices.

What targets are set will depend on a combination of the time available to address the gap as well as the ambition of the organization.

Step 4- Determine Current State

Now that we understand where we want to get to, it is important to understand where we are before putting the action plan together.

By understanding where we are it makes it more likely we'll create a realistic action plan. It also makes it easier to see if we are making progress towards our desired state, because if we don't know where we started then it's very difficult to measure progress towards our goal.

The difference between step 4 and step 3 is our "gap", that is, the gap between where we are and where we want to be.

Step 5- Determine Action Steps

Now that we understand the gap, we use this final step to describe the improvement steps we will take to close the gap and get to where we want to be. In essence, this step is our action plan to get to where we want to be.

The action plan should be prioritized to deliver the biggest return on investment. One way to do this is to prioritize the most critical gaps first, or to target low hanging gaps first.

Gap analysis of CL 1

Measurement	Symbol	Device	Symbol
		Controllers	C
Pressure	P	Transmitter	T
Temperature	T	Recorder	R
Level	L	Indicator	I
Flow	F	Alarm	A
Analysis	A	Switch safety	S
		Gauge	G

Table 6.1. Common abbreviation tables for gap analysis

Control room panel mounted instrument	Working condition (yes or no)	Function	Priority
FI – 01	SI	Flow indicator of solution in circulation	
FI – 02	SI	Flow indicator of concentrated solution	
FI – 03	NO	Flow indicator of hot water	1
FI – 04	NO	Flow indicator of cold water	1

TI -01	NO	Temperature indicator of concentrated solution	1
TI -02	NO	Temperature indicator IN of hot water	1
TI -03	NO	Temperature indicator OUT of hot water	1
TI -04	NO	Temperature indicator IN of separator	1
TI -05	NO	Temperature indicator of vapor	3
TI -06	NO	Temperature indicator of condensate solution	1
TI -07	NO	Temperature indicator of circulation pump	3
PC – 01	NO	Pressure controller IN	1
LC – 01	SI	Level controller of separator	
PI – 02	NO	Vacuum pressure indicator	1
Vacuum pump indicator			
DC-01	SI	Density indicator	
QI-02	SI	Concentrated solution totalizer	
FAL-04	NO	Minimum flux of condensate solution	3
Locally mounted device (field)			
FIT – 01	SI	Flow transmitter of solution in circulation	
FIT – 02	NO	Flow transmitter of concentrated solution	2
FIT – 03	NO	Flow transmitter of hot water	1
FIT – 04	NO	Flow transmitter of cold water	1
TT – 01	NO	Temperature transmitter of concentrated solution	1
TT – 02	SI	Temperature transmitter IN of hot water	
TT – 03	NO	Temperature transmitter OUT of hot water	1
TT – 04	NO	Temperature transmitter IN separator	1
TT – 05	SI	Temperature transmitter of vapor	
TT – 06	SI	Temperature transmitter of condensate	
TT – 07	SI	Temperature transmitter of circulation pump	
PI – 01	NO	Pressure indicator IN separator	1
PI – 02	SI	Vacuum pressure indicator	
PI – 03	NO	pressure indicator IN of hot water	3
PI – 04	NO	pressure indicator OUT of hot water	3
LCV – 01	SI	Level control valve of separator	
LCV – 02	NO	Level control valve IN of hot water	4
PCV – 01	SI	Pressure control valve IN separator	
DCV – 01	SI	Density control valve	
LI – 01	SI	Level indicator of condensate barrel	
PT-01	SI	Pressure transmitter IN separator	

PIC-01	SI	Pressure controller IN separator (in manual)	
PDT-01	SI	Differential pressure for level in separator	
LY-01	SI	separator level regulation	
DY-01	SI	Density regulation	
DT-01	SI	Density transmitter	
DX-01	SI	Density meter	
FR-01	NO	Air presence equipment	3
FR-02a	NO	Air presence modulating valve of hot water	3
FR-02b	NO	level transmitter of TK1	4

Table 6.2. Gap analysis report of CL1

Mancano CL1
FI-05
FI-06
TI-08
TI-09
FIT-05
FIT-06
TT-08
TT-09

Table 6.3. Missing instruments in CL1

Gap analysis of CL 2

Control room panel mounted instrument	Working condition (yes or no)	Function	Priority
FI - 01	SI	Flow indicator of solution in circulation	
FI - 03	SI	Flow indicator of dilute solution	
FI - 04	SI	Flow indicator of cold water	
FI - 05	SI	Flow indicator of concentrated solution	
FI - 06	NO	Flow indicator of hot water	1
TI -01	NO	Temperature indicator of concentrated solution	1
TI -02	SI	Temperature indicator IN of hot water	
TI -03	SI	Temperature indicator IN of separator	
TI -04	SI	Temperature indicator OUT of hot water	
TI -05	NO	Temperature indicator of vapor	3
TI -06	NO	Temperature indicator of condensate	1
TI -07	NO	Temperature indicator of circulation pump	3

PC - 01	NO	Pressure controller IN	1
LC - 01	SI	Level controller of separator	
PT - 02	NO	Vacuum pressure indicator	1
Vacuum pump indicator			
DC-01	SI	Density indicator	
QI-02	SI	Concentrated solution totalizer	
FAL-04	NO	Minimum flux of condensate solution	3
Locally mounted device (field)			
FIT - 01	SI	Flow transmitter of solution in circulation	
FIT - 03	SI	Flow transmitter of dilute solution	
FIT - 04	SI	Flow transmitter of cold water	
FIT - 05	NO	Flow transmitter of concentrated solution	2
TT - 01	SI	Temperature transmitter of concentrated solution	
TT - 02	SI	Temperature transmitter IN of hot water	
TT - 03	SI	Temperature transmitter OUT of hot water	
TT - 04	SI	Temperature transmitter IN of separator	
TT - 05	SI	Temperature transmitter of vapor	
TT - 06	SI	Temperature transmitter of condensate	
TT - 07	SI	Temperature transmitter of circulation pump	
PI - 01	SI	Pressure indicator IN separator	
PI - 02	NO	Vacuum pressure indicator	1
PI - 03	NO	pressure indicator IN of hot water	3
PI - 04	NO	pressure indicator OUT of hot water	3
LCV - 01	SI	Level control valve of separator	
LCV - 02	NO	Level control valve IN of hot water	4
PCV - 01	SI	Pressure control valve IN separator	
DCV - 01	SI	Density control valve	
LI - 01	SI	Level indicator of barrel	
PY-01	SI	pressure IN separator	
PDT-01	SI	Differential pressure for level in separator	
LY-01	SI	separator level regulation	
DY-01	SI	Density regulation	
DT-01	SI	Density transmitter	
DX-01	SI	Density meter	

FR-01	NO	Air presence equipment	3
FR-02a	NO	Air presence modulating valve of hot water	3
FR-02b	NO	level transmitter of TK1	4
QI-03	SI	Diluted solution totalizer	

Table 6.4. Gap analysis report of CL2

Mancano – CL2
FI-02
TI-08
TI-09
FIT-02
TT-08
TT-09

Table 6.5. Missing instruments in CL2

Gap analysis of CL 3

Control room panel mounted instrument	Working condition (yes or no)	Function	Priority
FI - 01	SI	Flow indicator of solution in circulation	
FI - 02	SI	Flow indicator of concentrated solution	
FI - 03	SI	Flow indicator of dilute solution	
FI - 04	SI	Minimum flow condensate in flowmeter	
FI - 05	SI	Flow indicator of cold water	
FI - 06	SI	Flow indicator of hot water	
TI -01	NO	Temperature indicator of concentrated solution	1
TI -02	NO	Temperature indicator IN of separator	1
TI -03	NO	Temperature indicator of vapor	1
TI -04	NO	Temperature indicator of condensate	1
TI -05	SI Verificare funzionamento/sostituire	Temperature indicator OUT of cold water	1
TI -06	NO	Temperature indicator IN of cold water	1
TI -07	NO	Temperature indicator IN of hot water	1
TI -08	NO	Temperature indicator OUT of hot	1

		water	
TI -09	NO	Temperature indicator of circulation pump	3
PC - 01/PT-01	NO	Pressure controller IN	1
LC - 01	SI	Level controller of separator	
PI - 02	SI	Vacuum pressure indicator	
DC-01	SI	Density indicator	
QI-02	SI	Concentrated solution totalizer	
FAL-04	SI	Minimum flux of condensate solution	
Locally mounted device (field)			
FIT - 01	SI	Flow transmitter of solution in circulation	
FIT - 02	SI	Flow transmitter of dilute solution	
FIT - 03	SI	Flow transmitter of concentrated solution	
FIT - 04	NO	Flowmeter transmitter in condensateflow	1
FIT - 05	SI	Flow transmitter of cold water	
FIT - 06	SI	Flow transmitter of hot water	
TT - 01	SI	Temperature transmitter of concentrated solution	
TT - 02	SI	Temperature transmitter IN of separator	
TT - 03	SI	Temperature transmitter of vapor	
TT - 04	SI	Temperature transmitter of condensate	
TT - 05	SI	Temperature transmitter OUT of cold water	
TT - 06	SI	Temperature transmitter IN of cold water	
TT - 07	SI	Temperature transmitter IN of hot water	
TT - 08	SI	Temperature transmitter OUT of hot water	
TT - 09	NO guasto	Temperature transmitter of circulation pump	3
PI - 01	NO guasto	Vacuum pressure indicator	3
PT - 02	NO	Vacuum pressure transmitter	1
PI - 03	SI	Pressure indicator IN of hot water	

PI - 04	SI	Pressure indicator OUT of hot water	
LCV - 01	SI	Level control valve of separator	
LCV - 02	SI Aperta in MANUALE	Level control valve IN of hot water	
PCV - 01	NO aperta in manuale	Pressure control valve IN separator	
DCV - 01	SI	Density control valve	
LI - 01	SI	Level indicator of barrel	
PT-01	NO	pressure transmitter IN separator	3
PY-01	NO guasto	Pressure controller IN separator (in manual)	3
PDT-01	SI	Differential pressure for level in separator	
LY-01	SI	separator level regulation	
DY-01	SI	Density regulation	
DT-01	SI	Density transmitter	
DX-01	SI	Density meter	
FR-01	NO	Air presence equipment	3
FR-02a	NO	Air presence modulating valve of hot water	3
FR-02b	NO	Level indicator of tank S11	2
PI-03	NO guasto	Pressure transmitter IN heat exchanger	3
QI-03	SI	Dilute solution totalizer	

Table 6.6. Gap analysis report of CL3

Chapter 7

7. FMEA (Failure mode and effects analysis)

Failure mode and effects analysis is the process of reviewing as many components, assemblies, and subsystems as possible to identify potential failure modes in a system and their causes and effects. For each component, the failure modes and their resulting effects on the rest of the system are recorded in a specific FMEA worksheet. There are numerous variations of such worksheets. An FMEA can be a qualitative analysis, but may be put on a quantitative basis when mathematical failure rate models are combined with a statistical failure mode ratio database. It was one of the first highly structured, systematic techniques for failure analysis. An FMEA is often the first step of a system reliability study.

A few different types of FMEA analyses exist, such as:

- Functional
- Design
- Process

Sometimes FMEA is extended to FMECA (failure mode, effects, and criticality analysis) to indicate that criticality analysis is performed too.

FMEA is an inductive reasoning (forward logic) single point of failure analysis and is a core task in reliability engineering, safety engineering and quality engineering.

A successful FMEA activity helps identify potential failure modes based on experience with similar products and processes or based on common physics of failure logic. It is widely used in development and manufacturing industries in various phases of the product life cycle. Effects analysis refers to studying the consequences of those failures on different system levels.

Functional analyses are needed as an input to determine correct failure modes, at all system levels, both for functional FMEA or Piece-Part (hardware) FMEA. An FMEA is used to structure Mitigation for Risk reduction based on either failure (mode) effect severity reduction or based on lowering the probability of failure or both. The FMEA is in principle a full inductive (forward logic) analysis, however the failure probability can only be estimated or reduced by understanding the failure mechanism. Hence, FMEA may include information on causes of failure (deductive analysis) to reduce the possibility of occurrence by eliminating identified (root) causes

In addition, each part failure postulated is the only failure in the system. In addition to the FMEAs done on systems to evaluate the impact lower level failures have on system operation, several other FMEAs are done. Special attention is paid to interfaces between systems and in fact at all functional interfaces. The purpose of these FMEAs is to assure that irreversible physical and/or functional damage is not propagated across the interface as a result of failures in one of the interfacing units. These analyses are done to the piece part level for the circuits that directly interface with the other units. The FMEA can be accomplished without a CA, but a CA requires that the FMEA has previously identified system level critical failures. When both steps are done, the total process is called an FMECA.

7.1 Ground rules

The ground rules of each FMEA include a set of project selected procedures; the assumptions on which the analysis is based; the hardware that has been included and excluded from the analysis and the rationale for the exclusions. The ground rules also describe the indenture level of the analysis, the basic hardware status, and the criteria for system and mission success. Every effort should be made to define all ground rules before the FMEA begins; however, the ground rules may be expanded and clarified as the analysis proceeds. A typical set of ground rules (assumptions) follows

1. Only one failure mode exists at a time.
2. All inputs (including software commands) to the item being analyzed are present and at nominal values.
3. All consumables are present in enough quantities.

4. Nominal power is available

7.2 Benefits

Major benefits derived from a properly implemented FMECA effort are as follows:

1. It provides a documented method for selecting a design with a high probability of successful operation and safety.
2. A documented uniform method of assessing potential failure mechanisms, failure modes and their impact on system operation, resulting in a list of failure modes ranked according to the seriousness of their system impact and likelihood of occurrence.
3. Early identification of single failure points (SFPS) and system interface problems, which may be critical to mission success and/or safety. They also provide a method of verifying that switching between redundant elements is not jeopardized by postulated single failures.
4. An effective method for evaluating the effect of proposed changes to the design and/or operational procedures on mission success and safety.
5. A basis for in-flight troubleshooting procedures and for locating performance monitoring and fault-detection devices.
6. Criteria for early planning of tests.

From the above list, early identifications of SFPS, input to the troubleshooting procedure and locating of performance monitoring / fault detection devices are probably the most important benefits of the FMECA. In addition, the FMECA procedures are straightforward and allow orderly evaluation of the design.

Process Step \ Function	Requirement	Modo di guasto potenziale - <i>Potential Failure Mode</i>	Effetto potenziale e del guasto - <i>Potential Effect(s) of Failure</i>	Sev	Potential Cause(s) / Mechanism (s) of Failure	Occ	Controlli per rilevare il difetto <i>Current Design or Process Controls Detection</i>	Det	RPN	Recommended Actions	Sev	Occ	Det	RPN
02.01- Pump G-1 / Solution in circulation between D-1 e E-1	Flow rate of solution in circulation (55 m ³ /h)	Low flow rate of solution in circulation	It will increase circulation time of the solution	7	Operator error in closing and opening of manual valve	4	Automatic control of FIT-01	9	252	Preventive control: Flow rate should be adjusted depends on the machines in production detection: standard automatic control with alarm (HH/H/L)	7	3	5	105

				7	Air will be mixed with solution input	2	Automatic control of FIT-01	9	126	detection: standard automatic control with alarm (HH/H/L)	7	2	5	70
		Flow rate of solution in circulation below LL	Evaporator shut down	8	Operator error in closing and opening of manual valve	3	Automatic control of FIT-01	9	216	detection: standard automatic control with alarm and block (LL)	8	3	3	72
02.02- Pump G-2 / To empty D-2 and collecting condensate to main tank	Flow rate should be 1.000 l/h	Minimum flow	Filling D-2 and line stops	8	Failure of pump	3	FIT04 seen	7	168	Control PLC				0
					Manual error in pump operating	3	FIT04 seen	7		Control PLC				
		Maximum flow	Empty D-2 and line stops	8	Manual error in pump operating	3	FIT04 seen	7	168	Control PLC				0
02.03- Pump G-3 / Vacuum pump	$p < 0,001^*$ atm	$0,001 < p < 0,01$ atm	KEVC solution with low density	8	Seal deterioration	4	Plant database on field Automatic control PT02 (broken)	9	288	Preventive control: gaskets verification G-03 Detection: Automatic transmission reset data from PI02 to PT02 + Set value (HH/H/L/LL)	8	3	5	120
		$p > 0,01$ atm	Empty D-2 and line stops	8	Dry running	4	LI01	7	224	- OCC: Restoration of the magnetic delivery detection system				0
02.04- Heat exchanger E-1 / Heating the solution in circulation	DT = [+19 - 26] °C	DT < +19°C	It will increase circulation time of the solution	7	Fouling in condenser / TT08 (60/75°C)	3	Automatic temperature control of hot water IN and OUT TT07 TT08 (not working)	9	189	- Set tolerance value of TT07 e TT08 with respect to P&I - correct operator parameters	7	3	5	105

				7	Water entering E-1 with low temperature / TT07 (84/86°C)	4	Automatic temperature control of hot water IN and OUT of TT07 and TT08 (not working)	9	252	- Set tolerance value of TT07 e TT08 with respect to P&I - correct operator parameters	7	3	5	105
				7	Water entering E-1 with minimum flow < 60 m ³ /h	4	Automatic control of FIT06 (not working)	9	252	- Set tolerance value of TT07 e TT08 with respect to P&I - correct operator parameters	7	3	5	105
	T entering < 95°C	T entering > 95°C	Deterioration of the exchanger plates	8	Error in set value parameter	5	Automatic temperature control of hot water IN and OUT of TT07 and TT08 (not working)	9	360		8	3	3	72
02.05- Condenser E-2 / Condensation of vapor from evaporator D-1	DT = [-14 / -7] C*	DT > -7°C*	It will increase circulation time of the solution	7	Fouling of condenser plates / TT06 (35/40°C)	3	Automatic temperature control of hot water IN and OUT of TT05 and TT06 (not working)	9	189	- Set tolerance value of TT05 e TT06 with respect to P&I - correct operator parameters - Cooling towers - anti algae - Component verification	7	3	5	105
				7	Water entering E-2 with high temperature / TT05 (26/28 °C) /inefficient cooling tower	4	Automatic temperature control of hot water IN and OUT of TT05 and TT06 (not working)	9	252		7	3	5	105
				7	Water entering E-2 with minimum flow < 100 m ³ /h	4	Automatic control FIT05	5	140		7	3	5	105
02.06- D-1 /Evaporator	p < 0,001* atm	0,001 < p < 0,01 atm	KEVC solution with low density	8	Hydraulic seal failure of the flanges	4	Automatic control density DIC01 (not set)	9	288					0

				8	Hydraulic seal failure of the pipes	2	Automatic control density DIC01 (not set)	9	144					0
	Minimum level solution	solution above maximum level	Concentration and less free of acidity / Higher consumption of chemicals	8	Failure to close the supply valve LCV01	3	Control post-process from applikon to etching machine	6	144					0
				8	Level meter failure PDT01				0	- Set tolerance value DIC01 (PLC) with product specification. -Insert technical specification of byproduct in wiki				0
	Maximum level solution	Solution below minimum level	Possible crystallization of the solute / particular line stops	8	Failure to close the supply valve LCV01	3	Automatic control density DIC01 (not set)	9	216	- Set tolerance value DIC01 (PLC) with product specification. -Insert technical specification of byproduct in wiki	8	3	5	120
				8	Level meter failure PDT01	3	Automatic control density DIC01(not set)	9	216	- Set tolerance value DIC01 (PLC) with product specification.- Insert technical specification of byproduct in wiki	8	3	5	120
			KEVC solution with low density / line stops process	8	Failure to close the valve which send concentrated solution DCV01	3	Automatic control density DIC01 (not set)	9	216		8	3	5	120
02.07- Demister / Separate solution and vapor in evaporator	To allow vapor passage	Passage of vapor partially	It will increase circulation time of the solution	7	Fouling in demister	2	[controls not present]	9	126					0

		Passage of vapor absent	Stops line	8	Fouling in demister	2	[controls not present]	9	144						0	
	Block liquid droplet passage	Passage liquid partial/total	Concentration and less free of acidity / Higher consumption of chemicals	7	Demister misalignment	3	Control post-process from applikon to etching machine	6	126							0
				7	Demister break	2	Control post-process from applikon to etching machine	6	84	Occurrence: procedure of reboot						0
02.08-D-2 Barrel to pump G-2	Minimum level of condensate in barrel to pump	No condensate in barrel	Dry running G-2	7	Empty totally D-2	5	LI01	9								0
02.08-D-2 Barrel to vacuum pump G-3	space required in barrel to create vacuum (G-3)	More condensate enters in barrel	Filling D-2 and line stops	7	-	-	LI01	9		Detection: Repair PT01 to restore the function of PCV01						0
02.09-Valve PCV01 / Pressure control valve between E1 and D1	Close for p<0,8 atm	Failure close below p<0,8 atm	Possible break E-1	8	Stops accidentally G-1	2	Automatic control of modulating valve PVC01 is required (not working)	9	144	Occurrence: verify the procedure to shutdown G-3 before G-1 Detection: Repair PT01 to restore the function of PCV01						0
				8	Voluntary detention G-1	3	Automatic control of modulating valve PVC01 is required (not working)	9	216		8	3	3			72

02.10- Valve LCV01 / To maintain solution level in D-1	Open when level below 60%	Failure to open	Potential crystalliz ation of the solutions	8	Opening parameter error	4	LIC01 / DIC01	7	224					0
				8	Compressed air failure	3	LIC01 / DIC01	7	168					
				8	Breakage of the membrane inside the valve	3	LIC01 / DIC01	7	168					
	Close when level above 60%	Failure to close	Concentration and less free of acidity / Higher consumption of chemicals	8	Opening parameter error	4	Control post-process from applikon to etching machine	6	192					0
02.11- Valve DCV01 /Regulate flow towards S12	Opening depends on density of KEVC	Failure to open depends on density	Potential crystalliz ation of the solutions	7	Compressed air failure	2	Density regulation DIC01	9	126	OCC: - preventive replacement/respect to the membrane of valve.				0
				7	Breakage of the membrane inside the valve	3	Density regulation DIC01	9	189					
				7	failure in communication DC01 e DCV01	3	Density regulation DIC01	9	189	Detection: correct the parameters in consistency with specification of KEVC (now L=1,16 instead of 1,21)				
		Opening valve for different density of product KEVC	KEVC with density sub specification / Empty D2 and potential	8	Error in setting parameters DIC01	3	Density regulation DIC01	9	216					0

			break G2											
				8	Error calibration DY01	3	-	9	216					

Table 7.1 Failure mode and effect analysis (FMEA) of evaporator

Chapter 8

8. Gross errors detected using gap analysis and FMEA

- Operating condition of hot water temperature in heat exchanger and cold-water temperature in condenser not maintained properly.
- Vacuum pump damage.
- Some of the indicators, transistors, flow maters, are not working properly.
- Cold water flow system and hot water flow system is interconnected with each system when one evaporator shut down the other evaporators flow rate increases gradually.
- Some leaks in the system.
- Gaskets problem in heat exchanger.
- Pressure valve failure (PCV-01).

Chapter 9

9. About software tool

The purpose of analysis/simulation is to model and predict the performance of a process. The process characteristics (e.g. flow rates, compositions, temperatures, pressures, properties, equipment sizes, etc.) are predicted using analysis techniques.

These techniques include mathematical models, empirical correlations and computer-aided process simulation tools (e.g. **ASPEN Plus**). In addition, process analysis may involve the use of experimental means to predict and validate performance. Therefore, in process simulation,

we are given the process inputs and flow sheet and are required to predict process outputs. The lab will focus on aspen Plus. It is a computer-aided software which uses the underlying physical relationships (e.g. material and energy balances, thermodynamic equilibrium, rate equations) to predict process performance (e.g. stream properties, operating conditions, and equipment sizes).

Aspen plus is a market leading process modelling tool for conceptual design, optimization, business planning, asset management and performance monitoring for oil and gas processing, petroleum refining, and air separation industries. Aspen plus is a core element of Aspen Tech's aspen ONE Engineering applications. Aspen plus has established itself as a very intuitive and easy to use process simulator in oil and gas refining industry. Users with little prior knowledge of Aspen plus can pick up and train themselves in its modelling capabilities. Some of the very intuitive capabilities include a highly interactive process flow diagram for building and navigating through large simulations. The program also provides a very flexible and easy to use environment. Additionally, the interactive nature of plus enables users to build and use their models quickly and effectively. Aspen plus offers a comprehensive thermodynamics foundation for accurate calculation of physical properties, transport properties, and phase behaviour for the oil & gas and refining and chemical industries. Comprehensive library of unit operation models including distillation, reactors, heat transfer operation, rotating equipment's, controllers, and logical operations in both the steady state and dynamic environments.

9.1 Advantages of aspen plus

1. Aspen Plus provides an extremely powerful approach to steady state modeling.
2. Aspen Plus approach to modeling maximizes return on simulation time through increased process understanding.
3. Aspen Plus offers a comprehensive thermodynamics foundation for accurate calculation of physical properties, transport properties, and phase behavior and newer versions of Plus have almost doubled in its capabilities on physical properties.

4. Aspen Plus introduced the novel approach of steady state and dynamic simulations in the same platform.
5. Aspen Plus let process engineers estimate the Green House Gas Emissions associated with a process.
6. Aspen Plus is efficient for monitoring a chemical process

9.2 Steady state simulation

Initially process simulation was used to simulate steady state processes. Steady state models perform a mass and energy balance of a stationary process (a process in an equilibrium state) it does not depend on time.

Components used in our system with specification

Components	Feed (g/l)	Vapour out (g/l)	Product (g/l)
HCL	37	40	33
NH ₄ CL	0.8	-	3
H ₂ O	960	990	920
ALCL ₃	66	-	250
ALPO ₄	6	-	25

Table 9.1 Feed composition of evaporator

9.3 Flow sheet description

All the components are selected from the aspen databank APV110ASPENPCD, APV110 AQUEOUS, APV110 SOLIDS, APV110 INORGANIC, APV110 PURE37, And chemistry reaction is done using Elec-wizard option which is shown in fig.9.2

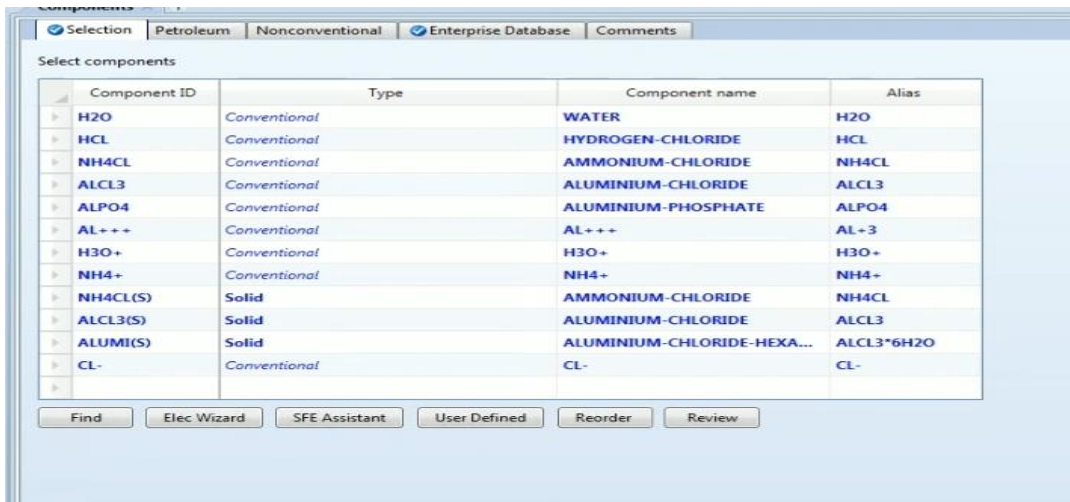


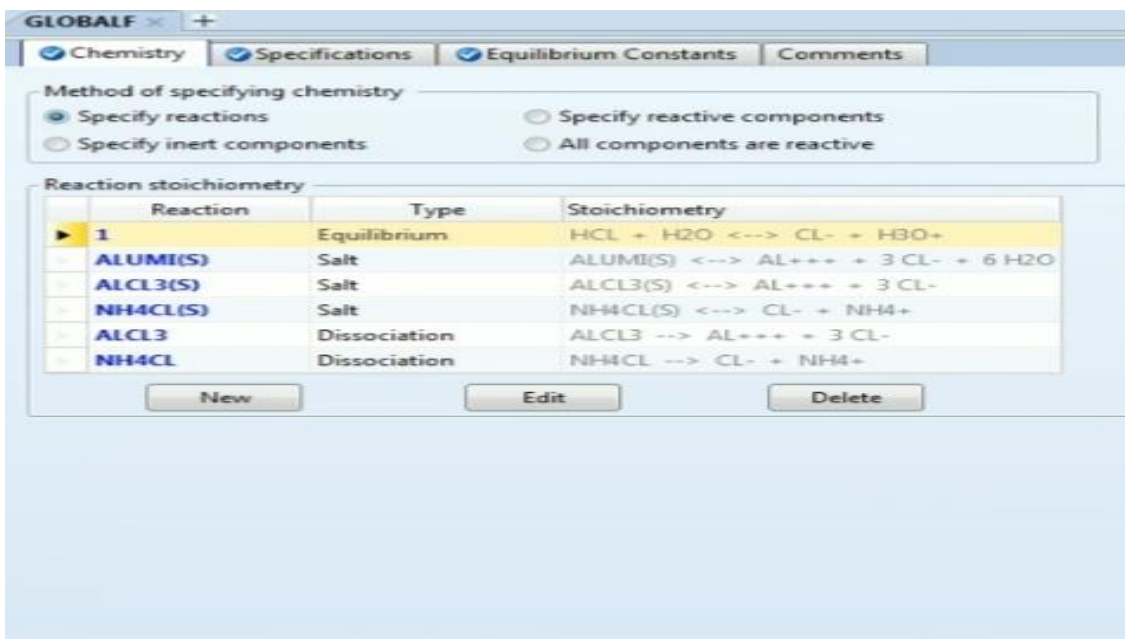
Figure 9.1. Components added in simulation from aspen databank

The methods used in our process is ELECNRTL because of electrolyte solution and solved with true component approach for sequential model. The chemistry reaction done by software are shown below in fig

In simulation environment all the blocks are selected according to the model for inlet and outlet condition of stream which is connected.

Some blocks are FLASH1, PUMP, SPLIT, MIX, HEAT-EX, COMPRESSOR, DESIGN-SPEC are selected to design the flowsheet of our evaporator

Figure 9.2. Chemistry reaction in simulation



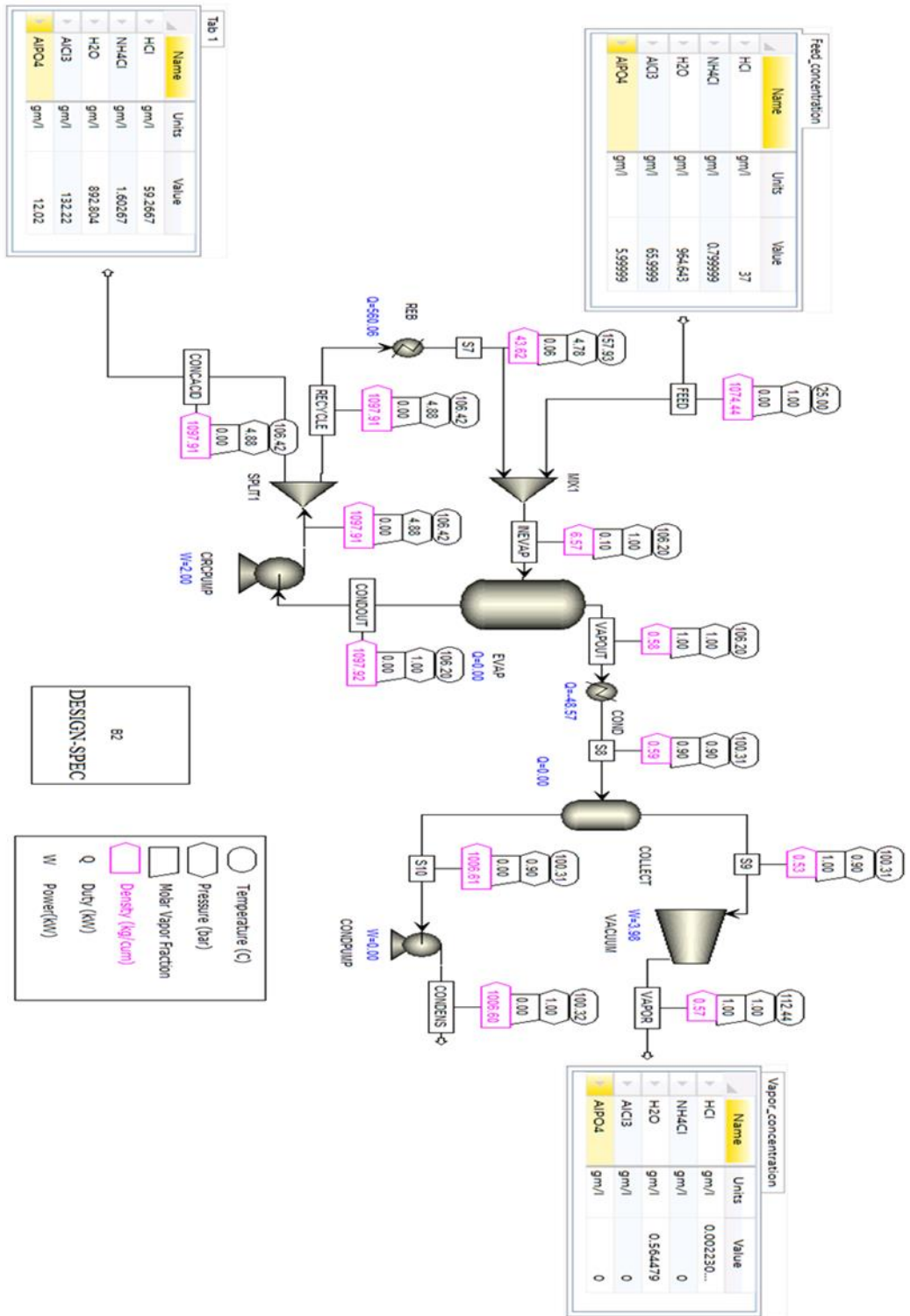


Figure 9.3. Process flow diagram in simulation

Chapter 10

10. Simulation results

Aspen Plus performs flowsheet calculations using the sequential modular method. Each unit operation block is executed in sequence. The calculated output streams of each block are used as feed to the next block.

Flowsheets with recycle loops, design specifications, or optimization problems must be solved iteratively. Execution requires that:

- Tear streams are chosen. A tear stream is a recycle stream with component flows, total mole flow, pressure, and enthalpy all determined by iteration. It can be any stream in a loop.
- Convergence blocks are defined to converge the tear streams, design specifications, or optimization problems. Convergence blocks determine how guesses for a tear stream or design specification manipulated variable are updated from iteration to iteration.
- A sequence is determined, which includes all the unit operation and convergence blocks.

All the mass and energy balance in each stream shown in table 10.1

Stream Name	Units	CONCAC ID	CONDENS	CONDOU T	FEED	INEVAP	RECYCL E	S4	S7	S8	S9	S10	VAPOR	VAPOUT
Description														
From		SPLIT1	CONDPU MP	EVAP		MIX1	SPLIT1	CIRCPUM P	REB	COND	COLLECT	COLLECT	VACUUM	EVAP
To				CIRCPUM P	MIX1	EVAP	REB	SPLIT1	MIX1	COLLECT	VACUUM	CONDPU MP		COND
Stream Class		CONVEN	CONVEN	CONVEN	CONVEN	CONVEN	CONVEN	CONVEN	CONVEN	CONVEN	CONVEN	CONVEN	CONVEN	CONVEN
Maximum Relative Error														
Cost Flow	\$/hr													
MIXED Sub stream														
Phase		Liquid Phase	Liquid Phase	Liquid Phase	Liquid Phase		Liquid Phase	Liquid Phase			Vapor Phase	Liquid Phase	Vapor Phase	Vapor Phase
Temperature	C	106.386021	100.3195172	106.2002956	25	106.199694	106.386021	106.3860208	157.9266184	100.3107332	100.310561	100.310561	112.4418696	106.2002956
Pressure	bar	4.876070794	1	1	1	1	4.876070794	4.876070794	4.776070794	0.9	0.9	0.9	1	1
Molar Vapor Fraction		0	0	0	0	0.099935319	0	0	0.059538051	0.9	1	0	1	1
Molar Liquid Fraction		1	1	1	1	0.900064681	1	1	0.940461949	0.1	0	1	0	0
Molar Solid Fraction		0	0	0	0	0	0	0	0	0	0	0	0	0
Mass Vapor Fraction		0	0	0	0	0.087571358	0	0	0.055914762	0.895371184	1	0	1	1
Mass Liquid Fraction		1	1	1	1	0.912428642	1	1	0.944085238	0.104628816	0	1	0	0
Mass Solid Fraction		0	0	0	0	0	0	0	0	0	0	0	0	0
Molar Enthalpy	kcal/mol	69.8781571	65.65592025	66.08634789	69.6264757	68.58484635	69.8781571	66.0822493	64.62893715	57.98560737	57.1333392	65.65607261	57.03503342	56.90594851

Mass Enthalpy	kcal/kg	3328.970893	3458.404703	3329.177364	3571.891862	3312.271854	3328.970893	3328.970893	3255.758587	3195.758621	3165.066627	3458.412729	3159.620694	3136.255423
Molar Entropy	cal/mol-K	35.63555263	34.91809187	34.10172333	39.22840468	33.30349394	35.63555263	33.69976501	30.52393994	11.16837873	8.508755575	35.10506754	8.45760723	8.472536648
Mass Entropy	cal/gm-K	1.697665228	1.839299376	1.71791435	2.012447392	1.60837607	1.697665228	1.697665228	1.537679311	0.615522441	0.471367133	1.84914826	0.468533628	0.466946597
Molar Density	kmol/cum	52.30530419	53.02253432	55.30871144	55.11975405	0.317656177	52.30530419	55.30983437	2.200272408	0.032408016	0.029169011	53.02291828	0.031394517	0.031919489
Mass Density	kg/cum	1097.936383	1006.603791	1097.914093	1074.443002	6.577479466	1097.936383	1097.936384	43.67684623	0.588028914	0.52653646	1006.61108	0.566709581	0.579164813
Enthalpy Flow	kW	3890.104794	406.1168625	38903.46058	-8182.8169	42423.34683	35010.94315	38901.04794	34240.96589	3586.67189	3180.555096	406.1178049	3175.082513	3519.89011
Average MW		20.99091862	18.98445263	19.85065398	19.49288455	20.70628541	20.99091862	19.85065398	19.85065398	18.14455165	18.05122796	18.98445263	18.05122796	18.14455165
Mole Flows	kmol/hr	47.86743357	5.318601047	506.1704283	101.0528824	531.8596493	430.8069022	506.1704283	455.5533854	53.18531354	47.86671258	5.318601047	47.86671258	53.18531354
H2O	kmol/hr	45.3545676	4.759691647	438.6670922	98.16735787	506.3582495	408.1911099	438.6670922	895.7228312	52.53312756	47.77342558	4.759691647	47.77342558	52.81257193
HCL	kmol/hr	1.487858544	1.19179E-14	2.56304E-12	1.86045124	15.25132705	13.39072689	2.56995E-12	0.922448277	0.093297249	0.093286915	1.19156E-14	0.093286915	0.372741615
NH4CL	kmol/hr	0.027417037	0	0	0.027418804	0.274170373	0.246753305	0	0	0	0	0	0	0
ALCL3	kmol/hr	0.907397406	0	0	0.907455867	9.073974057	8.166576651	0	0	0	0	0	0	0
ALPO4	kmol/hr	0.090192826	0	0.901928259	0.090198637	0.901928259	0.811735433	0.901928259	0.811735403	0	0	0	0	0
AL+++	kmol/hr	0	0	9.073974056	0	0	0	9.073974056	8.166576651	0	0	0	0	0
H3O+	kmol/hr	0	0.279454744	14.8785850	0	0	0	14.87858544	12.46827862	0.279444366	0	0.27945470	0	0
NH4+	kmol/hr	0	0	0.274170373	0	0	0	0.274170373	0.246753305	0	0	0	0	0
NH4CL(S)	kmol/hr	0	0	0	0	0	0	0	0	0	0	0	0	0
ALCL3(S)	kmol/hr	0	0	0	0	0	0	0	0	0	0	0	0	0
ALUMI(S)	kmol/hr	0	0	0	0	0	0	0	0	0	0	0	0	0
CL-	kmol/hr	0	0.279454798	42.3746770	0	0	0	42.37467798	37.2147619	0.279444366	0	0.27945470	0	0
Mole Fractions														
H2O		0.947503644	0.894914209	0.866639115	0.971445401	0.952052389	0.947503644	0.866639115	0.868664011	0.98773748	0.998051111	0.894914209	0.998051111	0.992991644
HCL		0.031082898	2.24079E-15	5.06359E-15	0.01841067	0.028675473	0.031082898	5.07725E-15	0.002024896	0.001754192	0.001948889	2.24037E-15	0.001948889	0.007008356
NH4CL		0.00057277	0	0	0.000271331	0.000515494	0.00057277	0	0	0	0	0	0	0
ALCL3		0.018956467	0	0	0.00898001	0.017060843	0.018956467	0	0	0	0	0	0	0
ALPO4		0.001884221	0	0.001781857	0.000892588	0.001695801	0.001884221	0.001781857	0.001781857	0.001781857	0	0	0	0
AL+++		0	0	0.017926717	0	0	0	0.017926717	0.017926717	0	0	0	0	0
H3O+		0	0.052542896	0.029394419	0	0	0	0.029394419	0.027369522	0.005254164	0	0.052542896	0	0
NH4+		0	0	0.000541656	0	0	0	0.000541656	0.000541656	0	0	0	0	0
NH4CL(S)		0	0	0	0	0	0	0	0	0	0	0	0	0
ALCL3(S)		0	0	0	0	0	0	0	0	0	0	0	0	0
ALUMI(S)		0	0	0	0	0	0	0	0	0	0	0	0	0
CL-		0	0.052542896	0.083716226	0	0	0	0.083716226	0.08169133	0.005254164	0	0.052542896	0	0
Mass Flows	kg/hr	1004.781403	100.9707296	10047.81403	1969.812171	11012.83769	9043.032623	10047.81403	9043.032623	965.0236686	864.0529323	100.9707296	864.0529323	965.0236686
H2O	kg/hr	817.0752375	85.7471773	7902.710492	1768.512439	9122.185646	7353.677138	7902.710492	7129.057607	946.3990023	860.6516384	85.7471773	860.6516384	951.4332708
HCL	kg/hr	54.24827473	4.34533E-13	9.345E-11	67.8332429	556.0731452	488.2344726	9.37021E-11	33.63305456	3.401677399	3.401300624	4.34451E-13	3.401300624	13.59039783

NH4CL	kg/hr	1.4665702 23	0	0	1.4666647 11	14.665702 23	13.199132 01	0	0	0	0	0	0	0
ALCL3	kg/hr	120.99204 34	0	0	120.99983 87	1209.9204 34	1088.9283 91	0	0	0	0	0	0	0
ALPO4	kg/hr	10.999276 67	0	109.99276 57	10.999985 34	109.99276 67	98.993490 06	109.99276 67	98.993490 06	0	0	0	0	0
AL+++	kg/hr	0	0	244.81482 19	0	0	0	244.81482 19	220.33333 97	0	0	0	0	0
H3O+	kg/hr	0	5.3159745 37	283.03042 08	0	0	0	283.03042 08	237.17994 96	5.3157779 62	0	5.3159745 37	0	0
NH4+	kg/hr	0	0	4.9454714 71	0	0	0	4.9454714 71	4.4509243 24	0	0	0	0	0
NH4CL(S)	kg/hr	0	0	0	0	0	0	0	0	0	0	0	0	0
ALCL3(S)	kg/hr	0	0	0	0	0	0	0	0	0	0	0	0	0
ALUMI(S)	kg/hr	0	0	0	0	0	0	0	0	0	0	0	0	0
CL-	kg/hr	0	9.9075773 4	1502.3200 52	0	0	0	1502.3200 52	1319.3842 57	9.9072109 76	0	9.9075773 4	0	0
Mass Fractions														
H2O		0.8131870 63	0.8492280 69	0.7865104 26	0.8978076 52	0.8283228 99	0.8131870 63	0.7865104 26	0.7883481 02	0.9807003 01	0.9960635 51	0.8492280 69	0.9960635 51	0.9859170 32
HCL		0.0539901 26	4.30355E- 15	9.30054E- 15	0.0344364 02	0.0504931 75	0.0539901 26	9.32563E- 15	0.0037192 23	0.0035249 68	0.0039364 49	4.30274E- 15	0.0039364 49	0.0140829 68
NH4CL		0.0014595 91	0	0	0.0007445 71	0.0013316 91	0.0014595 91	0	0	0	0	0	0	0
ALCL3		0.1204162 85	0	0	0.0614270 95	0.1098645 48	0.1204162 85	0	0	0	0	0	0	0
ALPO4		0.0109469 35	0	0.0109469 35	0.0055842 81	0.0099876 86	0.0109469 35	0.0109469 35	0.0109469 35	0	0	0	0	0
AL+++		0	0	0.0243649 83	0	0	0	0.0243649 83	0.0243649 83	0	0	0	0	0
H3O+		0	0.0526486 69	0.0281683 58	0	0	0	0.0281683 58	0.0262279 21	0.0055084 43	0	0.0526486 69	0	0
NH4+		0	0	0.0004921 94	0	0	0	0.0004921 94	0.0004921 94	0	0	0	0	0
NH4CL(S)		0	0	0	0	0	0	0	0	0	0	0	0	0
ALCL3(S)		0	0	0	0	0	0	0	0	0	0	0	0	0
ALUMI(S)		0	0	0	0	0	0	0	0	0	0	0	0	0
CL-		0	0.0981232 62	0.1495171 04	0	0	0	0.1495171 04	0.1459006 41	0.0102662 88	0	0.0981232 62	0	0
Volume Flow	cum/day	21.963707 57	2.4073995 47	219.64153 5	44	40183.797 76	197.67336 82	219.63707 57	4969.0580 18	39386.784 41	39384.301 21	2.4073821 14	36592.412 09	39989.597 97
Vapor Phase														
Molar Enthalpy	kcal/mol					-56.906031 23			-55.559633 94	-57.133330 19	-57.133339 2		-57.035033 42	-56.905948 51
Mass Enthalpy	kcal/kg					3136.2669 36			2980.2499 39	3165.0654 39	3165.0666 27		3159.6206 94	3136.2554 23
Molar Entropy	cal/mol-K					8.4725988 75			10.033155 29	8.5087464 38	8.5087555 75		8.4576073 23	8.4725366 48
Mass Entropy	cal/gm-K					0.4669510 62			0.5381840 8	0.4713665 24	0.4713671 33		0.4685336 28	0.4669465 97
Molar Density	kmol/cum					0.0319195 41			0.1363414 97	0.0291689 11	0.0291690 11		0.0313945 17	0.0319194 89
Mass Density	kg/cum					0.5791644 7			2.5417597 55	0.5265363 27	0.5265364 6		0.5667095 81	0.5791648 13
Enthalpy Flow	kW					-3517.6616			1752.5603 41	3180.5592 26	3180.5550 96		3175.0825 13	3519.8901 1
Average MW						18.144511 42			18.642608 86	18.051231 89	18.051227 96		18.051227 96	18.144551 65
Mole Flows	kmol/hr					53.151563 63			27.122760 52	47.866782 19	47.866712 5		47.866712 5	53.185313 54
H2O	kmol/hr					52.779174 49			26.200312 25	47.773484 94	47.773425 58		47.773425 58	52.812571 93

HCL	kmol/hr					0.372389144				0.922448277	0.093297249	0.093286915		0.093286915	0.372741615
NH4CL	kmol/hr					5.27908E-92				0	0	0		0	0
ALCL3	kmol/hr					2.31362E-18				0	0	0		0	0
ALPO4	kmol/hr					5.34797E-80				0	0	0		0	0
AL+++	kmol/hr					0				0	0	0		0	0

Table 10.1. Mass and energy balance results in simulation

10.1 Model summary results

Heater		
Name	COND	REB
Property method	ELECNRTL	ELECNRTL
Henry's component list ID	GLOBAL	GLOBAL
Electrolyte chemistry ID	GLOBALF	GLOBALF
Use true species approach for electrolytes	YES	YES
Free-water phase properties method	STEAM-TA	STEAM-TA
Water solubility method	3	3
Specified pressure [bar]	-0.1	-0.1
Specified temperature [C]		120
Specified vapor fraction	0.9	
Specified heat duty [kW]		
EO Model components		
Calculated pressure [bar]	0.9	4.77607321
Calculated temperature [C]	100.309804	157.926584
Calculated vapor fraction	0.9	0.059618343
Calculated heat duty [kW]	-66.7775236	770.435449
Temperature change [C]		
Degrees of superheating [C]		
Degrees of subcooling [C]		
Pressure-drop correlation parameter		
Net duty [kW]	-66.7775236	770.43544
First liquid / total liquid	1	1
Total feed stream CO2e flow [kg/hr]	0	0
Total product stream CO2e flow [kg/hr]	0	0
Net stream CO2e production [kg/hr]	0	0
Utility CO2e production [kg/hr]	0	182.370032
Total CO2e production [kg/hr]	0	182.370032
Utility usage [kg/hr]	8220.55934	1613.17446
Utility cost [\$ /hr]	0.050964606	6.93391904

Utility ID	COLDH2O	U-2
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Table 10.2. model summary result of condenser and heat exchanger

Model summary results shows about all stream balance and unit operation results we have simulated the process by sequential model and table 10.2. show as the heat exchanger working condition and condenser work condition and their utilities used for simulating the acid solution.

Flash		
Name	COLLECT	EVAP
Property method	ELECNRTL	ELECNRTL
Henry's component list ID	GLOBAL	GLOBAL
Electrolyte chemistry ID	GLOBALF	GLOBALF
Use true species approach for electrolytes	YES	YES
Free-water phase properties method	STEAM-TA	STEAM-TA
Water solubility method	3	3
Temperature [C]		
Pressure [bar]	0	0
Specified vapor fraction		
Specified heat duty [kW]	0	0
EO Model components		
Outlet temperature [C]	100.309632	106.19993
Outlet pressure [bar]	0.9	1
Vapor fraction	0.899998691	0.095071247
Heat duty [kW]	0	0
Net duty [kW]	0	0
First liquid / total liquid	1	1
Total feed stream CO2e flow [kg/hr]	0	0
Total product stream CO2e flow [kg/hr]	0	0
Net stream CO2e production [kg/hr]	0	0
Utility CO2e production [kg/hr]	0	0
Total CO2e production [kg/hr]	0	0
Utility usage		
Utility cost		
Utility ID		

Table 10.3. flash column in the system

Pump		
Name	CIRCPUMP	CONDPUMP
Property method	ELECNRTL	ELECNRTL
Henry's component list ID	GLOBAL	GLOBAL
Electrolyte chemistry ID	GLOBALF	GLOBALF
Use true species approach for electrolytes	YES	YES
Free-water phase properties method	STEAM-TA	STEAM-TA
Water solubility method	3	3
Model Type		
Specified discharge pressure [bar]		1
Specified pressure increase [bar]		
Specified pressure ratio		
Specified power required [kW]		
Pump efficiencies		
Driver efficiencies		
Suction area [sqm]		
Hydraulic static head [meter]		
Number of curves	1	
Operating shaft speed [rpm]	3000	
Impeller diameter [meter]	0.16	
EO Model components		
Fluid power [kW]	0.985429305	0.000278615
Calculated brake power [kW]	2.4172248	0.000942356
Electricity [kW]	2.4172248	0.000942356
Volumetric flow rate [cum/hr]	9.1524213	0.100301336
Calculated discharge pressure [bar]	4.87607321	1
Calculated pressure change [bar]	3.87607321	0.1
Calculated pressure ratio		
NPSH available [meter]	0	0
NPSH required		
Head developed [meter]	36.0000006	1.01302607
Pump efficiency used	0.407669699	0.295657636
Net work required [kW]	2.4172248	0.000942356
Specific speed, operating	531.5467	
Suction sp. speed, operating		
Head coefficient	0.558909425	

Flow coefficient	0.005031086	
Total feed stream CO2e flow [kg/hr]	0	0
Total product stream CO2e flow [kg/hr]	0	0
Net stream CO2e production [kg/hr]	0	0
Utility CO2e production [kg/hr]	0	0
Total CO2e production [kg/hr]	0	0
Utility usage		
Utility cost		
Utility ID		

Table 10.4. pumps in the system

Compressor	
Name	VACUUM
Property method	ELECNRTL
Henry's component list ID	GLOBAL
Electrolyte chemistry ID	GLOBALF
Use true species approach for electrolytes	NO
Free-water phase properties method	STEAM-TA
Water solubility method	3
Model Type	ISENTROPIC
Specified discharge pressure [bar]	1
Specified pressure increase [bar]	
Specified pressure ratio	
Specified power required [kW]	
Isentropic efficiency	0.8
Mechanical efficiency	1
Polytropic efficiency	
EO Model components	
Indicated horsepower [kW]	5.47223751
Calculated brake horsepower [kW]	5.47223751
Net work required [kW]	5.47223751
Power loss [kW]	0
Efficiency (polytropic / isentropic) used	0.8
Calculated discharge pressure [bar]	1
Calculated pressure change [bar]	0.1
Calculated pressure ratio	1.11111111
Outlet temperature [C]	112.440911

Isentropic outlet temperature [C]	110.050388
Vapor fraction	1
Displacement	
Volumetric efficiency	
Head developed [meter]	1860.0444
Isentropic power requirement [kW]	4.37779001
Inlet heat capacity ratio	1.32876295
Inlet volumetric flow rate [cum/hr]	1640.90894
Outlet volumetric flow rate [cum/hr]	1524.58757
Inlet compressibility factor	0.993685121
Outlet compressibility factor	0.993553021
Compressor percent above surge	
Percent below stonewall	
Surge volume flow rate	
Stonewall volume flow rate	
Shaft speed	
Specific speed	
Inlet Mach number	
Total feed stream CO2e flow [kg/hr]	0
Total product stream CO2e flow [kg/hr]	0
Net stream CO2e production [kg/hr]	0
Utility CO2e production [kg/hr]	0
Total CO2e production [kg/hr]	0
Utility usage	
Utility cost	
Utility ID	

Table 10.5. Vacuum pump replaced by compressor in simulation

Mixer	
Name	MIX1
Property method	ELECNRTL
Henry's component list ID	GLOBAL
Electrolyte chemistry ID	GLOBALF
Use true species approach for electrolytes	NO
Free-water phase properties method	STEAM-TA
Water solubility method	3
Specified pressure [bar]	0
Temperature estimate [C]	

EO Model components	
Outlet temperature [C]	106.200094
Calculated outlet pressure [bar]	1
Vapor fraction	0.100003033
First liquid /Total liquid	1
Total feed stream CO2e flow [kg/hr]	0
Total product stream CO2e flow [kg/hr]	0
Net stream CO2e production [kg/hr]	0

Table 10.6. mixer in the system

FSplit	
Name	SPLIT1
Property method	ELECNRTL
Henry's component list ID	GLOBAL
Electrolyte chemistry ID	GLOBALF
Use true species approach for electrolytes	NO
Free-water phase properties method	STEAM-TA
Water solubility method	3
First outlet stream	0.9
First specified split fraction	0.9
First calculated split fraction	0.9
First actual volume flow [cum/hr]	
First limit flow [kg/hr]	
First volume limit flow [cum/hr]	
First cum limit flow [kg/hr]	
First cum volume limit flow [cum/hr]	
First residual fraction	
Second outlet stream	
Second specified split fraction	
EO Model components	
Second calculated split fraction	0.1
Second actual volume flow [cum/hr]	
Second limit flow [kg/hr]	
Second volume limit flow [cum/hr]	
Second cum limit flow [kg/hr]	
Second cum volume limit flow [cum/hr]	

Second residual fraction	
Total feed stream CO2e flow [kg/hr]	0
Total product stream CO2e flow [kg/hr]	0
Net stream CO2e production [kg/hr]	0

Table 10.7. Fsplit in the system

Design Specs	
Name	B2
Specification	VFEVAP
Specification target	0.1
Specification tolerance	1.00E-04
Lower bound	80
Upper bound	300

Utilities				
Name	COLDH2O	HOTH2O	U-1	U-2
Utility type	WATER	WATER	STEAM	STEAM
Specified price [\$/kg]				
Specified cooling value [kcal/kg]				
Specified inlet degrees subcooled [C]				
Specified outlet degrees subcooled [C]				
Specified inlet degrees superheated [C]				
Specified outlet degrees superheated [C]				
Specified electricity price [\$/kWhr]				
Specified energy price [\$/cal]	8.87602E-10	8.87602E-10	0.0000019	0.0000025
Specified inlet pressure [bar]	1.01325	1.01325		
Specified outlet pressure [bar]	1.01325	1.01325		
Specified inlet temperature [C]	27	85	125	250
Specified outlet temperature [C]	34	75	124	249
Specified inlet vapor fraction			1	1
Specified outlet vapor fraction			0	0
Specified CO2 emission factor [kg/cal]			0.000000234	0.000000234
Specified CO2 energy source efficiency factor	1	1	0.85	0.85
Calculated heating/cooling value [kcal/kg]	-6.98472362	10.0211935	523.522534	410.653193
Calculated mass price				
Calculated inlet enthalpy [kcal/kg]	-3789.85776	-	-3169.02034	-3148.11488
Calculated outlet enthalpy [kcal/kg]	-3782.87303	-	-3692.54287	-3558.76807

Calculated inlet pressure [bar]	1.01325	1.01325	2.32178779	39.7537159
Calculated outlet pressure [bar]	1.01325	1.01325	2.25120518	39.0866691
Calculated inlet temperature [C]	27	85	125	250
Calculated outlet temperature [C]	34	75	124	249
Calculated inlet vapor fraction	0	0	1	1
Calculated outlet vapor fraction	0	0	0	0
Calculated purchase price [\$/cal]	8.87602E-10			1.0467E-08
Calculated total cost [\$/hr]	0.050964606	0	0	6.93391904
Calculated total usage rate [kg/hr]	8220.55934	0	0	1613.17446
Calculated total Electric usage				
Calculated CO2 emission factor [kg/cal]			0.000000234	0.000000234
Calculated CO2 emission rate [kg/hr]				182.370032

Table 10.8. Utilities in simulation

Chapter 11

11. Cost estimation

Cost analysis before project;

Cost analysis of EVC and TK1

- EVC – Disposal cost from April 2018 – till March 2019
=105,561.69
 - TK1 - Disposal cost from April 2018 – till March 2019
=89,991.18
- =105,561.69 + 89,991.18
=195,507.87 EURO (final disposal cost)

Cost analysis of KEVC and KC

- KEVC – Cost of sales from April 2018 – till March 2019
=142,768.75
 - KC – Cost of sales from April 2018 – till March 2019
=172,992.10
- =142,768.75 + 172,992.10

$$\begin{aligned}
&= 315,760.85 \text{ EURO (final cost of sales)} \\
&= \text{Final cost of sales} - \text{Final disposal cost} \\
&= 315,760.85 - 195,507.87 \\
&= 120,252.98 \text{ EURO (profit final)}
\end{aligned}$$

Cost analysis after project;

Cost analysis of EVC and TK1

- EVC – Disposal cost from April 2019 – till January 2020
= 52,804.52
 - TK1 - Disposal cost from April 2019 – till January 2020
= 41,507.67
- $$\begin{aligned}
&= 52,804.52 + 41,507.67 \\
&= 94,312.94 \text{ EURO (final disposal cost)}
\end{aligned}$$

Cost analysis of KEVC and KC

- KEVC – Cost of sales from April 2019 – till January 2020
= 175,894.69
 - KC – Cost of sales from April 2019 – till January 2020
= 190,709.89
- $$\begin{aligned}
&= 175,894.69 + 190,709.89 \\
&= 366,604.58 \text{ EURO (final cost of sales)} \\
&= \text{Final cost of sales} - \text{Final disposal cost} \\
&= 366,604.58 - 94,312.94 \\
&= 272,291.64 \text{ EURO (profit final)}
\end{aligned}$$

Final profit has increased by 120% respective to the previous year.

Chapter 12

12.Proposal for improvement and plant performance monitoring

- Cooling tower is replaced, and water flow system capacity is increased.
- Vacuum pump is changed.
- Pressure valve is changed, and gaskets of heat exchanger is replaced.

Plant performance monitoring can be done by two methods

- Real time data analysis
- Historical data analysis

Real time data analysis

Data is registered in the company database in daily basis and all shutdowns are calculated respect to the production process. Real time monitoring and historic data gives you clear idea about the plant performance monitoring.

CL1 Performance

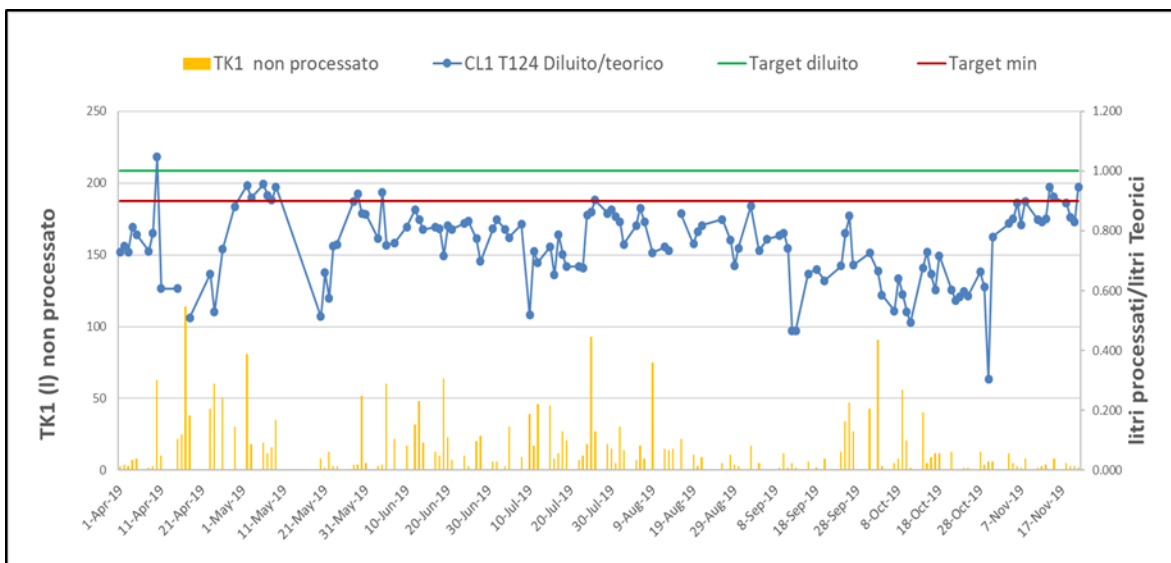


Figure 12.1. Performance monitoring of CL1

CL2 Performance

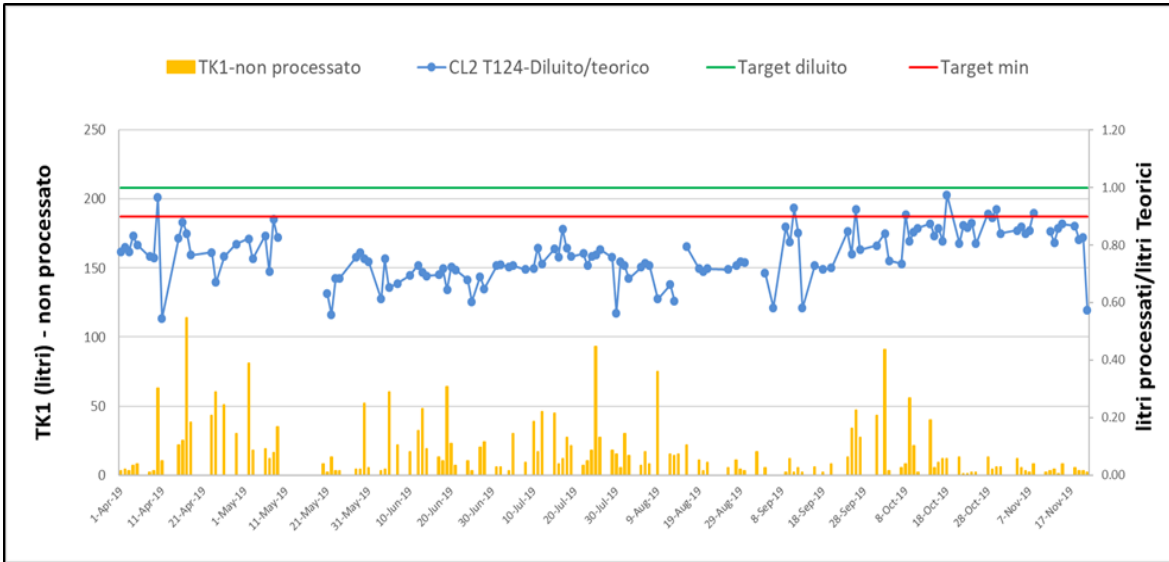


Figure 12.2. Performance monitoring of CL2

All three evaporator in series shows good performance after some modification of cold water and hot water temperature, flow rate increased with respect to the requirements

Vacuum pump is changed comparing all three evaporators CL3 has better performance due to feed availability.

CL3 performance

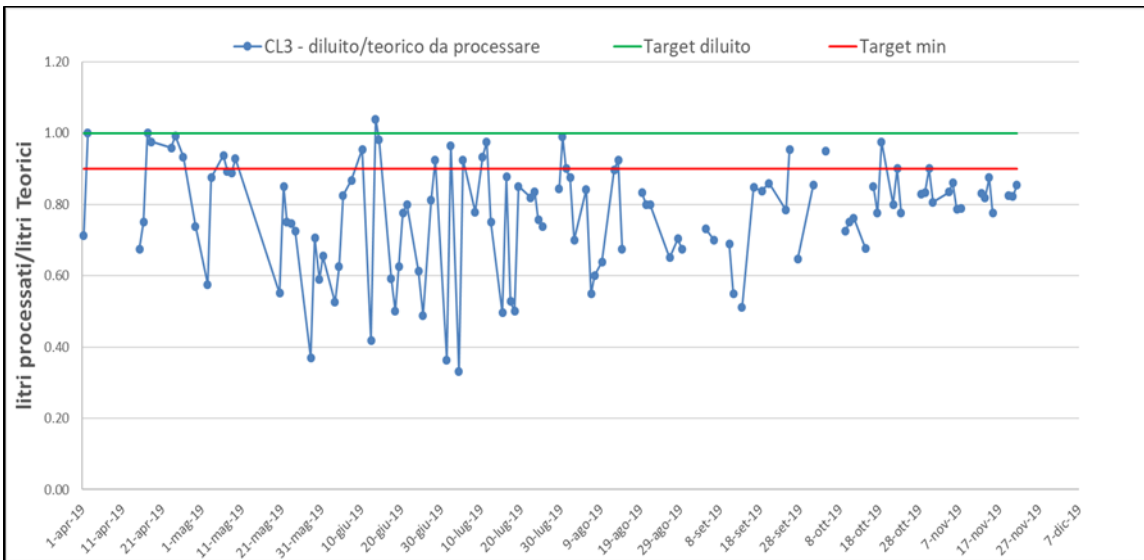


Figure 12.3. Performance monitoring of CL3

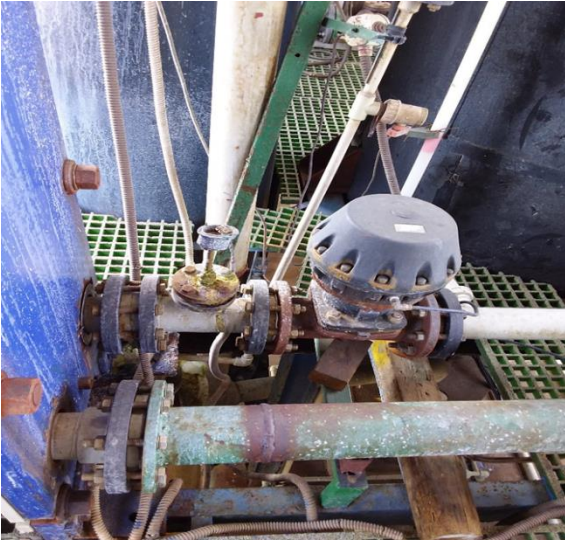


Figure 12.4 Modulating valve



Figure 12.5 Plate and Frame heat exchanger

Before project all equipment were like this shown in figures above that was a modulating valve and heat exchanger with full damage conditions.



Figure 12.6. Flash column and valve with repaired conditions

Figure 12.3 shows us Flash column and modulating valve with repaired condition after the project.

Performance of CL 1 (Evaporator 1) year 2019

Diluted feed solution	36.890 L/day
Concentrated solution	7580 L/day
Ratio between dilution/concentration	4.86 L/day

Performance of CL 2 (Evaporator 2) year 2019

Diluted feed solution	38.846 L/day
Concentrated solution	6700 L/day
Ratio between dilution/concentration	5.78 L/day

Performance of CL 3 (Evaporator 3) year 2019

Diluted feed solution	44.000 L/day
Concentrated solution	8500 L/day
Ratio between dilution/concentration	5.17 L/day

Chapter 13

13.CONCLUSION

Steady state simulation is done in ASPEN Plus to get deep process knowledge to detect gross errors in the system and process variable consistency. The efficiency of the evaporator is increased to reduce disposal cost of acid solution. The problem detected in the system was not treating solution properly due cold and hot temperature of water and vacuum pump damage.

We tried using simulation for our process to find out variable consistency and maximum capacity that system can process solution without problems.

Problems we found during simulation is it does not simulate the water temperature as it is and It need steam around 250 degree Celsius (steam) to heat up the solution also we cannot process vacuum system in simulation directly, but it takes as compressor with minimum pressure as required in the system to absorb the vapor phase.

Also, we have calculated maximum capacity that system can process a solution per day is 44 m³ using heat transfer coefficient in the simulation.

In future we can go for dynamic simulation with time dependent process to detect each variable and mass, energy balance with time dependent coordinates

Steady state process solved the problem by reducing disposal cost of the acid solution with treating more solution respective to the non-conventional behavior and software can help you to detect non-conventional behavior but not in numerical aspects.

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