بسم الله الرحمن الرحيم

Electrolysis Unit

Based on the following reports

[NLAP-WEDC 2017]

[NLAP-WEDC 2018]

[NLAP-WEDC 2019]

Detailed Design & Construction for:

- Electrolysis System

With contributions of:

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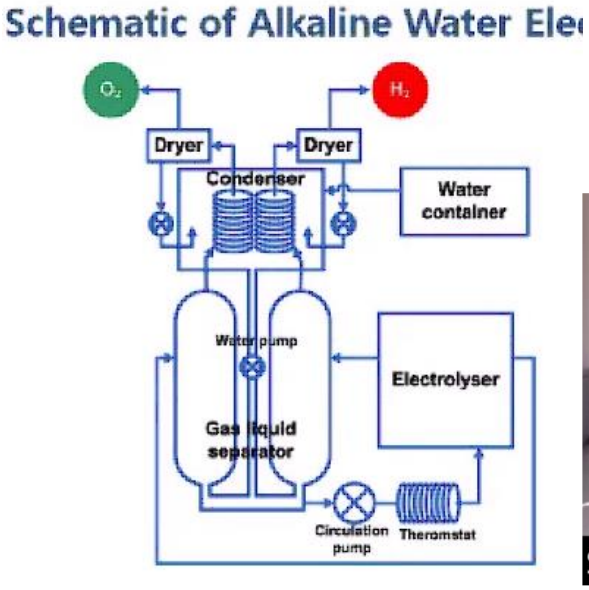
Othman Dhaibe

Samer Youssef

Last update: 26. Apr. 2022 / AthThulatha, 25 Ramadan, 1443

1 Conception and Predevelopment for Electrolysis Unit

1.1 Alkaline Electrolysis System Design from lightbridge.sales@gmail.com



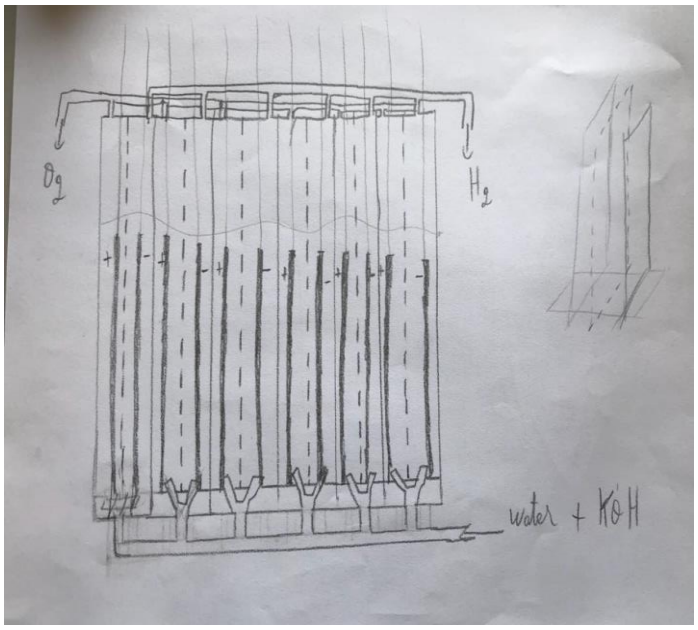

Stainless steel cutting test

Module of 2.5kW Electrolyser

Specification

Size:
52cm X 30cm X 50cm
Power Consumption:
<2.5kW
Gas production per hour:
hydrogen gas 500liter,
oxygen gas 250liter, separately
Pressure:
5 bar
Temperature:
50~80℃
Purity of gas:
hydrogen gas 99.9%,
oxygen gas 98%

1.2 Concept

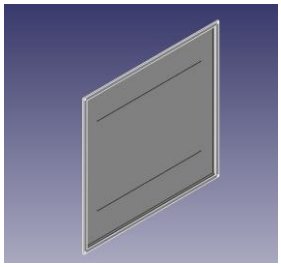


1.3 Design 1 (April 2018)

Electrolyse_cadre.FCStd

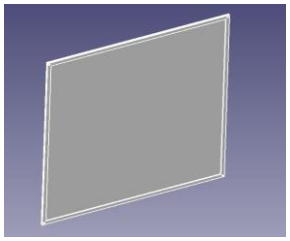
21042018_assemblage_electrolysis(color).F(

Base plate for anode and cathode



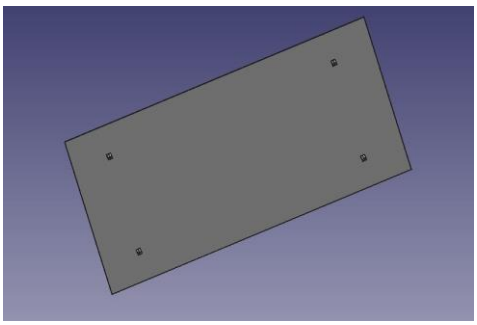
17042018_Prototype electrolysis.FCStd

Diaphragm



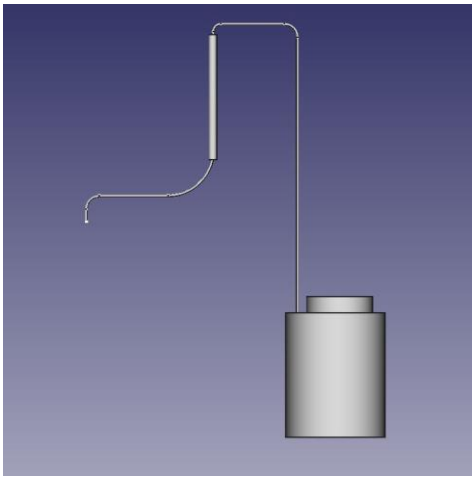
19042018_diaphragm.FCStd

Electrode



19042018_electrode.FCStd

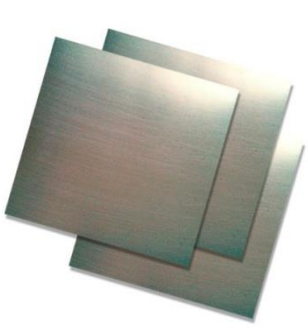
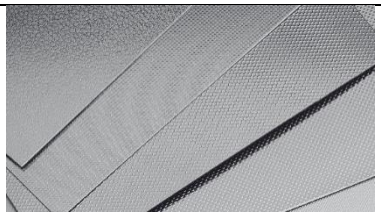
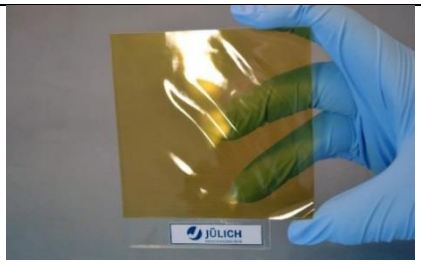
Pipe



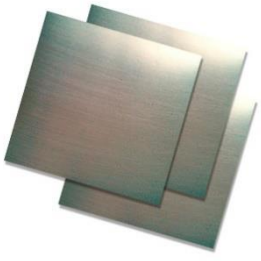
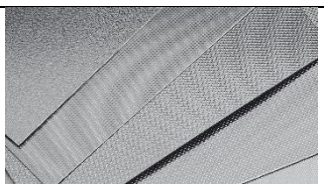
28042018_pipe.FCStd

1.3.1 Materials

2 plates plastic	1m * 1m
8 plates plastic	1.1 cm * 1m
4 plates caoutchouc	1m * 1m * 0.5 cm
1 plate Stainless	95 cm * 90 cm
1 plate Nickel	95 cm * 90 cm
2 tubes Nickel	Φ 1cm L:10 cm
2 tubes Stainless	Φ 1cm L:10 cm
6 tubes plastic	Φ 2cm L:10 cm
7 tubes plastic	Φ 2cm L:20 cm
7 elbows plastic	Φ 2cm ╔
2 tubes plastic	Φ 2cm L: 1m
2 T plastic	Φ 2cm ╣
2 condenser	
2 faucet	
2 tank plastic	
2 fixes bolt	

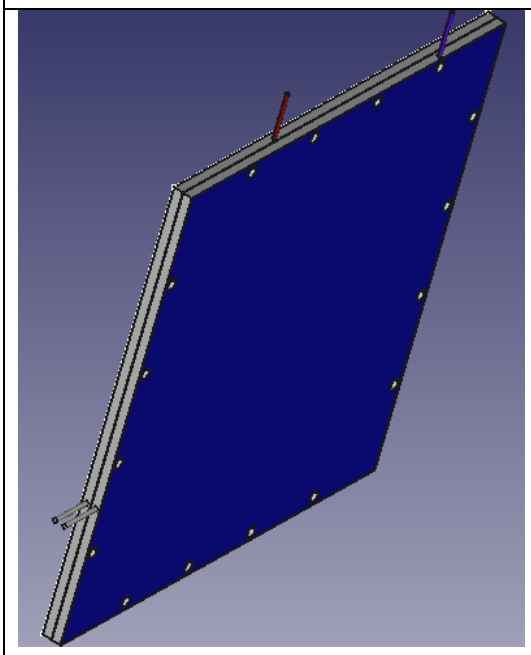
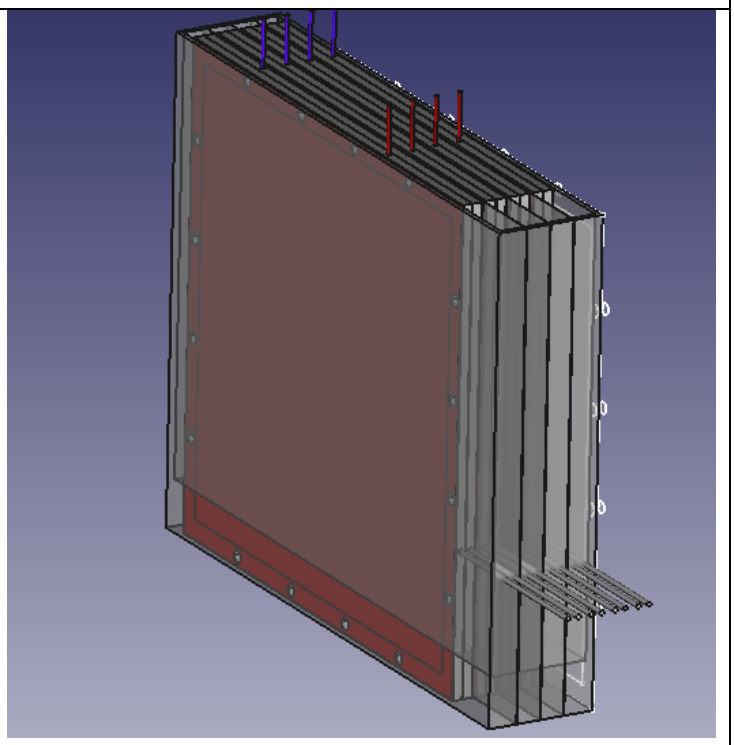
Electrolyte (KOH)	
Anode (Nickel)	
Cathode (Stainless)	
Diaphragm	

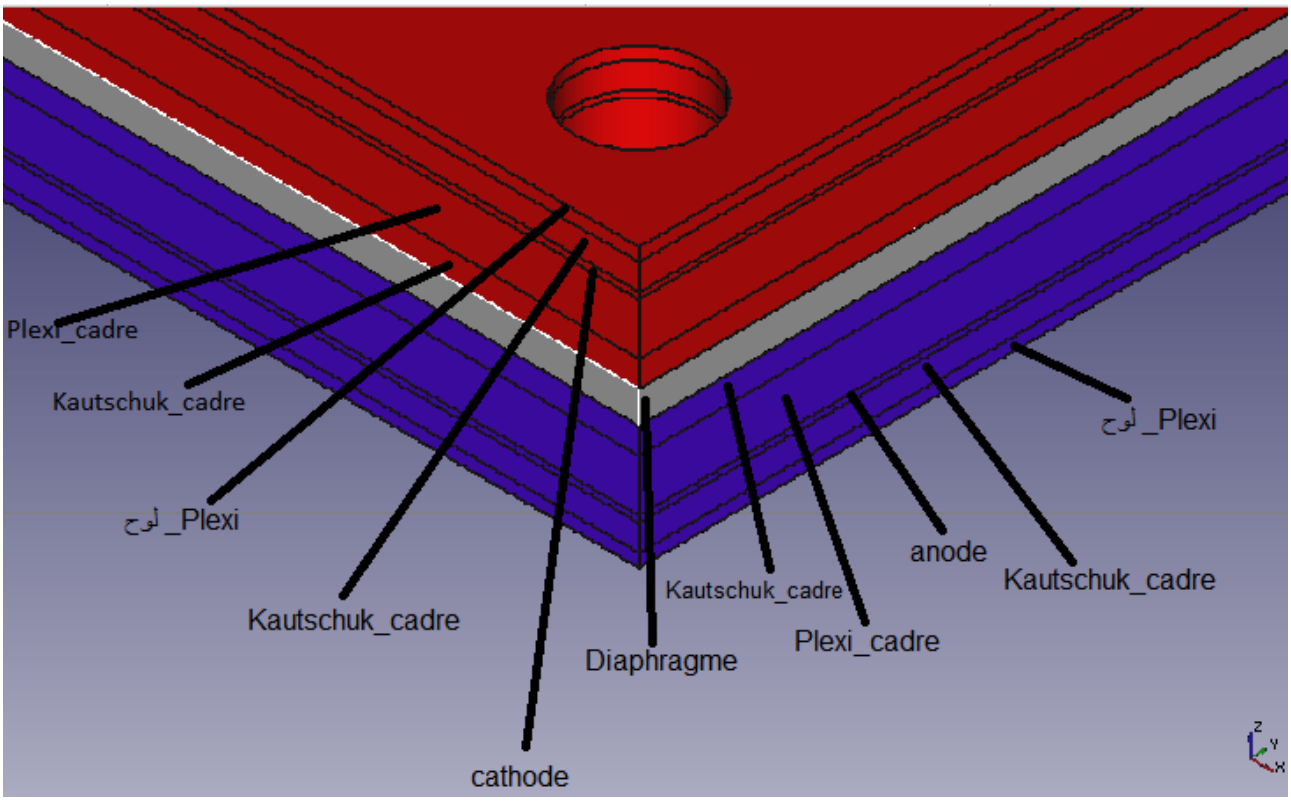
1.3.2 Cost of materials

Material	Suppliers	Prices	Pictures
Nickel	نوفل	1 kg = 2.5 $	
	Alibaba	1kg = [15$ - 40$]	
Stainless	نوفل	1kg = 4.5$	
	Alibaba	1 kg = 2.3$	

Diaphragm	Alibaba	Piece = [20$ - 500$]	

1.4 Design 2 (May 2018)

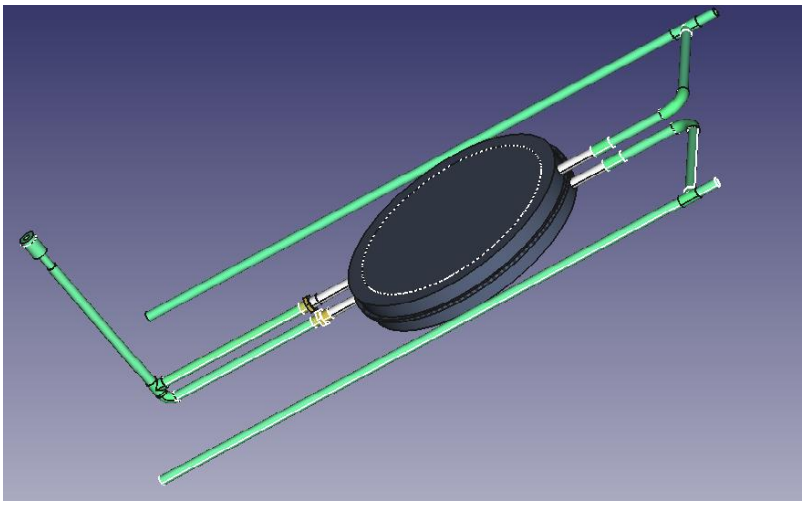
03052018_one_cell.FCStd	03052018_Stack_electr.FCStd
	



1.4.1 Result:

Plexi breaks, when two plates are pressed together such that the water can't flow out.

1.5 Design 3 (Aug 2018)



electrolyser 210818.FCStd

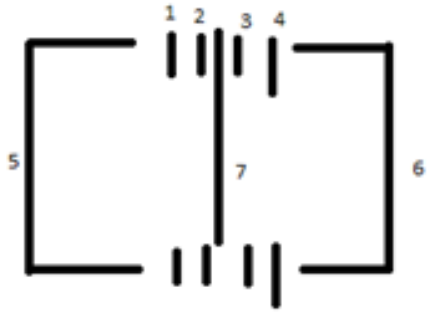
STEPS:

1-2 stainless plates tied up tightly

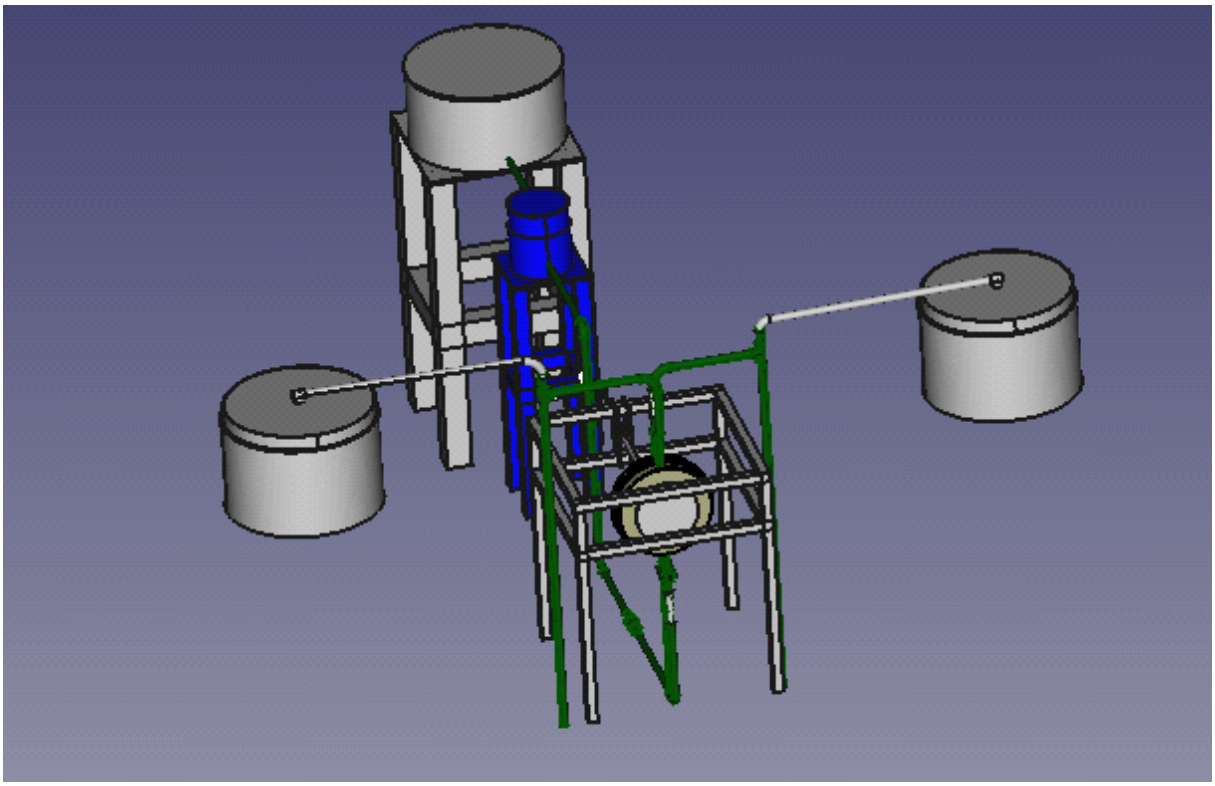
2- ppr pipes allowing the gas to flow freely

3- a plastic headed bound to prevent electrical contact between the 2 plates

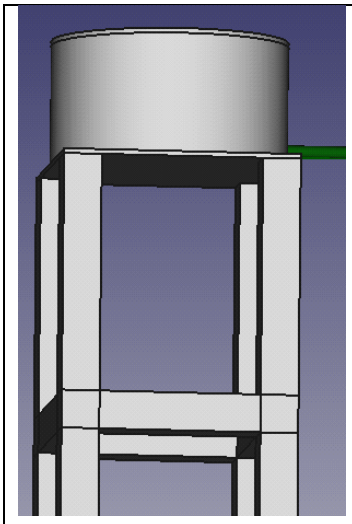
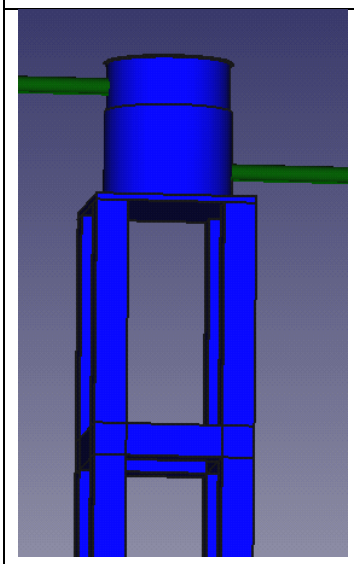
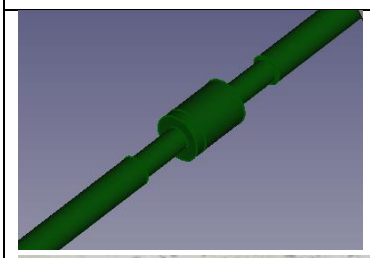
4-retatchebel iron link to separate the 2 basic compounds [pipes,plates] (قطع وصل).

	a check valve (NON-REVERSE LINK) to prevent the water from turning back once it has been pumped .
	The motor has initially the basic role to pump the water threw the device starting the mechanicsm witch whom it is meant for.
	1-industriel rolls 2-جلدة 3-جلدة 4-industriel rolls 5- stainless cathode 6-stainless anode 7- nafion membrain
	We have replaced the motor with a more accurate full-mechanic system , using a relatively small volume tank decreasing the water pressure in the pipes making a more efficient and accurate mechanicsm

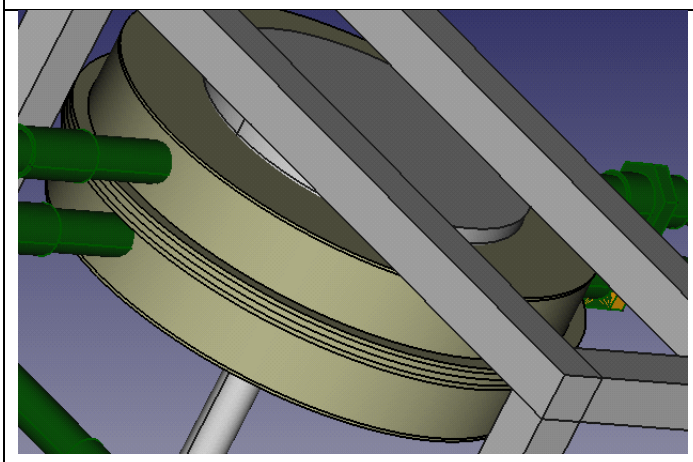
1.5.1 From report 10 Nov 2018 (Samer Youcef)



electrolyser 201018 - Copy (16).FCStd

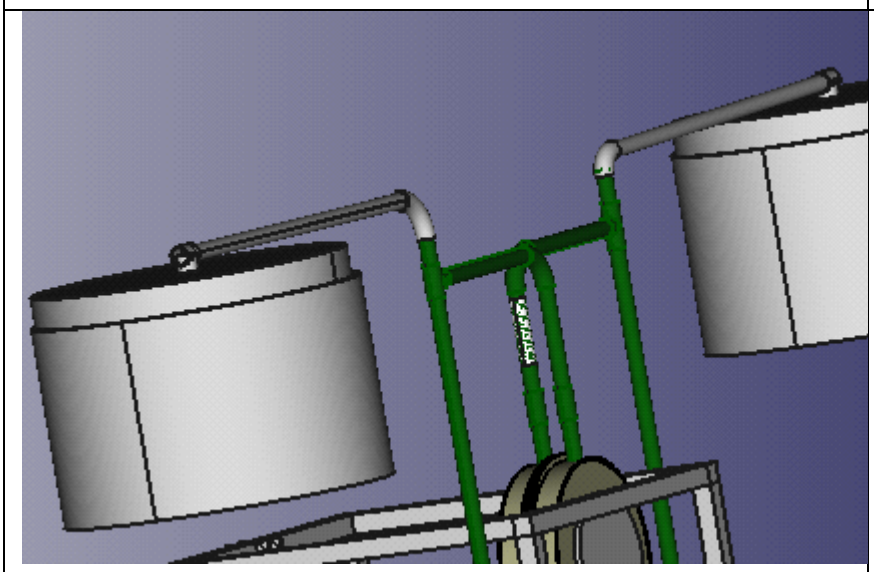
	big tank.FCStd A WATER TANK AT 50 cm OF DIAMETRE , STANDING ON A 90cm HEIGHT TABLE , WE ATTACHED A WATER TAP TO IT , CONTROLING THE WATER QUANTITY IN THE SYSTEME
 small tank (2).FCStd	A REALTIVELY SMALLER TANK, THIS TANK HAS NO WATER TAP, IT'S MAIN ROLE IS CONTROLING WATER LEVEL WITHIN THE SYSTEME , THREW A SPECIFIC WATER LEVELING INTRUMENT(FAWAYSHA); IT HAS LESS THEN 20cm IN DIAMETER, AND STANDING AT A TABLE HEIGHT OF 70cm .
 	stop check valve.FCStd A STOP CHECK VALVE, PREVENTING WATEER FROM TURNING BACK TO THE DIRECTION OF IT'S SOURCE, PLAYING A KEY ROLE IN THE STABILITY OF THE WATER IN THE SYSTEME, INCREASING LEVEL CONTROLING PRESICION; AND TO THE RIGHT WE HAVE A WATER TAP, WICH REPRESENTS THE SOUL EXIST OF THE WATER FROM THE SYSTEME, WHEN WANTED

.



stainless steal plates.FCStd

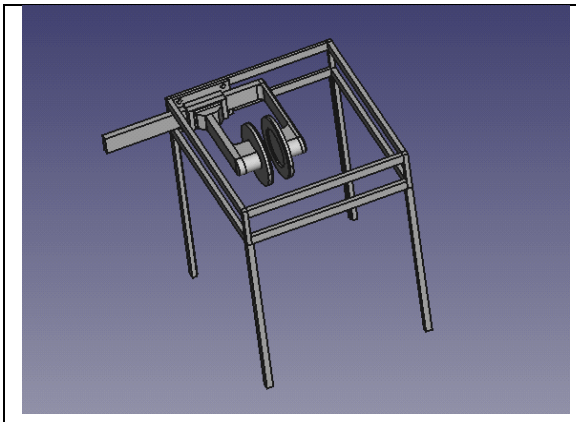
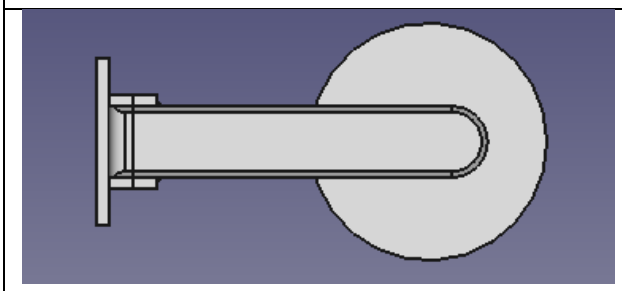
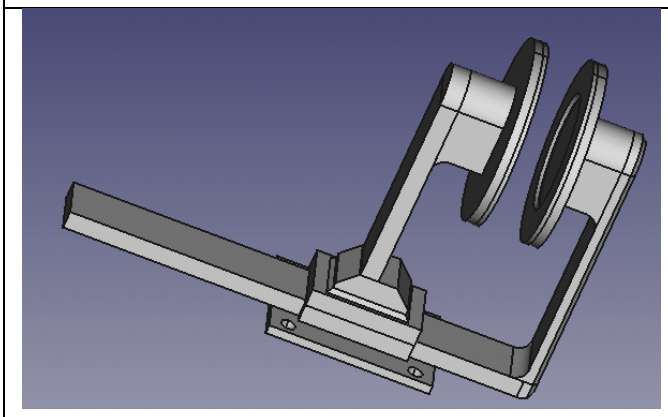
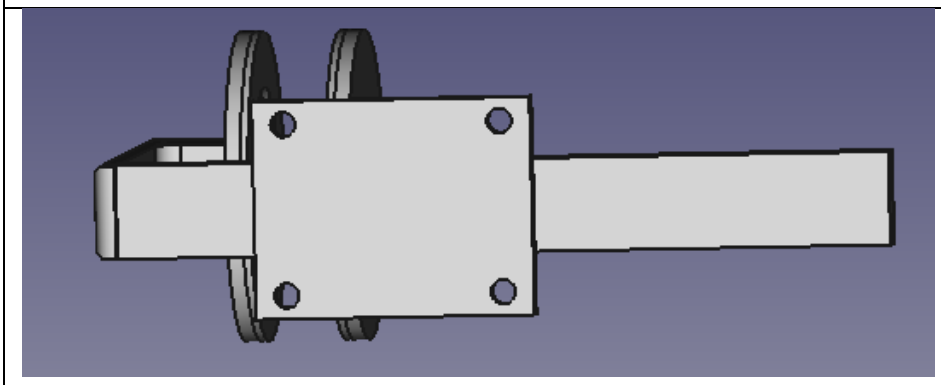
THE MAIN PART OF THE SYSTEME, 2 STAINLESS STEAL PLATES(D=30cm,edge:L,l=4mm,h=4 cm) PRESSED TOGETHER , LAYS IN BETWEEN THEM 2 RUBBER JOINTS TO ENDURE THE MASSIVE PRESSURE , AND THESE JOINTS ARE IDEAL IN PREVENTING ANY PENETRATION, BETWEEN THE PALTES



pressure table.FCStd

AFTER THE DECOMPOSASTION PROCESS, GAS WILL START FLOATING INSIDE THE PLAKSI PIPES , WICH WILL EVENTUALLY BE STOCKED IN THE PRESSURE CHAMPER BY A SPECIFIC WATER METHODE, EACH ONE OF THIS 2 CHAMPERS CONTAINS DIFERENT GASES (H2,O2).

Electrolyser base :180918

	ارتفاع الاقدام :60 سنتمتر الطول والعرض :55 سنتمتر
	قطر الدائرة :20 سنتمتر السماكة: 10 ملمتر
	قطر الدائرة الداخلية : 12 سنتمتر السماكة :5 ملمتر ارتفاع الدائرة : 25 سنتمتر تبعد الدائرة الاولى عن الثانية كحد اقصى : 50 سنتمتر
	طول : 14 سنتمتر عرض :18 سنتمتر

1.6 Hydrogenics electrolyzer

Technical specifications

MODEL	HySTAT®-10-10
Operating Pressure	10 ba
Max. Nominal Hydrogen Flow	10 Nm³/h
Hydrogen Flow range	40 - 10
Hydrogen Purity (before HPS)	99,9%; H
Hydrogen Purity (after HPS)	99,998% (99,999% Atm. Dew point: -6
Nr. of cell stacks	
Estimated AC power consumption (all included)	4,
Voltage	3 x 400 VAC ± 3%
Frequency	50 Hz ±
Installed power	100 KVA
Max. cooling water t° (electrolyte)	40°C
Design flow cooling water (electrolyte)	
Max. cooling water t° (gas cooling)	
Design flow cooling water (gas cooling)	
Demineralized water consumption	
Electrolyte	
Approx. Electrolyte Quantity	
Installation Area	Indo
Ambient Temperature Range	
Dimensions Process Part (LxWxH)**	
Dimensions Power Rack (LxWxH)	
Dimensions Control Panel (LxWxH)	
Approx. empty Weight Process Part	1.350 kg
Weight Power Rack	
Weight Control Panel	

(*) HPS = hydrogen purification system
(**) including 'ATEX' enclosure

2 Cascaded Design and Calculation for Alkaline Electrolysis Unit

2.1 Overview

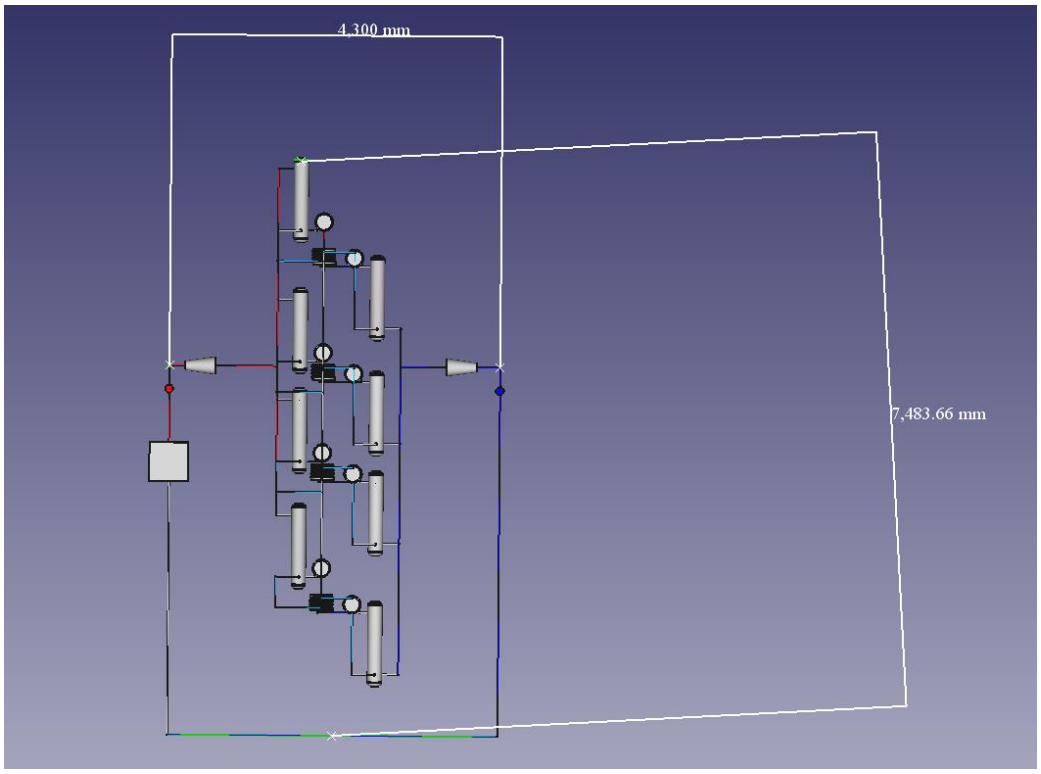


Figure 1: Plant of electrolysis (FreeCAD)

Specification	
Voltage	8 volt
Current	300 Ampere
Power	2.4 KW
KOH	5.7 Kg
Gas flow rate Hydrogen all stacks	2.27 $L.min^{-1}$
Gas flow rate Oxygen all stacks	1.13 $L.min^{-1}$
Dimensions	Electrode (Radius: 15 cm / thickness: 2cm) Stainless 304 Stack (Radius: 15 cm/ Thickness: 16 cm)

Table 1: Specification of electrolysis

8 Volt/ 300 Ampere

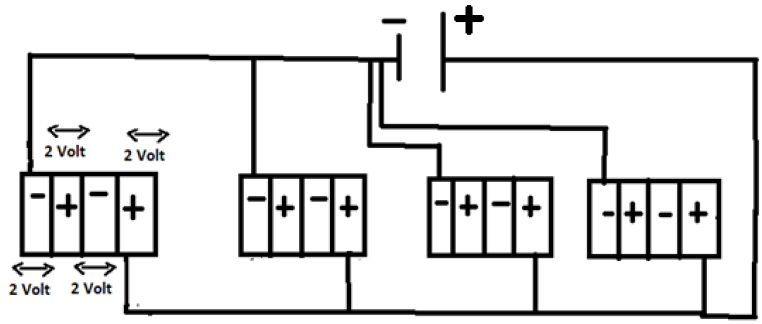


Figure 2:Multistack Amperage/Voltage

Each stack has 4 serial cells (2+2+2+2 = 8 Volt / 75 Ampere)

4 stack parallel (8 Volt/ 75 Ampere*4 = 300 Ampere)

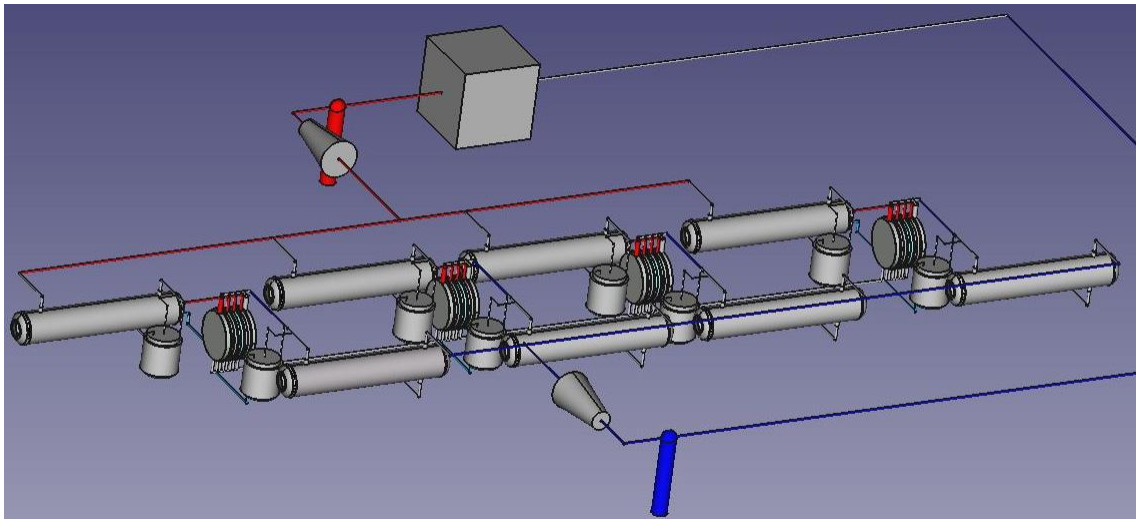
- Each electrode has thickness 2 cm: 166.6 g (KOH)

We have 30 electrodes (2 cm) => 30 * 166.6 = 5000 g (KOH)

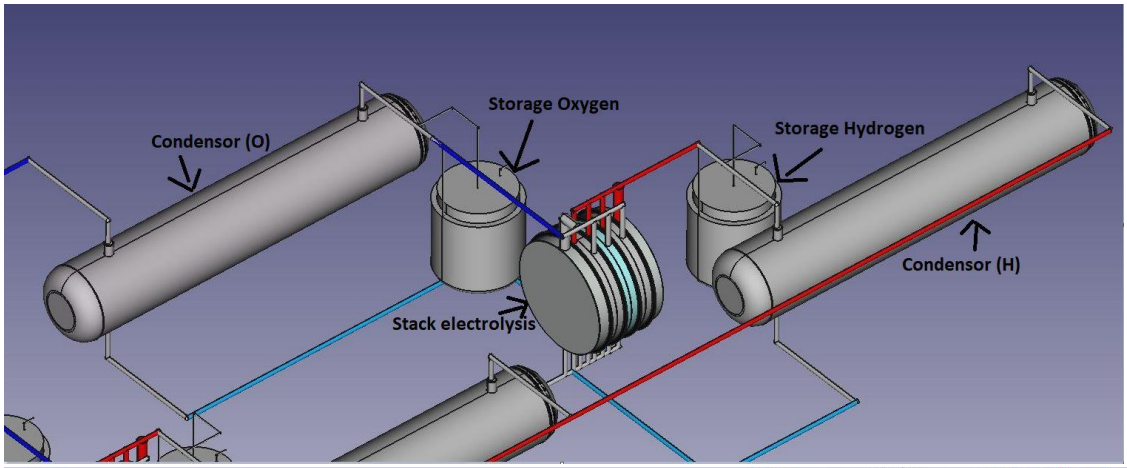
- Electrode has thickness 4 cm: 333.3 g (KOH)

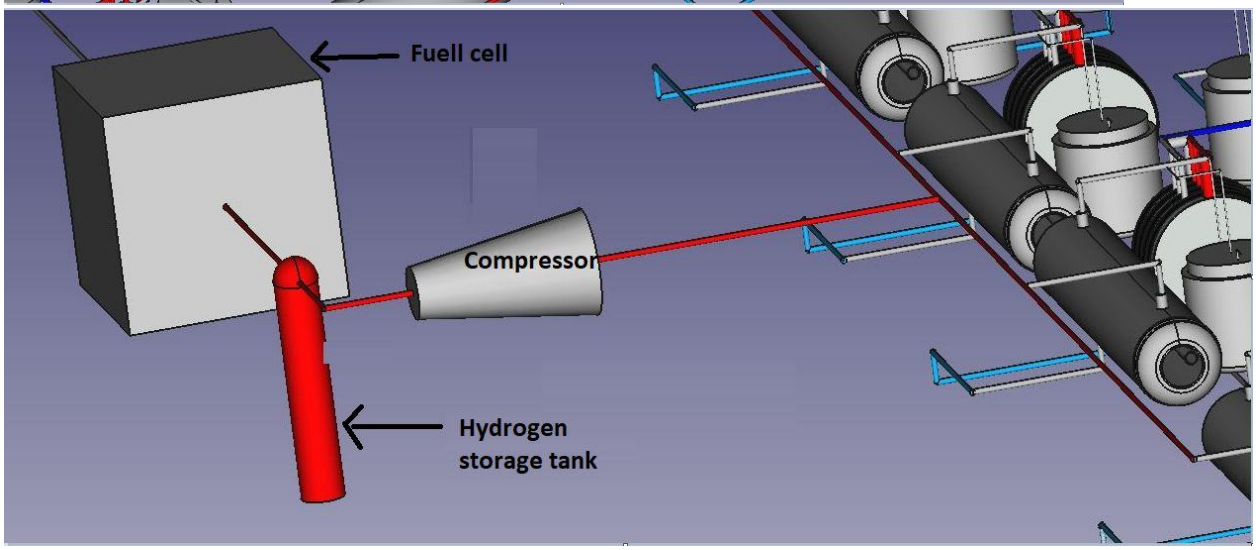
We have 2 electrodes (4 cm) => 2 * 333.33 = 666.6 g (KOH)

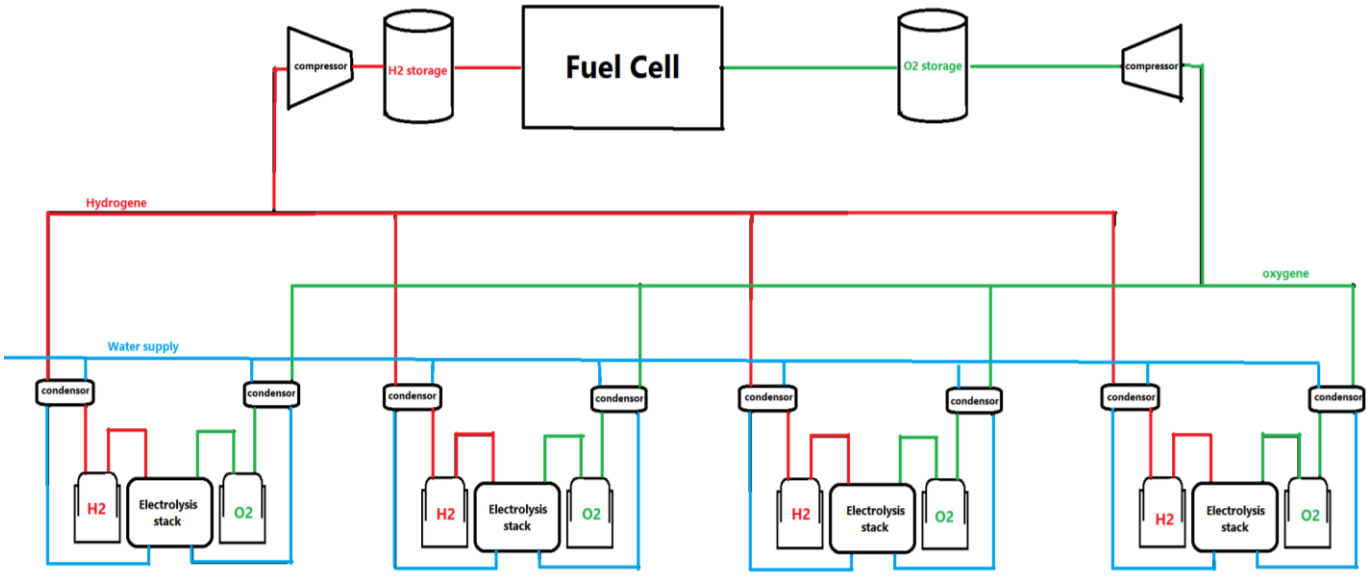
2.2 Design FreeCad



160319_electrolysis_
multistack.FCStd


Condensor (O)
Storage Oxygen
Storage Hydrogen
Condensor (H)
Stack electrolysis


Fuell cell
Compressor
Hydrogen
storage tank


compressor
H2 storage
Fuel Cell
O2 storage
compressor
Hydrogene
oxygene
Water supply
condensor
H2
Electrolysis stack
O2

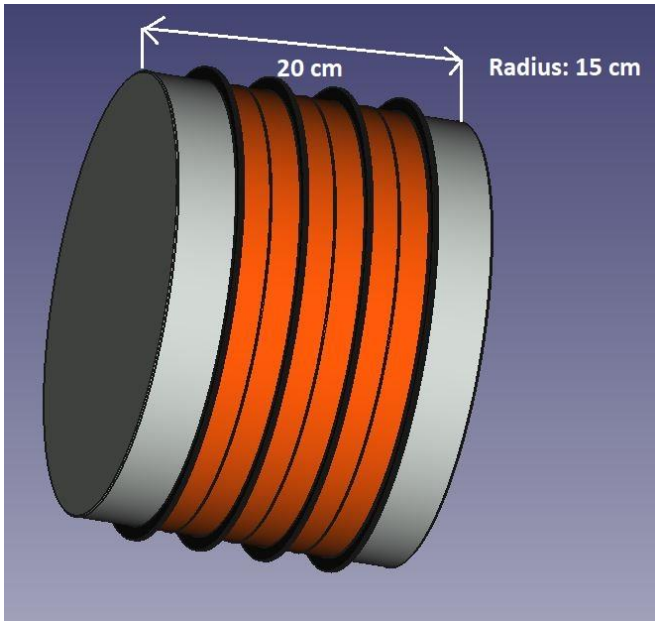
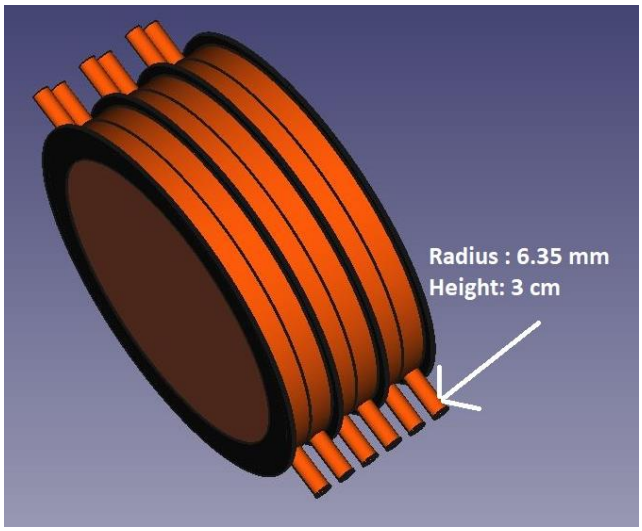


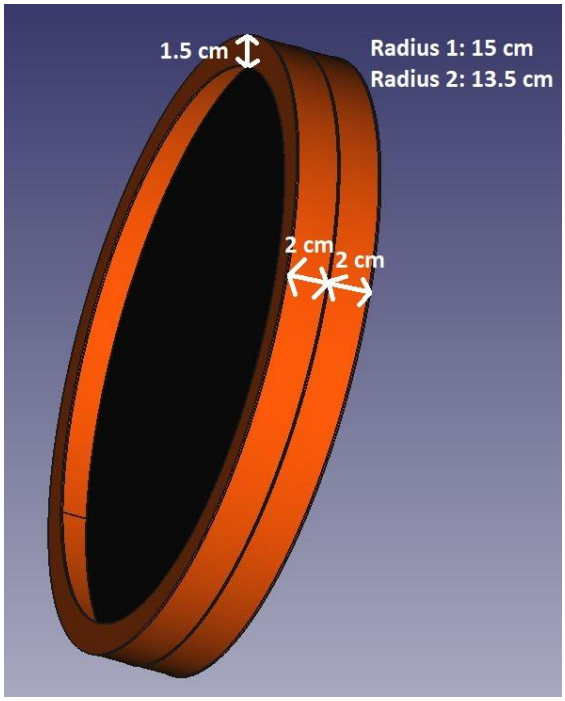
Figure 3: Serial stack

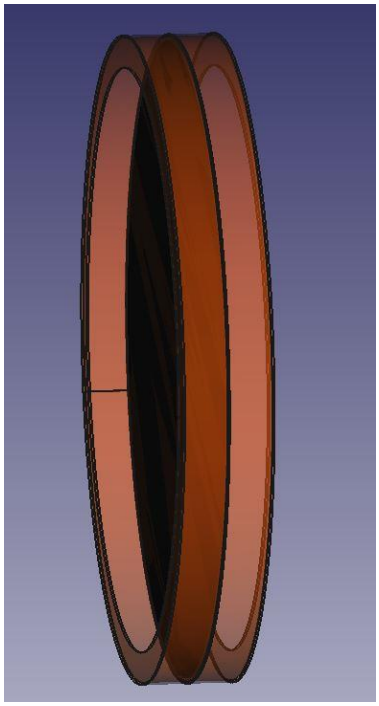
180319_Stack_electrolysis.FCStd

Stack

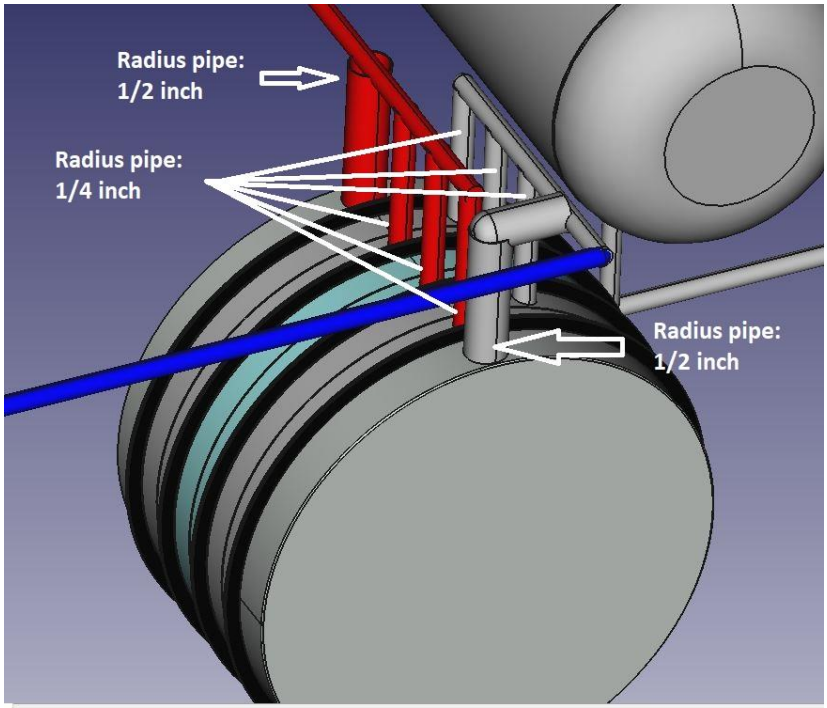


180319_baseplate_electrolysis.FCStd



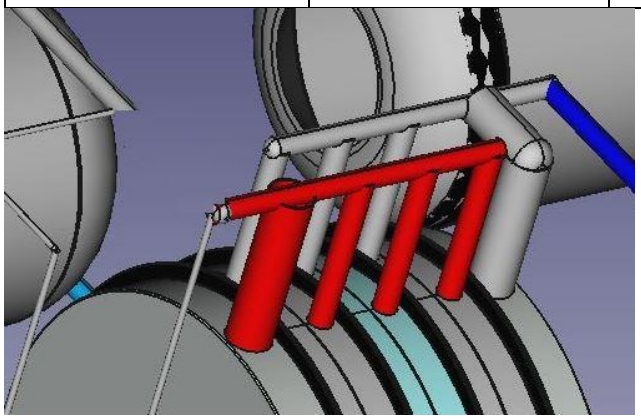


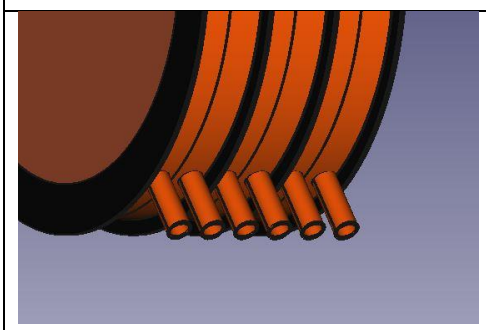
Base plate

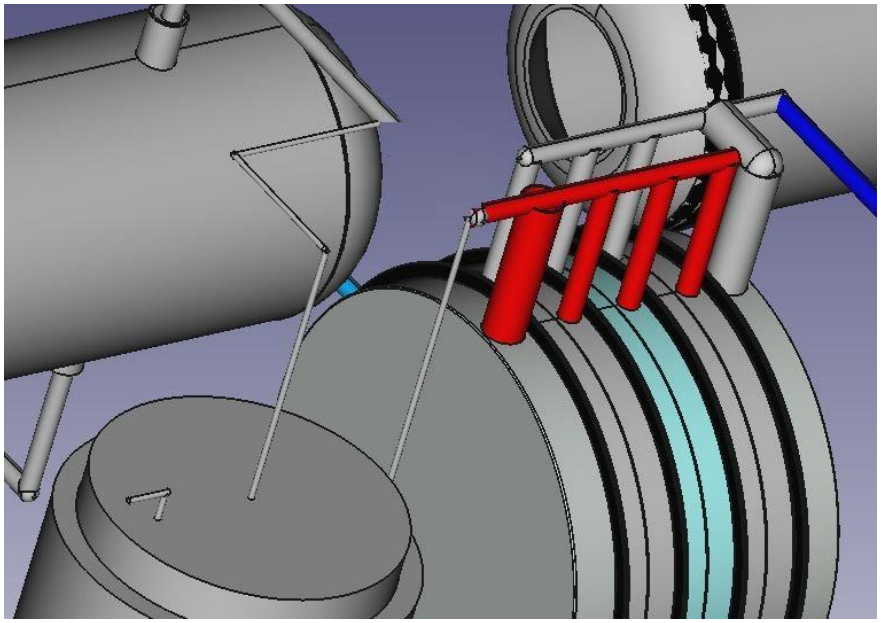


مواد	عدد	المقاس	الشكل
قسطل	6	¼ انش طول 10 سنتمتر	

محول	2	من ½ الى ¼	
كوع	1	½ انش	
كوع	4	¼ انش	
	4	¼ انش	



مواد	عدد	المقاس	الشكل
قسطل	6	¼ انش طول 10 سنتمتر	
	5	¼ انش	



2.3 Calculation of the amount of water and KOH

$V=\prod.R^2.h$

Radius: 15 cm

H_1 : 4 cm H_2 = 2 cm

$V_1=\prod.R^2.h_1$

$= \prod. 0.15^2 . 0.04$

$= 2.82* 10^{-3}\ m^3$

$= 2.82* 10^{-3}.10^6\ cm^3$

$=2.82*10^3\ cm^3$

=2.82 liter

$V2 =\prod.R^2.h_2$

$= \prod. 0.15^2 . 0.02$

$= 1.41* 10^{-3}\ m^3$

$= 1.41* 10^{-3}.10^6\ cm^3$

$=1.41*10^3\ cm^3$

=1.41 liter

The cell can contain 2.82 liter and 1.41 liter but in reality we want fell cell a)1 liter and b) 0.5 liter respectively

KOH

A. *The electrolysis need 25 % KOH in 1000 ml so 75 % is water*

250 g → 750 ml

?? <--1000 ml

Amount of KOH in one cell end plate electrode $= \frac{1000\ ml * 250\ g}{750\ ml} = 333.33\ g$

We have 2 electrodes end plate: 2*333.3 g = 666.6 g

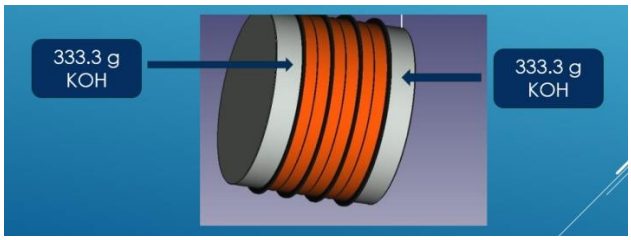


Figure 4: Amount of KOH

B. *The electrolysis need 25 % KOH in 500 ml so 75 % is water*

125 g → 375 ml

?? <--500 ml

Amount of KOH in one cell base plate $= \frac{500\ ml * 125\ g}{375\ ml} = 166.66\ g$

We have 30 electrodes base plate: 30 * 166.66 g= 5000 g

2.4 Calculate gas flow rate

The maximum cell current value of 75 A is selected for the calculation. Faraday constant (F= 96485 C.mol^{-1} or C: coulomb (1C = 1A.s)). Moreover, Eq. 1 is used to calculate the number of hydrogen moles as follows.

$$n_{(H_2)} = \frac{I * t}{2F} = \frac{75\ (A) * 60(s)}{2(electrons) * 96485\ C.mol^{-1}} = 0.0233\ mol/min$$

Considering Eq. 2, assuming the pressure of 1 atm and the operating temperature of 25°C, the theoretical $V_{H2(g)}$ can be determined as,

$$V_{H_{2(g)}} = \frac{n_{H_2} RT}{P} = \frac{0.0233\ mol/\min * 0.082\ Latm\ K^{-1} mol^{-1} * 298\ K}{1\ atm}$$

$$V_{H_2} = 0.569\ L.\ min^{-1}$$

Each stack produce 0.569 L.min^{-1} => 4 stack produce = 0.569 L.min^{-1} * 4 (stack) = 2.279 L.min^{-1}

For oxygen:

The amount of substance for O_2 (g) can be determined by using either Eq. 5.1 or the electrochemical reaction of the alkaline electrolysis cell. According to the electro chemical reaction, the number of O_2(g) moles should be half of H_2(g) moles. Hence, the number of O_2(g) moles can be easily determined as in Eq.

$$n_{O_2} = \frac{n_{H_2}}{2}$$

$$n_{O_2} = 0.0116\ mol/min$$

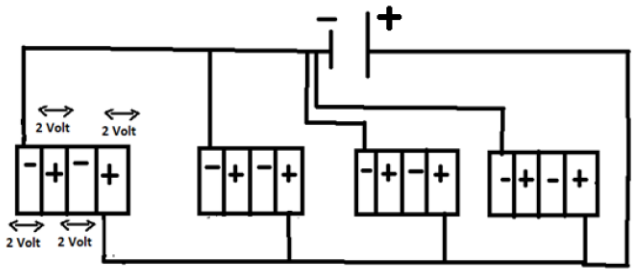
$$V_{O_{2(g)}} = \frac{n_{O_2} RT}{P} = \frac{0.0116\ mol/\min * 0.082\ Latm\ K^{-1} mol^{-1} * 298\ K}{1\ atm}$$

$$V_{O_2} = 0.284\ L.min^{-1}$$

Each stack produce 0.284 L.min^{-1} => 4 stacks produce = 0.284 $L.min^{-1}$ * 4 (stacks)= 1.138 L.min^{-1}

Other https://www.editions-petiteelisabeth.fr/calculs_electrolyse_3.php

2.5 Power supply

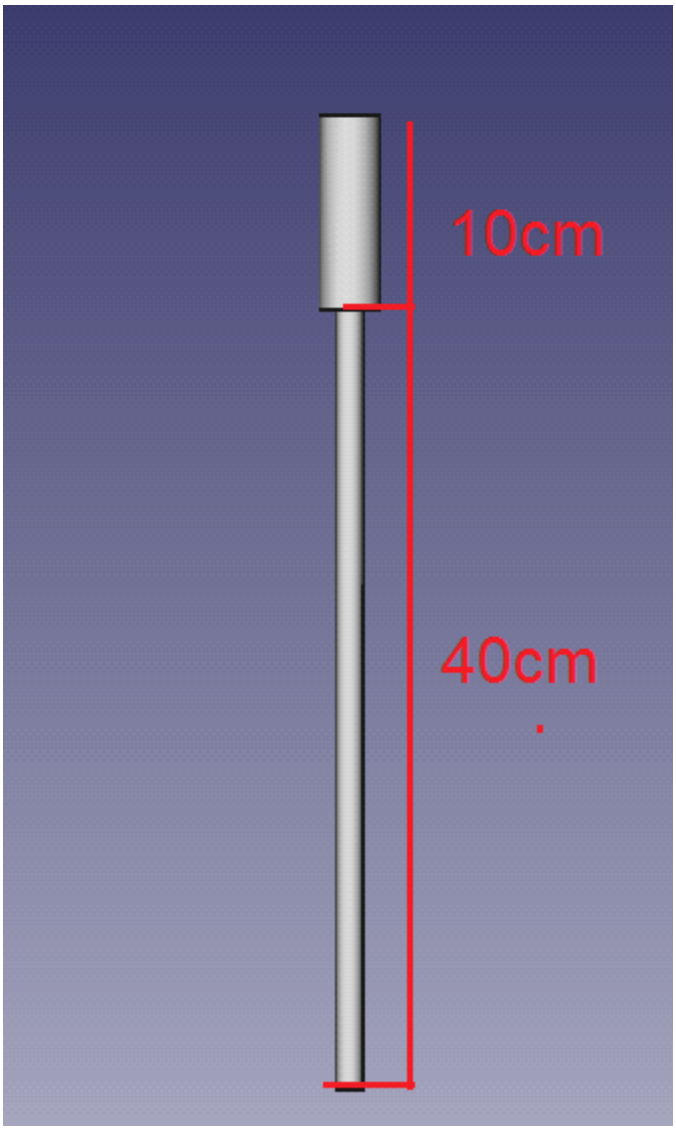


- Density current for electrolysis: 0.2 – 0.4 A/cm²
- Our cell contains 0.5 liter = 250 cm²
- Current apply for each cell = $\frac{250\ cm^2 * 0.3\ A/cm^2}{1 cm^2} = 75\ A$
- Voltage apply for each cell is 2V
- Each stack has 4 serial cell => voltage = 4*2 = 8 V
  Current = 75A
- The total is 4 parallel stack => voltage = 8 V
  Current = 4 * 75 = 300 A
- Power apply: Power = voltage x Current = 8 Volt x 300 Ampere = 2.4 KW

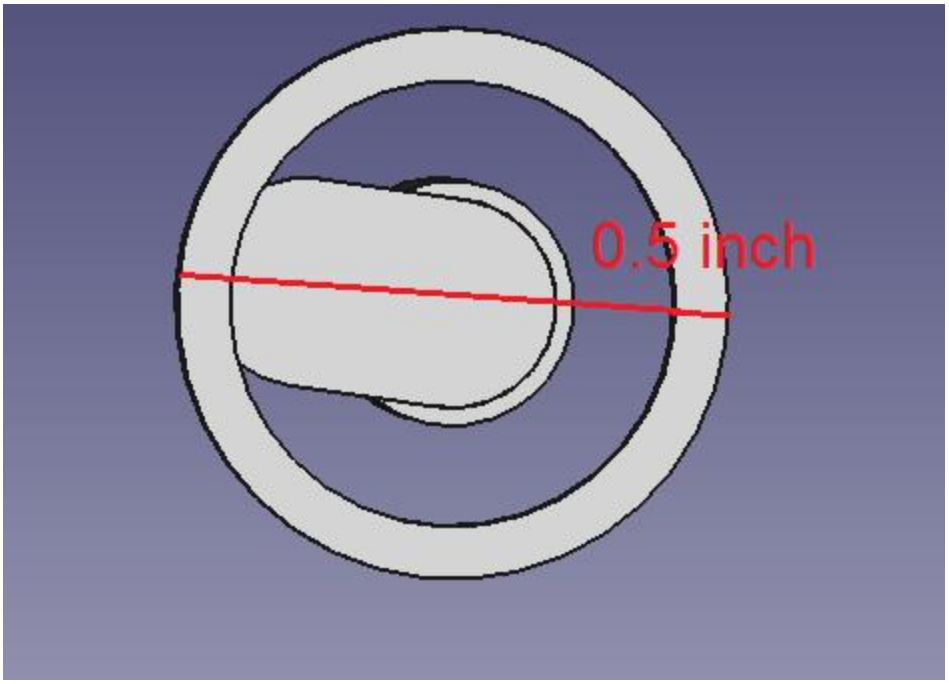
2.6 Simplified Design[1]

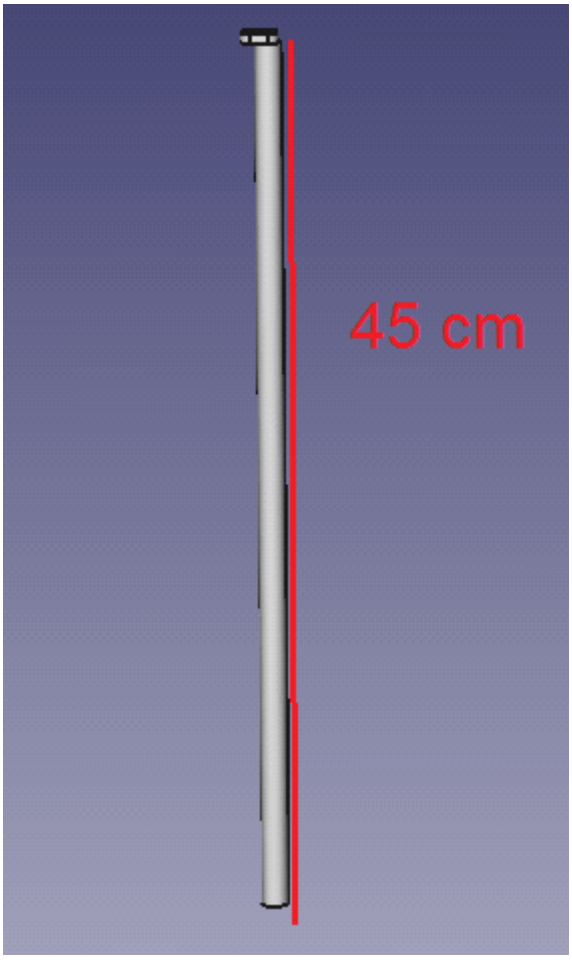
2.6.1 Level Control System

tubes=12.5mm,6mm

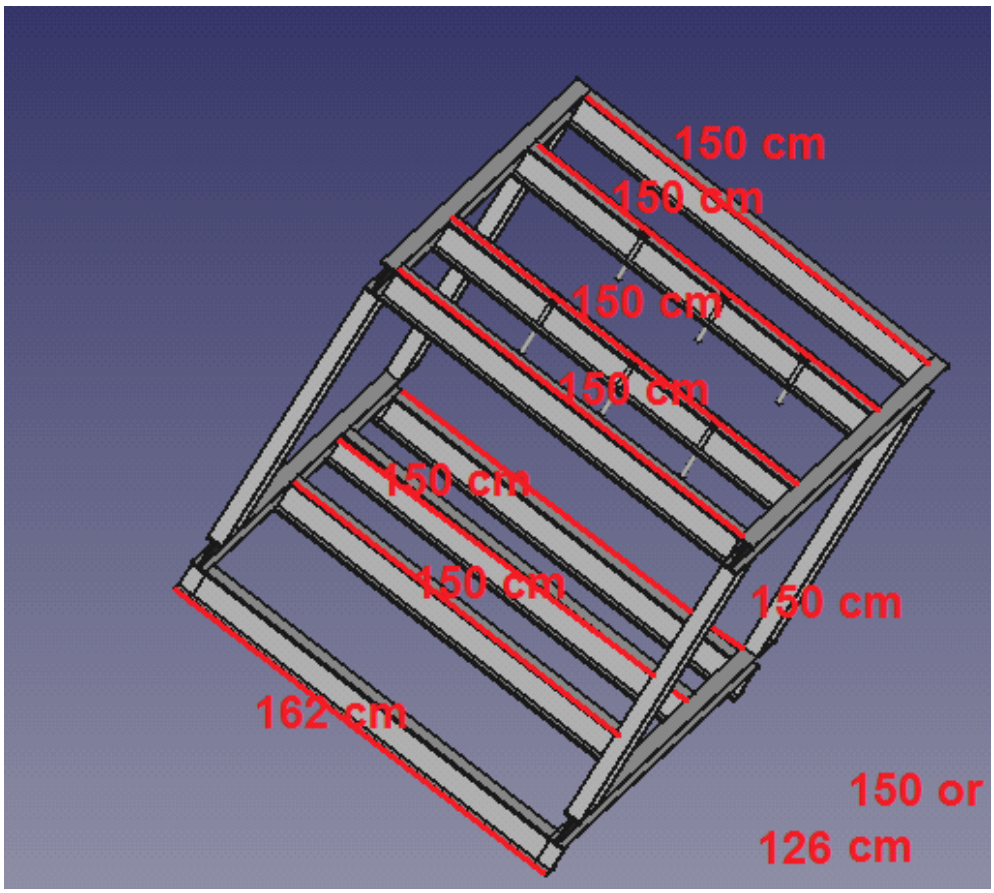


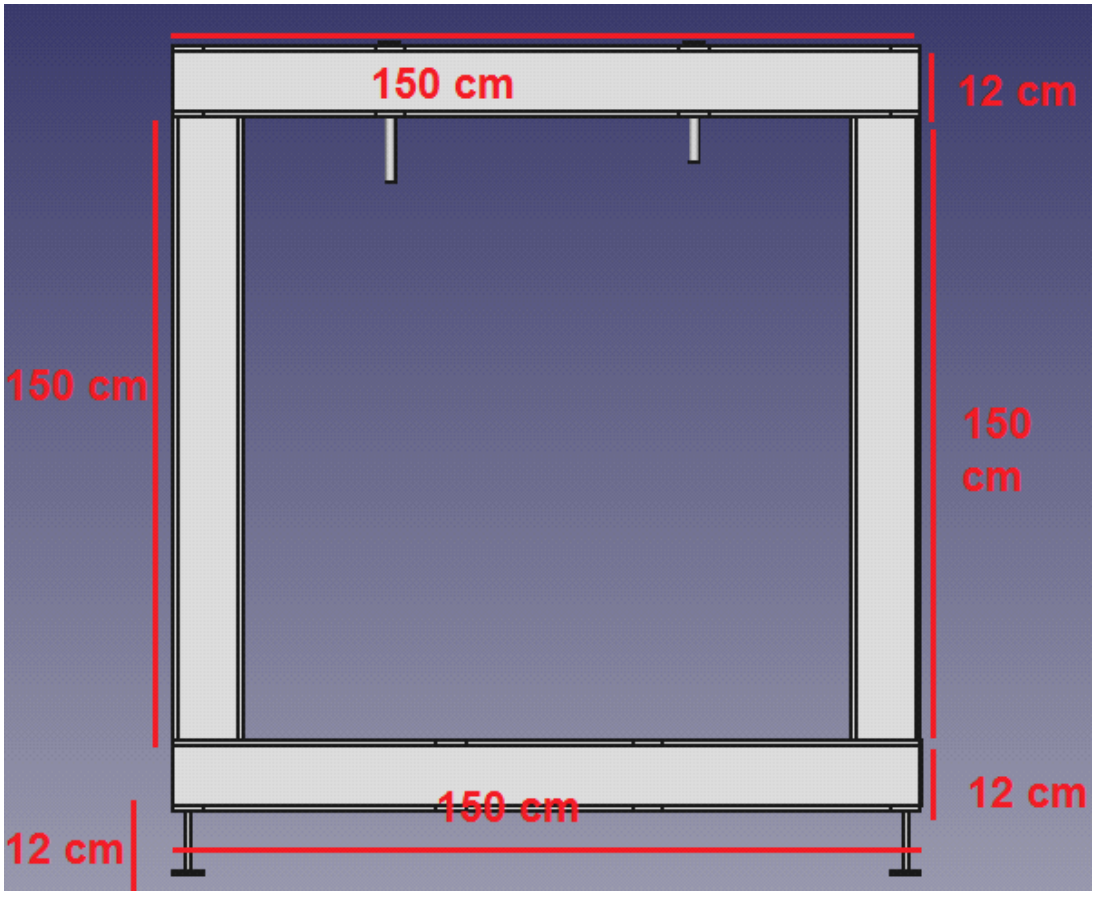
[1] Samer Youssef, July/Aug 2019


0.5 inch


45 cm

2.6.2 Electrolysor Container



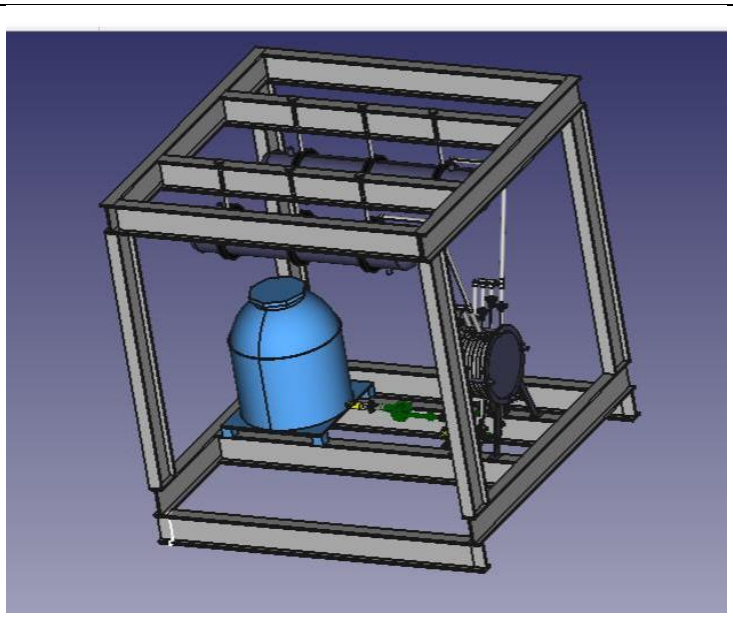


Number of columns: 2-(162) cm

14-(150) cm or 12(126)cm

2(150)cm.

2.6.3 Integration



110619NLAP-WEDC_ElectrolysisUnit.FCStd

3 Alkaline Electrolysis of Water Unit including Fuel Burner

3.1 Overview

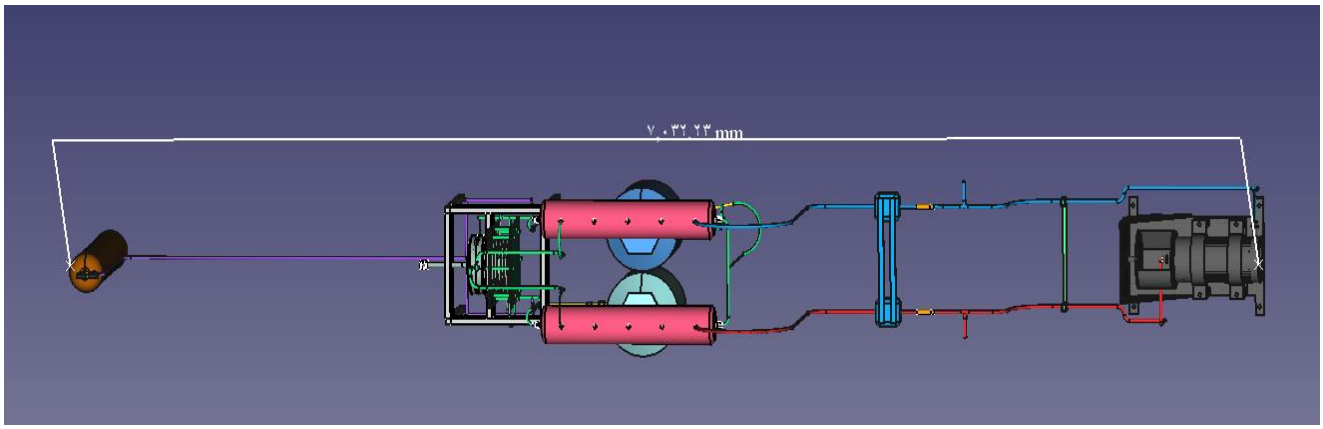


Figure 5 : Plant of electrolysis (FreeCAD

Specification	
Voltage	4 volt
Current	150 Ampere
Power	0.6 KW
KOH	1.33 Kg
Gas flow rate Hydrogen all stacks	2.27 $L.min^{-1}$
Gas flow rate Oxygen all stacks	1.13 $L.min^{-1}$
Dimensions	Electrode (Radius: 15 cm / thickness: 2cm) Stainless 304 Stack (Radius: 15 cm/ Thickness: 16 cm)

Table 2: Specification of electrolysis

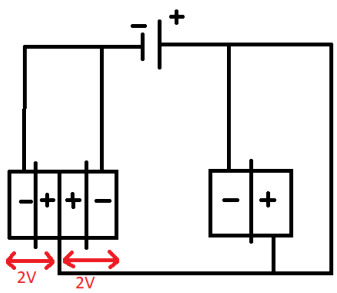


Figure 6 :Multistack Amperage/Voltage

Each stack has 2 serial cells (2+2 = 4 Volt / 75 Ampere)

2 stack parallel (4 Volt/ 75 Ampere * 2 = 150 Ampere)

- Each electrode has thickness 2 cm: 166.6 g (KOH)

We have 6 electrodes (2 cm) => 4 * 166.6 = 666.6 g (KOH)

- Electrode has thickness 4 cm: 333.3 g (KOH)

We have 2 electrodes (4 cm) => 2 * 333.33 = 666.6 g (KOH)

3.2 FreeCad Design

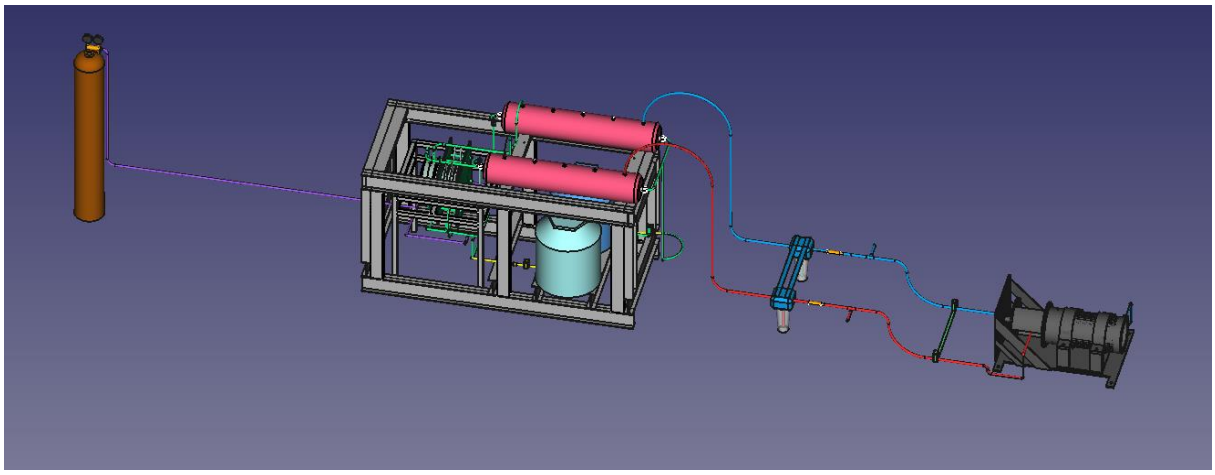


Figure 7

electrolyser+fuel burnner 010120.FCStd

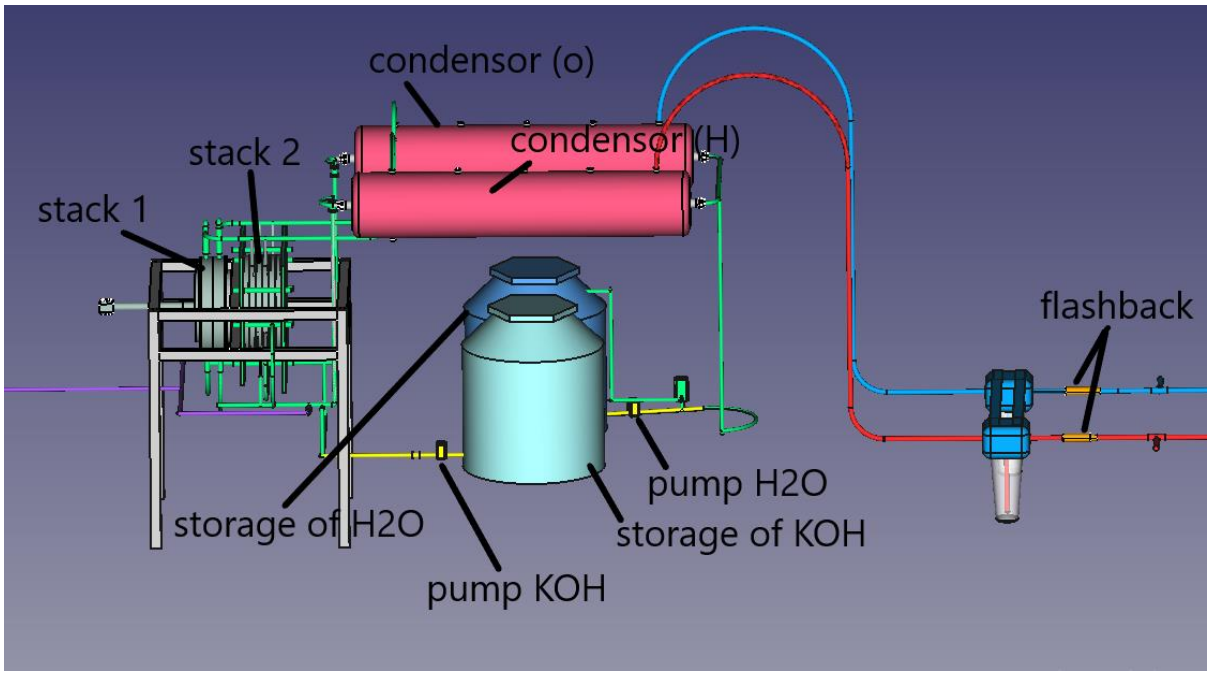


Figure 8

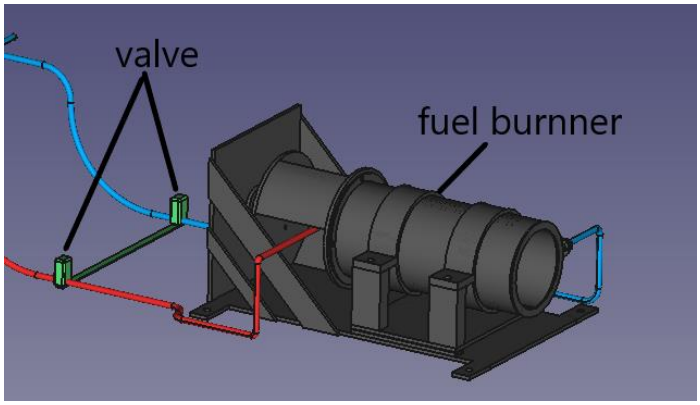


Figure 9

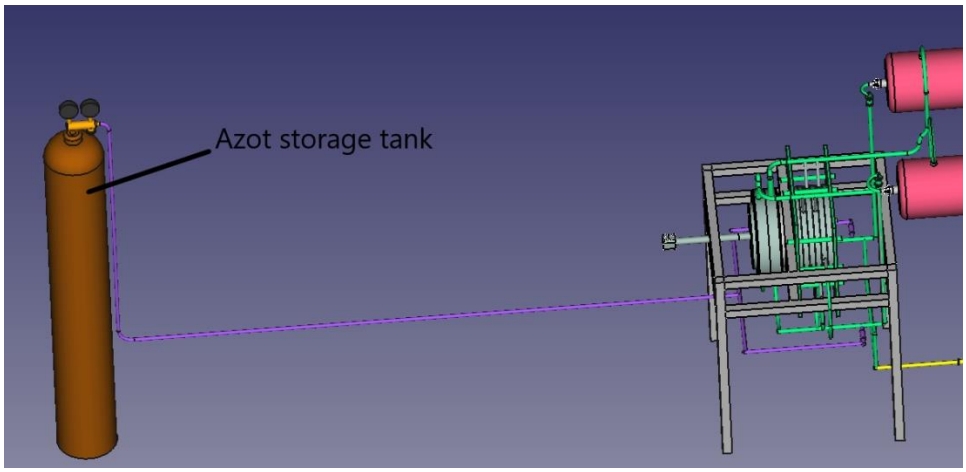


Figure 10

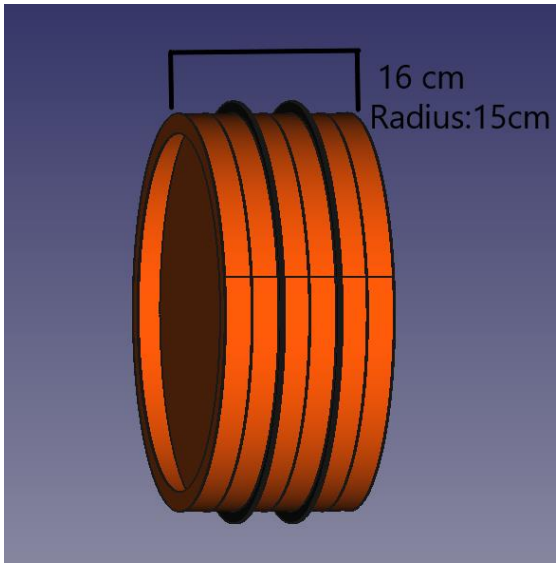


Figure 11: Serial stack

180319_Stack_electrolysis.FCStd

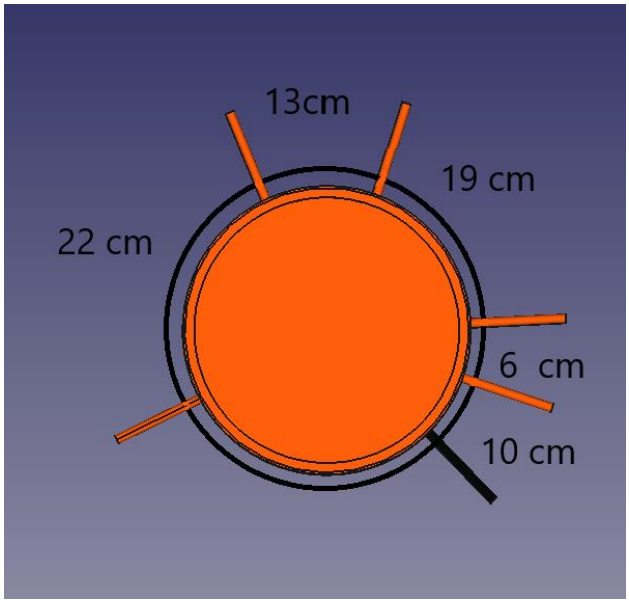


Figure 12

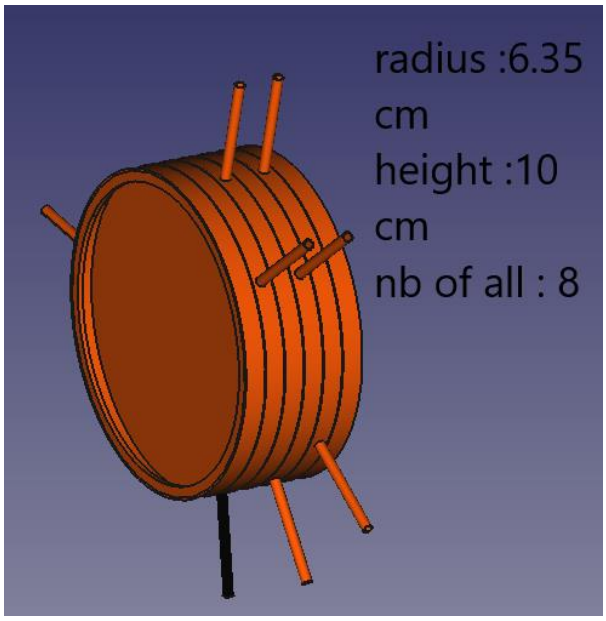


Figure 13

original electroluser.FCStd

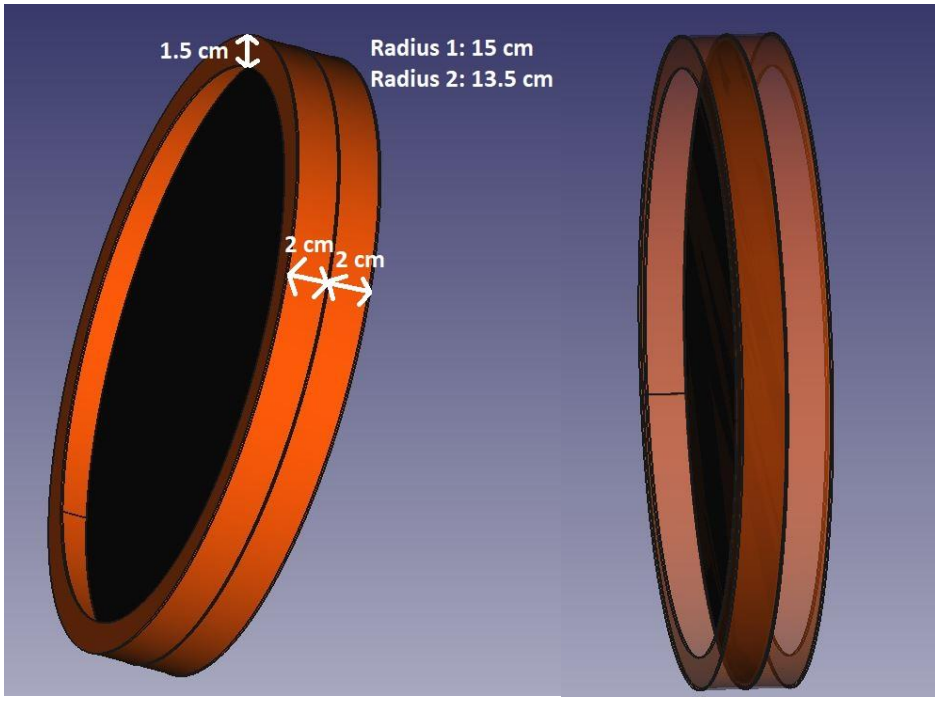


Figure 14

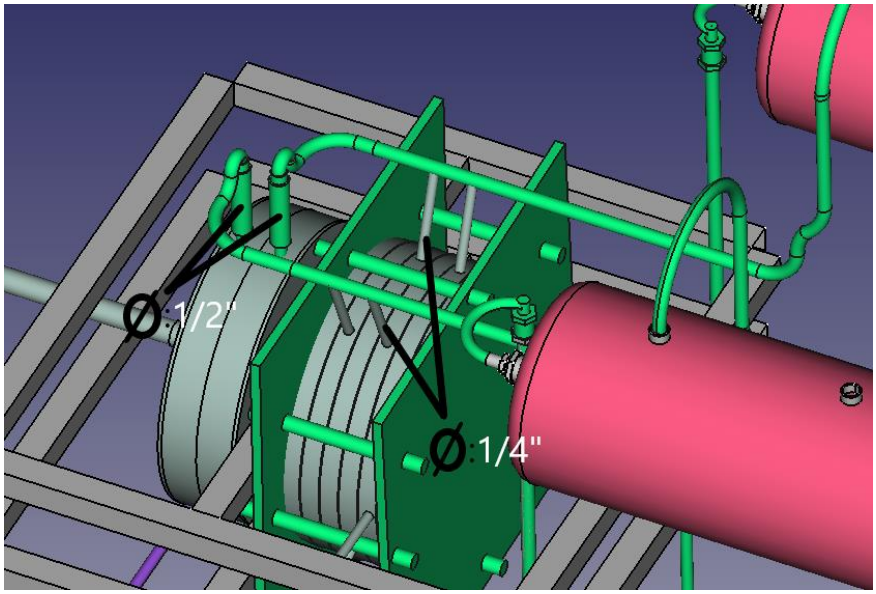
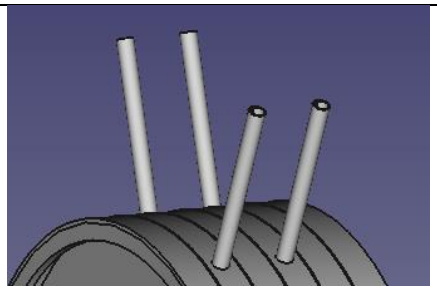


Figure 15

مواد	عدد	المقاس	الشكل
قسطل	8	قطر: " 1/4 طول 10سنتمتر	

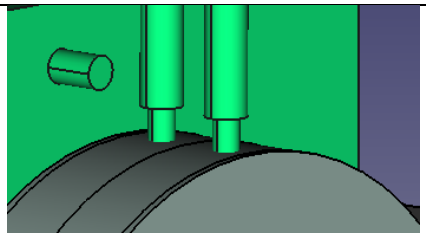
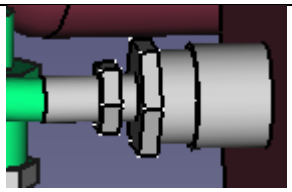
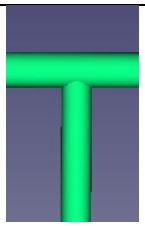
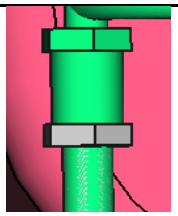
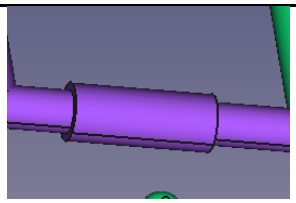
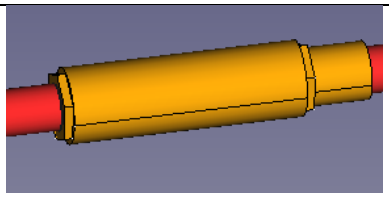
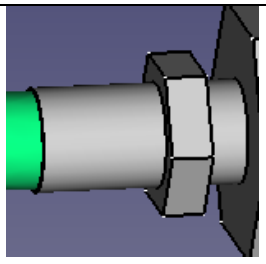
قسطل	4	قطر: 1/2" طول10سنتمتر	
محول	4	من "1 الى 1/2"	
T(بلاستك)	16	1/4"	
صباب عدم رجوع(ماء)	3	1/2"	
صباب عدم رجوع (azot)	2	Ø:16 mm	
صباب عدم رجوع(Hyd,Oxy)	2	Ø:16 mm	
شريط بعزقة	8	1/2"	
حبسة حجم صغير	43	20 mm	
حبسة حجم كبير	35	40 mm	

Table 3

3.3 Calculation of the amount of water and KOH

$V=\prod.R^2.h$

Radius: 15 cm

H_1 : 4 cm H_2 = 2 cm

$V_1=\prod.R^2.h_1$

$= \prod. 0.15^2 . 0.04$

$= 2.82* 10^{-3}\ m^3$

$= 2.82* 10^{-3}.10^6\ cm^3$

$=2.82*10^3\ cm^3$

=2.82 liter

$V2 =\prod.R^2.h_2$

$= \prod. 0.15^2 . 0.02$

$= 1.41* 10^{-3}\ m^3$

$= 1.41* 10^{-3}.10^6\ cm^3$

$=1.41*10^3\ cm^3$

=1.41 liter

The cell can contain 2.82 liter and 1.41 liter but in reality we want fell cell a)1 liter and b) 0.5 liter respectively

KOH

B. *The electrolysis need 25 % KOH in 1000 ml so 75 % is water*

250 g → 750 ml

?? <--1000 ml

Amount of KOH in one cell end plate electrode $= \frac{1000\ ml*250\ g}{750\ ml} = 333.33\ g$

We have 2 electrodes end plate: 2*333.3 g = 666.6 g

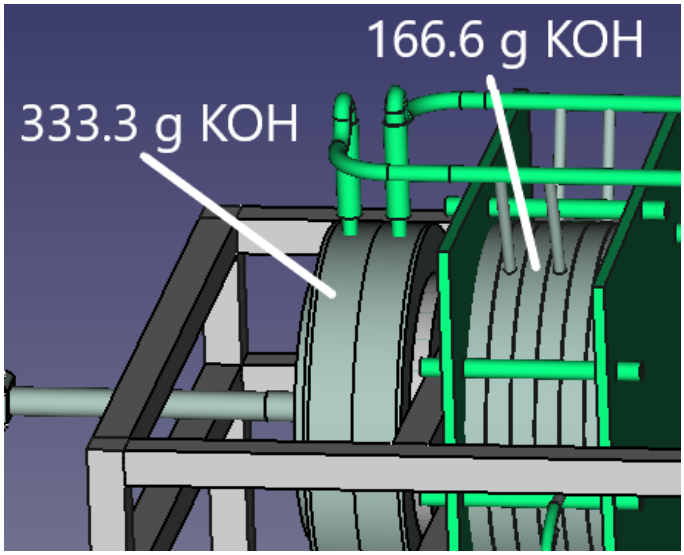


Figure 16: Amount of KOH

C. *The electrolysis need 25 % KOH in 500 ml so 75 % is water*

125 g → 375 ml

?? <--500 ml

Amount of KOH in one cell base plate $= \frac{500\ ml * 125\ g}{375\ ml} = 166.66\ g$

We have 4 electrodes base plate: 4 * 166.66 g= 666.6 g

3.4 Calculation of gas flow rate

The maximum cell current value of 75 A is selected for the calculation. Faraday constant (F= 96485 C.mol^{-1} or C: coulomb (1C = 1A.s)). Moreover, Eq. 1 is used to calculate the number of hydrogen moles as follows.

$$n_{(H_2)} = \frac{I * t}{2F} = \frac{75\ (A) * 60(s)}{2(electrons) * 96485\ C.mol^{-1}} = 0.0233\ mol/min$$

Considering Eq. 2, assuming the pressure of 1 atm and the operating temperature of 25°C, the theoretical $V_{H2(g)}$ can be determined as,

$$V_{H_{2(g)}} = \frac{n_{H_2} RT}{P} = \frac{0.0233\ mol/\min * 0.082\ Latm\ K^{-1} mol^{-1} * 298\ K}{1\ atm}$$

$$V_{H_2} = 0.569\ L.\ min^{-1}$$

Each stack produce 0.569 L.min^{-1} => 4 stack produce = 0.569 L.min^{-1} * 2 (stack) = 1.138 L.min^{-1}

For oxygen:

The amount of substance for O_2 (g) can be determined by using either Eq. 5.1 or the electrochemical reaction of the alkaline electrolysis cell. According to the electro chemical reaction, the number of O_2(g) moles should be half of H_2(g) moles. Hence, the number of O_2(g) moles can be easily determined as in Eq.

$$n_{O_2} = \frac{n_{H_2}}{2}$$

$$n_{O_2} = 0.0116\ mol/min$$

$$V_{O_{2(g)}} = \frac{n_{O_2} RT}{P} = \frac{0.0116\ mol/\min * 0.082\ Latm\ K^{-1} mol^{-1} * 298\ K}{1\ atm}$$

$$V_{O_2} = 0.284\ L.min^{-1}$$

Each stack produce 0.284 L.min^{-1} => 2 stacks produce = 0.284 $L.min^{-1}$ * 2 (stacks)= 0.568 L.min^{-1}

Other https://www.editions-petiteelisabeth.fr/calculs_electrolyse_3.php

3.5 Power supply

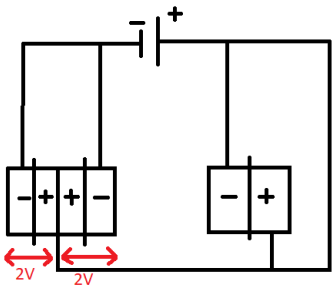


Figure 17

- Density current for electrolysis: 0.2 – 0.4 A/cm²
- Our cell contains 0.5 liter = 250 cm²
- Current apply for each cell = $\frac{250\ cm^2 * 0.3\ A/cm^2}{1 cm^2} = 75\ A$
- Voltage apply for each cell is 2V
- Each stack has 2 serial cell => voltage = 2*2 = 4 V
  Current = 75A
- The total is 2 parallel stack => voltage = 8 V
  Current = 2 * 75 = 150 A
- Power apply: Power = voltage x Current = 4 Volt x 150 Ampere = 0.6 KW

3.6 Compact Design[2]

3.6.1 Level Control System

tubes=12.5mm,6mm

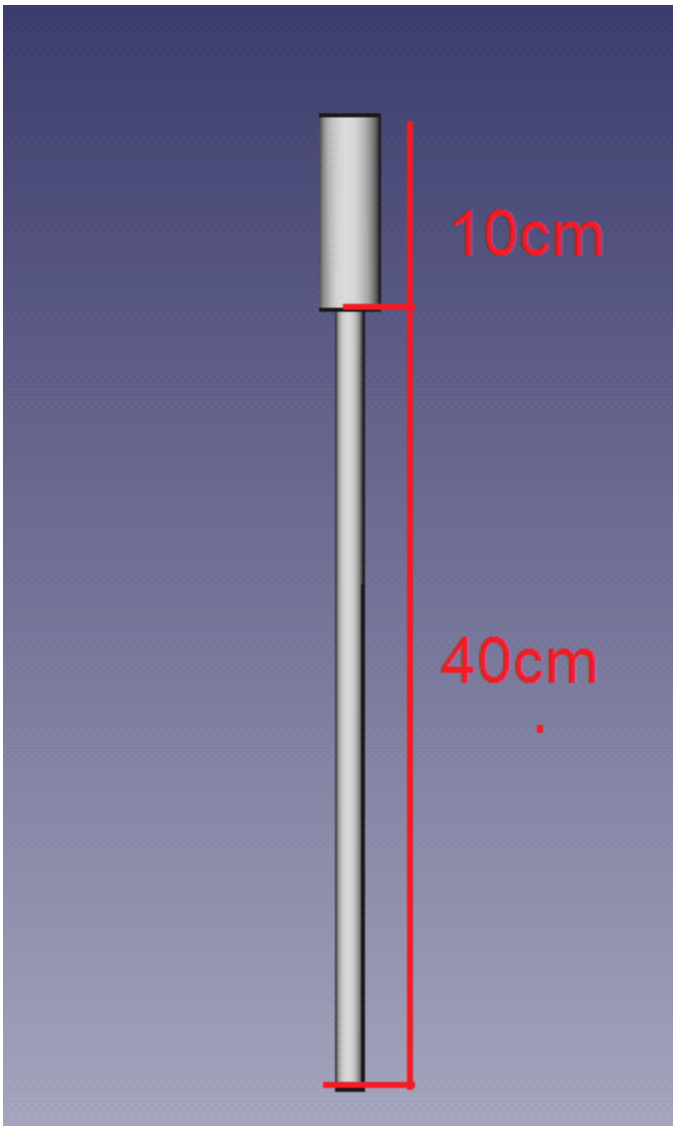


Figure 18

[2] Samer Youssef, July/Aug 2019

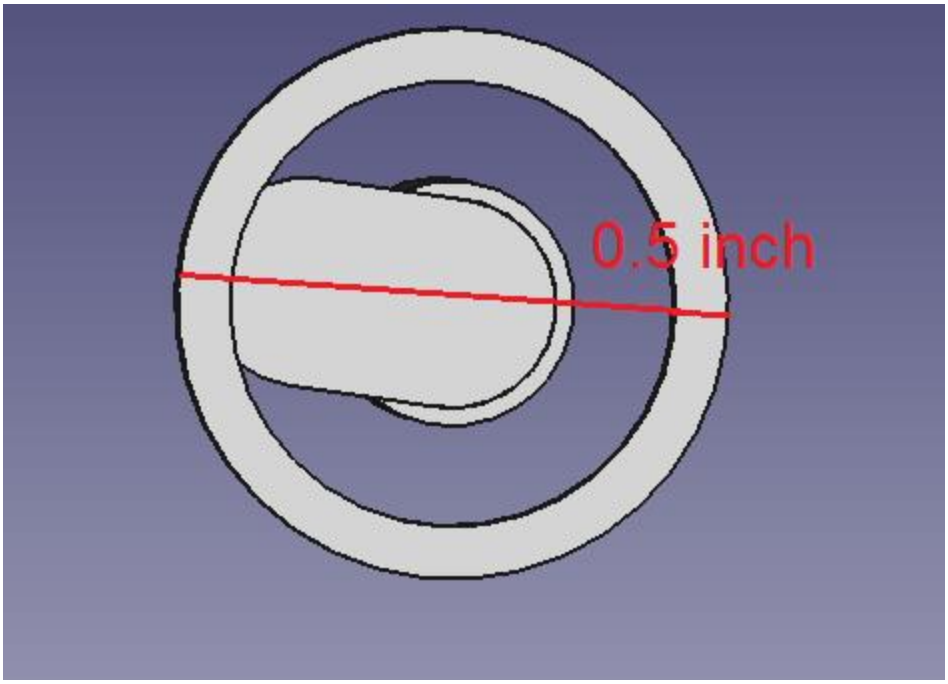


Figure 19

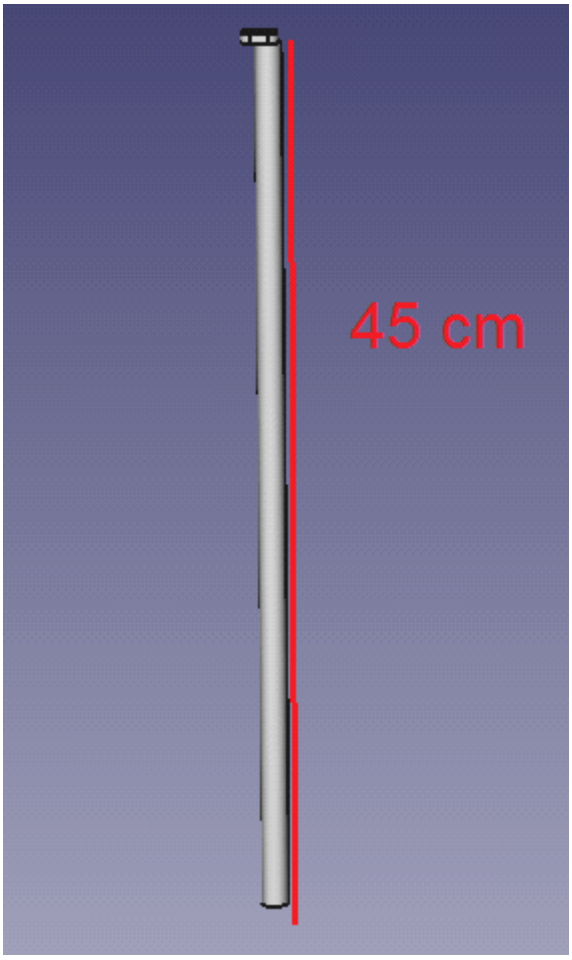


Figure 20

3.6.2 Electrolyser Container

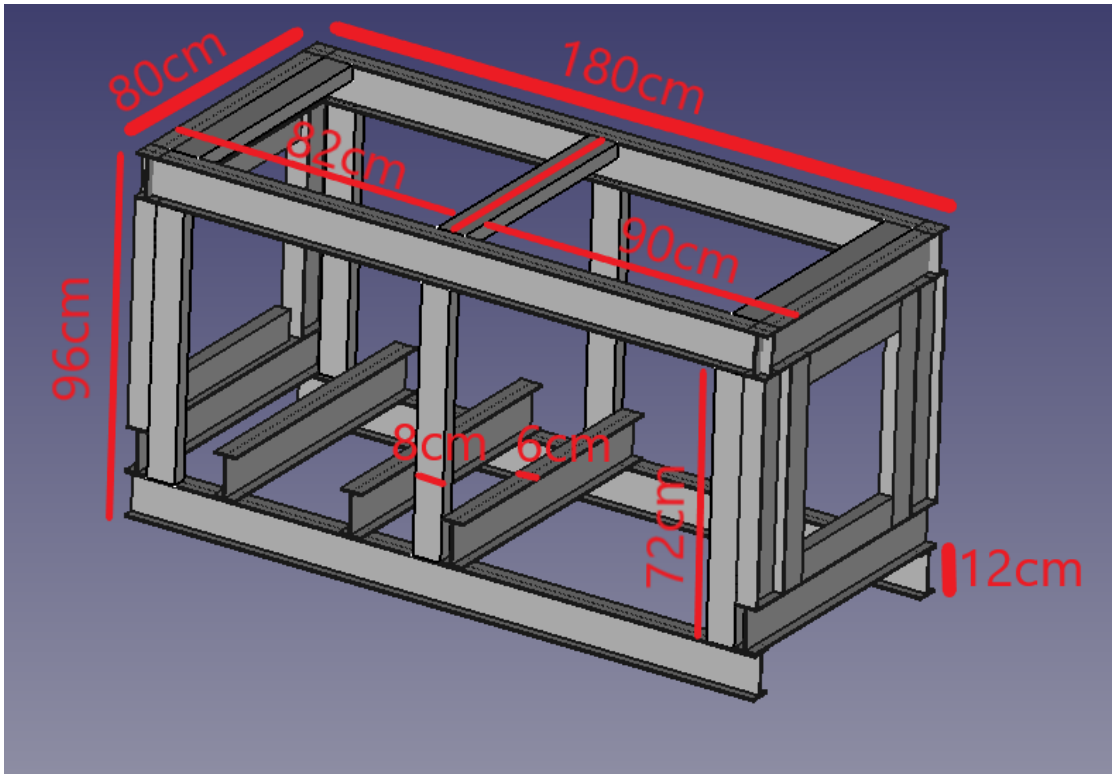


Figure 21

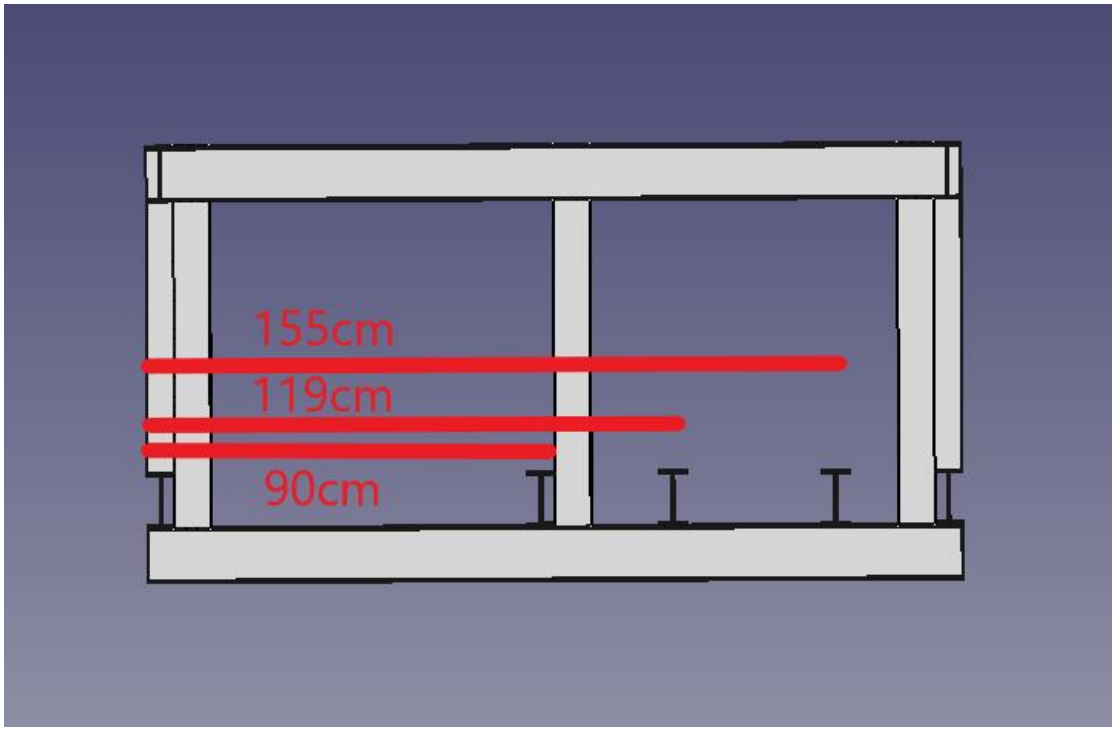


Figure 22

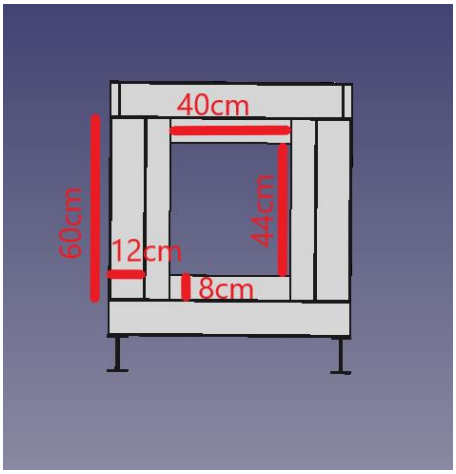


Figure 23

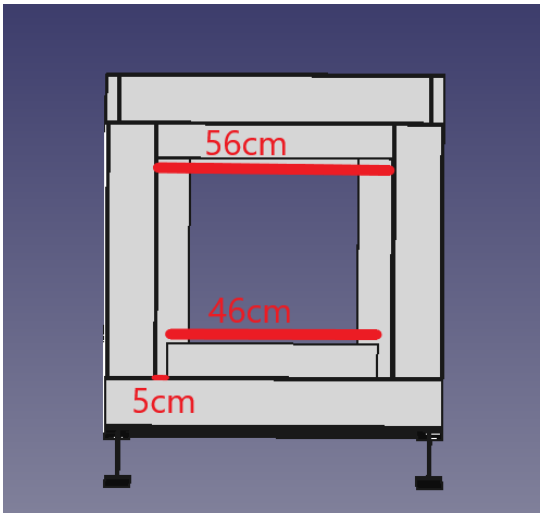


Figure 24

numbers of columns : 4-(180)cm

6-(72) cm

5-(80) cm

5-(68) cm

6-(60) cm

2-(40) cm

1-(56) cm

1-(46) cm.

3.6.3 Integration

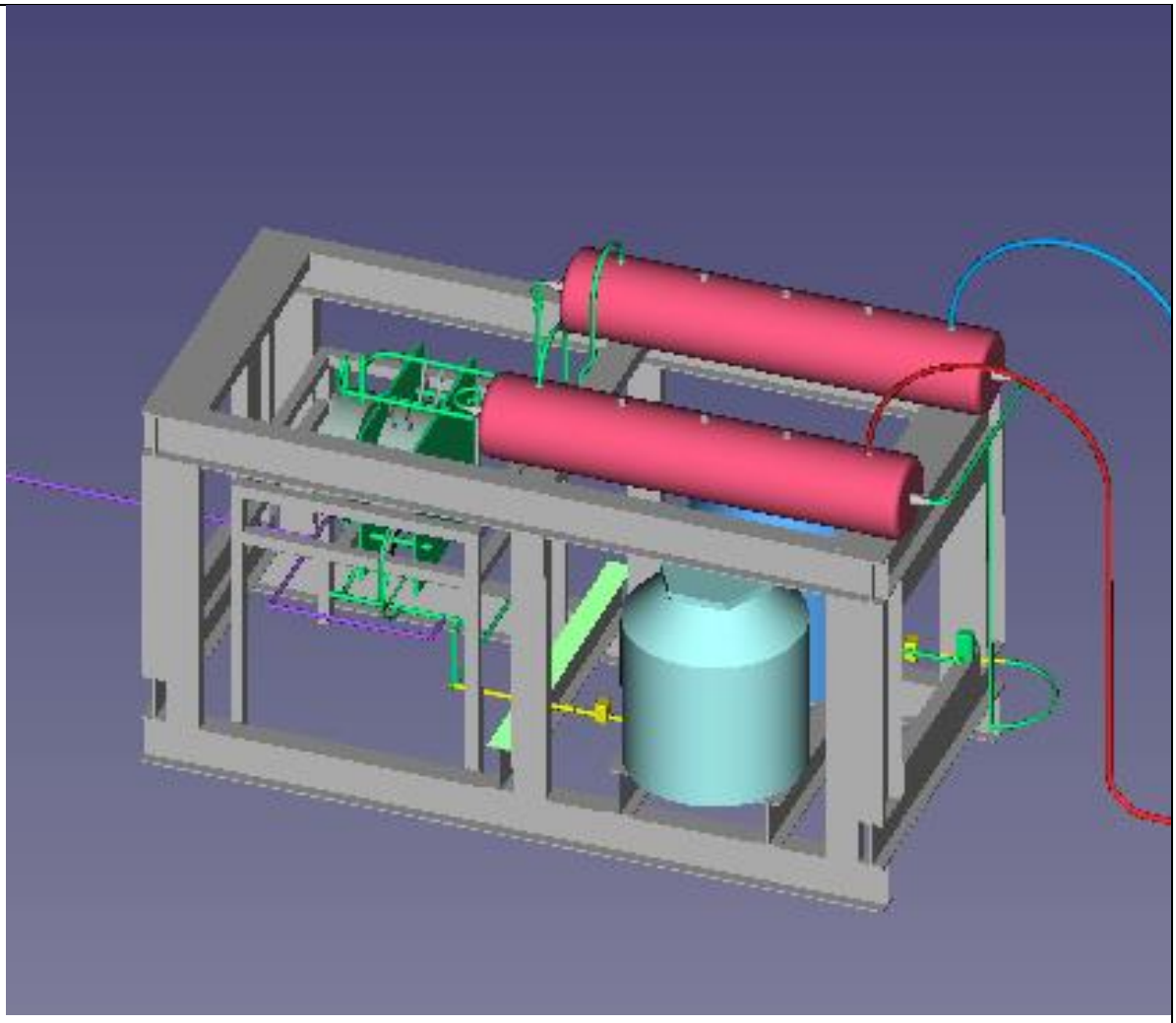


Figure 25

electrolyser+fuel burnner 010120.FCStd