AECENAR
Association for Economical and Technological Cooperation in the Euro-Asian and North-African Region
www.aecenar.com

مركز أبحاث تكنولوجيا العمليات الكيميائية
Institute for Chemical Process Technology (ICPT)
http://aecenar.com/institutes/icpt

Air Liquefaction and Cryogenics – Report 1 (2021), Part II:

LOX Prototype System Concept & Mechanical Design

Author: Mariam El Rez
Editor: Samir Mourad

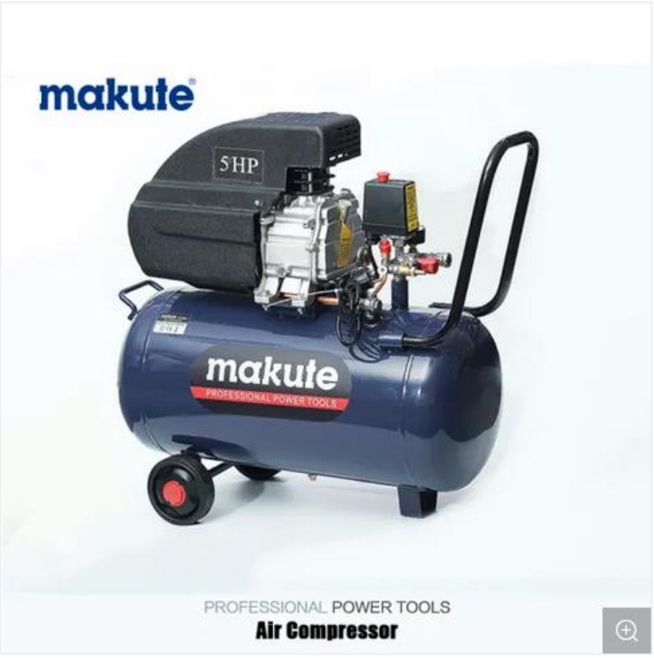
Last update: 11 August 2021

Contents

1 System Design of LOX Production Prototype

1.1 Air Compressor

#1 (with oil)



Makute Portable Air Compressor Oil Air Pump 50L

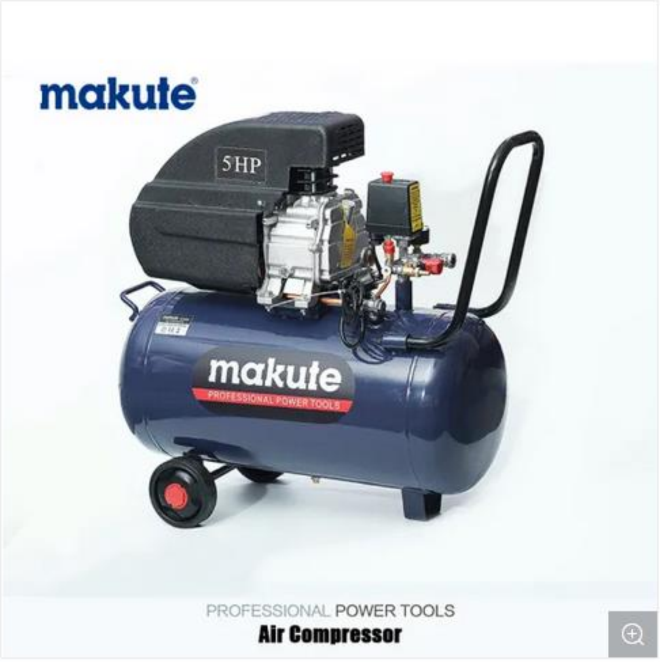
Get Latest Price > Chat with Supplier.

Purchase Qty. / Reference FOB Price	
100-499 Pieces	US $95.44
500+ Pieces	US $93.5

Port:	Ningbo, China
Production Capacity:	10000PCS/Month
Payment Terms:	L/C, T/T, D/P, Western Union, Paypal, Money Gram
Lubrication Style:	Lubricated
Cooling System:	Air Cooling
Cylinder Arrangement:	Balanced Opposed Arrangement
Cylinder Position:	Angular

Model:	XZ-0.036/8
Rated Volatge:	220-240/110V
Rated Frequency:	50/60Hz
Air Tank	30-50L
No Load Speed:	2850 r/min
Pressure	8Bar

#2 (oil free)



(CE/GS) 8bar Air Compressor (5050BM)

Get Latest Price > Chat with Supplier.

Purchase Qty. / Reference FOB Price	
500-999 Pieces	US $62.28
1,000+ Pieces	US $62.43

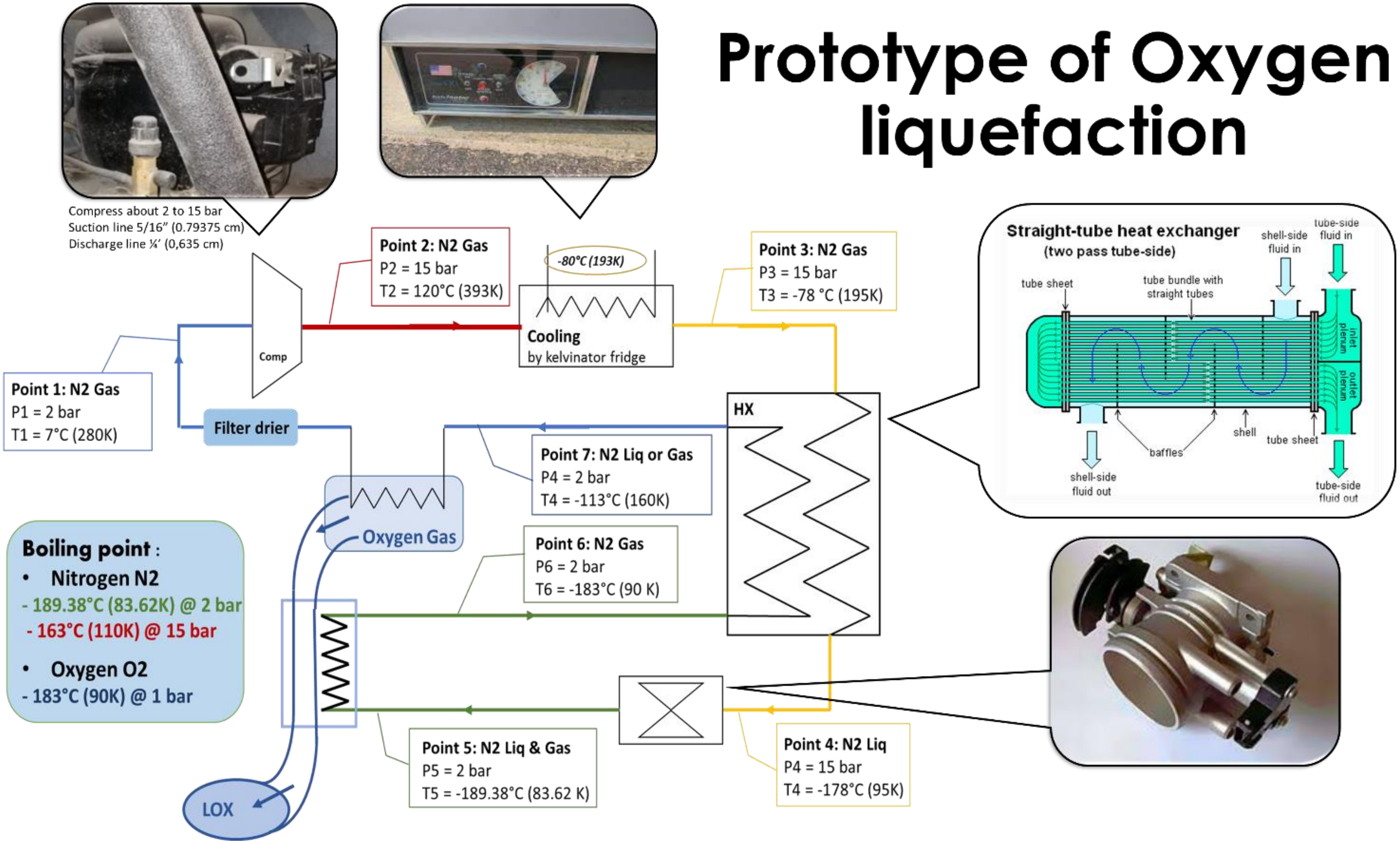
Port:	Ningbo, China
Production Capacity:	40000PCS/Month
Payment Terms:	L/C, T/T, Western Union, Money Gram
Lubrication Style:	Oil-free
Cooling System:	Air Cooling
Cylinder Arrangement:	Balanced Opposed Arrangement
Cylinder Position:	Vertical
Structure Type:	Semi-Closed Type

Model:	5050BM
Rated Voltage:	220-240/110V
Rated Frequency:	50/60HZ
Rated Input power:	5.0HP
No Load Speed:	2850R/MIN
Air Tank:	50L
Pressure:	8BAR

Air Compressor (Antar store)

- 10 bar , 50L price 165 dollars (makute company)
- 10 bar, 150L price 395 dollars
- 10 bar, 200 L price 450 dollars

1.2 Prototype cycle of Oxygen liquefaction



In this prototype the oxygen will be liquefied by cascade cooling of nitrogen.

The nitrogen gas will be compressed (from 2 bar to about 15 bar)[use for that the laboratory refrigerator], The nitrogen will then be cooled down to 195 K by means of a Kelvinator fridge operated with a cascade of R-502 and R-503 refrigerants.

Then the nitrogen will be cooled to lower temperatures (83.6 K) using the expansion valve and heat exchanger.

This nitrogen temperature (<90 K) would be sufficient to liquefy the oxygen at 1atm.

Oxygen gas can also be prepared and cooled to about 170 K in nitrogen before returning directly to the compressor (160 K).

1.3 Prototype Heat exchanger (HX - N_2/N_2)

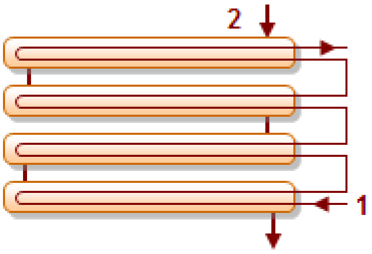
LMTD Correction Factor Charts

Calculates Logarithmic Mean Temperature Difference (LMTD) Correction factor for different configuration of exchangers.

1.3.1 Data:

Exchanger Type

4 Shell 8 Tube Tema E



Stream 1

Temperature In (T1)

195

Temperature Out (T2)

95

Stream 2

Temperature In (t1)

90

Temperature Out (t2)

160

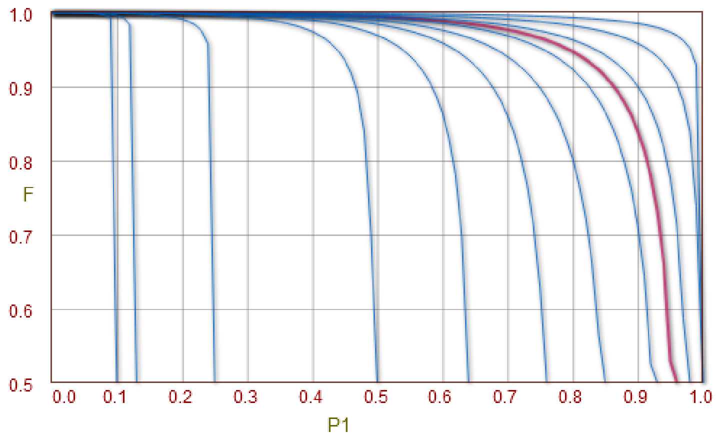
1.3.2 Result:

```
R1    = (t1 - t2)/ (T2 - T1)
      = 0.7000
```

```
P1    = (T2 - T1)/ (t1 - T1)
      = 0.9524
```

```
LMTD = 15.4170
```

```
F                = 0.4706
LMTD Corrected  = 7.2549
```



Shortcut Heat Exchanger Sizing

Estimates LMTD (Log Mean Temperature Difference), Exchanger surface area, number of tubes, shell diameter and number of shell in series.

1.3.3 Data:

Heat Duty

350	W

U Value

500	W/m².°K

Hot Side

Temperature In

195	°K

Temperature Out

95	°K

Cold Side

Temperature In

90	°K

Temperature Out

130	°K

Geometry

Tube Pass

Multiple

Tube Length

1	m

Tube Outside Diameter (OD)

15	mm

Tube Pattern

Square

1.3.4 Result:

Tube Pitch	21.3500	mm
LMTD	23.39	°K
Correction Factor (F)	0.8381	
LMTD (Corrected)	19.61	°K
Shell in Series	3	
Total Area	0.04	m^2
Area per Shell	0.01	m^2
Tubes per Shell	0	
Shell ID (Estimate)	88.31	mm

1.4 Prototype Heat exchanger (HX - N_2/O_2)

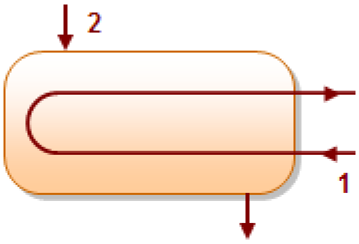
LMTD Correction Factor Charts

Calculates Logarithmic Mean Temperature Difference (LMTD) Correction factor for different configuration of exchangers.

1.4.1 Data:

Exchanger Type

1 Shell 2 Tube Tema E



Stream 1

Temperature In (T1)

180

Temperature Out (T2)

89

Stream 2

Temperature In (t1)

83

Temperature Out (t2)

90

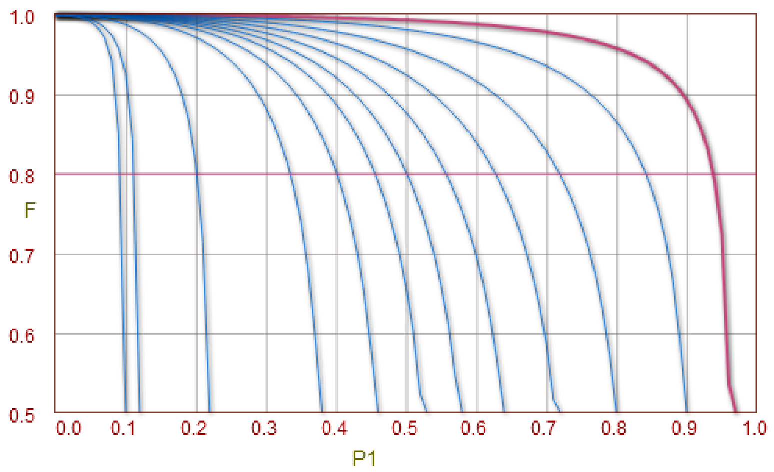
1.4.2 Result:

```
R1   = (t1 - t2)/ (T2 - T1)
     = 0.0769
```

```
P1   = (T2 - T1)/ (t1 - T1)
     = 0.9381
```

```
LMTD = 31.0186
```

```
F              = 0.7999
LMTD corrected = 24.8123
```



Model Number	00402-01 (17 Series Sanitary HX, 4 Inch Tube Bundle)				
Tube Side (product)	Oxygen		Shell Side (working)	Nitrogen	
Flow Rate	0.4	kg/hr	Flow Rate	25	kg/hr
Inlet Temperature	140	K	Inlet Temperature	83	K
Inlet Pressure	100	kPa	Inlet Pressure	200	kPa

Metric Units			
Heat Exchanger Model		00402-01	
	Tube Side	Shell Side	
Fluid	Oxygen	Nitrogen	
Temperature In	-133.15	-190.15	C
Temperature Out	-184.29	-189.43	C
Mass Flow	0.11	6.95	g/sec
Volumetric Flow	N/A	N/A	lpm
Pressure Drop	0.01	11.04	kPa
Heat Transfer	5	Watts	
Effectiveness	0.897		

[1]

[1] http://calc.exergyllc.com/

Shortcut Heat Exchanger Sizing

Estimates LMTD (Log Mean Temperature Difference), Exchanger surface area, number of tubes, shell diameter and number of shell in series.

1.4.3 Data:

Heat Duty

5	W

U Value

150	$W/m^2.°K$

Hot Side

Temperature In

140.00	°K

Temperature Out

89.00	°K

Cold Side

Temperature In

83.00	°K

Temperature Out

90.00	°K

Geometry

Tube Pass

Multiple

Tube Length

1	m

Tube Outside Diameter (OD)

15	mm

Tube Pattern

Square

1.4.4 Result:

Tube Pitch	21.3500	mm
LMTD	20.75	°K
Correction Factor (F)	0.9623	
LMTD (Corrected)	19.97	°K
Shell in Series	2	
Total Area	0.00	m^2
Area per Shell	0.00	m^2
Tubes per Shell	0	
Shell ID (Estimate)	79.41	mm

[2]

[2] https://checalc.com/calc/ShortExch.html

2 Components of Oxygen liquefaction prototype

2.1 Overview

- Compressor: It is LR25B Laboratory refrigerator compressor
- Cooling of N2: using kelvinator refrigerator
- Heat exchanger (HX-N2 / N2): should be manufactured
- Heat exchanger (HX-N2 / O2): should be manufactured
- Cooling of O2: should be manufactured
- Expansion valve: Purchase
- Filter drier: Purchase
- Cryometer (measures up to 80 K): Purchase
- Connections: The available LR25B Laboratory refrigerator and air-conditioner parts can be used if they are suitable for work.
- Gaseous oxygen preservation tank: manufacture / purchase
- Liquid oxygen storage tank: manufacture / purchase
- Gaseous oxygen (volume?)
- Nitrogen (volume?)
- Thermal isolations

2.2 Cryometer

2.2.1 Features

Digitized the conventional type (MBM) to a more compact design.

- In combination with the MBS CRYO-METER, the accurate temperature can be obsrved at remote position.
- MBD CRYO-METER can be used as a power sorce unit of the MBS CRYO-METER.

2.2.2 Specification

Display		Digital
Temperature range		10K～350K (-263℃～+77℃)
Accuracy		±2% (Full scale) （However,10～30K are ±1K）
Voltage		AC100V±10%
Cryo thermocouple thermometer power supply		DC24V（Internal）
Cable Length	Input power cable Analog signal input cable Power supply cable (MBS) For power supply	3m 5m 5m
Weight		520 g

3 Heat exchangers for prototype project

The central variables in any heat exchanger analysis are the heat transfer rate *q* [W], heat transfer area *A* [m2], heat capacity rates *C*& (=*m*& *c*p) [W/K], and the overall heat transfer coefficient *U*. On the basis of these variables and the fluid temperatures, we can write two basic equations for the heat transfer rate; first, for heat transfer rate it must hold that

$$q = U\,A\,\Delta T_m$$

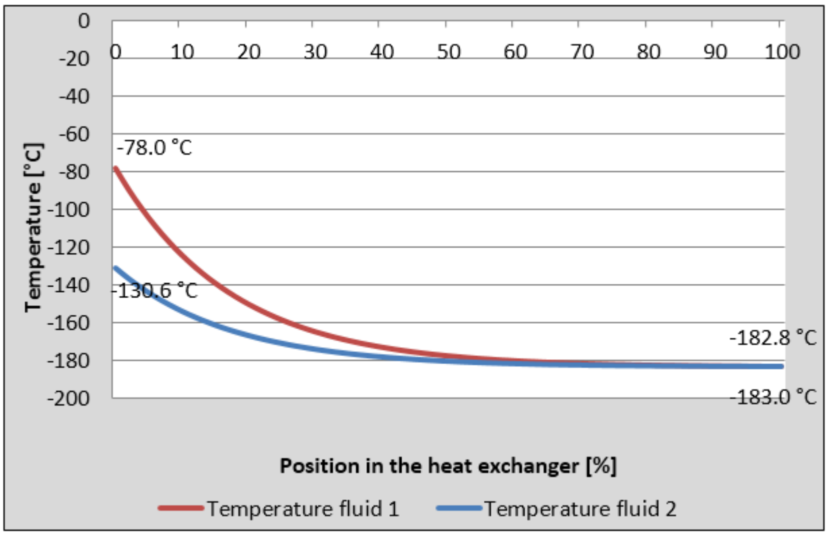
where ΔT_m is the average (mean) temperature difference of the two fluids in the heat exchanger, and the area A in equation the heat transfer area, meaning the contact area between one of the fluids, and the surface of the wall that separates the fluid.

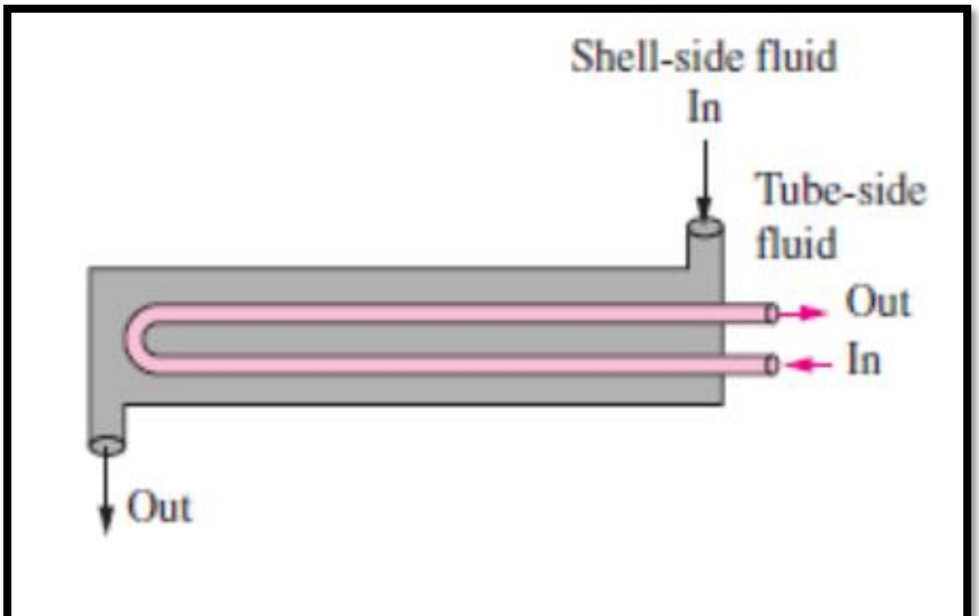
Second, on the basis of 1st law of thermodynamics, the heat transfer rate q must also equal the rate of heat lost by the hot fluid stream and gained by the cold fluid stream:

$$q = \dot{C}_{hot}\left(T_{hot,in} - T_{hot,out}\right) = \dot{C}_{cold}\left(T_{cold,out} - T_{cold,in}\right)$$

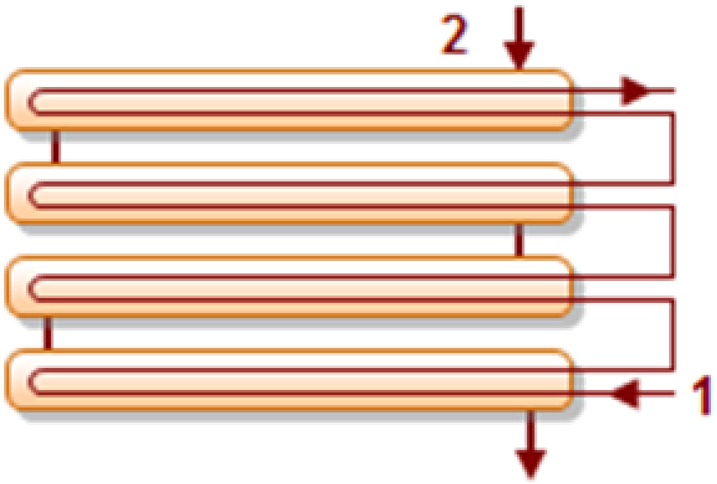
3.1 HX- N_2/N_2

Input		
Name of HX	**HX-N2/N2**	
Type of heat exchanger	Shell & tubes	
	Unit	
Heat duty	W	868
Heat transfer coefficient	$W/m^2.°K$	500
Area	m^1	1.2
Fluid 1 _ hot side		
Mass flow 1	Kg/h	25
	Kg/s	0.00694
Inlet temperature 1	K	195
Heat capacity 1	KJ/Kg.K	1.251
Fluid 2 _ Cold side		
Mass flow 2	Kg/h	58.24
	Kg/s	0.01618
Inlet temperature 2	K	89
Heat capacity 2	KJ/Kg.K	1.074
Geometry		
Tube pass		Single
Tube length	m	0.4
Tube Outside Diameter (OD)	mm	9.525
Tube Pattern		square
Output		
Outlet temperature 1	K	90
	°C	-183
Outlet temperature 2	K	142.5
	°C	-130.5
Result		
Tube pitch	mm	15.875
Shell in Series		6
Total Area	cm^2	1637.95
No. of Tubes		2
Shell ID (Estimate)	mm	103.25



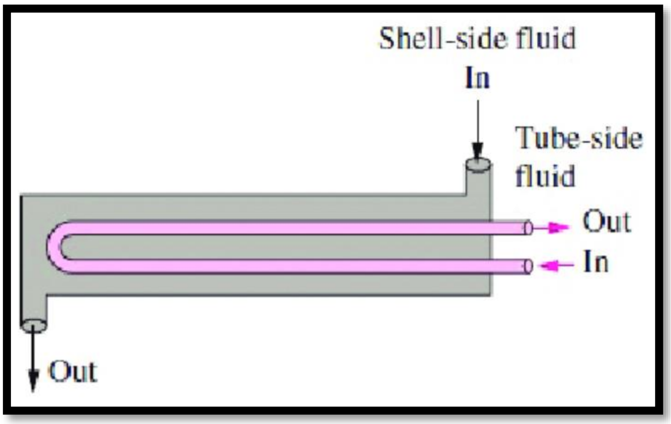


(a) One-shell pass and two-tube passes



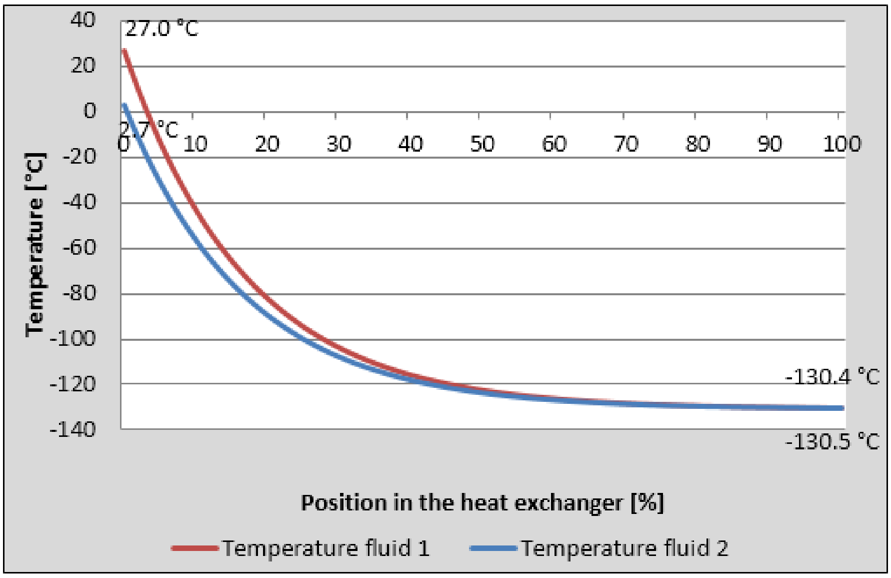
3.2 HX-N2/O2 main

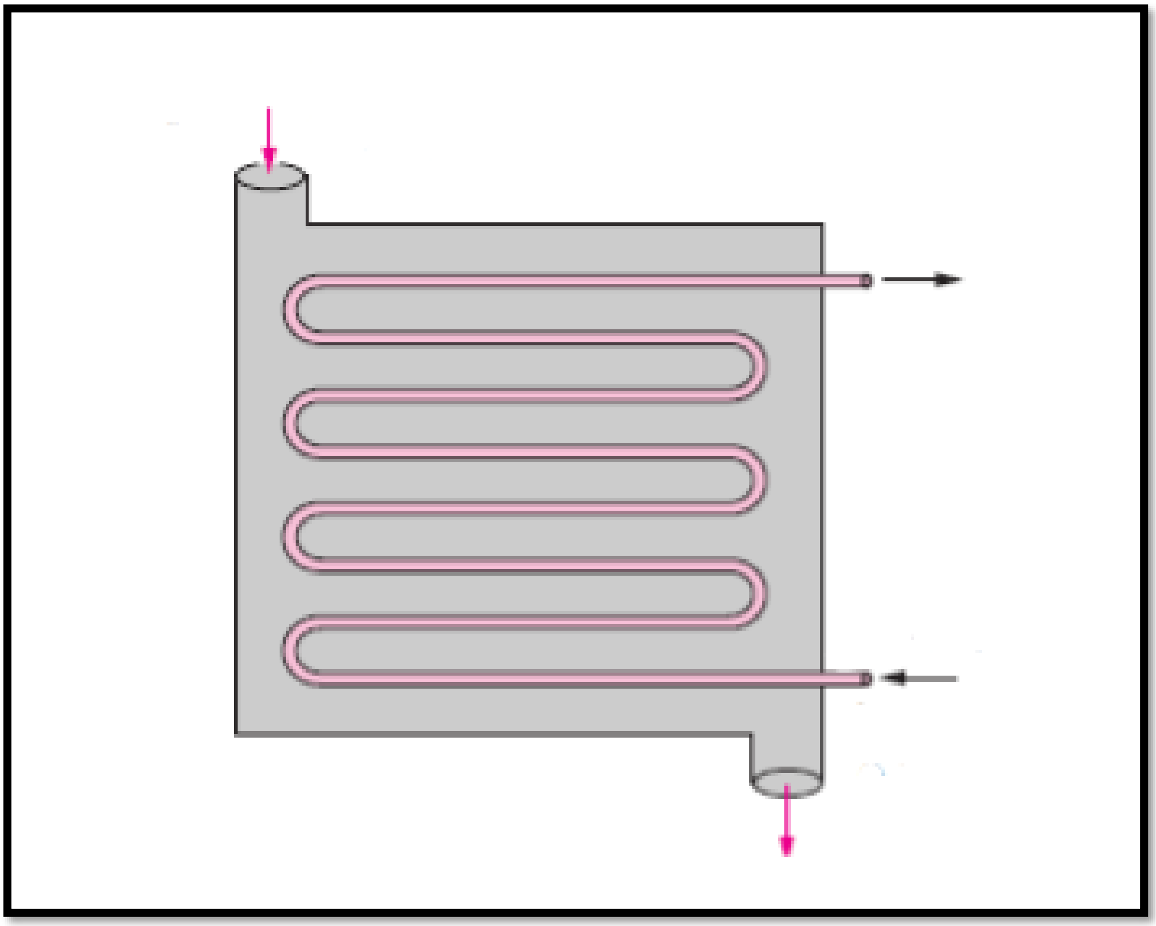
Input		
Name of HX	**HX-N2/O2 Main**	
Type of heat exchanger	shell & tubes	
	Unit	
Heat duty	W	92.42
Heat transfer coefficient	$W/m^2.°K$	500
Area	m^2	0.018
Fluid 1 _ hot side _ O2		
Mass flow 1	Kg/h	4.739
	Kg/s	0.001316
Inlet temperature 1	K	142.5
Heat capacity 1	KJ/Kg.K	0.9298
Fluid 2 _ Cold side _ N2		
Mass flow 2	Kg/h	25
	Kg/s	0.00694
Inlet temperature 2	K	83
Heat capacity 2	KJ/Kg.K	1.284
Geometry		
Tube pass		Single
Tube length	m	0.2
Tube Outside Diameter (OD)	mm	9.525
Tube Pattern		Square
Output		
Outlet temperature 1	K	88
	°C	-190.5
Outlet temperature 2	K	90
	°C	-183
Result		
Tube pitch	mm	15.875
Shell in Series		1
Total Area	cm^2	91.5
No. of Tubes		2
Shell ID (Estimate)	mm	98.35



3.2. HX-N2/O2 (2nd)

Input		
Name of HX	**HX-N2/O2 (2nd)**	
Type of heat exchanger	Shell & tubes	
	Unit	
Heat duty	W	2300
Heat transfer coefficient	$W/m^2.°K$	500
Area	m^2	1
Fluid 1 _ hot side _ O2		
Mass flow 1	Kg/h	56.52
	Kg/s	0.0157
Inlet temperature 1	K	300
Heat capacity 1	KJ/Kg.K	0.9142
Fluid 2 _ Cold side _ N2		
Mass flow 2	Kg/h	58.23
	Kg/s	0.0157
Inlet temperature 2	K	142.5
Heat capacity 2	KJ/Kg.K	1.047
Geometry		
Tube pass		Single
Tube length	m	0.2
Tube Outside Diameter (OD)	mm	9.525
Tube Pattern		Square
Output		
Outlet temperature 1	K	142.5
	°C	-130.5
Outlet temperature 2	K	275.7
	°C	2.7
Result		
Tube pitch	mm	15.875
Shell in Series		1
Total Area	cm^2	2456.98
No. of Tubes		8
Shell ID (Estimate)	mm	127.53


27.0 °C
2.7 °C
-130.4 °C
-130.5 °C
Temperature [°C]
40
20
0
-20
-40
-60
-80
-100
-120
-140
0
10
20
30
40
50
60
70
80
90
100
Position in the heat exchanger [%]
Temperature fluid 1
Temperature fluid 2



3.3 HX- final calculation

For HX-N2/N2											
Stream data				Results			Units	Final results			Units
	Units	Hot	Cold	Heat capacity ratio	Cr	0.3995		LMDT	LMDT	25.05	
Flow rate	Kg/hr	**25**	**58.24**	Number of transfer units	NTU	7.3548		Surface Area	S	0.65133467	m2
Inlet temp.	K	**195**	**89**	Effectivenes	ξ	0.9434		Diameter of pipe	D	0.009525	m
Specific heat	KJ/Kg.K	1.1163	1.1995	Heat transfer	Q	**775.17**	W	Length	L	21.76653698	m
Outlet temp.	K	**95**	**128.947**	Overall U	U	**47.51**	W/m2.K	Length per shell	$L_{/shell}$	3.627756163	m
				Heat exchanger area	A	**1.2**	m2	Tube lenght	T_L	**1.793928082**	**m**

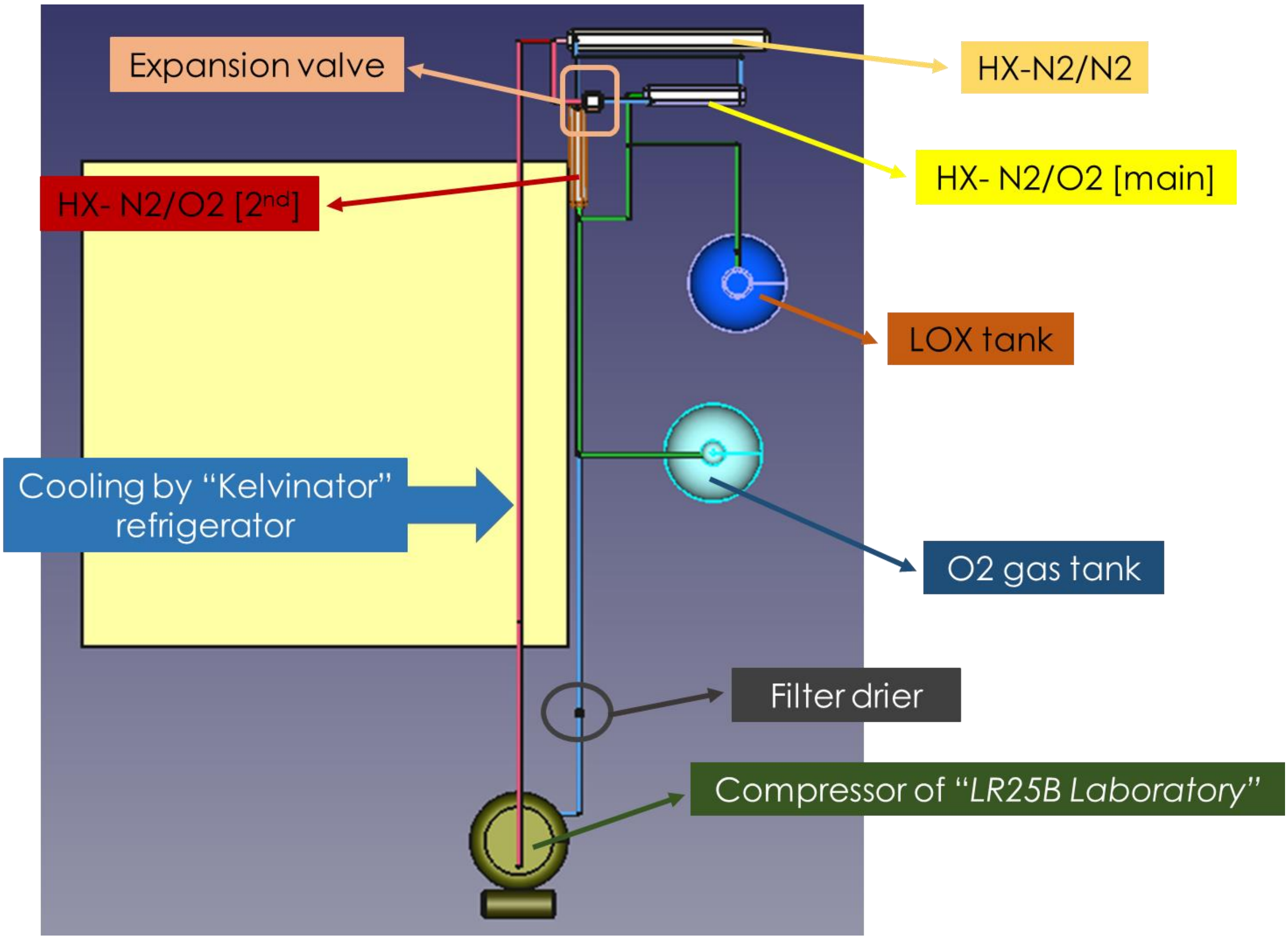
For HX-N2/O2 [2nd]											
Stream data				Results			Units	Final results			Units
	Units	Hot	Cold	Heat capacity ratio	Cr	0.8363		LMDT	LMDT	60.5	
Flow rate	Kg/hr	**56.52**	**58.23**	Number of transfer units	NTU	3.5192		Surface Area	S	0.507249982	m2
Inlet temp.	K	**300**	**129**	Effectivenes	ξ	0.6316		Diameter of pipe	D	0.02222	m
Specific heat	KJ/Kg.K	0.9199	1.0677	Heat transfer	Q	**1559.78**	W	Length	L	7.266547442	m
Outlet temp.	K	**192**	**219.317**	Overall U	U	**50.826**	W/m2.K	Tube length	T_L	**0.85599343**	**m**
				Heat exchanger area	A	**1**	m2				

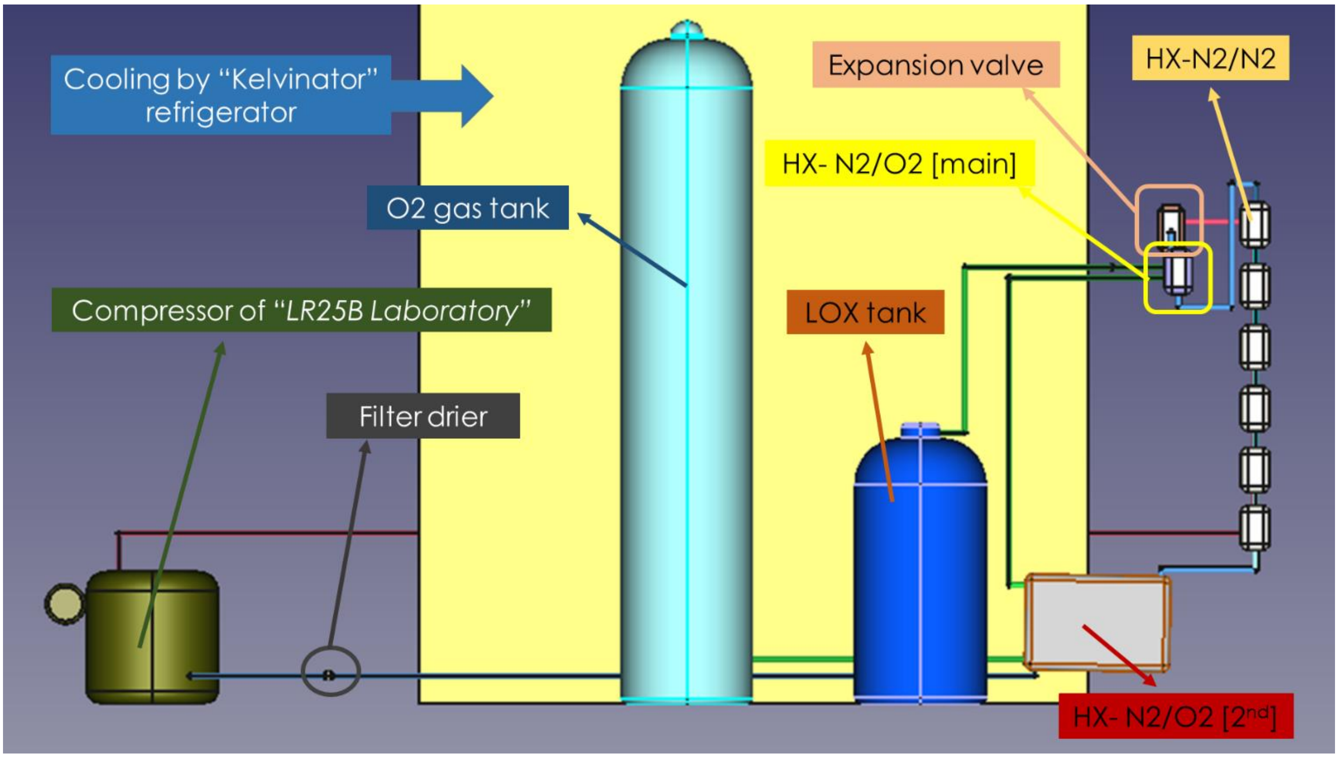
For HX-N2/O2 [Main]											
Stream data				Results			Units	Final results			Units
	Units	Hot	Cold	Heat capacity ratio	Cr	0.0834		LMDT	LMDT	31.787	
Flow rate	Kg/hr	**4.739**	**25**	Number of transfer units	NTU	3.4197		Surface Area	S	0.027718617	m2
Inlet temp.	K	**192**	**83**	Effectivenes	ξ	0.9541		Diameter of pipe	D	0.0025	m
Specific heat	KJ/Kg.K	0.915	2.08	Heat transfer	Q	**52.8655**	W	Length	L	3.529243881	m
Outlet temp.	K	**88**	**91.672**	Overall U	U	**60**	W/m2.K	Tube length	T_L	**1.750191941**	**m**
				Heat exchanger area	A	**0.01356**	m2				

4 FreeCad Design

4.1 Prototype design on FreeCad

prototype cycle of oxygen liquefaction.FCStd





4.2 Heat exchanger design HX-N_2/N_2

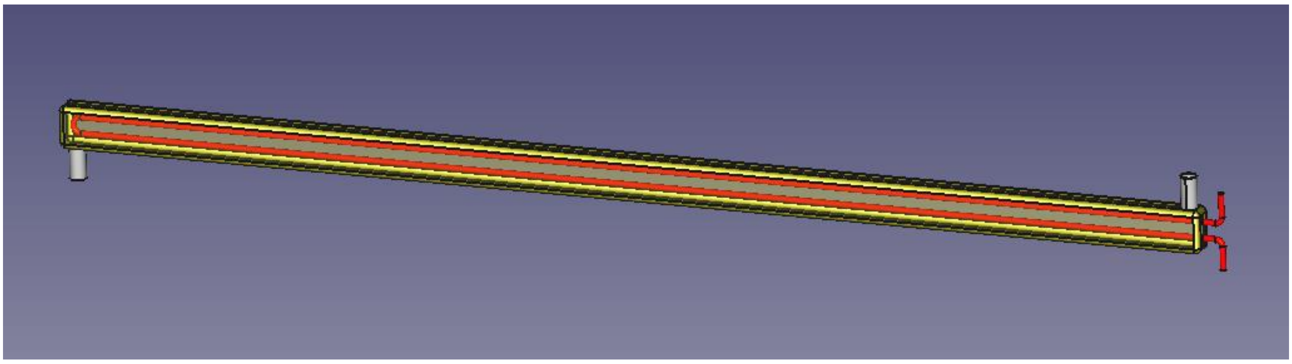
6 shell , 12 tubes

Shell – Cold side – N_2

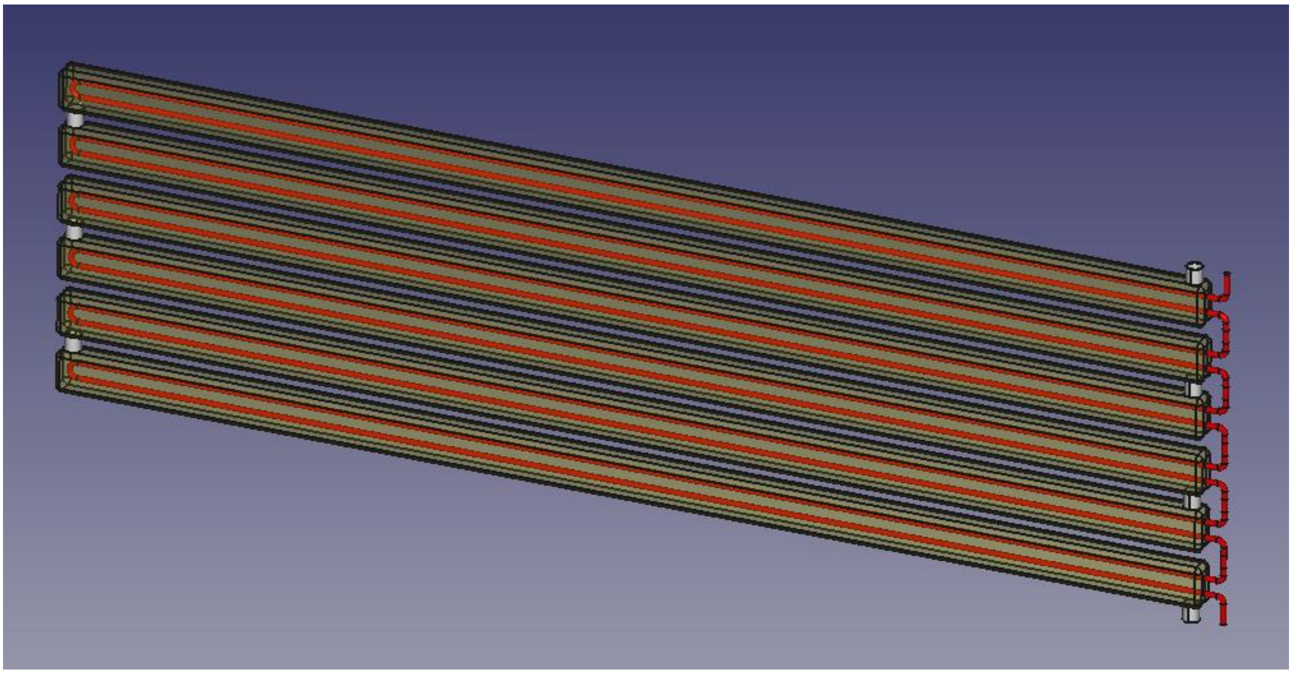
Tubes – Hot side – N_2

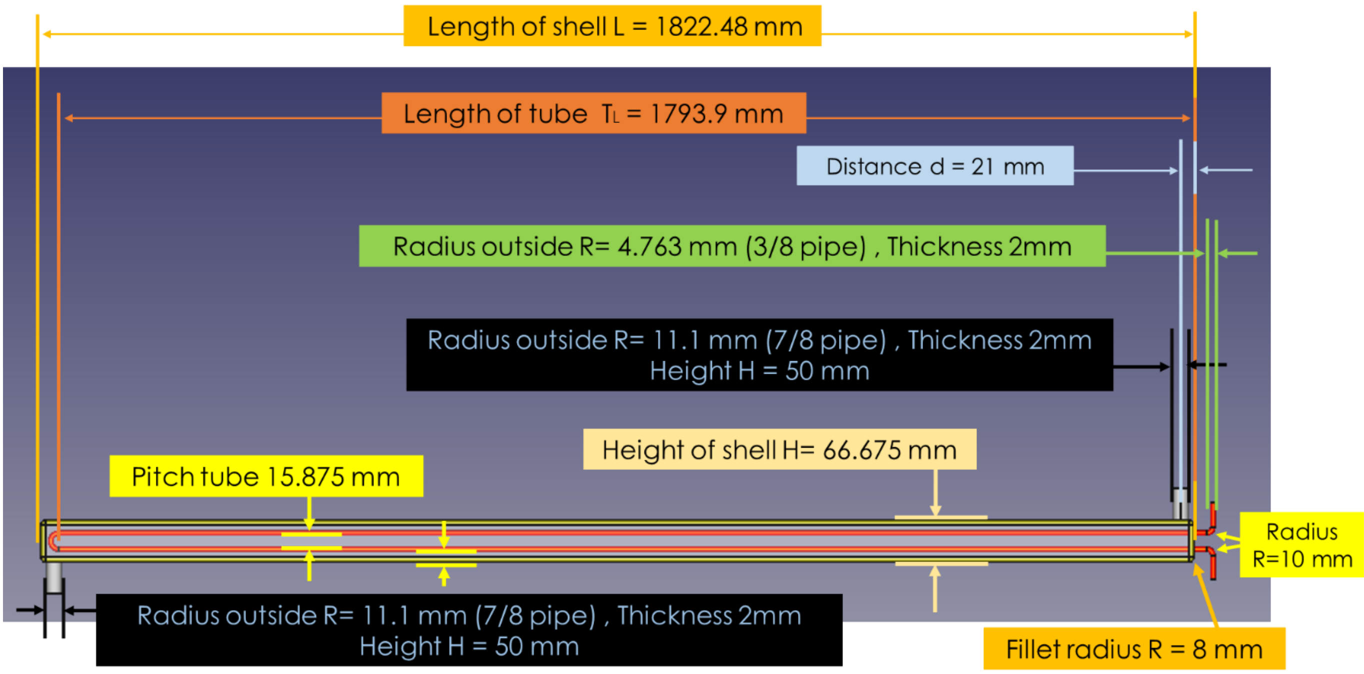
HX_N2-N2 _ ONE SHELL.FCStd

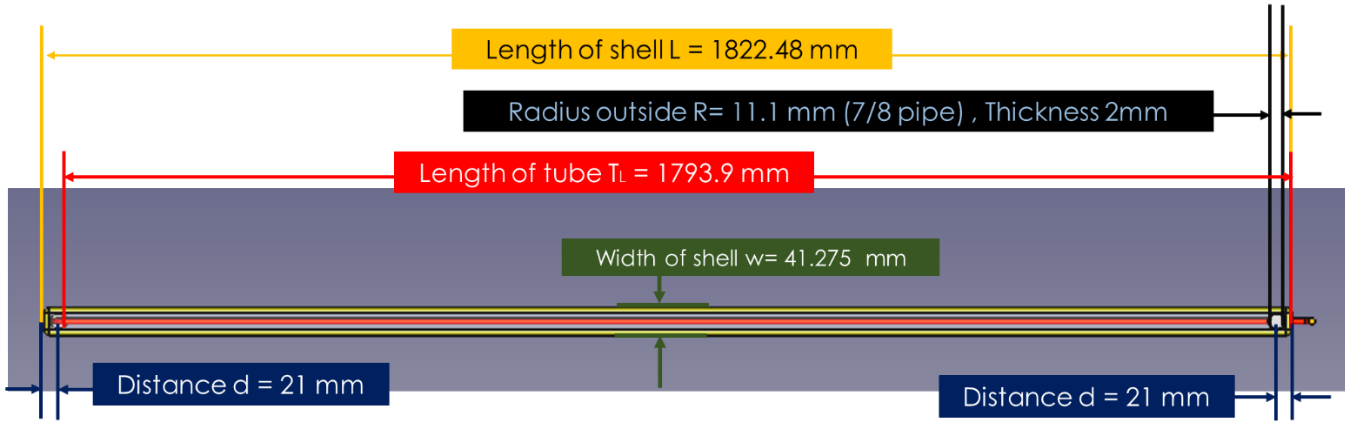
HX_N2-N2.FCStd

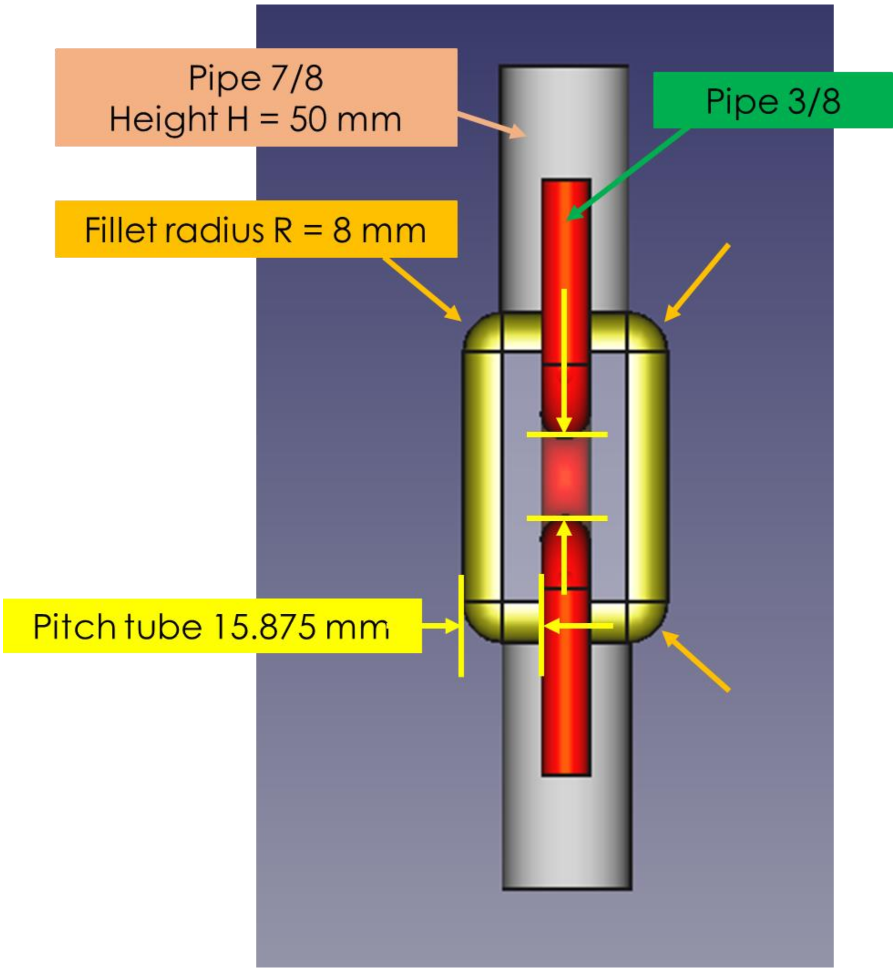


FreeCad Design

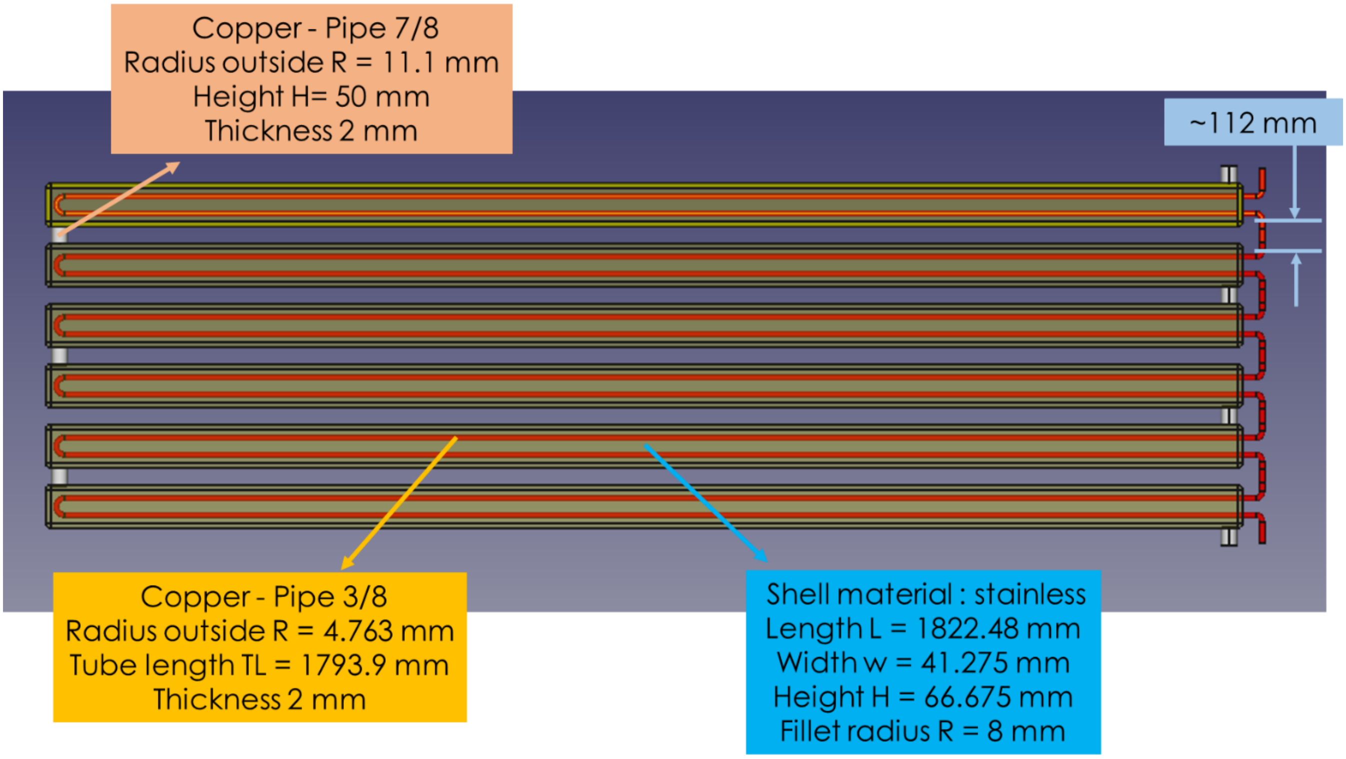





Length of shell L = 1822.48 mm
Radius outside R= 11.1 mm (7/8 pipe) , Thickness 2mm
Length of tube TL = 1793.9 mm
Width of shell w= 41.275 mm
Distance d = 21 mm
Distance d = 21 mm


Pipe 7/8
Height H = 50 mm
Pipe 3/8
Fillet radius R = 8 mm
Pitch tube 15.875 mm

FreeCad Design



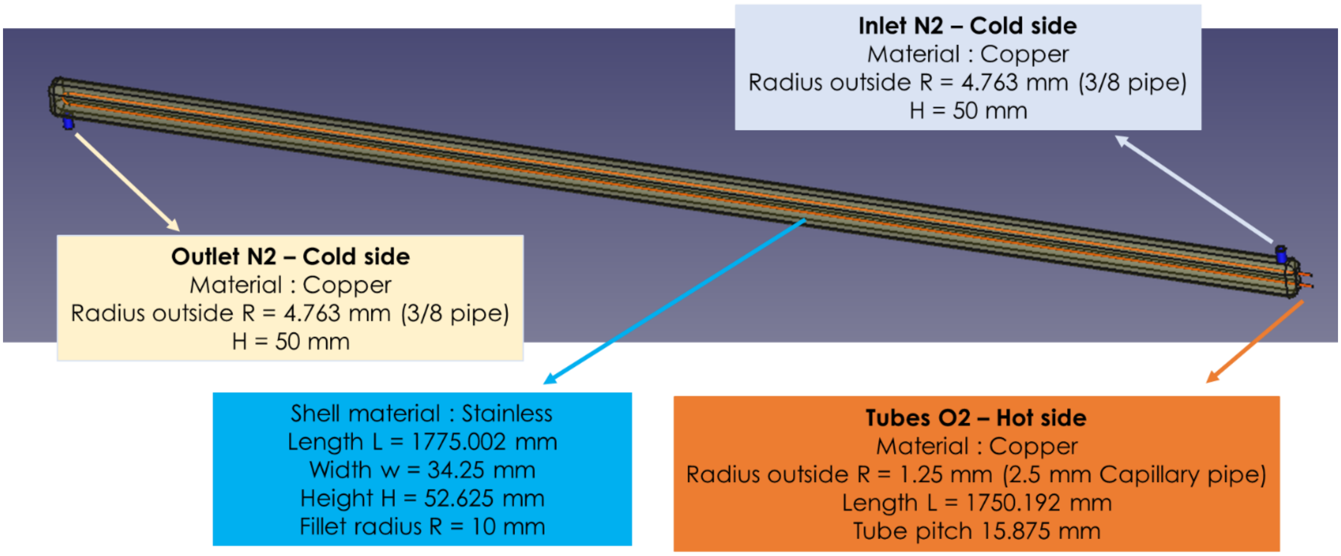
4.3 Heat exchanger design HX-N_2/O_2 [Main]

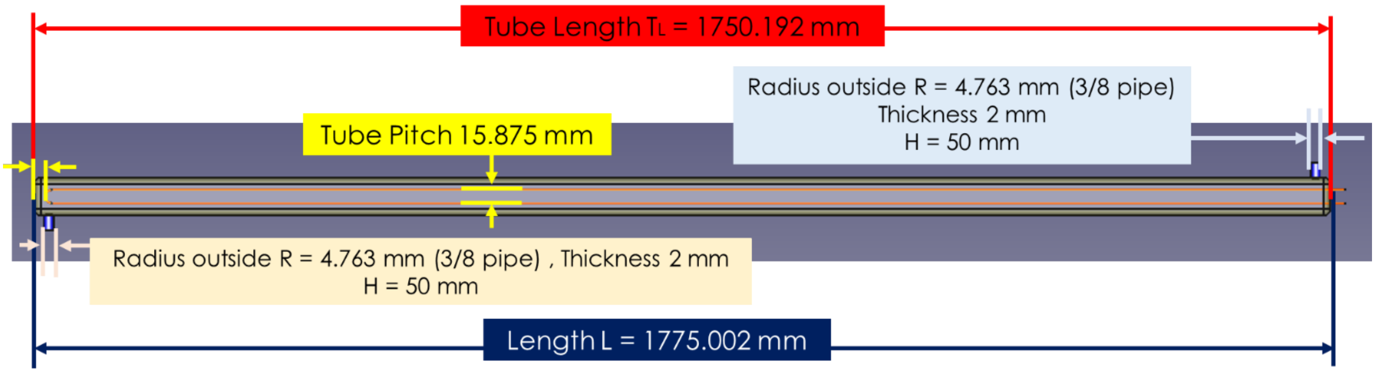
1 shell , 2 tubes

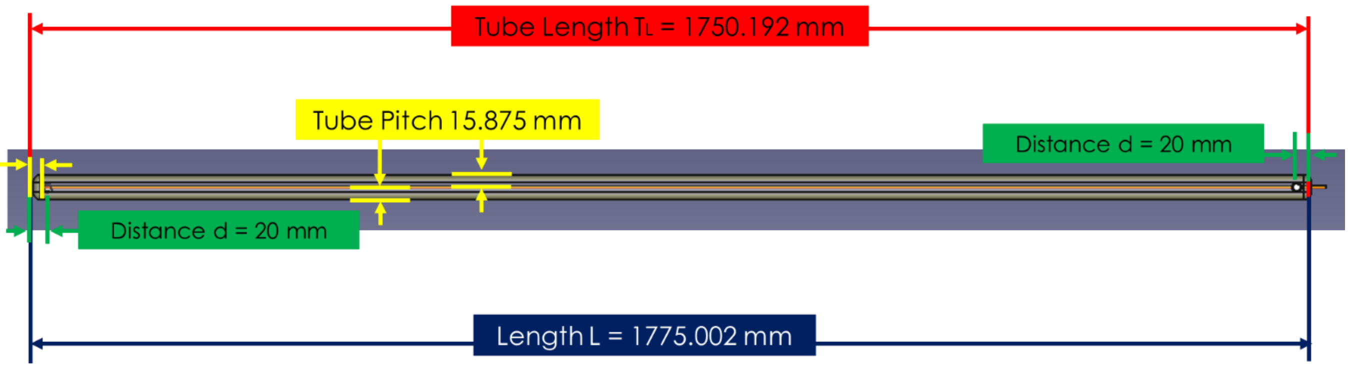
Shell – Cold side – N_2

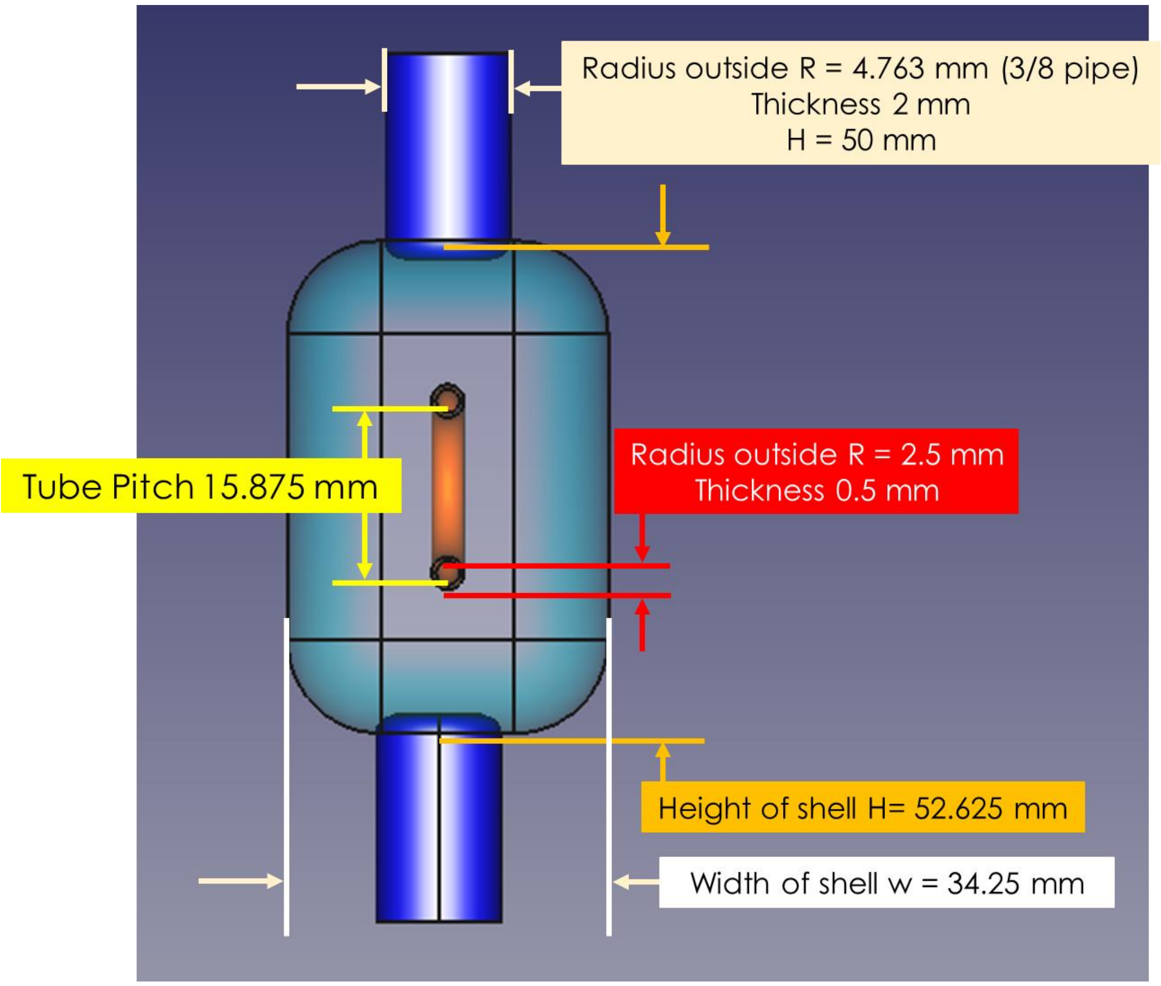
Tubes – Hot side – O_2

HX_N2-O2 Main.FCStd




Tube Length TL = 1750.192 mm
Radius outside R = 4.763 mm (3/8 pipe)
Thickness 2 mm
H = 50 mm
Tube Pitch 15.875 mm
Radius outside R = 4.763 mm (3/8 pipe) , Thickness 2 mm
H = 50 mm
Length L = 1775.002 mm


Tube Length TL = 1750.192 mm
Tube Pitch 15.875 mm
Distance d = 20 mm
Distance d = 20 mm
Length L = 1775.002 mm


Radius outside R = 4.763 mm (3/8 pipe)
Thickness 2 mm
H = 50 mm
Tube Pitch 15.875 mm
Radius outside R = 2.5 mm
Thickness 0.5 mm
Height of shell H= 52.625 mm
Width of shell w = 34.25 mm

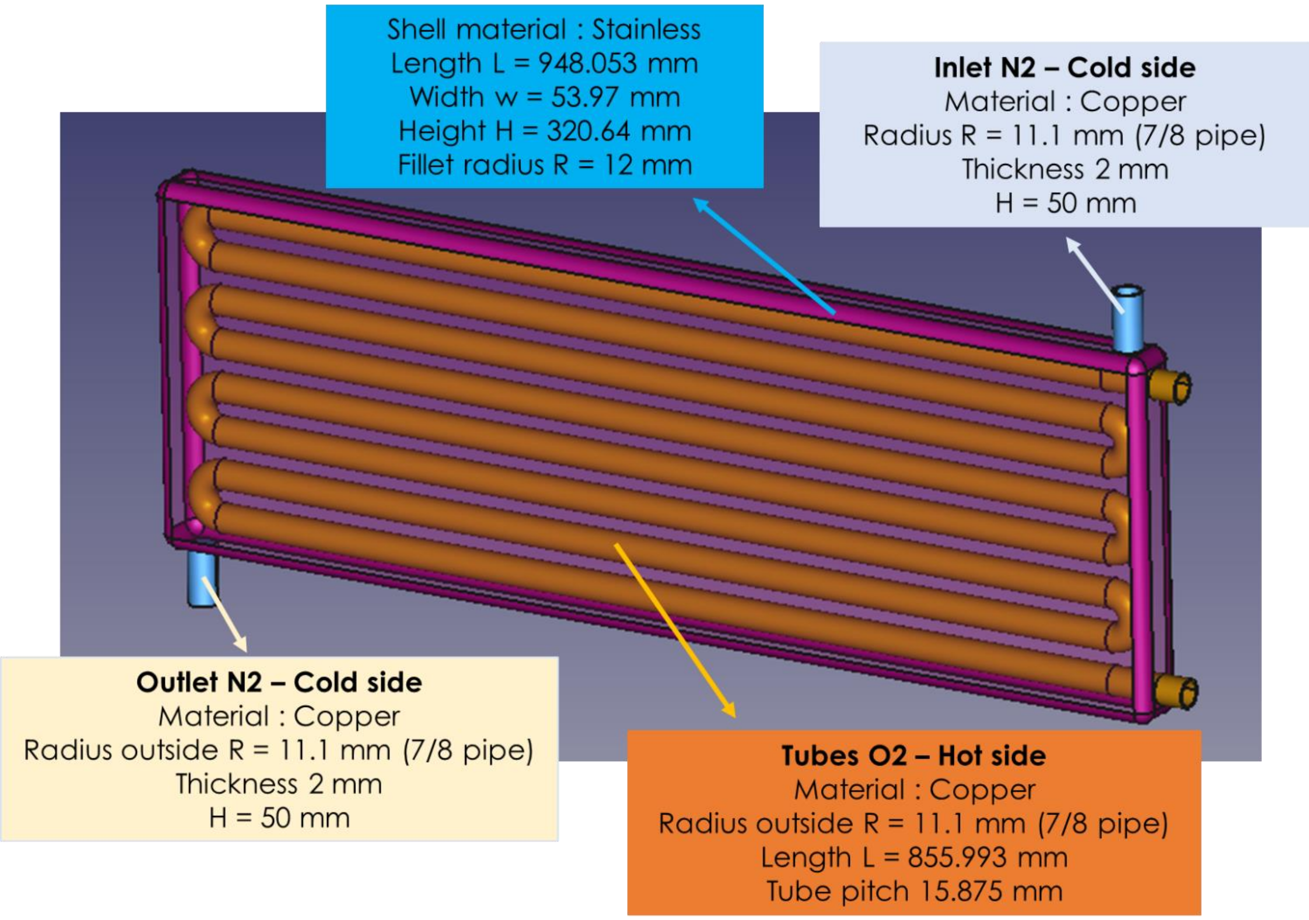
4.4 Heat exchanger design HX-N_2/O_2 [2nd]

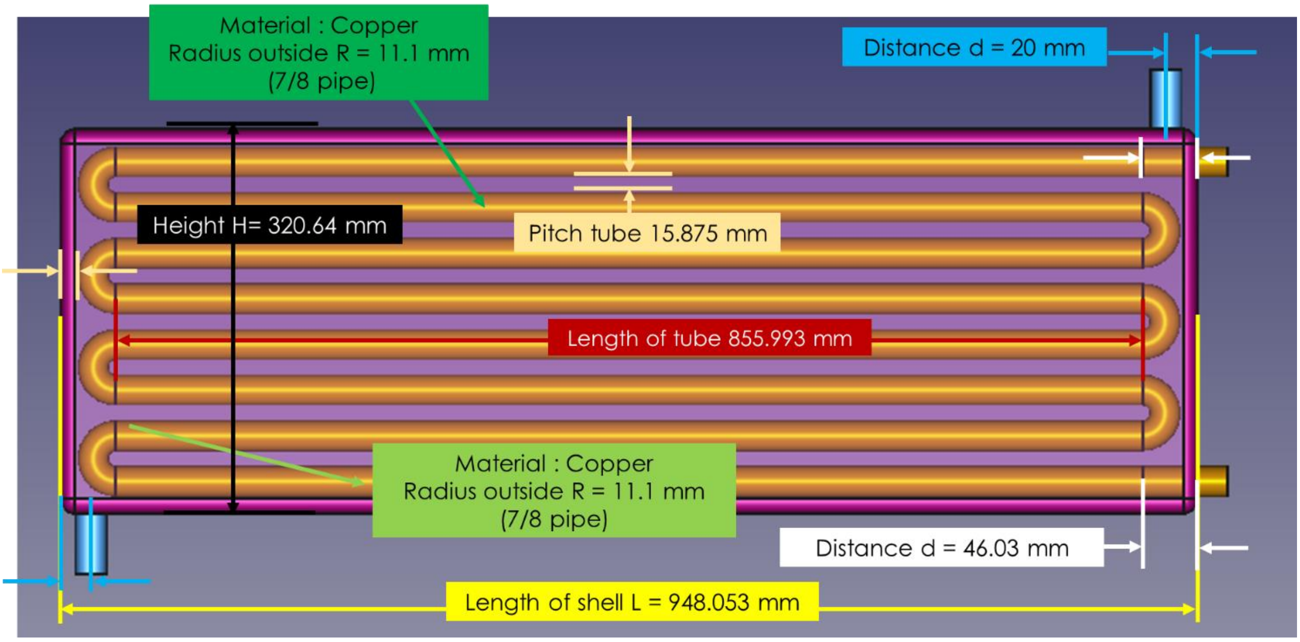
1 shell , 8 tubes

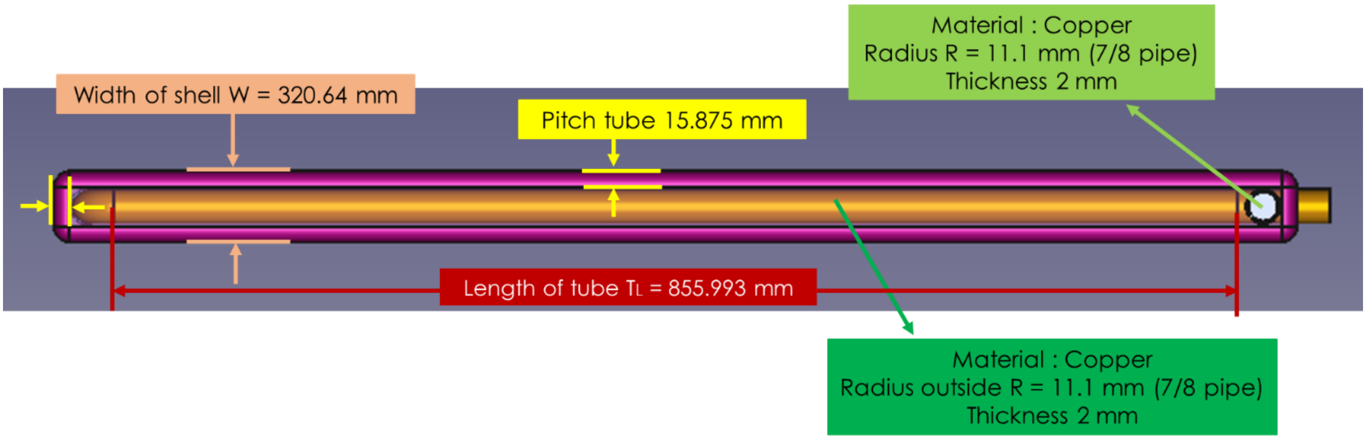
Shell – Cold side – N2

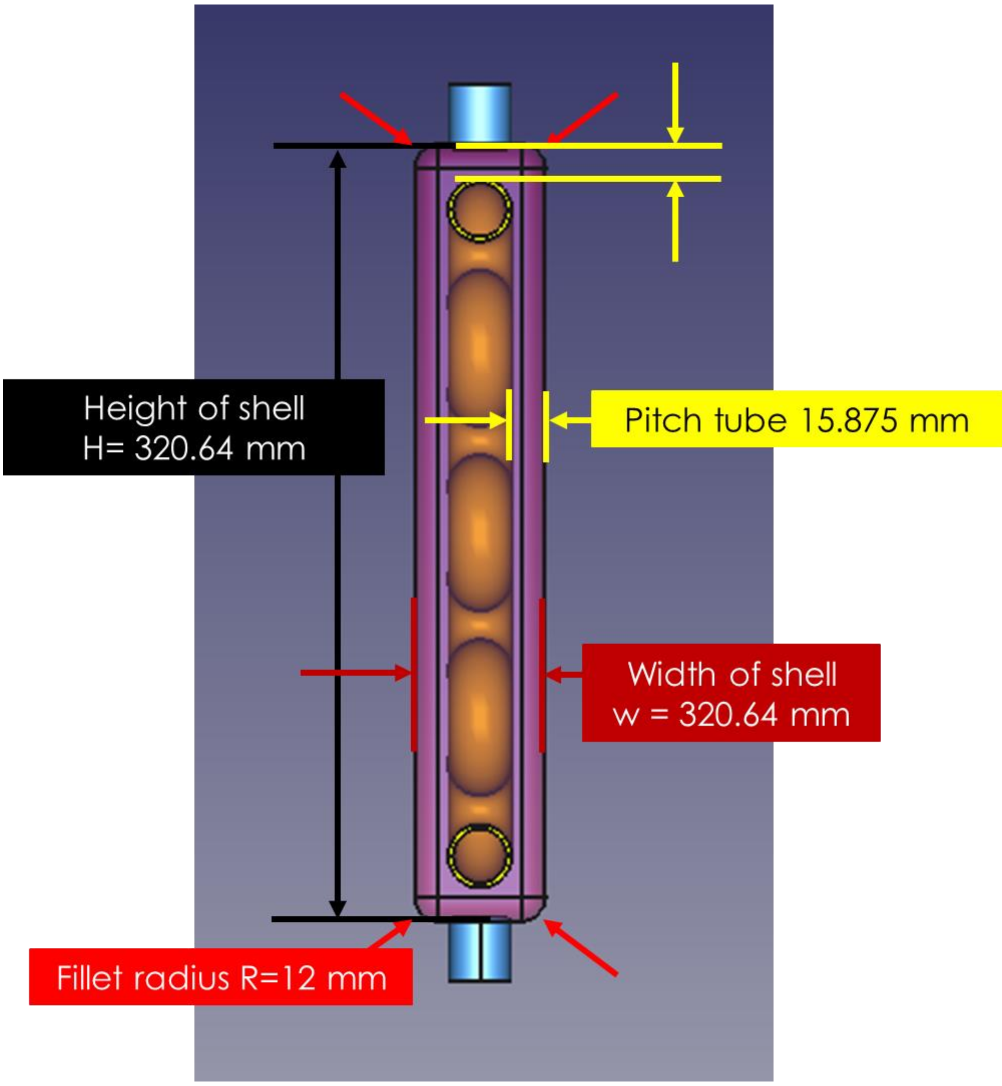
Tubes – Hot side – O2

HX_N2-O2 (2nd).FCStd




Material : Copper
Radius outside R = 11.1 mm
(7/8 pipe)
Distance d = 20 mm
Height H= 320.64 mm
Pitch tube 15.875 mm
Length of tube 855.993 mm
Material : Copper
Radius outside R = 11.1 mm
(7/8 pipe)
Distance d = 46.03 mm
Length of shell L = 948.053 mm


Material : Copper
Radius R = 11.1 mm (7/8 pipe)
Thickness 2 mm
Width of shell W = 320.64 mm
Pitch tube 15.875 mm
Length of tube TL = 855.993 mm
Material : Copper
Radius outside R = 11.1 mm (7/8 pipe)
Thickness 2 mm



4.5 Cooling design [Inside kelvinator]

Q_{conv} = m_{dot} * C_p* (T_i - T_o)

= 25 kg/h * 1.088375 KJ/Kg.K * (335 - 195)

= 25/3600 * 1.088375 *140 = 1.0575 KW = 1057.5 W

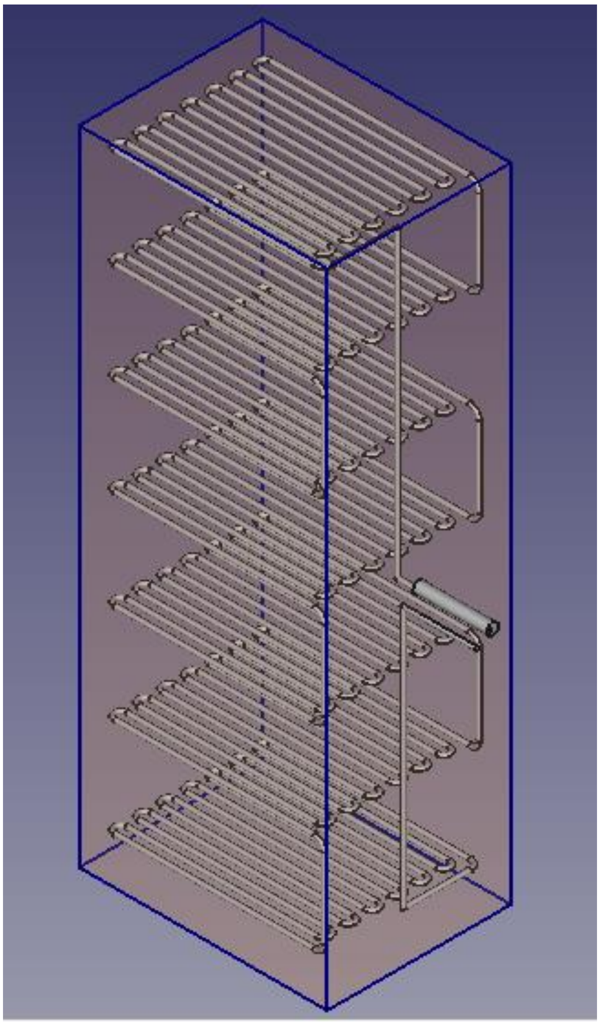
Q_{conv} = h*A_s*LMTD or $LMTD = \frac{\Delta To - \Delta Ti}{\ln\left(\frac{\Delta To}{\Delta Ti}\right)} = 33.2$

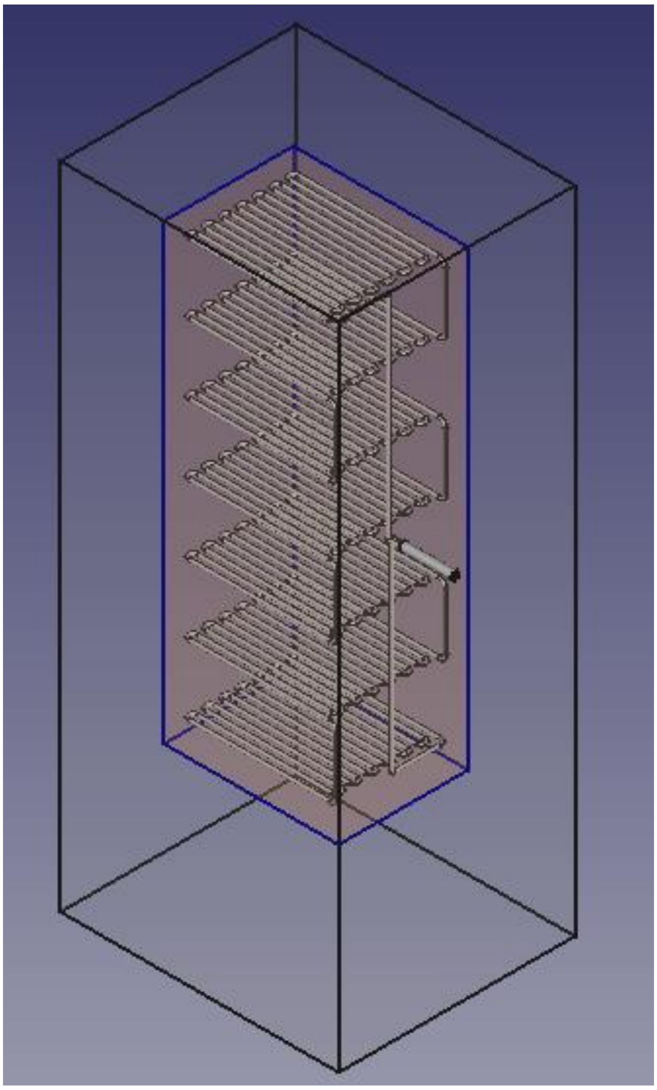
$A_s = \frac{1057.5}{h*33.2} = \frac{1057.5}{25*33.2} = 1.274\ m^2$

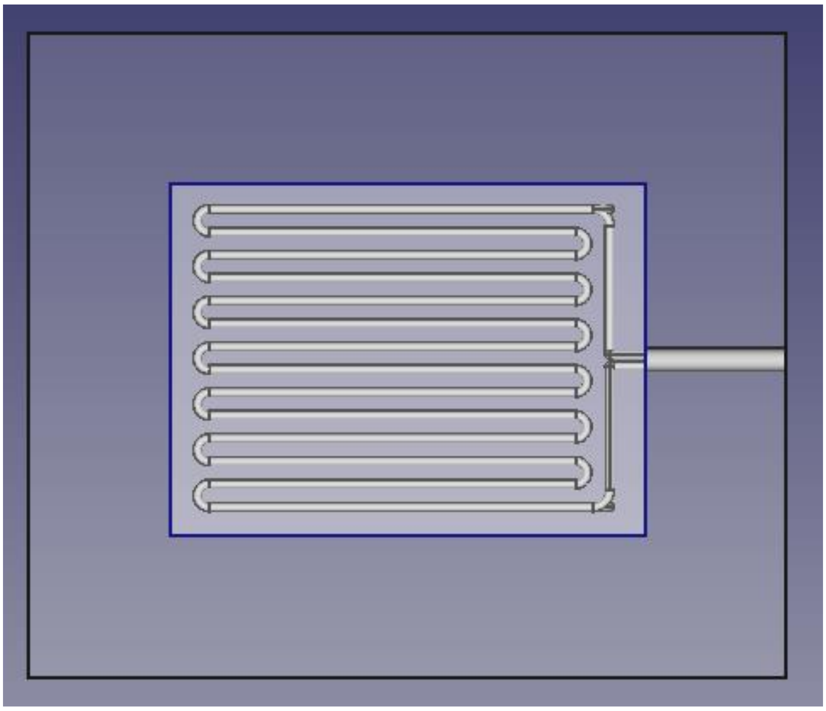
Or $A_s = 2 * \pi * R * h \rightarrow h = \frac{As}{2*\pi*R} = \frac{1.274}{\pi*9.525*10^{\wedge}-3} = 42.58\ m$

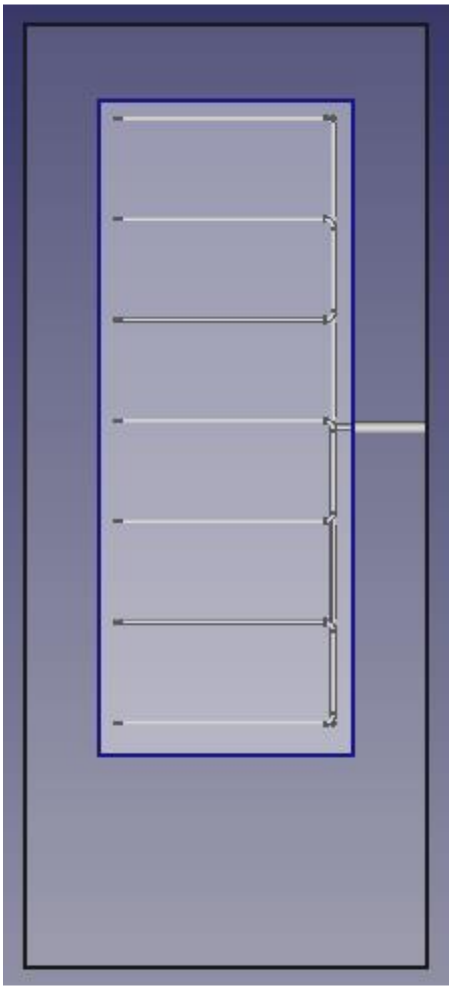
4.6 Cooling FreeCad design

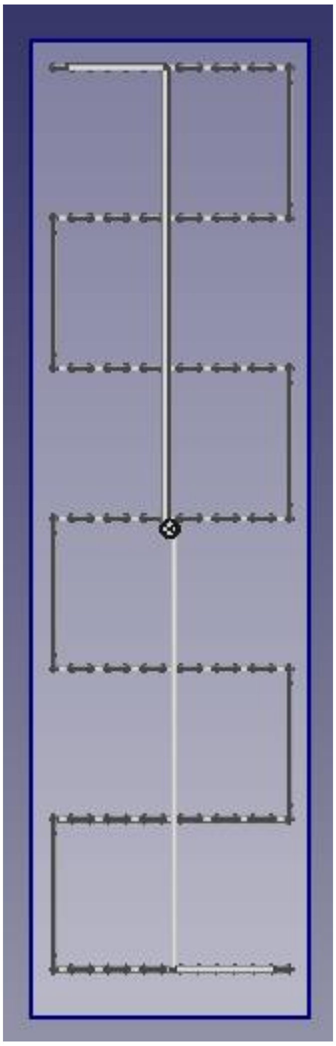
COOLING.FCStd

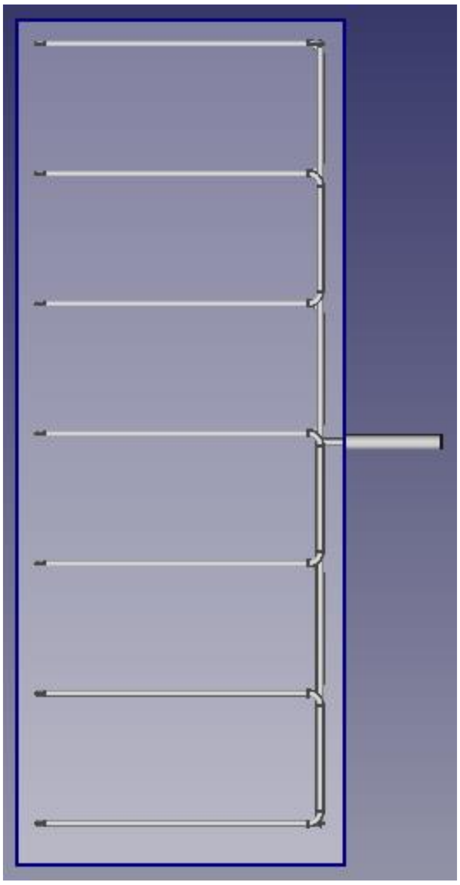


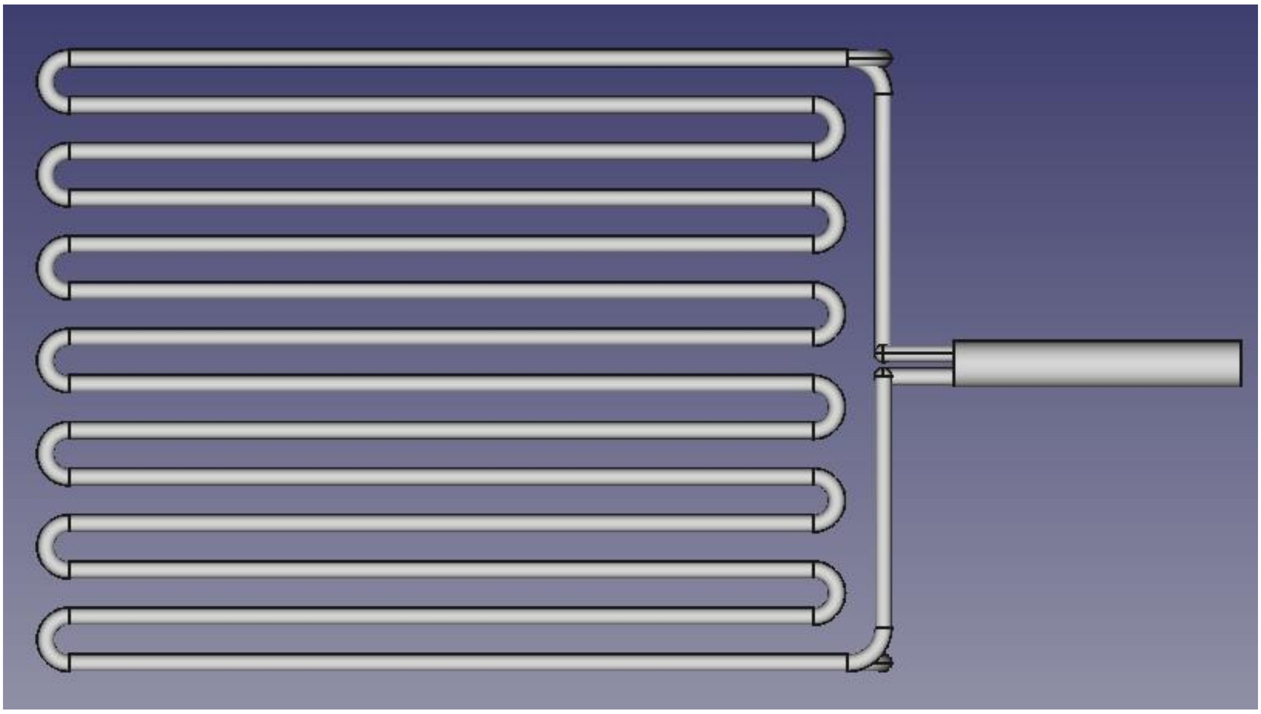


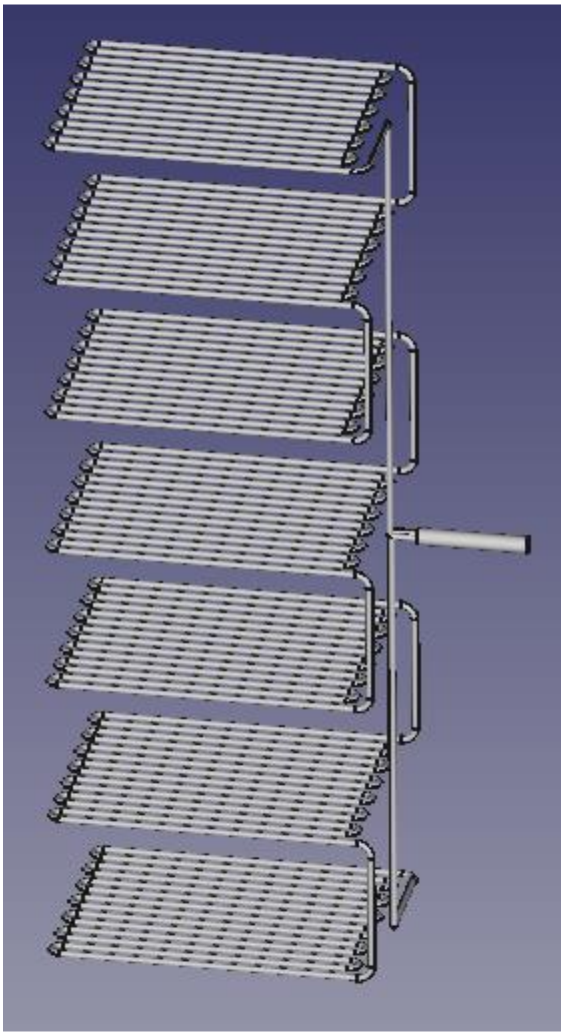


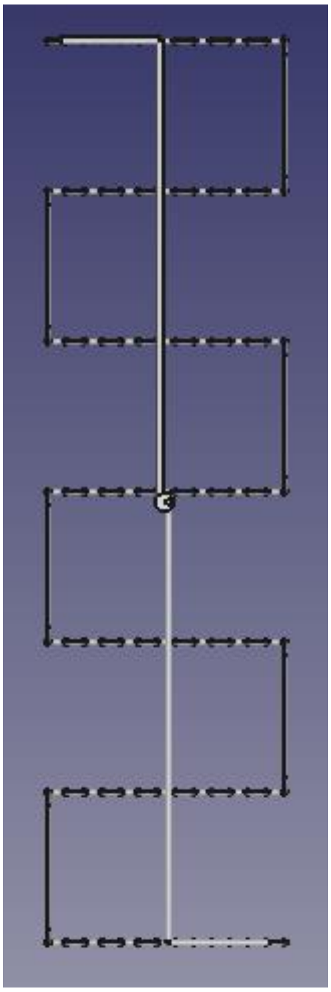


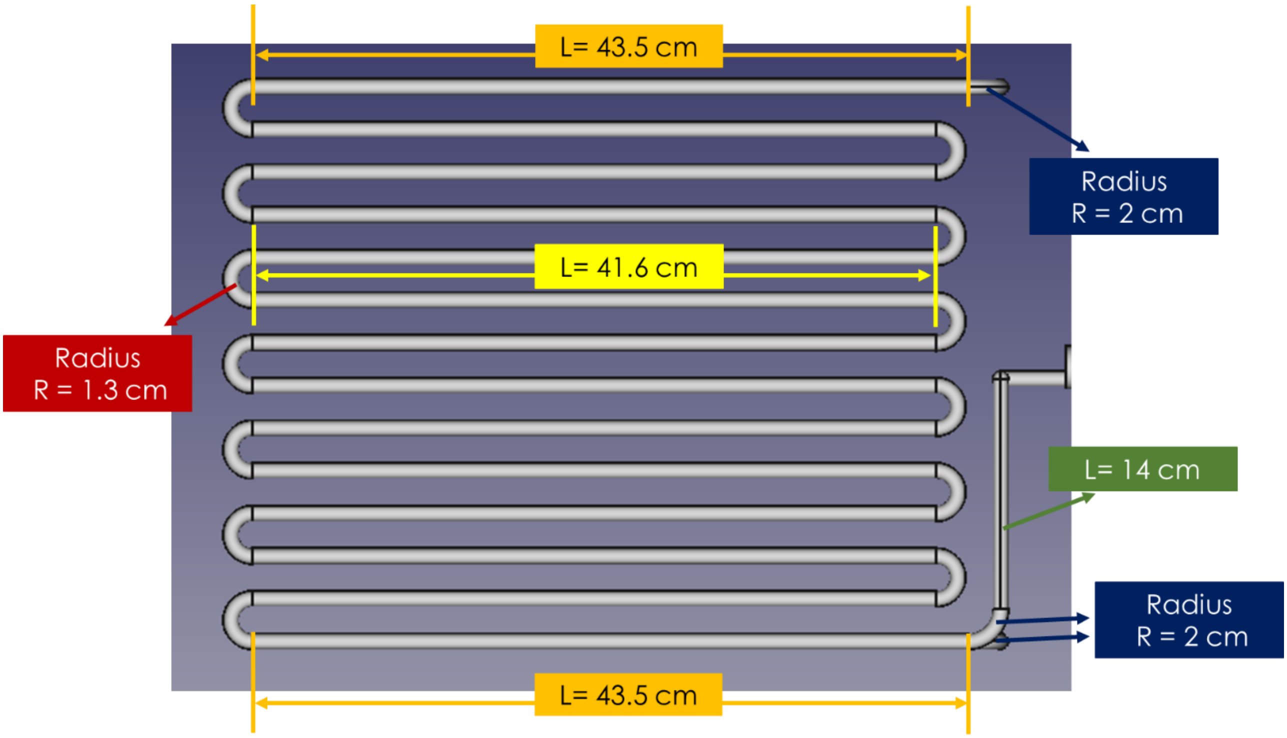


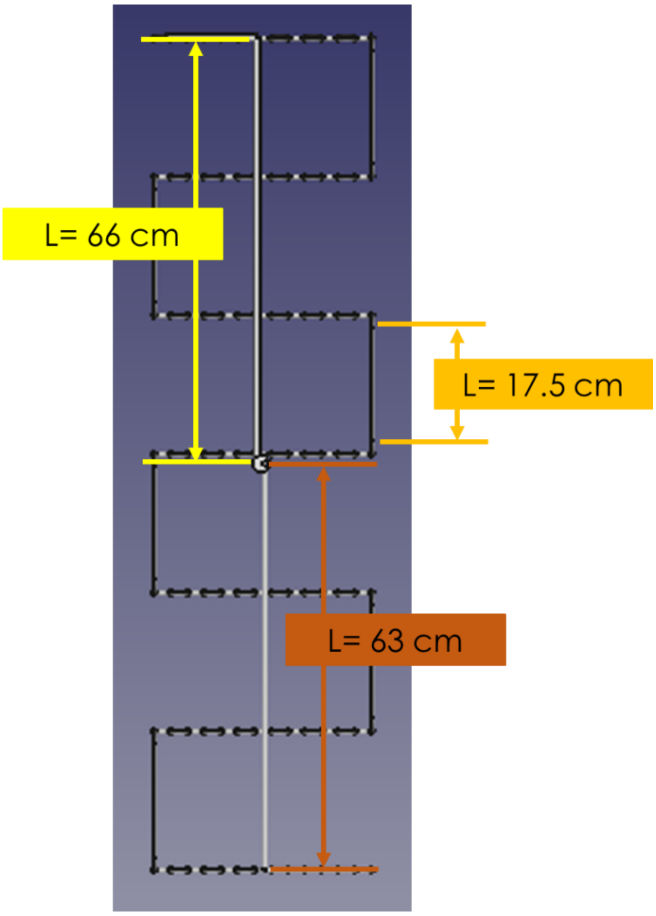




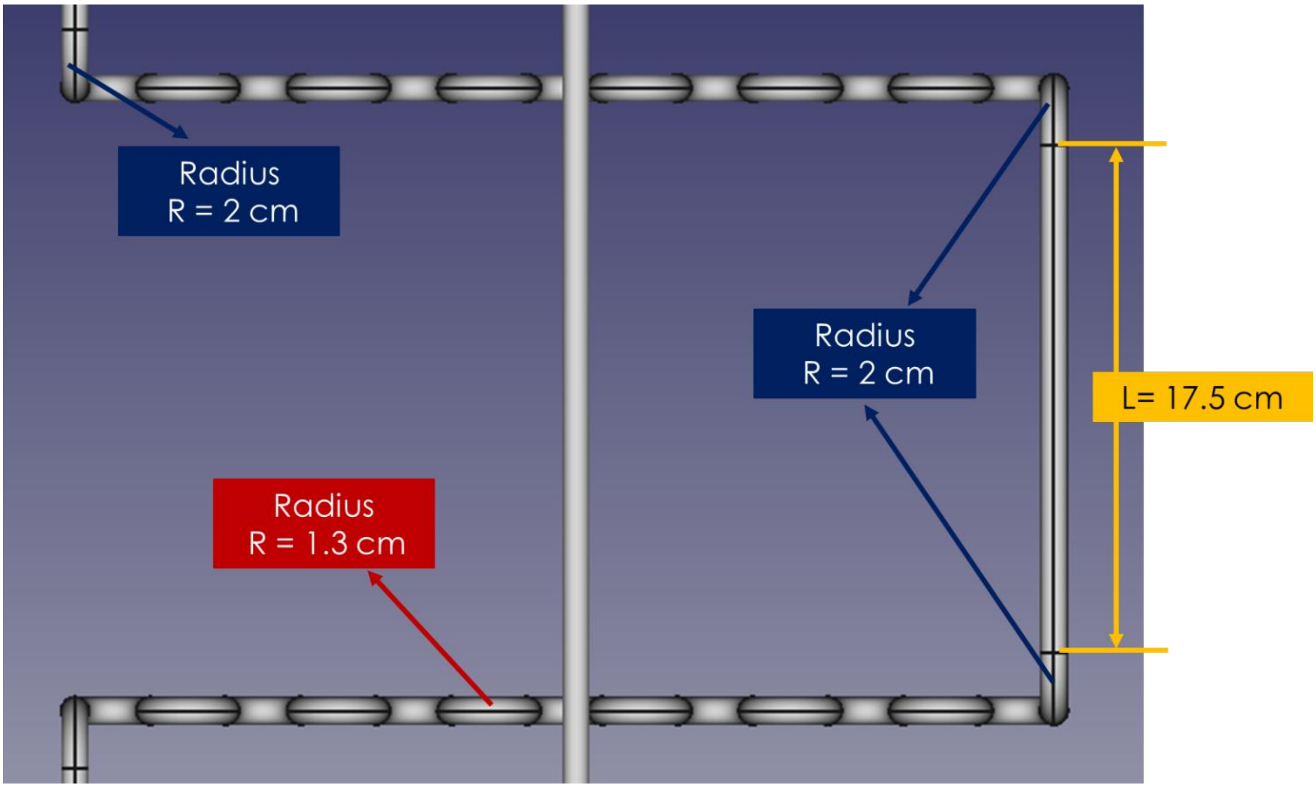





L= 43.5 cm
Radius
R = 2 cm
L= 41.6 cm
Radius
R = 1.3 cm
L= 14 cm
Radius
R = 2 cm
L= 43.5 cm


L= 66 cm
L= 17.5 cm
L= 63 cm

0



5 Price of prototype components

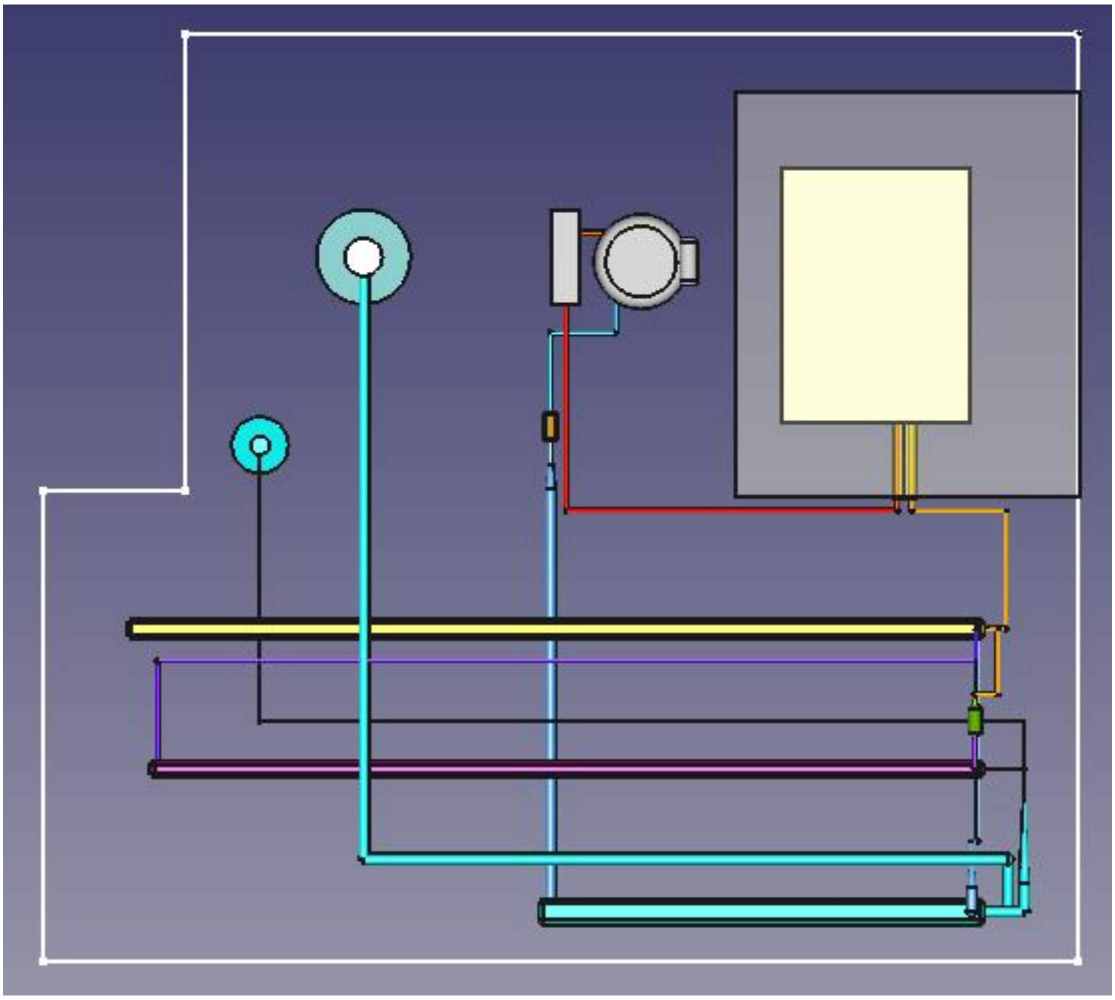
Components of prototype	Source	Characteristics	General price	# of piece	Total cost excluding hand cost		Notes
Compressor	*LR25B laboratory* refrigerator	Press 2 bar to 15 bar	___	1	___		
Condenser	*LR25B laboratory* refrigerator	Air cooling	___	1	___		
Cooling	*Kelvinator* refrigerator	Copper pipes (3/8)	pipe (3/8) : 15 m / $ 55	L= 43 m	$	157.70	Total pipe 3/8: L= 65.8 m , cost = $ 241.3
HX - N2/N2 (6 shells , 12 tubes)	Manifacture	Copper pipes (3/8)	pipe (3/8) : 15 m / $ 55	L= 22.5 m (L= 3.63 m per shell)	$	27.50	Total capillaries copper pipes: L = 3.7 m , Cost = 111 000 L.L.
		Copper pipes (7/8)	1.5 m / $ 15 (or Roller 15 m , 140$)	L= 0.6 m (L= 0.2 m per shell)	$	6.00	Total pipe 7/8: L= 8.2 m , Cost = $ 82
		Shell copper or stainless		Area = 2.4115 m2 (A = 0.402 m2 per shell)	17.4 - 26.1 $ (2.9 - 4.35 $/shell)		Total volume V = 0.003391912 Kg/m3 , Costs = (Stainless 38.2 $, Steel 8.2 $, Copper 287 $)
Expansion valve	Purphase	15 bar, 80 K		1	$	35.00	
HX - N2/O2 [main] (1 shell , 2 tubes)	Manifacture	Capillaries copper pipes (2.5 mm outside)	1 m / 30 000 L.L.	L= 3.7 m	L.L.	111 000	
		Copper pipes (3/8)	15 m / $ 55	L= 0.1m	$	0.37	
		Shell copper or stainless		Area A = 0.3134 m2			
HX - N2/O2 [2nd] (1 shell , 8 tubes)	Manifacture	Copper pipes (7/8)	1.5 m / $ 15 (or Roller 15 m , 140$)	L= 7.4 m	$	102.00	
		Shell copper or stainless		Area A = 0.7457 m2			
Filter drier	Purphase	N2 gas, mass flow 25 Kg/hr		1	$	15.00	
Pressure valve	Purphase	**Gas** 15 bar		1			
Check valve	Purphase			1	$	10.00	
Thermal insulation materials	Purphase	Area per meter					
Cryometer	Purphase (not available)	Low than 80 K		5			
Solenoid valve	Purphase			1			
N2 gas	Purphase						
O2 gas	Purphase						
O2 gas tank	Purphase			1			

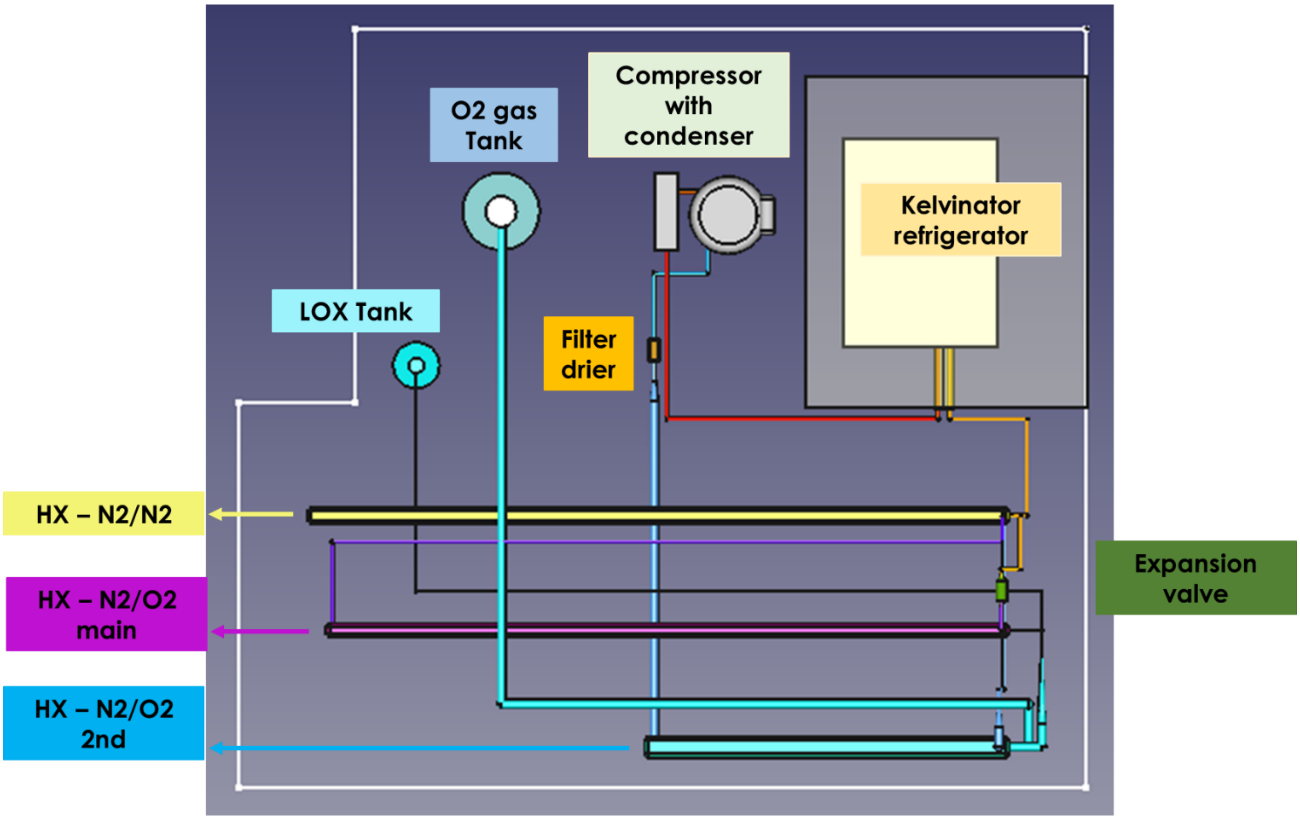
- General space of prototype is : L * W * H = 1.93 m * 2 m * 1.2 m (except height of kelvinator refrigerator = ~ 1.7 m)

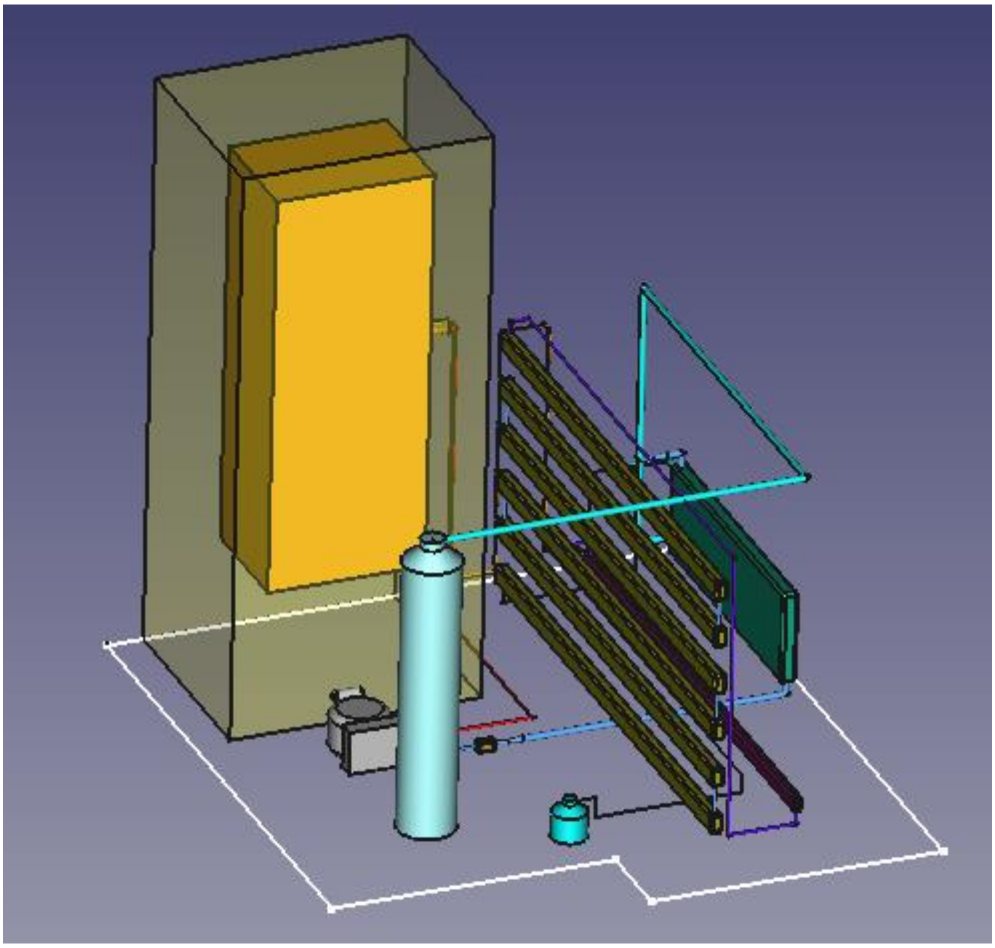
		Stainless steel	Steel	Copper
Price		1 - 1.5 $/Kg	100 - 300 $/Ton	9.35 $/Kg
Density		7500 Kg/m3	8050 Kg/m3	8.96 g/cm3
HX-N2/N2	Volume needed	0.002348004 m3	0.002348004 m3	2348.004 cm3
	Mass	17.61 Kg	18.90 Kg	21.038 Kg
	Cost	17.61 - 26.415 $	1.89 - 5.67 $	196.71 $
HX-N2/O2 main	Volume needed	0.000305524 Kg/m3	0.000305524 Kg/m3	305.524 Kg/cm3
	Mass	2.29 Kg	2.46 Kg	2.737 Kg
	Cost	2.29 - 3.435 $	0.246 - 0.738 $	25.6 $
HX-N2/O2	Volume needed	0.000738384 Kg/m3	0.000738384 Kg/m3	738.384 Kg/cm3
	Mass	5.54 Kg	5.94 Kg	6.91 Kg
	Cost	5.54 - 8.31 $	0.594 - 1.782 $	64.61 $
Total volume		0.003391912 Kg/m3	0.003391912 Kg/m3	0.003391912 Kg/m3
Total mass		25.44 Kg	27.305 Kg	30.685 Kg
Total cost		25.44 - 38.16 $	2.731 - 8.192 $	286.91 $

6 Real layout design of prototype in AECENAR Facility

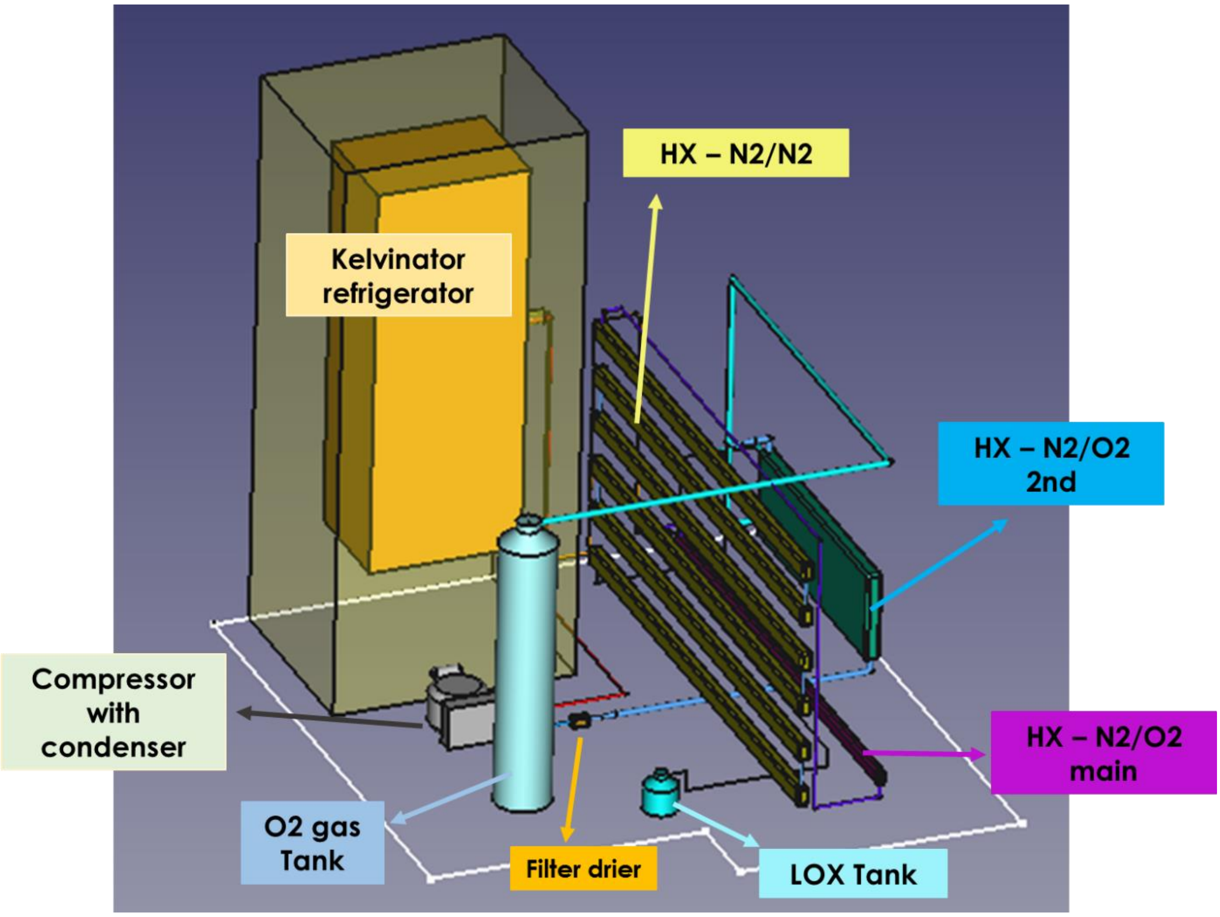
real prototype.FCStd

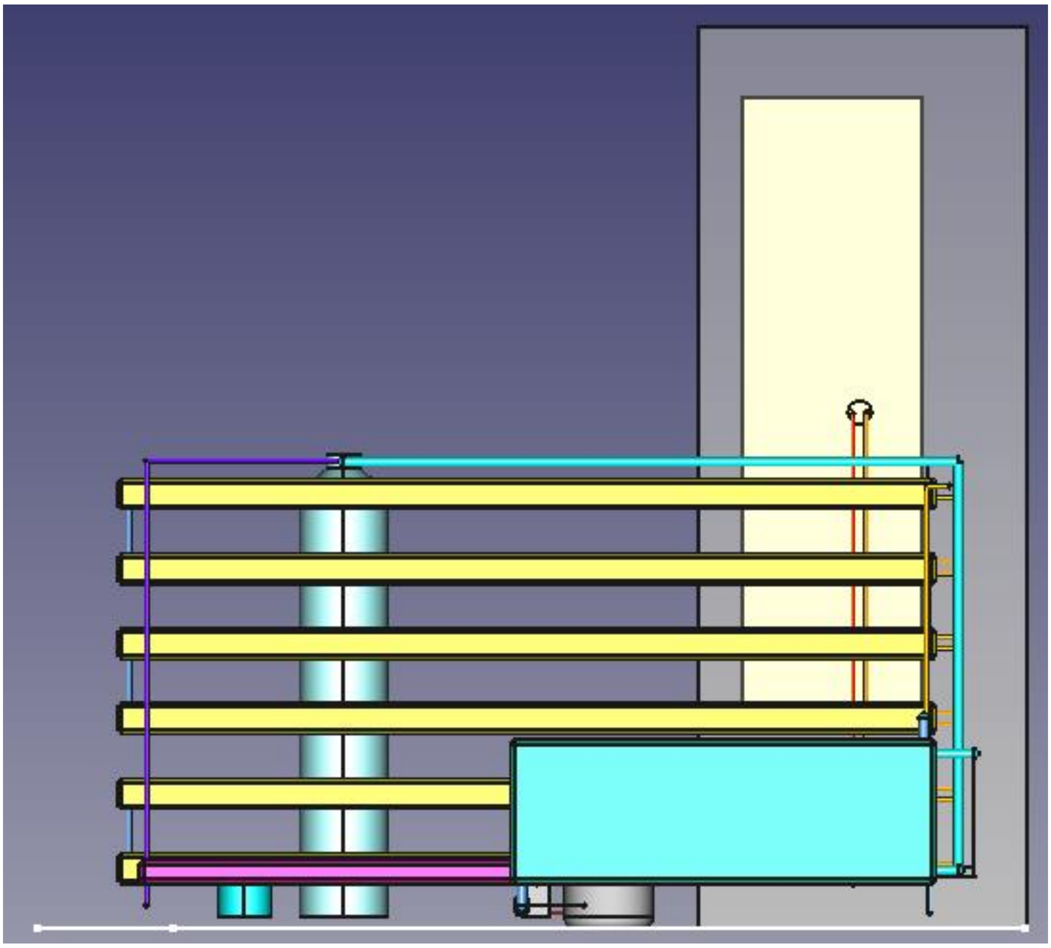


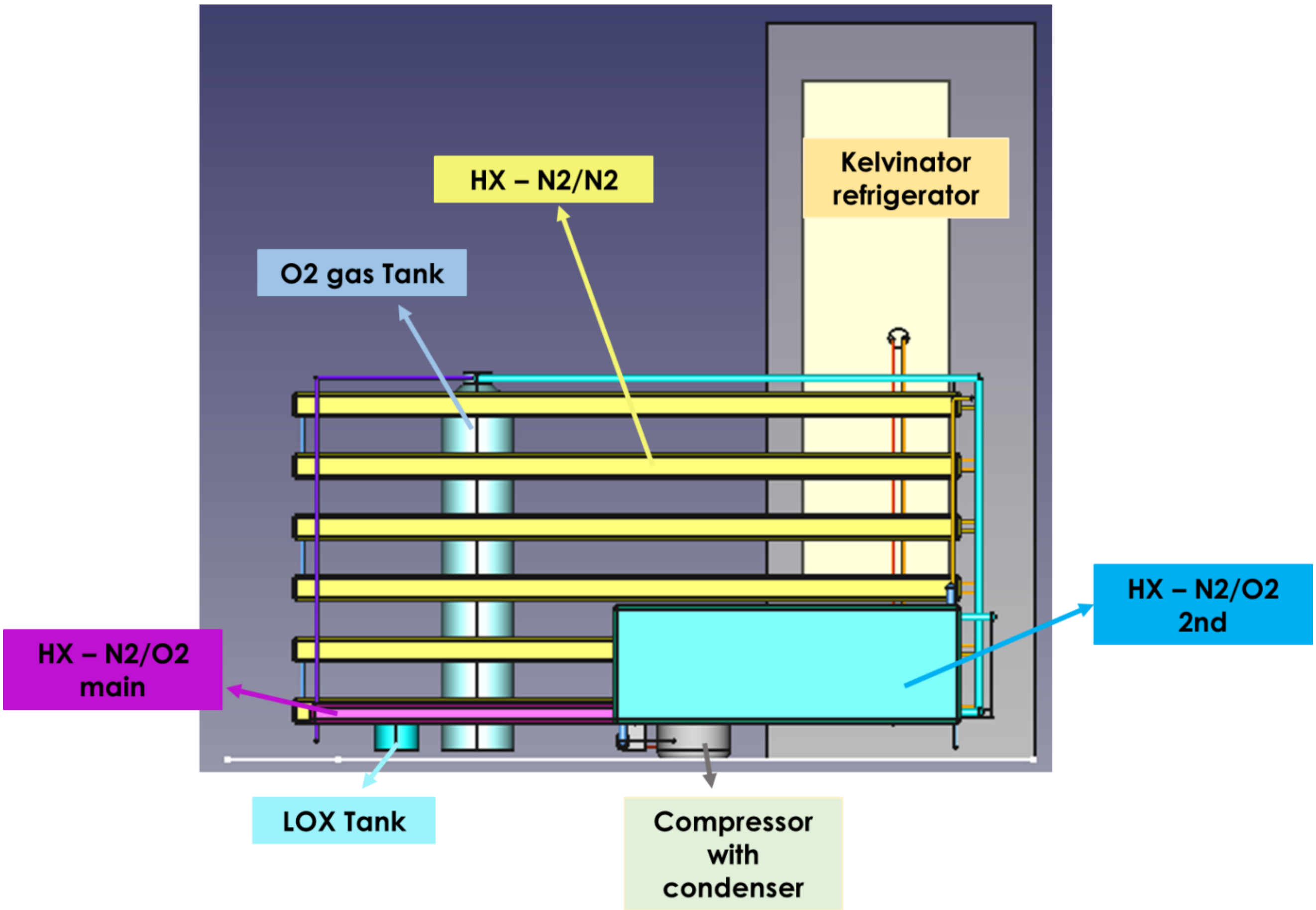

Compressor with condenser
O2 gas Tank
Kelvinator refrigerator
LOX Tank
Filter drier
HX – N2/N2
HX – N2/O2 main
HX – N2/O2 2nd
Expansion valve



Real layout design of prototype in AECENAR Facility






HX – N2/N2
Kelvinator refrigerator
O2 gas Tank
HX – N2/O2 2nd
HX – N2/O2 main
LOX Tank
Compressor with condenser

Real layout design of prototype in AECENAR Facility


IP Camera

Real layout design of prototype in AECENAR Facility

7 Real design of cooling (inside kelvinator refrigerator)

In this evaporator, we have 20 pipes (size 3/8, length L=~ 32 cm) with 19 tees (Radius R= 1.5 cm)

So: (32cm x 20 pipes)+($\frac{2 \text{ x } \pi \text{ x } 1.5\text{cm x } 180^{\circ}}{360}$ x 19 tees) = 729.535 cm = ~ 7.29 m

Real design of cooling (inside kelvinator refrigerator)

The length required for cooling was previously calculated : 42.58 m =~43 m

43 m /7.29 m = 5.98 floor → we need 6 floor for cooling

But the measurements of evaporator are not accurate so we will use 7 floors or pieces of this evaporator

Price of one piece of evaporator = ~200 000 L.L.

Total price excluding hand cost = ~ 200 000 x 7 = ~ 1 400 000 L.L.

8 First experiment (Expr #1)

The first experiment (Expr #1) aims to:

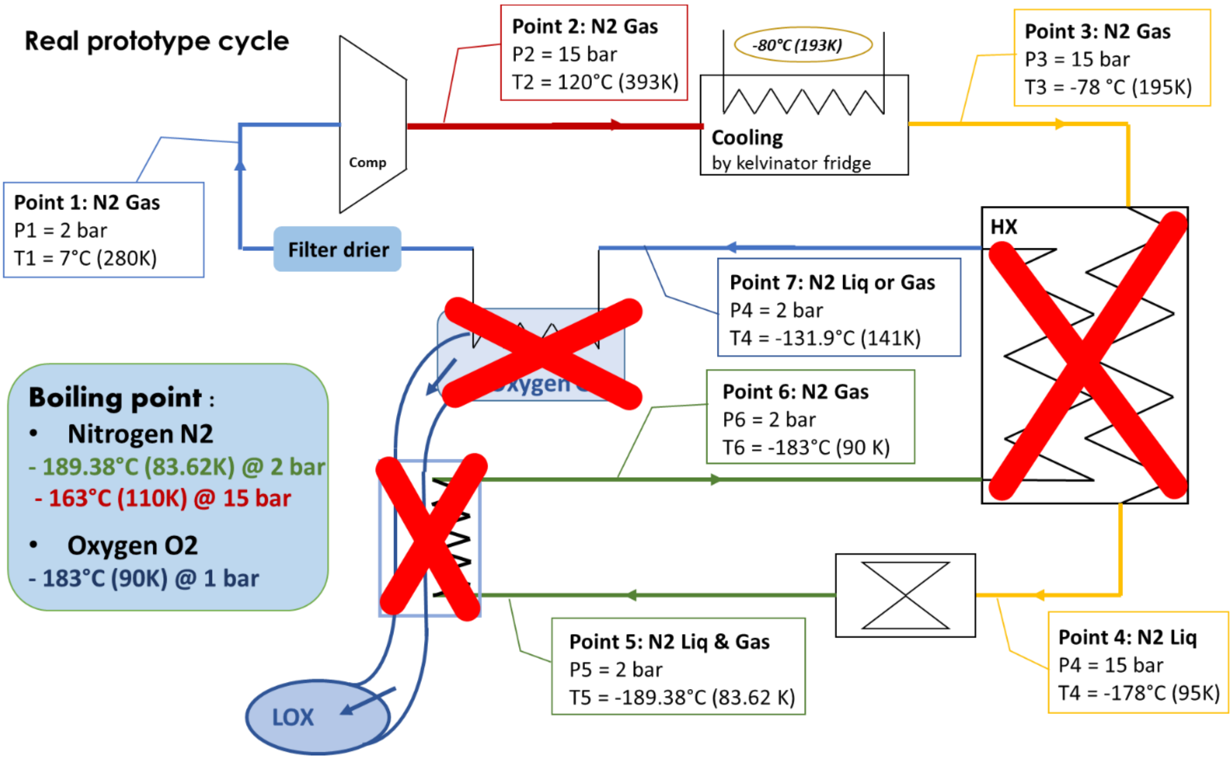
1- Compressor operation test with nitrogen gas instead of R-134a,

2- Make sure that the Kelvinator refrigerator is running correctly

3- Ensure that the expansion valve is compatible with the design.

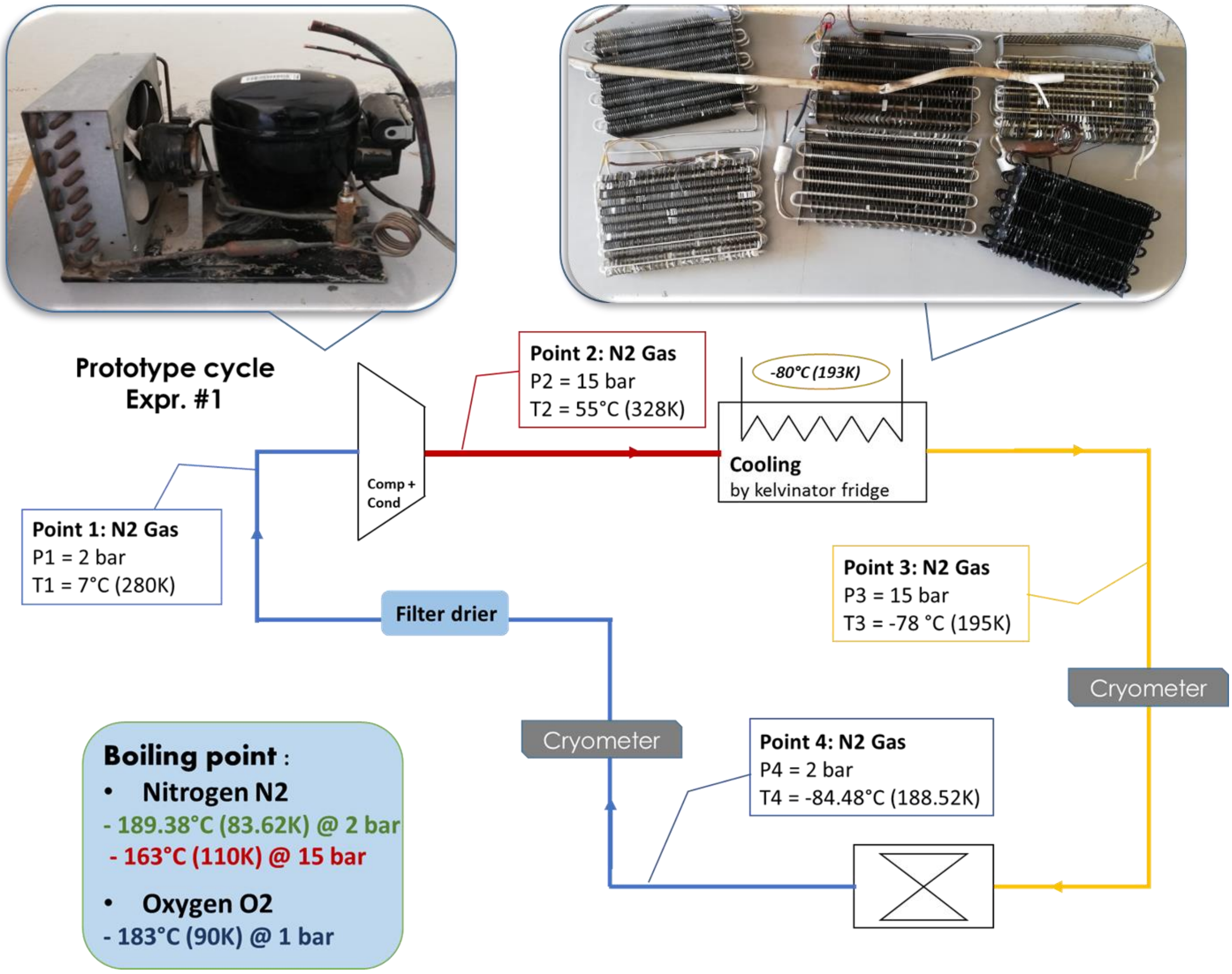
Therefore, the three heat exchangers (HX-N2/N2, HX-N2/O2 main, HX-N2/O2 2nd) will be excluded from this experiment.

In this experiment, the oxygen will not be liquefied, but only the components will be tested and designed to ensure the proper functioning of the refrigeration cycle.



The first experiment consists of a simple cycle consisting of a compressor (LR25B Laboratory) with a condenser, cooling through a Kelvinator refrigerator, and an expansion valve (taken from an LR25B Laboratory refrigerator).

First experiment (Expr #1)



The components that must be provided to carry out this experiment:

1- Filling the design with nitrogen gas, immediately before the pump.
2- Covering the design with a thermal insulation material to maintain the temperature of the refrigeration cycle,
3- The presence of a thermometer (below -100˚C (173 K)) to measure the cooling outlet (inlet of the expansion valve) and the outlet of the expansion valve,
4- Also, a weather thermometer (from -10˚C to 20˚C (263 K to 293 K)) to measure the temperature of the compressor inlet.

For **the safety of the compressor**:

- In the **first hour of operation**, a 5-minute break must be taken for the compressor every 15 minutes of operation, in order to avoid an explosion of the compressor or one of the designed cables.

- Also, the compressor must **not run for more than two hours** in a row.

- Also, **cold nitrogen gas must be entered into the compressor** to reduce the speed of nitrogen flow, in addition to its role in cooling the compressor.

During this experiment (Expr. #1), the **amount of nitrogen gas filled** to the cycle, the **time of the experiment**, the **temperature reached** by the refrigeration cycle, the **pressure during operation** will be calculated.

Literature

…