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Air Liquefaction and Cryogenics – Report 1 (2021)

Part I : Basics

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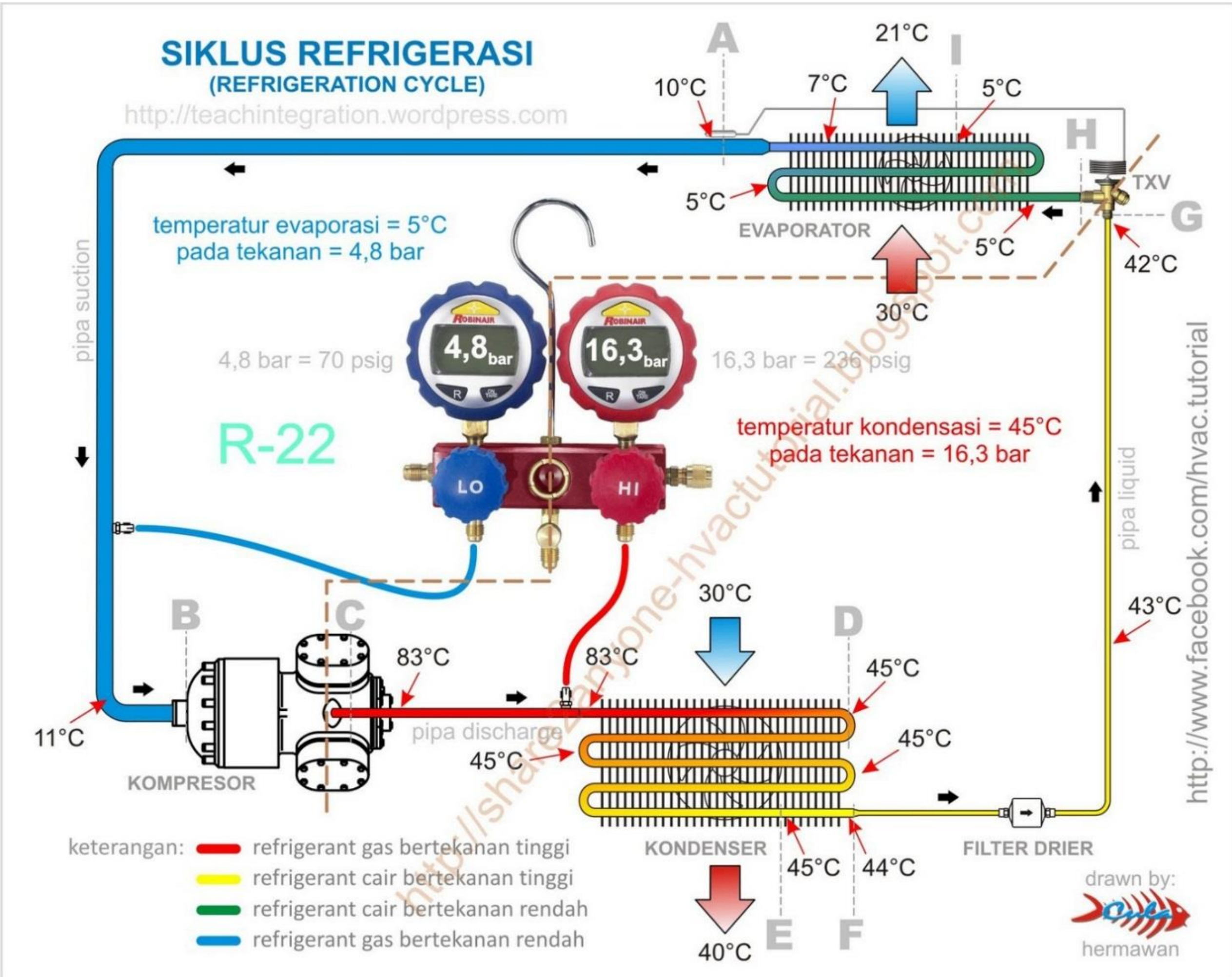

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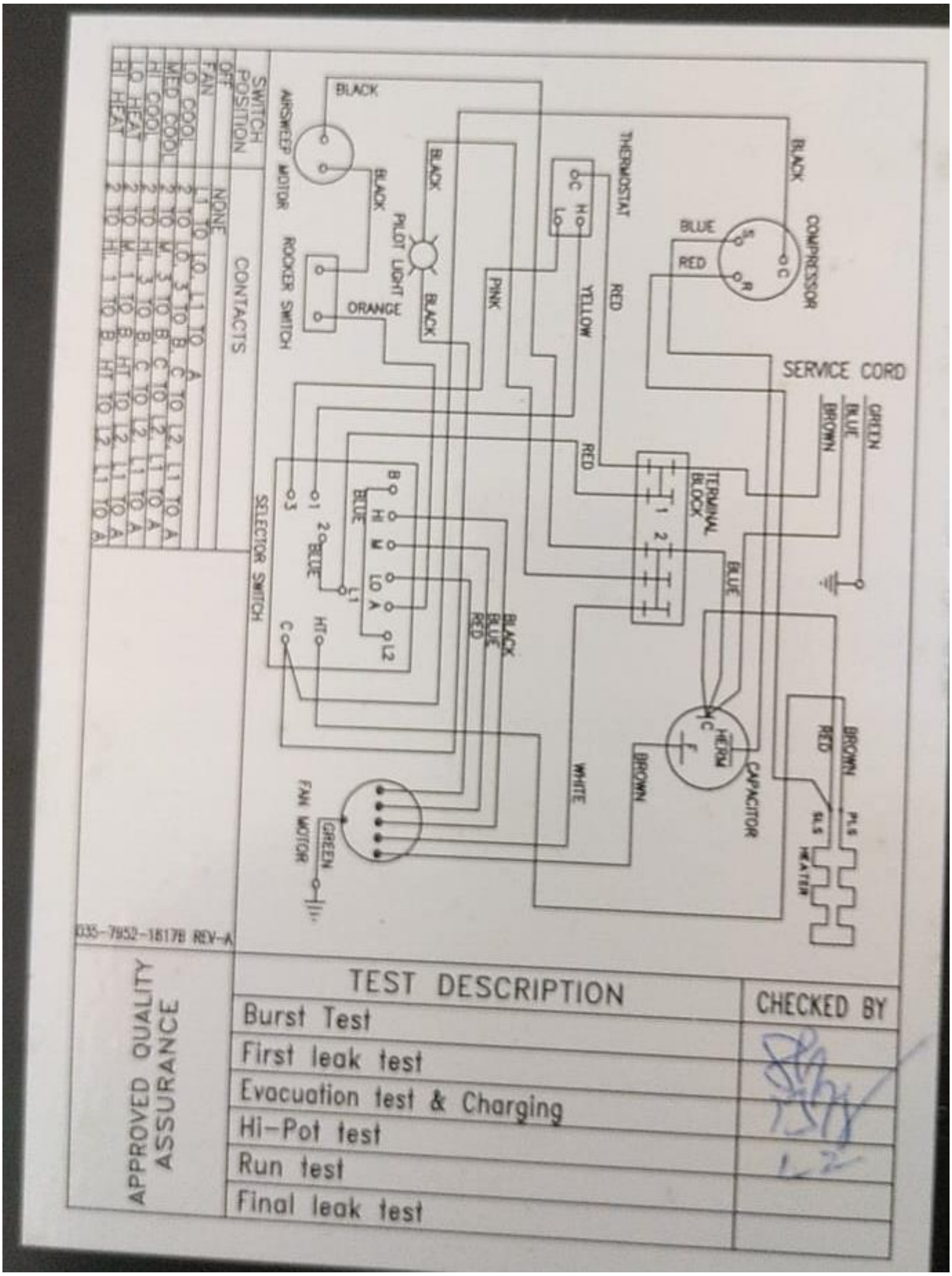
Filter dryer: 122

So the refrigerant enters through the inlet, it passes across the spring, then surrounds the outside of the solid core. The refrigerant then passes through the solid core and as it does so the dirt, moisture and acids are absorbed, the refrigerant then collects in the groove at the centre of the core and then pass through the screen. It then passes through the perforated plate and exits the unit having been filtered and dried, it then continues to the expansion valve. 122



APPROVED QUALITY ASSURANCE
TEST DESCRIPTION
CHECKED BY
Burst Test
First leak test
Evacuation test & Charging
Hi-Pot test
Run test
Final leak test
COMPRESSOR
SERVICE CORD
GREEN
BLUE
BROWN
THERMOSTAT
TERMINAL BLOCK
CAPACITOR
HERM
HEATER
FAN MOTOR
SELECTOR SWITCH
ROCKER SWITCH
PILOT LIGHT
AIRSWEEP MOTOR
SWITCH POSITION
CONTACTS
OFF
FAN
LO COOL
MED COOL
HI COOL
LO HEAT
HI HEAT
NONE
BLACK
RED
YELLOW
PINK
ORANGE
WHITE
035-7952-1817B REV-A

...... 123

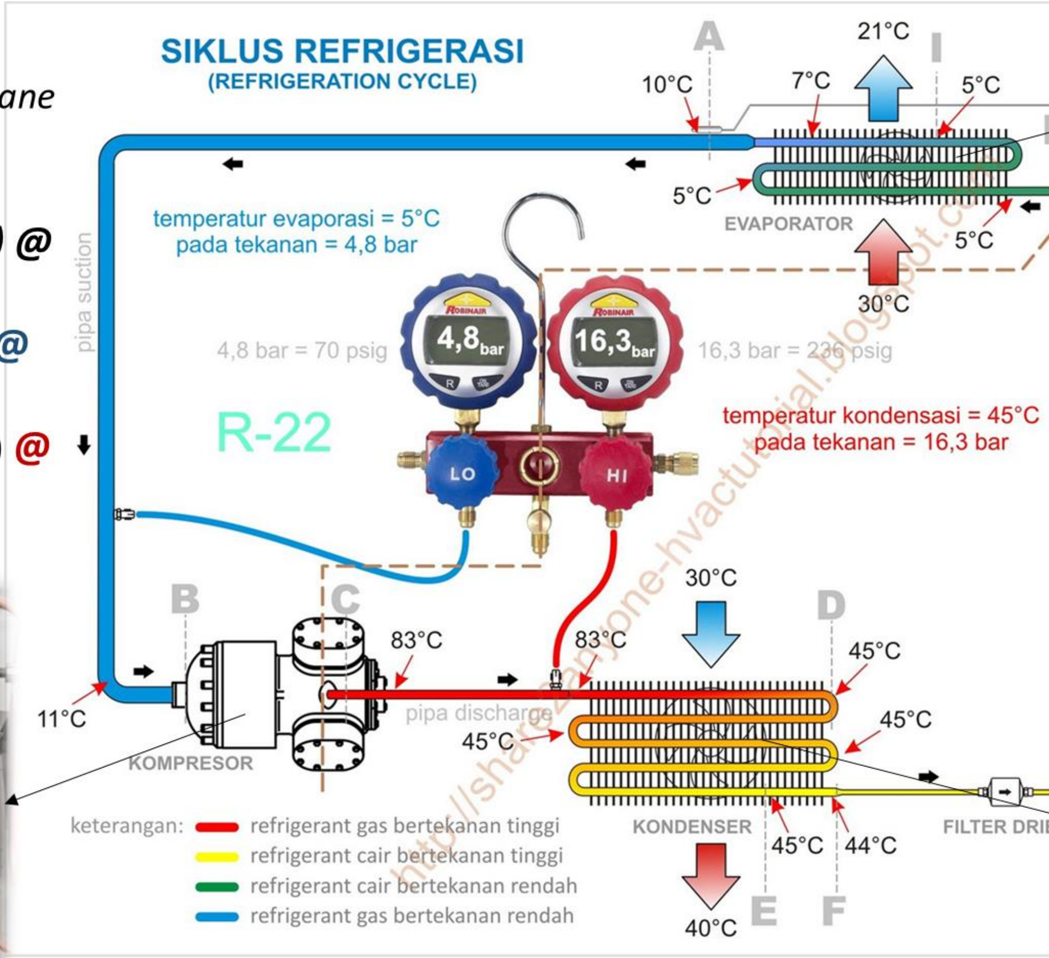
R-22

- **Nomenclature:** *Chlorodifluoromethane*
- **Symbol:** *$CHClF_2$*
- **Boiling point :**

T= - *40.7°C* *(232.5 K)* @ *1 bar*

T= *4.9°C* (278.05 K) **@ 4.8 bar**

T= 45.6°C (318.75 K) **@ 16.3 bar**

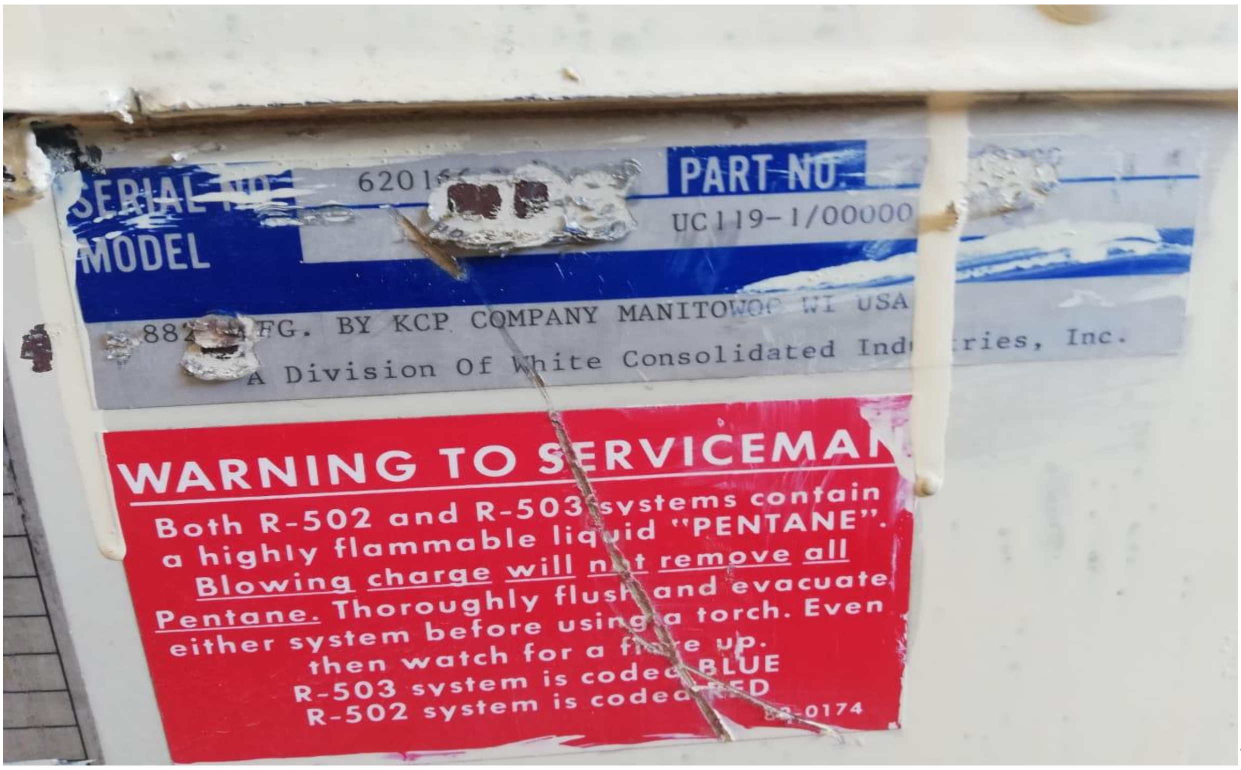


.... 124

10.3. Fridge 2 : Kelvinator fridge 125


HIGH STAGE
L.S.
162
H.S.
375
REFRIGERANT
502
9.5
OZ.
503
CHARGE
OZ.
PENTANE
35
C.C.
RATED LOAD
LOCKED ROTOR
AMPERES
FANS
COND. HTR.
TOTAL CAB.
12
H.P.
280
50
MODEL
WARN

125


SERIAL NO.
MODEL
PART NO.
UC119-1/00000
FG. BY KCP COMPANY MANITOWO
A Division Of White Consolidated Ind
WARNING TO SERVICEMAN
Both R-502 and R-503 systems contain
a highly flammable liquid "PENTANE".
Blowing charge will not remove all
Pentane. Thoroughly flush and evacuate
either system before using a torch. Even
then watch for a flare up.
R-503 system is coded BLUE
R-502 system is coded RED

125

.... 126

Number	Ozone Friendly	Uses	Chemical Components	Alternatives	Notes
R410A HFC	Yes	Designed for new R22 applications, but can also be used to retrofit R13b1 systems.	HFC 125 - 50% HFC 32 -50%		Long term ozone friendly replacement for R502 / R22 Low GWP
R500 CFC	No; banned under Montreal protocol	Low temperature R12 CFC.	CFC 12 -CFC 115 -	R401b; R407d	
R502 CFC	No; banned under Montreal protocol	Widely used low temperature refrigerant in the United Kingdom.	HCFC 22 -48% CFC 115 -52%		
R503 CFC	No; banned under Montreal protocol	Low temperature refrigerant -80 to -100°C.		R95, R508a, R508b	

CFCs: Chlorofluorocarbons. These products have ceased production within the RSA for internal consumption with effect from 1996.
HCFCs: Hydrochlorofluorocarbons. Full availability within the RSA, and the present production phase out date is 2015. There is a widespread belief that this will be reduced to 2005 within the next 2-3 years.
HFCs: Hydrofluorocarbons. At the moment there is no production phase out date for HFCs and there is unrestricted use on their applications.
HCs & NH3: This product group mainly used in industrial equipment due to flammability concerns.

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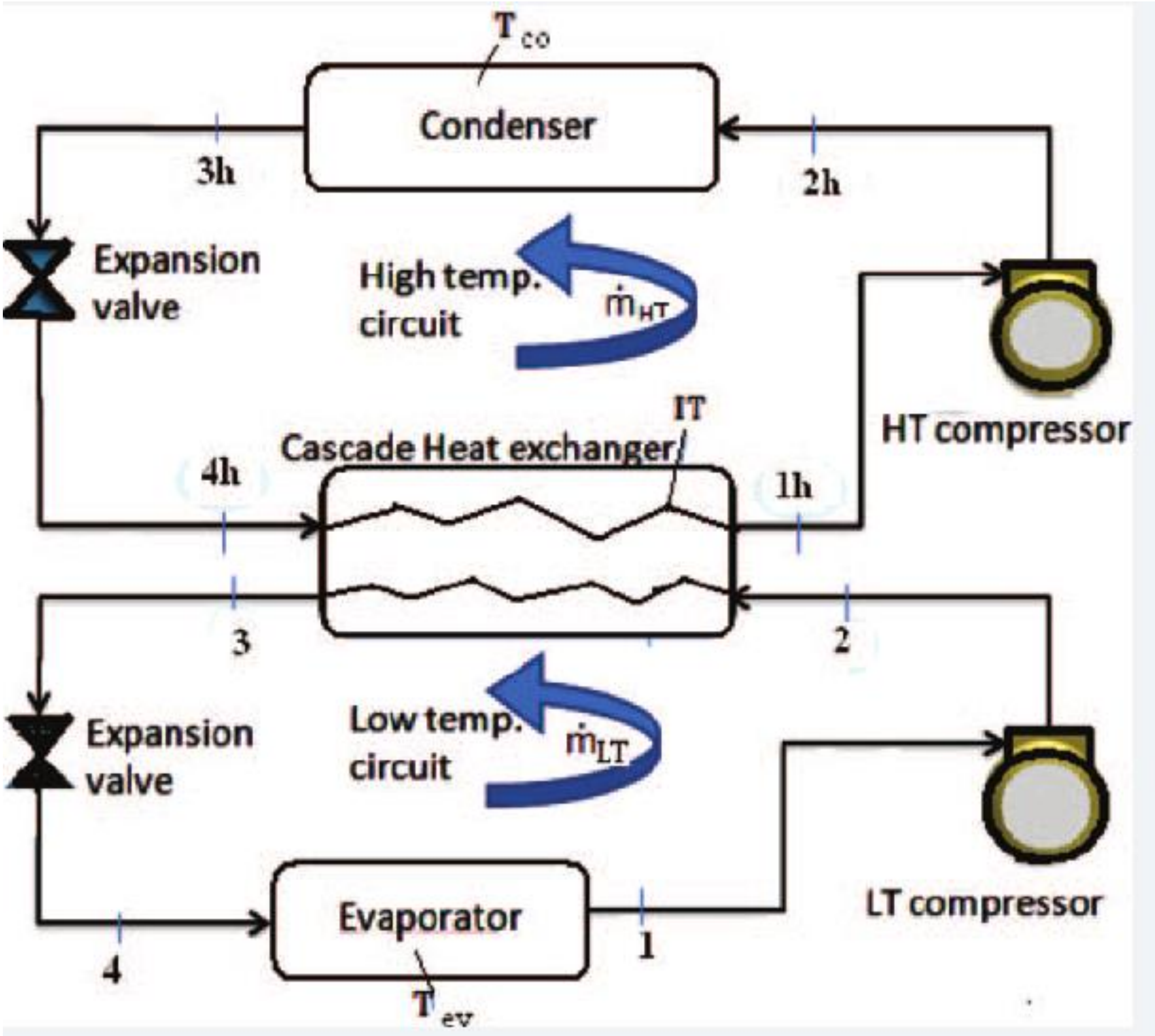


T_{co}
Condenser
3h
2h
Expansion valve
High temp. circuit
$\dot{m}_{HT}$
HT compressor
IT
Cascade Heat exchanger
4h
1h
3
2
Expansion valve
Low temp. circuit
$\dot{m}_{LT}$
LT compressor
Evaporator
4
1
T_{ev}

127

XII

R-502 (High stage)

- **Nomenclature:** Chlorodifluoromethane, Chloropentafluoroethane
- **Symbol:** CHC1F2, CC1F2CF3
- **Compress:** 375 psi = 25.85 bar
- **Boiling point :**

T= - *45.6°C* *(227.4 K)* **@ 1 bar**

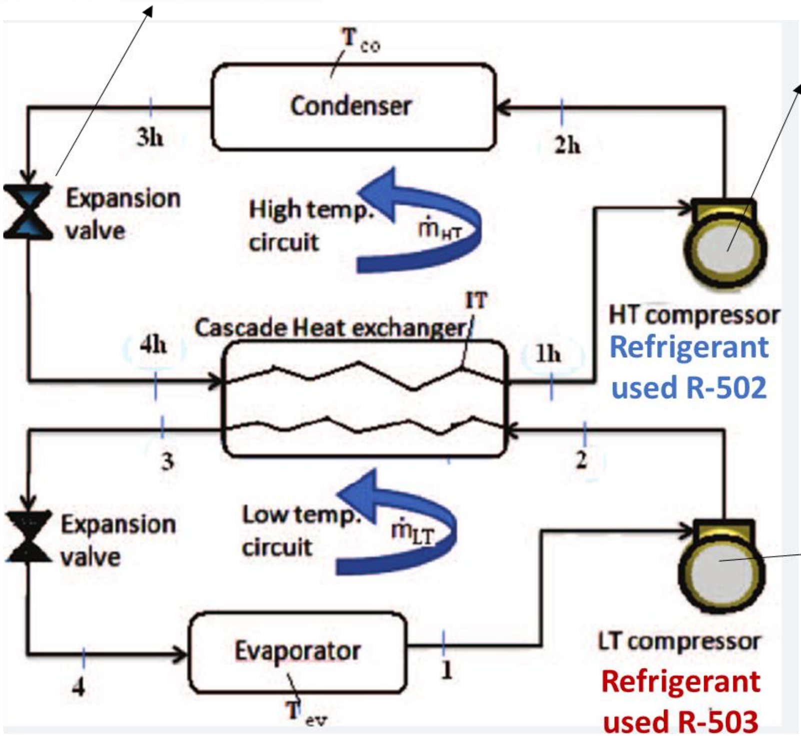
T= 61.5°C (334.7 K) **@ 25.85 bar**

R-503 (Low stage)

- **Nomenclature:** Azeotropic Blend
- **Symbol:** CHF3
- **Compress:** 375 psi = 25.85 bar
- **Boiling point :**

T= - *88.9°C* *(184.1 K)* **@ 1 bar**

T= - 20°C (253.2 K) **@ 25.85 bar**



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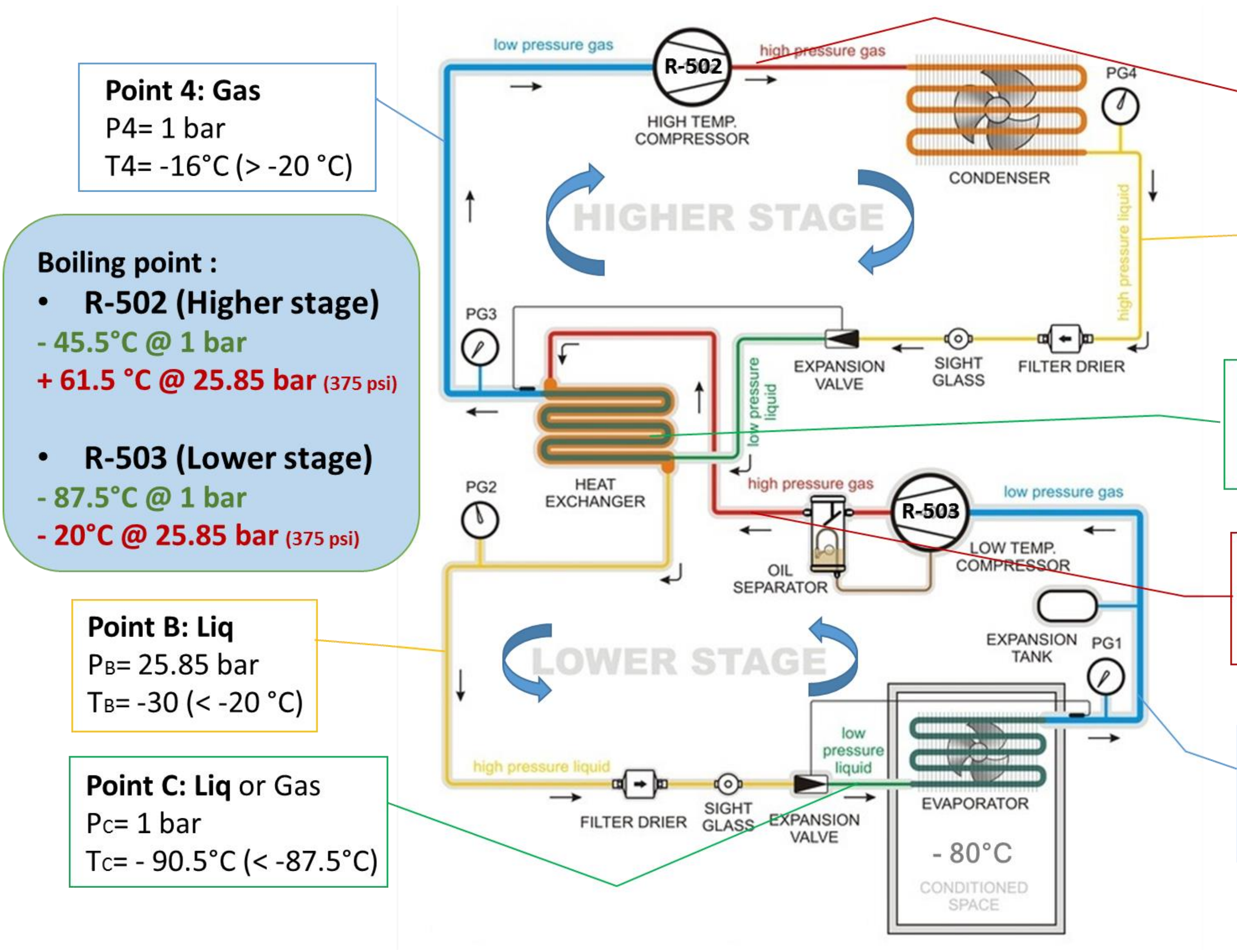

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The cascade refrigeration system consists of a low-temperature loop (Low stage) and a high-temperature loop (high stage). 130

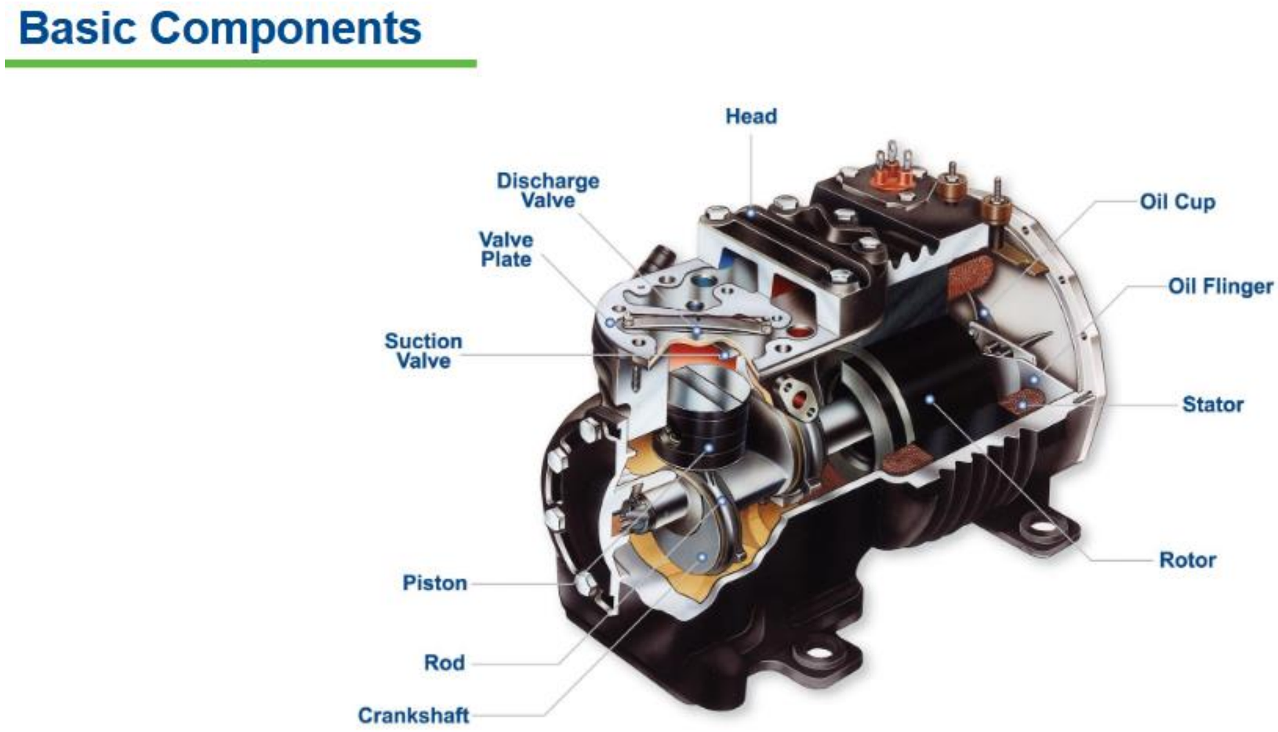
Each stage consists of a compressor, condenser, expansion valve and evaporator 130

The high stage condenser is cooled by air cooled, while the low stage condenser is cooled by the high stage evaporator. 130

So the high stage evaporator acts as a coolant for the pressurized refrigerant in the low stage. 130

Advantages of a cascade cooling system: 130

- Repair is easy.. 130
- The Cascade refrigeration allows to low-temperature operation. 130
- You can reduce the use of power up to 10% with the help of cascade refrigeration. 130



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✍ Connecting 2 compressors to get combined pressure and volume........................... 133

بسم الله الرحمن الرحيم

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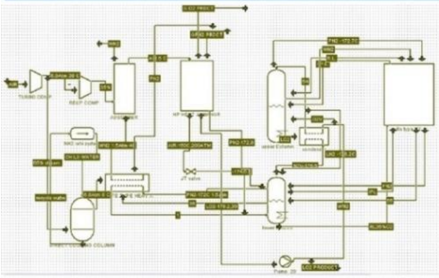
طاقة الشمال
North Lebanon Alternative Power
www.nlap-lb.com

Liquefaction of air(oxygen)

Process of purification and liquefaction of air :



In this process at first air is **filtered & compressed to 6.8 atm** in turbo compressor. During the compression cooling is done to maintain the temp to **35 - 40°C.**

After compression the air is divided into two streams. One is **65% stream** & the other **is 35%,** now the larger stream is then passed through after cooler and heat exchanger where it is cooled to **-150°C to -170°C** by the incoming pure nitrogen & waste nitrogen streams produced from rectification columns.

The smaller stream is passed through **reciprocating compressor** to increase the pressure to about **200atm.**Here the air temp is maintained at **4-8°C** by intermediate cooling between stages using **cold water obtained by ammonia refrigeration.**

Then the air goes through **high pressure heat exchanger** where the temp of air is brought down to about **-120 -140°C.** Now the air undergoes expansion to about **6.5 atm in the expansion engine.**

The temperature of air is brought down from -170 to -174°C by joule Thompson effect.

Now the air will be in liquid state & mixes with the larger stream & changes the whole air stream into saturated liquid state.

This saturation liquid is fed to **Linde rectification column**. This column may be **single, double** or compound depending on requirement. the liquid product coming out will have a purity of about **99.4 -99.99%.**

This liquid is partially vaporized in condenser, to **liquefy the nitrogen vapor** &the rest may be taken as liquid product or it may be obtained in gaseous state if it is used for cooling of incoming air, the other products that obtained are pure **nitrogen of purity above 98% &** waste nitrogen product of purity of about 92-96%.

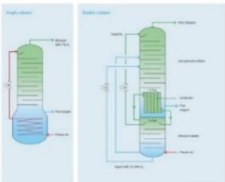


TABLE 5.6a: Specification sheet for Compressor

Power of Compressor	364.355KW
Rotational Speed	2300.0698rpm
Inlet absolute velocity from Imp	50.45m/s
Outlet absolute velocity from Imp	74.726m/s
Radius of Impeller 1 tip	0.0755m
Radius of Impeller 2 tip	0.151m
Number of impeller blades	20
Width of diffuser 1	0.033m
Width of diffuser 2	0.00938

TABLE 5.6c: Specification sheet for the main heat exchanger

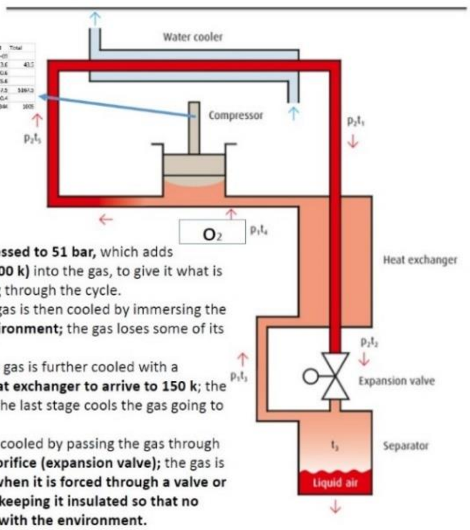
fin thickness(t)	30mm
fin frequency (f)	0.3425 fin per meter
fin length (l)	230mm
fin height (h)	50mm
fin spacing (s)	110mm
plate thickness (b)	80mm
free flow area (Aff)	4000mm^2
frontal area (A)	11200mm^2
heat transfer area (As)	83000mm^2
fin area (Af)	29000mm^2
equilibrium diameter (Dh)	48.19mm
fin area/total surface area	0.3373
frontal area ratio (ξ)	0.3571
height-spacing ratio (α)	0.45453
length- spacing ratio (δ)	2.7272
thickness-spacing (γ)	0.27273

HIGH PRESSURE COLUMN, P = 5.0 atm			
COMPONENT	FEED, F1	DISTILLATE, D1	BOTTOM, B1
OXYGEN	0.21	0.005	0.4
NITROGEN	0.79	0.995	0.6
FLOWRATES (Kmol/h)			
F1 = 145.379	D1 = 69.92	B1 = 75.459	
Vn1 = 209.76	Ln1 = 139.84	Vm1 = 209.76	Lm1 = 285.219
FEED TEMPERATURE : -200°C			
FEED POINT : 2			
NUMBER OF STAGES, N = 7			
MINIMUM REFLUX RATIO, Rm = 0.5			
REFLUX RATIO, R = 2			
MINIMUM NUMBER OF STAGES, Nm = 4			
LOW PRESSURE COLUMN, P = 1.4 atm			
COMPONENT	FEED, F2	DISTILLATE, D2	BOTTOM, B2
OXYGEN	0.6	0.005	0.01
NITROGEN	0.4	0.995	0.99
FLOWRATES (Kmol/h)	D2 = 45.20	B2 = 30.26	
F2 = 75.459	Ln2 = 0	Vm2 = 103.030	Lm2 = 213.299
Vn1 = 209.76			
FEED POINT : 3			

NUMBER OF STAGES, N = 7			
PLATE SIZING	PLATE SPACING: 500mm	PLATE THICKNESS: 5mm	
PLATE EFFIENCY : 50%			
HOLE SIZING	HOLE PITCH, LP : 15mm	AREA OF PITCH, : 218.2mm²	
HOLE SIZE, dh : 5mm			
COLUMN SIZING	COLUMN EFFICIENCY : 70%		
COLUMN DIAMETER, Dc : 4700mm			
WEIR/DOWNCOMER SIZING	WEIR LIQUID CREST, how : 50mm liquid	LENGTH OF WEIR, Lw :3619mm	
HEIGHT OF WEIR, hw : 50.0mm			
DOWNCOMER CLEARANCE, hd : 13mm			
VAPOUR LIQUID FLOW RATE, FLV : 0.62			
FLOOD VELOCITY, Uf : 7.300mm/s			
NUMBER OF REAL STAGES, N : 19			

Process of liquefaction of oxygen

Stage 1		Stage 2	Stage 3	Total
1.12E-03	mass flow rate, kg/s	1.12E-03	1.12E-03	
3	Pressure ratio	4	3.6	43.2
0.6	Pump Efficiency	0.6	0.6	
118.8	Input pressure, kPa	356.4	1425.6	
356.4	Outlet Pressure, kPa	1425.6	5167.5	5167.5
1.7	Inlet Density, kg/m3	5.0	20.4	
285	Pump Input Power, W	337	344	1005



- The gas is **compressed to 51 bar,** which adds external energy **(300 k)** into the gas, to give it what is needed for running through the cycle.

The high pressure gas is then cooled by immersing the gas in **a cooler environment;** the gas loses some of its energy (heat).

- The high pressure gas is further cooled with a **countercurrent heat exchanger to arrive to 150 k;** the cooler gas leaving the last stage cools the gas going to the last stage .

- The gas is further cooled by passing the gas through a **Joule–Thomson orifice (expansion valve);** the gas is now **at the lower when it is forced through a valve or porous plug while keeping it insulated so that no heat is exchanged with the environment.**

- The low pressure gas is now at its coolest in the current cycle.

Some of the gas may condense and become output product.

The low pressure gas is directed back to the countercurrent heat exchanger to cool the warmer, incoming, high-pressure gas.

After leaving the countercurrent heat exchanger, the gas is warmer than it was at its coldest, but cooler than it started out at step 1.

The gas is sent back to the compressor to make another trip through the cycle (and become still colder).

Oxygen properties

OXYGEN IN SOLID STATE: It is a hard, pale blue, doubly refracting crystalline solid.

Melting point:	-218.81°C
Density at -252.5°C:	1.4256 gm/cc
Specific heat at -256°C:	0.078 cal
Heat of fusion at -219°C:	313 cal/gm

OXYGEN IN LIQUID STATE: It is a pale steel blue, transparent and very mobile liquid

Boiling point:	-182.02°C
Density at boiling point:	1.14gm/cc
Surface tension at B.P.:	13074 dynes/cm

It is a non-conductor of electricity and strongly magnetic when compared to iron.

OXYGEN IN GASEOUS STATE: It is a colourless, odourless, tasteless, diatomic gas, a volume of it slightly heavier than equal volume of air. One Litre of oxygen under standard condition weighs 1.42901gm and the corresponding weight of air is 1.2929gm. The oxygen is only slightly soluble in water at ordinary temperature and pressures

Table 12 Work Required to Liquefy Selected Gases*

Substance	Work cal/mole	Work J/mole	Work Btu/lb	Thermal Energy (Btu/lb)	Electricity kWh/lb	Electricity kWh/kg
Air	5,000	20,900	310	930	0.091	0.20
Oxygen	4,800	20,300	273	819	0.080	0.18
Nitrogen	5,100	21,400	328	984	0.096	0.21
Helium	6,500	27,200	2,935	8,805	0.86	1.89
Hydrogen	5,700	23,800	5,119	15,357	1.50	3.30

*Using ideal (thermodynamically reversible) process: $W_{rev} = T_a\Delta S - \Delta H$, where T_a = 298 K (25°C), and P_a = 1 atm.

Note: The values given for each gas are equivalent amounts of energy (or work) expressed in several units of measure.

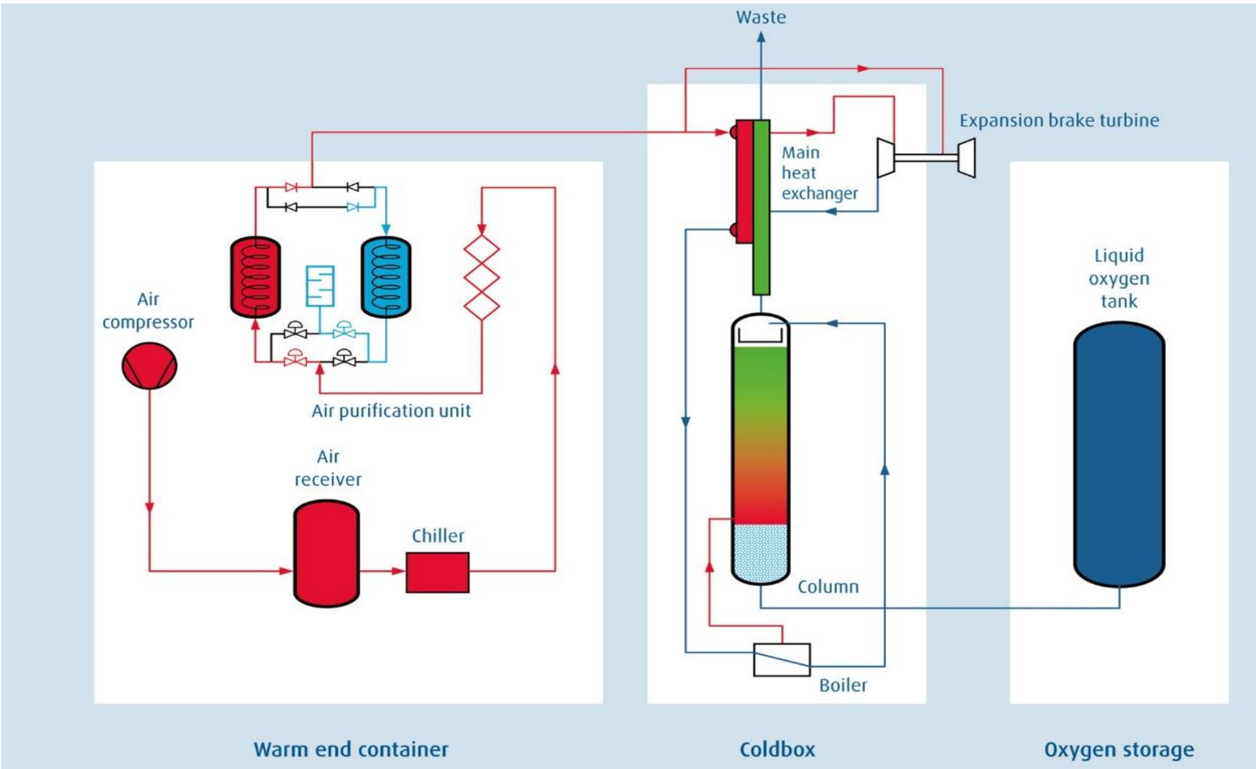
2 Cryogenic air plant principle

A cryogenic air plant is an industrial facility that creates molecular oxygen at relatively high purity. Air is the most common element in the earth's crust and the second largest industrial gas.

2.1 Purpose

The cryogenic air separation achieves high purity oxygen of more than 99.5%. The resulting high purity product can be stored as a liquid and/or filled into cylinders. These cylinders can even be distributed to customer in the medical sector, welding or mixed with other gases and used as breathing gas for diving. Typical production ranges from 50 normal m^3/hour up to 860,000 Nm^3/hour

2.2 Plant modules

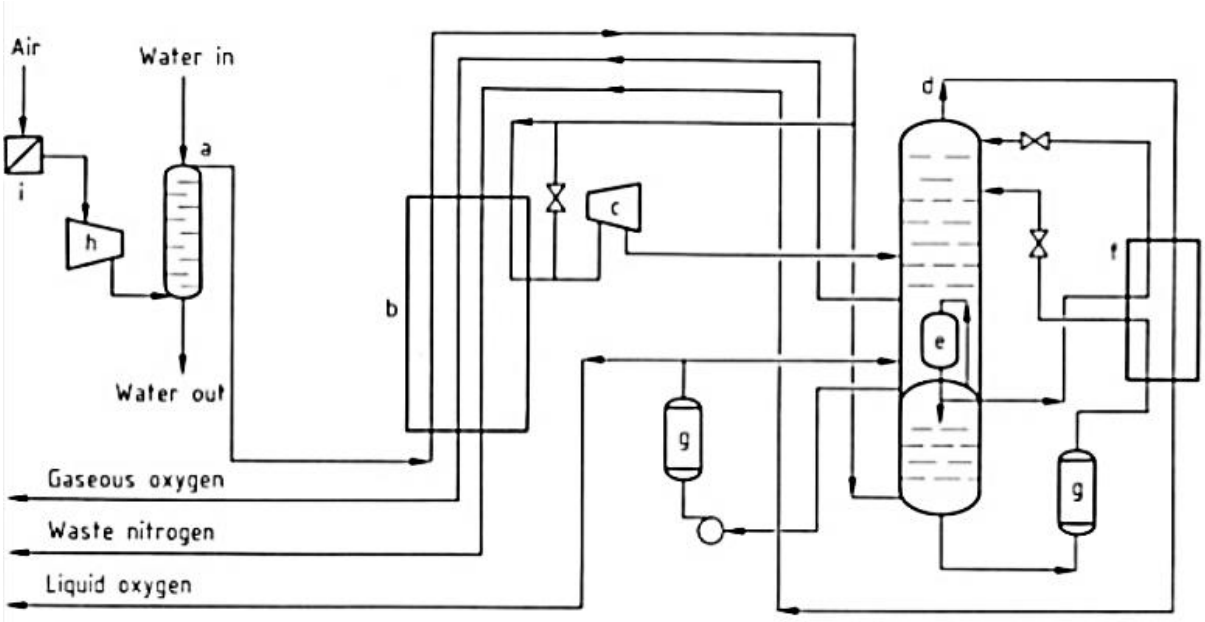


A cryogenic air plant comprises:

- Warm end (W/E) container
    - Compressor
    - Air receiver
    - Chiller (Heat exchanger)
    - Pre-filter
    - Air purification unit (APU)
- Coldbox
    - Main heat exchanger
    - Boiler
    - Distillation column

- Expansion brake turbine
- Storage
  - Liquid oxygen tank
  - Vaporizer
  - Filling station

2.2.1 Annotated diagram



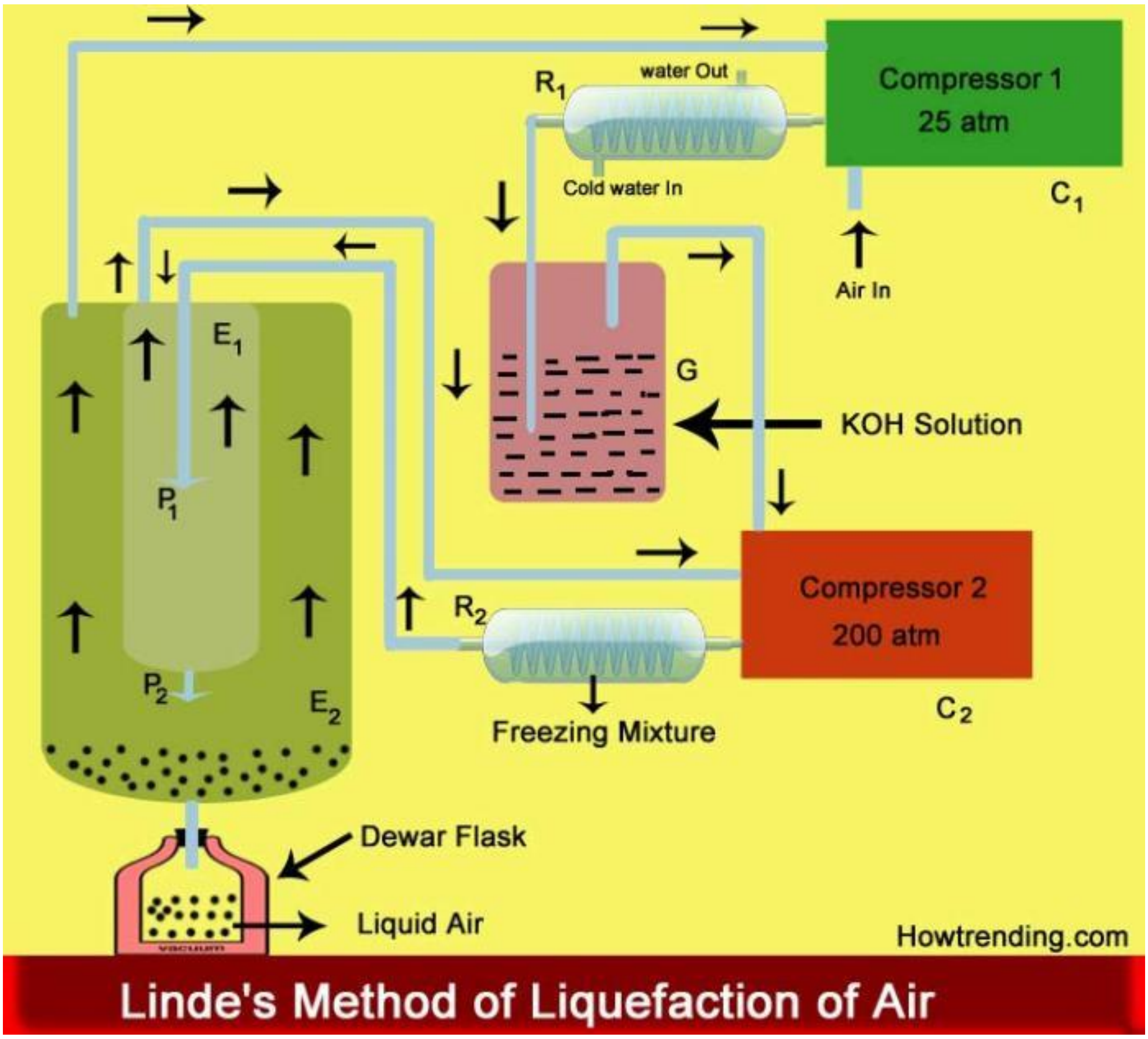
a) Water wash cooler; b) Reversing heat exchanger; c) Expansion turbine; d) Double column rectifier; e) Condenser; f) Subcooler; g) Adsorber; h) Compressor; i) Filter

- **Raw materials**
  - Basis: 1000kg Oxygen (95%)
  - Air = 3600Nm^3
  - Steam = 1750kg
  - Cooling water = 5000kg
  - Electricity = 450-480kWH

2.3 Linde’s Method of liquefaction of gases.1

The Hampson-Linde cycle or the Linde’s liquefaction process is used by coupled with regenerative cooling and the Joule Thomson effect.

By this method, we can easily liquefy air, and many other gases too.



Linde’s Method of Liquefaction of Gases – Howtrending.com

The above figure is Linde’s method for Liquefaction of Air and some other gases too.

---

1 https://www.howtrending.com/liquefaction-of-gases/

By this figure, you can understand that liquefaction of air or those gases that have a low value of critical temperatures is hard, as compared to those that have high critical temperature values.

2.3.1 About this apparatus

1. In this method, two compressors C_1 at (25 atm pressure) and C_2 (200 atm pressure) are used.
2. Heat exchangers R_1 and R_2 are used into which cold water and a freezing mixture is used as a refrigerant.
3. A Liquid solution of KOH (Potassium Hydroxide), that is required to get pure air.
4. Two chambers E_1 and E_2, and P_1 and P_2 are the two small nozzles.
5. At last, the liquid air is collected into a Dewar flask.

2.3.2 Principle

Linde's process of liquefaction is work on the principle of the **Joule Thomson effect** coupled with **regenerative cooling**.

2.3.3 Linde's process Working

This method is quite different as we compared to the previous one, the Cascade method.

First, the air is pumped at a pressure of 25 atm into the spiral tube. The air gets cooled after passing through the R_1 heat exchangers. Here the gas becomes cool because of cool water inside the R1 heat exchangers. This cooled air then passes through a liquid solution of Potassium hydroxide (KOH).

The reason for the use of the KOH solution is that air contains many gases and water vapors too. To separate air from water vapors this solution is used, and also this solution absorbs CO_2 gas from the air (The **Critical temperature of water = 374°C**). After this, the air further moves in the second compressor C_2.

In the C_2 compressor, the air is pumped at a pressure of 200 atm into the next spiral tube. Now the gas becomes cool again, after passing through the second heat exchangers R_2. Here the gas-cooled because of the Freezing mixture inside the R_2 heat exchangers.

Now the temperature of this air decreases to around −20°C. Then this pre-cooled air is allowed to expand through nozzle P_1 in a chamber E_1 and suffers the Joule Thomson effect. Due to this effect, more cooling is produced into the chamber E_1, and pressure reduces to about 50 atm.

This cooled air then returns back to the compressor C_2 and where it again pumped at a pressure of 200 atm into the spiral tube. This air again suffers Joule Thomson effect, and more cooling produced in chamber E_1.

Repeating some cycles of this process, more and more cooling is produced in chamber E_1. After getting sufficient temperature, the cooled air is allowed to expand through nozzle P_2 in chamber E_2 and again suffers the Joule Thomson effect, and pressure reduces to about 1 atm.

Now the temperature decreases to around −188°C in chamber E_2 and the air gets liquefied. This liquefied air is collected into the Dewar flask.

Also, in chamber E_2 the un-liquefied air is returned back to the compressor C_1, this further cooled the air, and where it again pumped at a pressure of 25 atm into the spiral tube.

This is the overall Linde's process for liquefaction of air.

2.4 Claude's method of liquefaction of gases

Claude's process works on the same principle as Linde's process. Hence cooling of the air, or if we say liquefaction of gases is carried out by the help of the Joule Thomson effect.

But, the only difference between Linde Claude's process of liquefaction of air, or other gases is that in Claude's process there is an isentropic expansion.

That's why Claude's process is more efficient than Linde's process.

The principle used in Claude's Process

Claude's method works on two principles.

First, the Joule Thomson effect.

Second is a mechanical expansion (By, the use of an expansion turbine).

What is an expansion turbine or the turboexpander?

"The expansion turbine or the turboexpander is an axial-flow or centrifugal turbine, through which a high pressurized gas is allowed to expand to produce work. This work is used to rotate a shaft, which is often connected with a compressor or generator.

Due to the turbo-expander, the outcoming gas has a very low temperature as compared to the temperature of input gas. This is because, in this process, the work is done by the gas, and due to this the gas loses its kinetic energy and resulting in a decrease in temperature of the gas".

Working of Claude's process

As you know Claude's process is modified Linde's process, Therefore, like Linde's process, the gas which is at 200 atm pressure is pumped into the spiral tube, the gas then moved further. In Claude's process, this gas is divided into two sections. In the first section, the gas is allowed to expand through the expansion turbine (turbo-expander). In the second section, the gas is allowed to suffers the Joule Thomson effect.

Therefore, more cooling is produced inside the chamber. One is by turbo-expander, and the second is by the Joule Thomson effect. The overall process is repeated until the gas gets liquefied completely, and during each cycle of repetition, the un-liquefied gas is returned back to the Compressors.

The very low critical temperature of H_2, and He

Now I will discuss the very low values of critical temperatures for gases like Neon, Hydrogen, and the Helium gas.

The Critical temperature (T_C) values of these gases are

Neon (Ne) = −228.7°C

Hydrogen (H_2) = −240°C

Helium (He) = −267.8°C

For liquefying these, we need a very low-temperature range. The hydrogen and helium must be kept below their inversion temperature while suffers the Joule Thomson effect.

The principle used in Hydrogen and Helium's liquefaction.

Liquefaction of Hydrogen and helium works on the principle of the Joule-Thomson effect coupled with regenerative cooling.

In the liquefaction of Hydrogen, liquid air is used as a refrigerant, and in the liquefaction of Helium, Liquid hydrogen is used as a refrigerant.

By the use of previous processes, we can get liquefied Hydrogen and helium too.

https://www.sciencedirect.com/science/article/abs/pii/S0140700701000032

3 Large Scale Factory study

3.1 Overview

Factory					
	Equipment	**Details**	**Price per unit**	**Total Price**	
Warm End Container	Filter per year	unit per week	~10$	~ 520 $	
	Air Compressor (364.5 KW)		~ 2 500 $	~ 2 500 $	
	Air Receiver (Pre-Cooler)	unit (300 L, 0.8 Mpa)	200 $		قابل للتصنيع
	Chiller				
	Air Purification Unit (13x Zeolite)	Stainless stell (710 Kg)	710 $	1 707.4 $	
		Brazed Aluminum fins (1	10 $		
		Aluminun (195 kg)	390 $		
		Lagging (2.45$/m2)	29.4 $		
		Bed packed with 13x Zeo	520 $		
		Column (4 columns)	48 $		
ColdBox	Main Heat Exchanger		3 869 406.9 $	3 869 406.9 $	**مذكور بpdf دراسة المشروع**
			1 000 $ - 5 500 $	1 000 $ - 5 500 $	**حسب موقع alibaba.com**
	Expansion Brake Turbine	Absorber Column (stains	180 $	196 $	
		Adsorption (Aluminum)	16 $		
		turbine (40 KW)	19 300 $		
	Cryogenic Distillation column		386 562.4 $	386 562.4 $	قابل للتصنيع
		HP Tower	499 000 $	2 653 000 $	**ref: Study_Dynamic Design of a Cryogenic Air Separation Unit**
		LP Tower	1 250 000 $		
		Crude Argon Tower	904 000 $		
	Boiler				
Storage	Cylinder 50L (50 $ /piece)	Liquid Oxygen Tank			
		Liquid Nitrogen Tank			
		Liquid Argon Tank			

3.2 Dynamic design of a cryogenic air separation unit (Source?)

***Study_Dynamic Design of a* Cryogenic Air Separation Unit**	**ASU will produce (per day)**	
	Oxygen (99.5%)	1 500 metric tons
	Nitrogen (99.5%)	5 000 metric tons
	Argon	58 metric tons
	Total Annual Cost	
	Compressor capital cost	16 500 000 $
	Venture guidance appraisal	118 500 000 $
	Worth of products (Sell)	113 900 000 $
	Annual cost for equipment and utilities	39 000 000 $
	Yield yearly profit	73 400 000 $

** ASU: Air Seperation Unit*

3.3 Total annual cost of plant equipment

Total annual cost of Plant Equipment			
Equipment	**Capital Cost ($)**	**Utility Costs ($)**	
Air receiver			
Air Compressor	~ 2 500 $	~ 850 $	
Chiller		0 $	
Air purification unit			
Main heat exchanger	1 000 $ - 5 500 $		
Distillation column			
Reboiler/condenser	1 041 000 $	0 $	ref: Study_Dynamic Design of a Cryogenic Air Separation Unit
Turbine			
Pumps			
Controls			

3.4 Costs of modules

3.4.1 Air receiver tank

Air Receiver Tank 0.8Mpa 1.0Mpa 1.3Mpa 1.6Mpa 2.5Mpa 3.0Mpa 4.0Mpa 6.0Mpa

FOB **Référence** Prix: Obtenir le Dernier Prix

>=1 Ensembles

200,00 $US

Livraison : Assistance Fret maritime

Alibaba.com Freight | Compare Rates | Learn more

Paiement : VISA T/T Online Transfe Pay WesternUnion WU

medical grade bottle 50l oxygen gas cylinders 50kg

50 - 499 Cubic Met...	>=500 Cubic Meters
$3.00	**$2.00**

- Filter

Prix pas cher De Chine Approvisionnement Commercial Et Industriel De Qualité Alimentaire Mini Haute .

Produits de commerce électronique

10,00 $US-50,00 $US/ Unité

1 Unité (Commande minimum)

Guangzhou Jielv Environment Technology Co., Ltd. > CN 3 YRS

93.9% Taux de réponse US $440,000+ in 81 Transaction (s)

Contacter le fournisseur Leave Messages Comparer

3.4.2 Air/Oxygene Compressor

Choice 1:

https://toplongcompressor.en.made-in-china.com/product/IvVmtGBbhyhA/China-5nm3-3stage-High-Pressure-Oil-Free-Oxygen-Compressor-Nitrogen-Compressor.html

5nm3 3stage High Pressure Oil Free Oxygen Compressor Nitrogen Compressor

Get Latest Price › Leave a message

Min. Order / Reference FOB Price	
1 Piece	US $6,500-8,000/ Piece

Port:	Shanghai, China
Production Capacity:	200PCS/Month
Payment Terms:	L/C, T/T, D/P, Western Union, Paypal, Money Gram
Lubrication Style:	Oil-free
Cooling System:	Air Cooling
Cylinder Arrangement:	Balanced Opposed Arrangement
Cylinder Position:	Vertical
Structure Type:	Closed Type
Compress Level:	Multistage

Product Description
Oil-free Special Gas Compressor

Oil-free special gas compressor booster is the kind of semi-hermetic compressor, it adopts hermetic construction for its motor without pollution to the medium to be compressed and without leakage. This series compressor has numerous advantage of reliable performance, simple operation, compact construction, quick connection and so on. It can be applied in the compression and recovery of toxic, rare and precious gas such as SF6, helium, methane, ammonia, Freon, carbon dioxide and so on.

Performance Characteristics

Oil free high pressure oxygen nitrogen helium Co2 gas compressor
Principle 1: Oil-free type reciprocating piston
2 Cooling Type: Air-cooled or water-cooled
(3) Power consumption: ≤ 110kw4 Speed: . 300-560rpm
5 Flow: . ≤ 2000Nm3 / h6
Suction pressure: . 0-5Mpa7
Exhaust pressure: . ≤ 16.5Mpa8 Compression Level: 1-4Winds oil-free compressors
Product Features: No oil lubrication with clean and non-polluting.
High efficiency, low energy consumption. High reliability, continuous 24-hour operation. The unit uses air-cooled or water-cooled, compact structure, operation and low maintenance cost

All our models can be customized. For more information, pleaes do not hesitate to contact.

Model	gas	inlet .barg	outlet .barg	flow rate NM3/hr	power.KW	voltage/frequency	inlet/outlet.mm	cooling way	net eight.kg	dimension.mm	pressure riato stage
GOWW-4-10/4-150	oxygen	3-4	150	4-10	3	220/380 /440/50/60/3	DN15/M16X1.5	air cooling	380	1300X750X1000	3stage
GOWW-11-20/4-150	oxygen	3-4	150	11-20	4-7.5	220/380 /440/50/60/3	DN15/M16X1.5	air cooling	420	1300X750X1000	3stage

Choice 2:

https://www.alibaba.com/product-detail/BROTIE-oxygen-compressor_1600122723363.html?spm=a2700.galleryofferlist.topad_classic.d_image.35d821fd7VGM2u

BROTIE oxygen compressor

FOB **Reference** Price: Get Latest Price

$6,500.00 - $10,000.00 / Set | 1 Set/Sets (Min. Order)

Power:	3-22kw
Warranty:	**1 Year** for machinery warranty | **1 Year** for Core Components
Shipping:	Support Express · Sea freight · Land freight · Air freight
Lead Time:	

Quantity(Sets)	1 - 100	>100
Est. Time(days)	30	Negotiable

Overview

Quick Details

Applicable Industri...	Garment Shops, Building Material Shops, Manufacturing Plant...	After Warranty Serv...	Video technical support, Online support, Spare parts, Field ma...
Local Service Locat...	United Kingdom, United States, Germany, Viet Nam, Philippine...	Showroom Location:	Turkey, United Kingdom, United States, Viet Nam, Philippines, ...
Condition:	New, New	Type:	PISTON
Configuration:	PORTABLE	Power Source:	AC POWER
Lubrication Style:	Oil-free	Mute:	yes
Place of Origin:	China	Brand Name:	BROTIE
Model Number:	02-3/4-150, 02-5/4-150, 02-10/4-150, 02-15/4-150, 02-20/4-...	Voltage:	customized
Dimension(L*W*H):	customized	Weight:	300-650kg
Certification:	ISO	Warranty:	1 Year
After-sales Service ...	Field installation, commissioning and training	Working Pressure:	150bar, 200bar
Air capacity:	3-75Nm3/h	Machinery Test Re...	Provided
Video outgoing-ins...	Provided	Marketing Type:	New Product 2020
Warranty of core co...	1 Year	Core Components:	Motor, compressor block
Gas Type:	oxygen	Model:	02-3,5,10,15,20,25,30,40,50,75/4-150
Flow Capacity:	3,5,10,15,20,25,30,40,50,75Nm3/h	Compressing Stage:	3Stages
Inlet Pressure:	4bar	Outlet Pressure:	150, 200bar
Outlet Temperature:	50C	Inlet Size:	DN20-DN32
Outlet Size:	8-15mm	Cooling System:	Wind cooling/Water cooling
Lubrication:	no oil lubricated		

3.4.3 Main Heat exchanger

View larger image

XINREN SS201 stainless steel crossflow finned tube pipes water to air heat exchanger

FOB **Reference** Price: Get Latest Price

$1,000.00 - $5,500.00 / Set | 1 Set/Sets (Min. Order)

Model Number:	XRFT201
Power:	100KW
Warranty:	**1 Year** for machinery warranty | **1 Year** for Core Components
Shipping:	Support Sea freight
Lead Time:	

Quantity(Sets)	1 - 1	2 - 2	3 - 5	>5
Est. Time(days)	20	30	35	Negotiable

Customization: Customized logo (Min. Order: 2 Sets)
Customized packaging (Min. Order: 2 Sets)

Overview

Quick Details

Applicable Industri...	Hotels, Garment Shops, Building Material Shops, Machinery R...	After Warranty Serv...	Video technical support, Online support, Spare parts
Local Service Locat...	None	Showroom Location:	None
Video outgoing-ins...	Provided	Machinery Test Re...	Provided
Marketing Type:	New Product 2021	Warranty of core co...	1 Year
Core Components:	Pressure vessel	Condition:	New
Place of Origin:	China	Brand Name:	XINREN
Structure:	Tube Heat Exchanger	Liquid Flow Rate:	Max 75 M3/h
Maximum Working ...	10MPa	Voltage:	220V/50Hz
Weight:	500-2500KG	Dimension(L*W*H):	CUSTOMIZED
Certification:	ce	Warranty:	1 Year
After-sales Service ...	Video technical support, Online support	Working Temperatu...	-100-370℃
Key Selling Points:	Competitive Price	Product Name:	FINNED TUBE Heat Exchanger
Application:	Cooling	Type:	Fin
Material:	SS201	Name:	finned tube heat exchanger
Tube material:	S20100	Fin material:	AISI 201

item	value
Applicable Industries	Hotels, Garment Shops, Building Material Shops, Machinery Repair Shops, Manufacturing Plant, Food & Beverage Factory, Farms, Restaurant, Home Use, Retail, Food Shop, Printing Shops, Construction works , Energy & Mining, Food & Beverage Shops, Advertising Company

3.4.4 Distillation column tower

vertical pressure vessel distillation column towers

FOB **Reference** Price: Get Latest Price

$10,000.00 - $900,000.00 / Set | 1 Set/Sets (Min. Order)

Warranty: **24 months** for machinery warranty

Shipping: Support Sea freight

Alibaba.com Freight | Compare Rates | Learn more

Payments: VISA T/T Online Transfe Pay WesternUnion WU

3.4.5 Industrial oxygen generator (whole system)

Pure oxygen generator industrial oxygen generator

FOB **Reference** Price: Get Latest Price

$8,000.00 - $200,000.00 / Set | 1 Set/Sets (Min. Order)

Model Number: CBO

Power: 5-200W

Samples: $100.00 /Set | 1 Set (Min. Order) | Buy Samples

Warranty: **1 Year** for machinery warranty | **1 Year** for Core Components

High purity Medical and industrial oxygen generator

FOB **Reference** Price: Get Latest Price

$8,000.00 - $200,000.00 / Set | 1 Set/Sets (Min. Order)

Model Number: CBO

Power: 5-200W

Samples: $100.00 /Set | 1 Set (Min. Order) | Buy Samples

Warranty: **1 Year** for machinery warranty | **1 Year** for Core Components

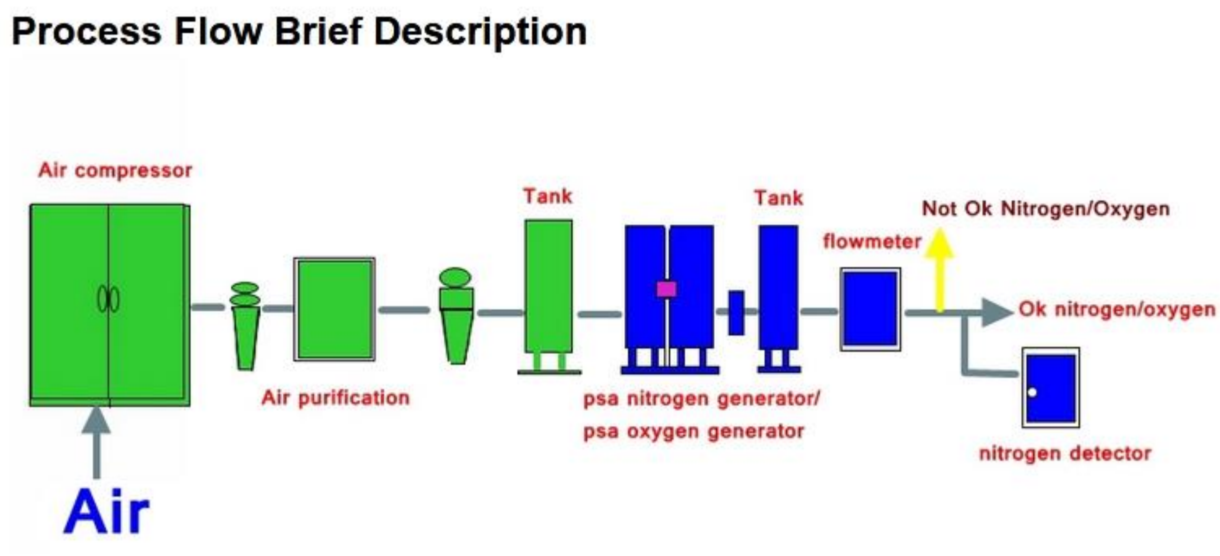
Technical Parameters

Oxygen Capacity	3-400Nm3/h
Oxygen Purity	90%-93%
Output Pressure	0.1-0.3Mpa(1-3bar)adjustable/15Mpa Filling pressure offered

Oxygen Generator Specification

Specification	Output (Nm^3/h)	Effective gas consumption (Nm^3/h)	air cleaning system
CBO-5	5	0.95	KJ-1
CBO-10	10	2.1	KJ-2
CBO-20	20	4.0	KJ-6
CBO-40	40	8.2	KJ-10
CBO-60	60	12.3	KJ-12
CBO-80	80	16.3	KJ-20
CBO-100	100	20.8	KJ-20
CBO-150	150	30.7	KJ-30
CBO-200	200	41	KJ-40

4 Process Flow Brief Description



4.1 ملخص_الهواء في حالة سائلة

4.2 نظرة عامة

محرك دورة الهواء السائل (LACE) هو نوع من محركات دفع المركبات الفضائية التي تحاول زيادة كفاءتها من خلال جمع جزء من مؤكسده من الجو. يستخدم محرك دورة الهواء السائل وقود الهيدروجين السائل (LH2) لتسييل الهواء . في صاروخ الأكسجين السائل / الهيدروجين السائل ، يكون الأكسجين السائل (LOX) اللازم للاحتراق هو الجزء الأكبر من وزن المركبة الفضائية عند الإقلاع ، لذلك إذا كان من الممكن جمع بعض هذا من الهواء في الطريق ، فقد يحدث ذلك بشكل كبير خفض وزن الاقلاع للمركبة الفضائية .

تمت دراسة LACE إلى حد ما في الولايات المتحدة الأمريكية خلال أواخر الخمسينيات وأوائل الستينيات ، وفي أواخر عام 1960 ، كان لدى ماركوارت نظام اختبار يعمل. ومع ذلك ، عندما انتقلت ناسا إلى كبسولات بالستية خلال مشروع ميركوري ، اختفى تمويل البحث عن المركبات المجنحة ببطء ، ويعمل LACE معها .

السائل الذي تم الحصول عليه عن طريق خفض درجة حرارة الهواء. ويسمى الهواء المسال في القانون. 1895 يقوم CPGRvon Linde بالضغط على الهواء وتوسيعه ، مما تسبب في انخفاض درجة حرارة الهواء تأثير جول طومسون باستخدام الهواء تمييع بالإضافة إلى ذلك ، جعل G. Claude الإنتاج الضخم الصناعي ممكنًا. في الآونة الأخيرة ، تم طرح سوائل نيتروجين الهواء في السوق التي تضغط غاز الهيليوم ثم تقوم بتوسيعه لإنشاء درجة حرارة منخفضة واستخدامه لتسييل الهواء. الجهاز صغير ومفيد مع القليل من القوى العاملة. الهواء السائل عبارة عن سائل أزرق فاتح ، وهو مزيج من النيتروجين السائل) نقطة الغليان

77.3 كيلو ، الثقل النوعي 0.810) والأكسجين السائل (نقطة الغليان 90.17 K، الثقل النوعي 1.144) ، الثقل النوعي حوالي 1 ، نقطة الغليان حوالي −190 ℃. إذا تم السماح للهواء السائل بالوقوف ، فإن النيتروجين السائل ذو نقطة الغليان المنخفضة والضغط الجزئي العالي يتم تبخيره أولاً ، ويزداد تركيز الأكسجين السائل في الهواء السائل. الاستفادة من هذه الخاصية ، يتم إرفاق برج تجزئة بوحدة تسييل النيتروجين في الهواء لفصل واستخدام النيتروجين السائل. من الناحية الصناعية ، يتم استخدام كمية كبيرة من الهواء السائل لفصل الأكسجين المستخدم في صناعة الصلب والنيتروجين المستخدم في تخليق الأمونيا . الأرجون ، النيون ، الخ الغاز النبيل يستخدم أيضا بشكل منفصل عن الهواء السائل. لا ينبغي أن يكون الهواء السائل على اتصال مباشر مع المواد القابلة للاشتعال ، وخاصة المذيبات العضوية القابلة للاشتعال مثل الكحول والإيثر وثاني أكسيد الكربون والأسيتون والمساحيق العضوية القابلة للاشتعال مثل السكر والنافثالين والكافور. وذلك لأن هذه المواد العضوية تتأكسد مرة واحدة وخطر الانفجار كبير. كان الهواء السائل عبارة عن مادة تجميد نموذجية في المختبر ، ولكن الآن يتم استخدام النيتروجين السائل الذي لا ينفجر ، ونادراً ما يستخدم الهواء السائل والأكسجين السائل. ومع ذلك ، فإن الأكسجين السائل)الحرارة الكامنة 6820 (J / mol والهواء السائل الذي يحتوي على الكثير منه أقل عرضة للتبخر من النيتروجين السائل (الحرارة الكامنة 5577 (J / mol ، لذلك فهو مناسب للاستخدام كمبرد طويل الأمد 2 **.**

يتم سائله عن طريق ضغط الهواء عند درجة حرارة منخفضة −140 درجة مئوية أو أقل. السائل السائل مع طفيف مزرق. درجة الغليان عند حوالي 1.1 الضغط الجوي حوالي −190 درجة مئوية. تستخدم في تجارب درجات الحرارة المنخفضة للحصول على الأكسجين والنيتروجين باستخدام الفرق في نقاط الغليان3 **.**

2 World Encyclopedia

3 Encyclopedia Mypedia

5 توليد النيتروجين (N2) باستخدام تقنية الامتزاز بالضغط المتأرجح (PSA)

https://www.atlascopco.com/ar-eg/compressors/wiki/compressed-air-articles/what-is-nitrogen

5.1 توليد النيتروجين باستخدام تقنية الأغشية

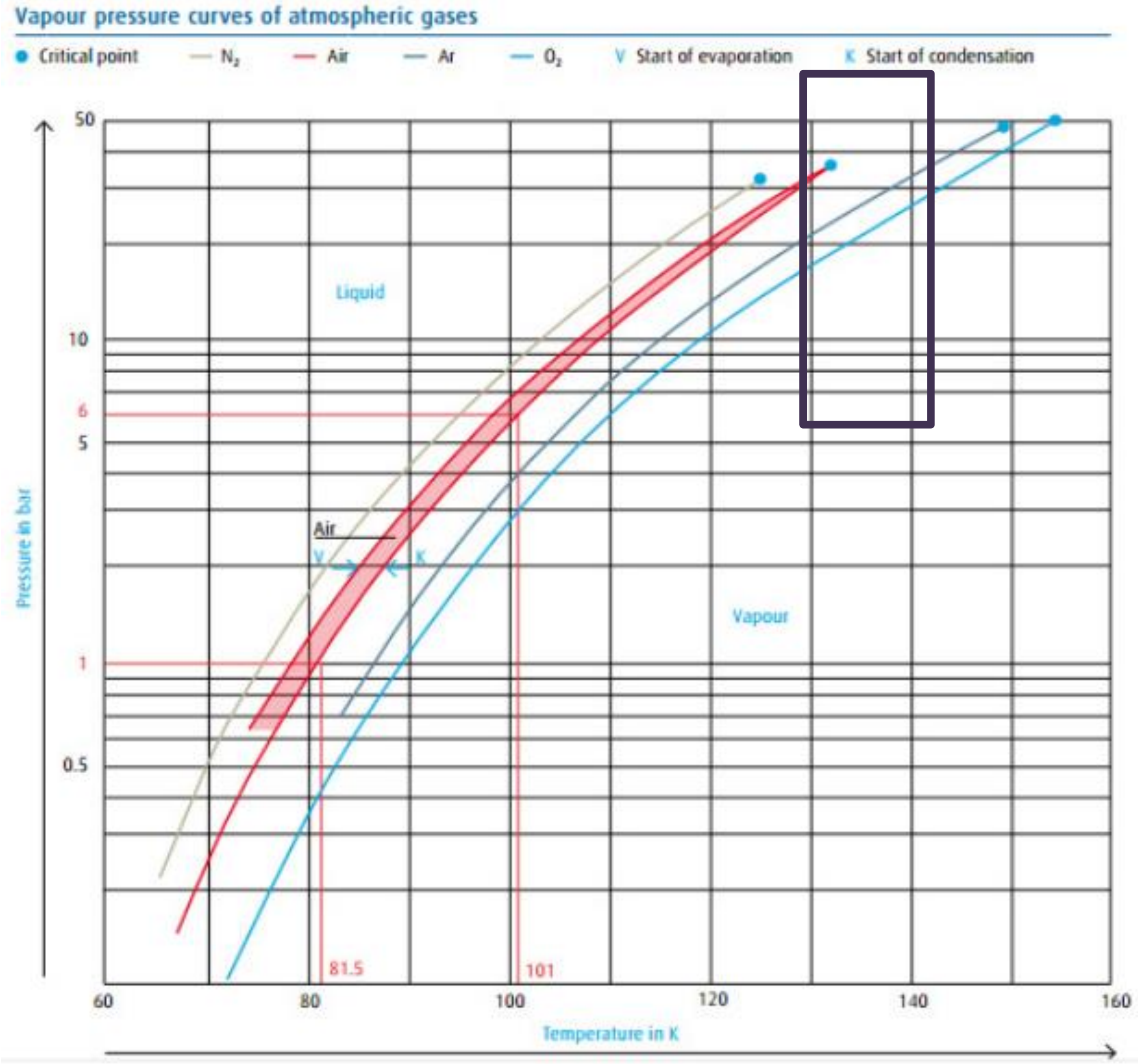
https://www.atlascopco.com/ar-eg/compressors/wiki/compressed-air-articles/generating-nitrogen-membrane

	غشائي	الامتزاز بالضغط المتأرجح (PSA)
النقاء الذي يمكن تحقيقه	كفاءة تصل إلى 99.9%	كفاءة تصل إلى 99.999%
الكفاءة	عالية	أعلى
الأداء مقابل درجة الحرارة	أعلى عند درجة الحرارة المرتفعة*	أقل عند درجة الحرارة المرتفعة
تعقيد النظام	منخفض	متوسط
كثافة الصيانة	منخفضة للغاية	منخفض
استقرار الضغط	ثابت	دخل/خرج متقلب
استقرار التدفق	ثابت	دخل/خرج متقلب
سرعة بدء التشغيل	ثوانٍ	دقائق/ ساعات**
حساسية الماء (البخار)	لا يوجد ماء سائل	ارتفاع حرارة مرشحات PDP عند 8 درجات مئوية كحد أقصى (بشكل عام)
حساسية الزيت	غير مسموح (< 0,01 مجم/م٣)	غير مسموح (< 0,01 مجم/م٣)
مستوى الضوضاء	منخفضة للغاية	مرتفع (ذروات التصريف)
الوزن	منخفض	متوسط

جدول المقارنة: مولدات النيتروجين الغشائية وتلك التي تعمل بتقنية الامتزاز بالضغط المتأرجح (PSA). *اعتمادًا على نوع الغشاء المستخدم **اعتمادًا على النقاء ووقت الإعداد المطلوبين

6 Parameters of Liquefaction of Oxygen

6.1 Properties of Oxygen



FLUID PROPERTIES

REF: NBS TM No. 36, p. 41

Properties	Liquid Hydrogen	Liquid Nitrogen	Water	Oxygen	Freon-11	Freon-22
Heat of Vaporization (cal./gr.)	106.5	47.6	586	50.8	43.5	55.9
Vapor Pressure (mm Hg)	760	760	18.8	760	760	760
Molecular Weight (gr./gr.mole)	2	28	18	32	137.4	86.5
Specific Volume (cc/gr.)	14.1	1.24	1.00	0.871	0.673	0.706
Temperature (°K)	20	77	294 (70°F)	90.13	297	232
C_p - Specific Heat (cal./gr.°K)	2.3	0.49	1.00	0.405	0.210	0.255
Viscosity (centipoises)	0.0130	0.158	0.98	0.190	0.429	———

BOILING POINTS OF GASES

Gas		Boiling Point at 1 atm. C°	F°	K°	Mass Of Liquid C gm/liter	Volume Of Gas (STP) Produced Cu.Ft./liter	Heat Of Vaporization cal/liter
Helium	He^3	-269.9	-453.8	3.2			
Helium	He^4	-268.9	-452.0	4.2	125.2	24.7	650
Hydrogen	H_2	-252.7	-422.9	20.4	70.8	27.5	7640
Deuterium	D_2	-249.5	-417.1	23.6	164	32.5	12,000
Tritium	T_2	-248.0	-414.4	25.1			
Neon	Ne	-245.9	-410.6	27.2	1204	47.3	26,300
Nitrogen	N_2	-195.8	-320.4	77.3	808	23.05	38,600
Carbon Monoxide	CO	-192.0	-313.6	81.1	793	22.4	40900
Fluorine	F_2	-187.0	-304.6	86.0	1108	23.1	47,500
Argon	A	-185.7	-302.3	87.4	1410	27.9	56300
Oxygen	O_2	-183.0	-297.4	90.1	1140	28.2	58,100
Methane	CH_4	-161.4	-258.5	111.7	415	20.5	50,500
Krypton	Kr	-151.8	-241.1	121.3	2155	20.5	59,400
Xenon	Xe	-109.1	-164.4	164.0	3520	21.2	83,400
Ethylene	C_2H_4	-103.8	-154.8	169.3	566	16.1	65,000
Nitrous Oxide	N_2O	- 90.7	-129.1	183.6	1226	22.5	110,000
Ethane	C_2H_6	- 88.3	-126.9	184.8	547	14.3	64,000
Acetylene*	C_2H_2	- 84.0	-119.2	189.1	620.8	18.7	
Carbon Dioxide*	CO_2	- 78.5	-109.3	194.6	1560	27.8	214,000
Propylene	C_3H_6	- 47.0	- 52.6	226.1			
Propane	C_3H_8	- 42.3	- 44.1	230.8			
Ketene	C_2H_2O	- 41.0	- 41.8	232.1			
Freon 22	$CHClF_2$	- 40.6	- 41.0	232.5			
Ammonia	NH_3	- 33.3	- 27.9	239.8			
Freon 12	CCl_2F_2	- 30.0	- 22.0	243.1			
Methyl Chloride	CH_3Cl	- 23.7	- 10.7	249.4			
Isobutane	$(CH_3)_2C_2H_4$	- 10.2	13.6	262.9			
Sulphur Dioxide	SO_2	- 10.0	14.0	263.1			
Butane	C_4H_{10}	- 0.6	30.9	272.5			

*Sublimes

Table 11.1 Candidate refrigerant fluids

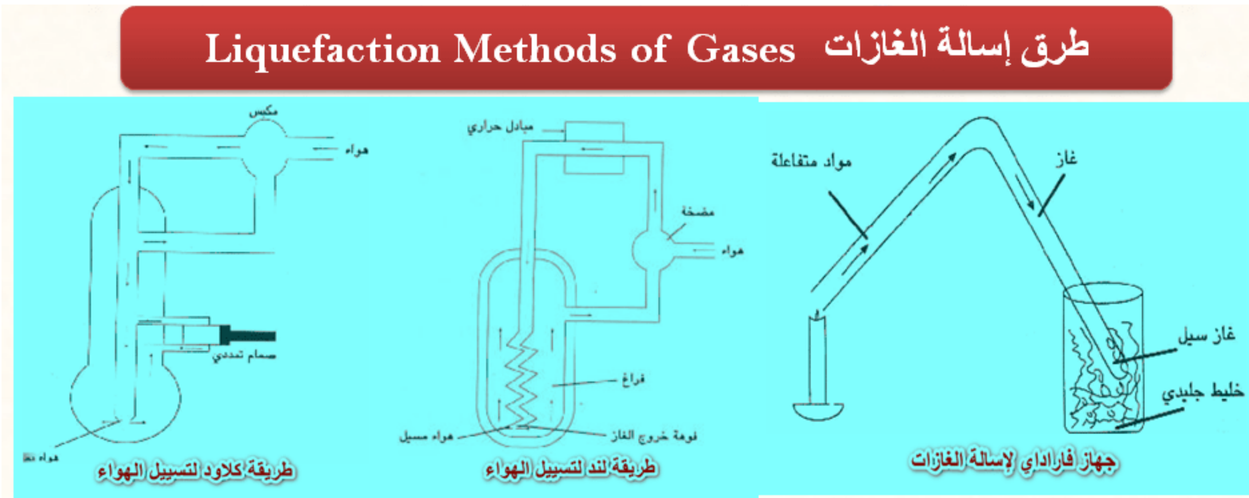
Fluid	*Critical pressure (bar)*	*Critical temp. (K)*	*Saturation temp. @1.0 bar (K)*	*Latent heat (kJ/kg)*	*Gas constant (kJ/kg K)*	*Ratio Cp/Cv (300 K)*
Oxygen	50.9	154.77	90.18	212.3	0.2598	1.396
Argon	50.0	150.86	87.29	159.6	0.2082	1.670
Nitrogen	33.96	126.25	77.35	197.6	0.2968	1.404
Neon	26.54	44.40	27.09	86.1	0.4117	1.640
Hydrogen	12.76	32.98	20.27	434.0	4.157	1.410
Helium	2.3	5.25	4.2	21.0	2.075	1.662

Parameters of Liquefaction of Oxygen

Table 1 Properties of Principal Cryogens

Name	Normal Boiling Point T (K)	Liquid Density (kg/m³)	Latent Heat (J/kg·mole)	Critical Point T (K)	Critical Point P (kPa)	Triple Point T (K)	Triple Point P (kPa)	Reference
Helium	4.22	123.9	91,860	5.28	227			1
Hydrogen	20.39	70.40	902,300	33.28	1296	14.00	7.20	2, 3
Deuterium	23.56	170.0	1,253,000	38.28	1648	18.72	17.10	4
Neon	27.22	1188.7	1,737,000	44.44	2723	26.28	43.23	5
Nitrogen	77.33	800.9	5,579,000	126.17	3385	63.22	12.55	6
Air	78.78	867.7	5,929,000					7, 8
Carbon monoxide	82.11	783.5	6,024,000	132.9	3502	68.11	15.38	9
Fluorine	85.06	1490.6	6,530,000	144.2	5571			10
Argon	87.28	1390.5	6,504,000	151.2	4861	83.78		11, 12, 13
Oxygen	90.22	1131.5	6,801,000	154.8	5081	54.39	0.14	6
Methane	111.72	421.1	8,163,000	190.61	4619	90.67	11.65	14
Krypton	119.83	2145.4	9,009,000	209.4	5488	116.00	73.22	15
Nitric oxide	121.50	1260.2	13,809,000	179.2	6516	108.94		
Nitrogen trifluoride	144.72	1525.6	11,561,000	233.9	4530			
Refrigerant-14	145.11	1945.1	11,969,000	227.7	3737	89.17	0.12	16
Ozone	161.28	1617.8	14,321,000	261.1	5454			
Xenon	164.83	3035.3	12,609,000	289.8	5840	161.39	81.50	17
Ethylene	169.39	559.4	13,514,000	282.7	5068	104.00	0.12	18

6.2 Liquefaction Methods of gases



عملية الإسالة عكس عملية التبخير

– إن عملية التسييل معاكسة لعملية التبخير.

– تعتمد عملية الإسالة على طبيعة الغاز فأبخرة المواد التي تكون سائلة في أو قرب درجة حرارة الغرفة والضغط الجوي تتكثف بسهولة بالتبريد.

– وأما المواد التي تكون سائلة في درجات حرارة منخفضة فإنها تتكثف إما بواسطة الضغط أو بالضغط والتبريد.

القيم الحرجة لإسالة الغازات

– قد وجد أن الضغط وحده لا يكفي لتسييل غازات معينة مثل ما يعرف بالغازات الدائمة كالأكسجين (O_2)والهيدروجين (H_2) والهيليوم (He) والنيتروجين (N_2) والتي لها درجات حرارة حرجة منخفضة جداً، ولكن بالضغط العالي وتبريدها الى درجات حرارة أدنى من درجات حرارتها الحرجة أمكن تسييل هذه الغازات.

– يوجد لكل غاز درجة حرارة لا يمكن إسالته فوقها مهما زاد الضغط وتعرف هذا الدرجة بدرجة الحرارة الحرجة critical temperature والضغط الحرج critical pressure هو الضغط اللازم لإسالة الغاز عند درجة الحرارة الحرجة للغاز.

–الجدول التالي يمثل درجات الحرارة الحرجة والضغط الحرج لبعض الغازات:

قيم (P, V, and T) عند النقطة الحرجة. الغازات مرتبة حسب الكتل الجزيئية

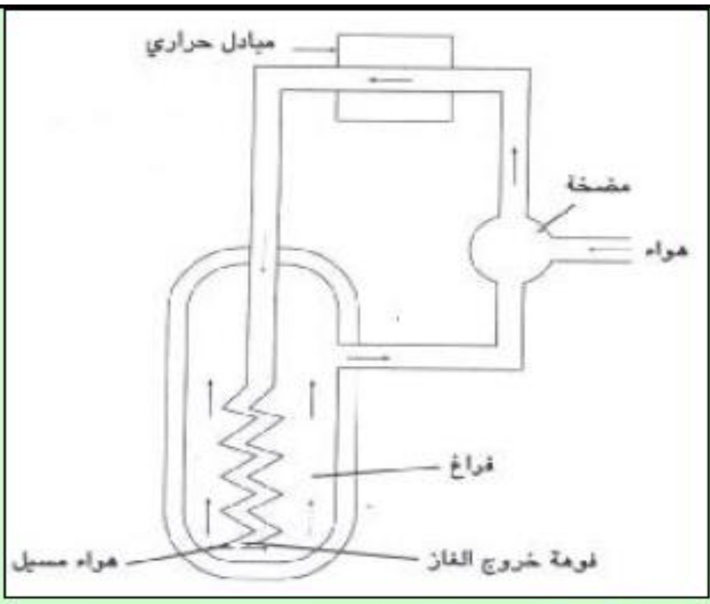
الغاز	Pc, atm	Vc Liters/mol	Tc, K
H_2	12.8	0.070	33.3
He	2.26	0.062	5.3
CH_4	45.6	0.099	190.2
NH_3	112.2	0.072	405.6
H_2O	217.7	0.056	647.2
CO	35.0	0.090	134.4
Ne	26.9	0.044	44.8
N_2	33.5	0.090	126.0
NO	65	0.058	179
O_2	49.7	0.074	154.4
CH_3OH	78.5	0.118	513.1
HCl	81.6	0.087	324.6
Ar	48.0	0.076	150.7
CO_2	72.8	0.094	304.2
SO_2	77.7	0.123	430.4
n-C_5H_{12}	33.0	0.310	470.3
Cl_2	76.1	0.124	417
C_6H_6	47.9	0.256	561.6
Kr	54.3	0.107	209.4
Xe	57.9	0.120	289.8

6.2.1.1 الطريقة الأولى لتسييل الغازات: طريقة ليند و هامبسون Lind-Hampson's Method

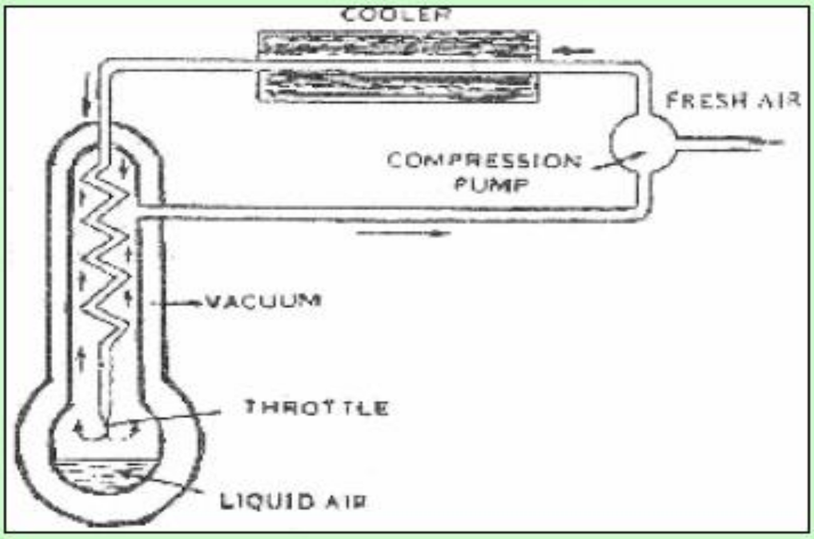
-تعتمد طريقة ليند وهامبسون على تأثير جول- طومسون والذي ينص على أنه:

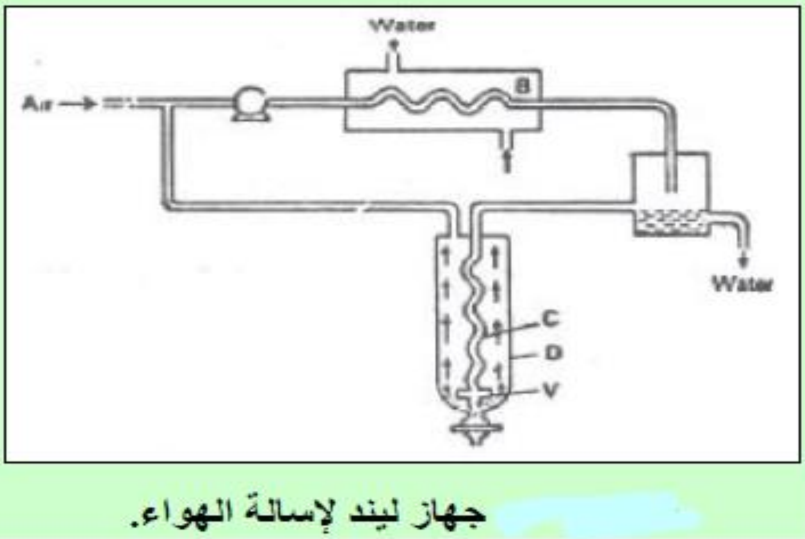
عندما يسمح لأي غاز موجود تحت ضغط عال بالتمدد المفاجيء في منطقة ذات ضغط منخفض، فإن درجة حرارته سوف تنخفض. ويبرد الغاز بسبب حقيقة أنه أثناء التمدد سوف تستغل الطاقة الحركية للغاز المتمدد في التغلب على قوى التجاذب بين الجزيئات حيث أن الغاز يقوم بشغل داخلي .

-الأشكال التالية توضح الجهاز الذي استخدمه ليند في إسالة الهواء :



طريقة لند لتسييل الهواء





جهاز ليند لإسالة الهواء.

لذا نستطيع تسييل الأكسجين وذلك بالتمدد المفاجئ للغاز المضغوط تحت ضغوط عالية مما ينتج عنه انخفاضاً في درجة حرارة ذلك الغاز .

6.3 *خطوات العمل 4*

(1) ينقى الأكسجين المراد تبريده من ثاني أكسيد الكربون CO_2 والمواد العضوية والرطوبة.

(2) يضخ الأكسجين في أنبوبة حلزونية (جهاز ضغط Compressor) حيث يضغط إلى ضغط حوالي (50 bar)[حسب الجدول المذكور أعلاه]

ونتيجة لارتفاع الضغط فإن درجة حرارة الأكسجين تزداد (تتولد حرارة أثناء الضغط).

(3) ولما كان الغرض من هذه العملية تخفيض درجة الحرارة وليس زيادتها فإن هذا الأكسجين الذي ارتفعت درجة حرارته يتم التخلص من حرارته حيث يمرر في مبادل حراري (heat exchanger أنابيب نحاسية حلزونية مبردة) لتخفيض درجة الحرارة. حيث تصل درجة تبريده إلى حوالي ($< -123^oC$) [< 150 K]

(4) حيث يمرر هذا الأكسجين في أنبوب حلزوني (c) ينتهى بفوهة صغيرة جداً لينتهي بالمحيط ذي الضغط المنخفض (الغرفة D) ليصل ضغطها إلى حوالى (1 atm) وذلك بضبط الصمام (V) [العملية هنا هي عملية تمدد مفاجئ]. ونتيجة للتمدد سوف تهبط درجة حرارة غاز الأكسجين الى حوالي (-183^oC) أو أدنى [حالة الأكسجين السائل].

(5) يمرر الأكسجين الذي تم تبريده بهذه الطريقة مرة ثانية فوق الحلزونات النحاسية (c) وبهذه الطريقة سوف يؤدي الى تبريد الغاز الداخل الى درجة أقل حتى قبيل تمدده.

(6) بعد إتمام الدورة عدة مرات (يعود الى الضاغطة compressor) تعاد العملية مرة ثانية وثالثة ...الخ حتى الوصول الى الضغط ودرجة الحرارة الحرجين حيث يتحول الى سائل)، فإن درجة حرارة الغاز المتمدد سوف تصبح منخفضة للغاية لدرجة أن الأكسجين السائل سوف يتدفق عبر الصمام (V) أما الأكسجين الذي لم يتكثف بعد، فإنه يعاد مرة ثانية الى جهاز الضغط حيث تكتمل الدورة .

4 https://learnchemistry12.com/2019/02/liquefaction-methods-of-gases.html

خطوات العمل

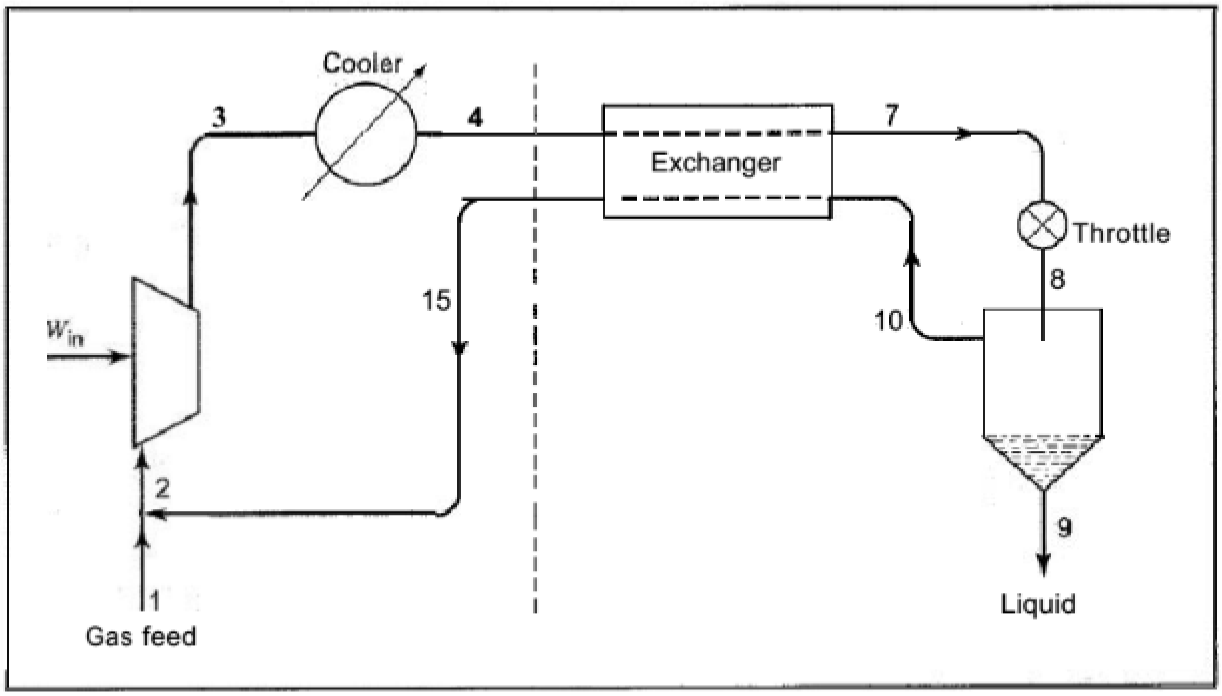


Figure 9.6 Linde liquefaction process

7 Static Analysis

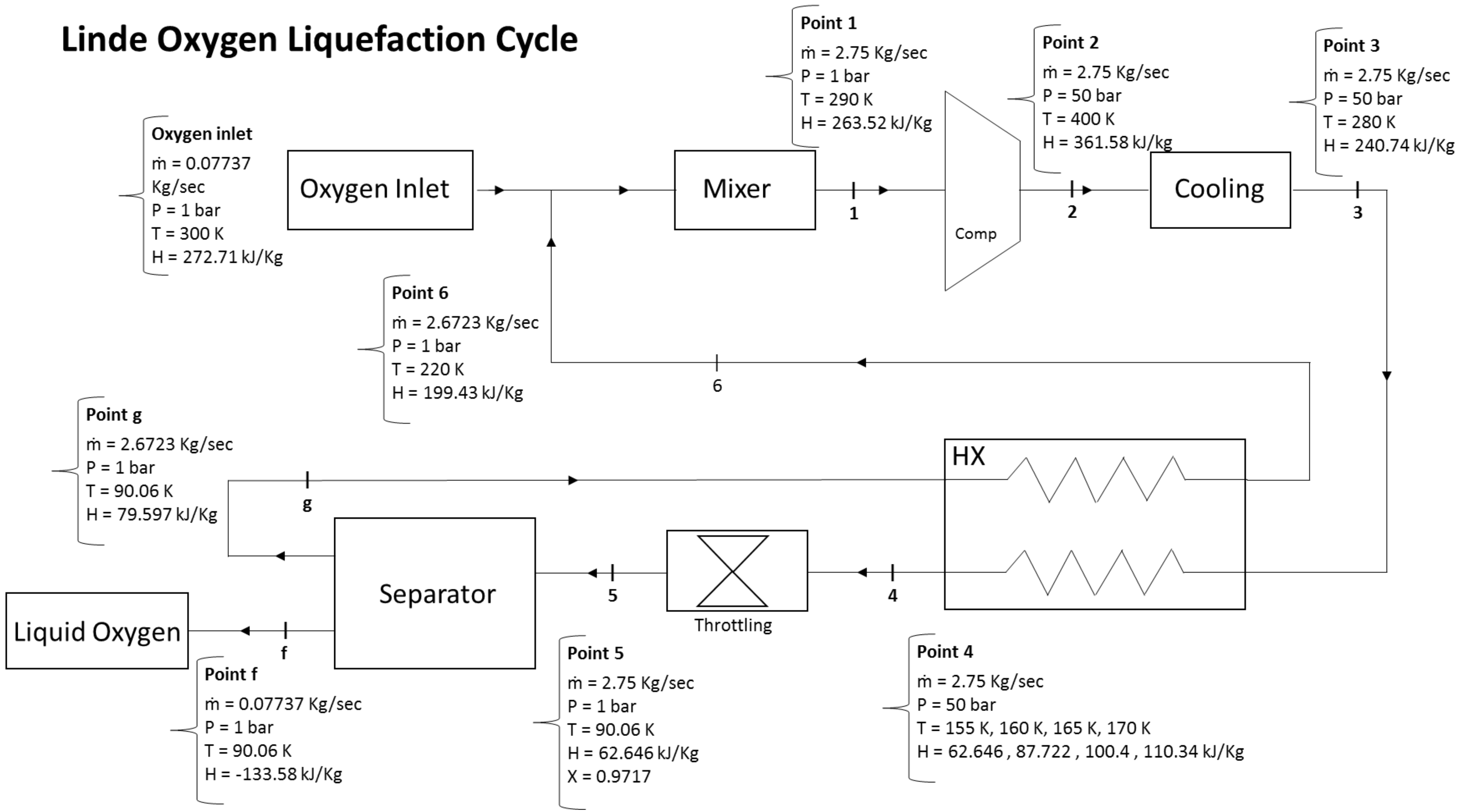
At the start of the first cycle, the oxygen gas passes from the oxygen inlet towards the compressor at the ambient temperature (300 K, 1 bar), through the mixer. It is at this stage that the mixer plays the role of the tank. The oxygen gas comes out hot from the compressor (400 K, 50 bar) in the direction of cooling in order to reduce the temperature of the compressed oxygen gas (280 K, 50 bar). Then the chilled oxygen gas goes to the heat exchanger, and here and in the first gas cycle the gas is not cooled through the heat exchanger due to the vacuum of the heat exchanger from the cold refrigerant gas. The compressed gas exits the heat exchanger with the cooling temperature (280 K, 50 bar) towards the throttle. In the throttle, the compressed gas (280 K, 50 bar) passes through a small aperture, allowing the gas to expand and expand suddenly and expand causing a sudden drop in pressure (from 50 bar to 1 bar) accompanied by a sudden drop in the temperature of the oxygen gas. The table below shows the temperature change before and after the throttle (at the outlet of the heat exchanger).

# of cycle	Heat exchanger			Throttling	ΔT (K)
	T inlet (K)	T outlet (K)	H outlet (kJ/Kg)	T outlet (K)	
1	280	280	240.71	265	15
2	280	~ 270	230.55	255	15
3	280	~ 260	220.23	245	15
4	280	~ 250	209.78	231	19
5	280	~ 237.5	196.5	216.8	20.7
6	280	~ 227.5	185.55	204	23.5
7	280	~ 210	165.67	183	27
8	280	~ 190	140.79	156	34
9	280	~ 165	100.4	107.5	57.5
10	280	~ 155	62.646	90.062	64.94

Note: The temperature change at the outlet of the heat exchanger (throttle inlet) occurs due to the temperature change of the cold oxygen gas entering the heat exchanger.

When oxygen is out of the throttle, it goes directly to the separator. At 90 K, oxygen is in a mixture of a gas and a liquid. And oxygen is in a gas state with a temperature higher than 90 K, while it is in a liquid state with a temperature below 90 K. The separator has two outlets, one for liquid oxygen and the second for gas oxygen. Liquid oxygen exits from the outlet of the first separator to the tank, while the oxygen gas exits, at a temperature of approximately 90 K, from the outlet of the second separator towards the mixer, passing through the heat exchanger. The cold oxygen gas coming out from the separator plays an important role in cooling the hot gas entering the heat exchanger (leaving the coolant) towards the throttle. After the cold gas passes through the heat exchanger, its temperature is heated up (about 220 K) and then it reaches the mixer where it is mixed with the oxygen gas coming from the oxygen inlet.

7.1 Schema of Linde-Hampson liquefaction cycle of Oxgene with example values



Schema of Linde-Hampson liquefaction cycle of Oxgene with example values

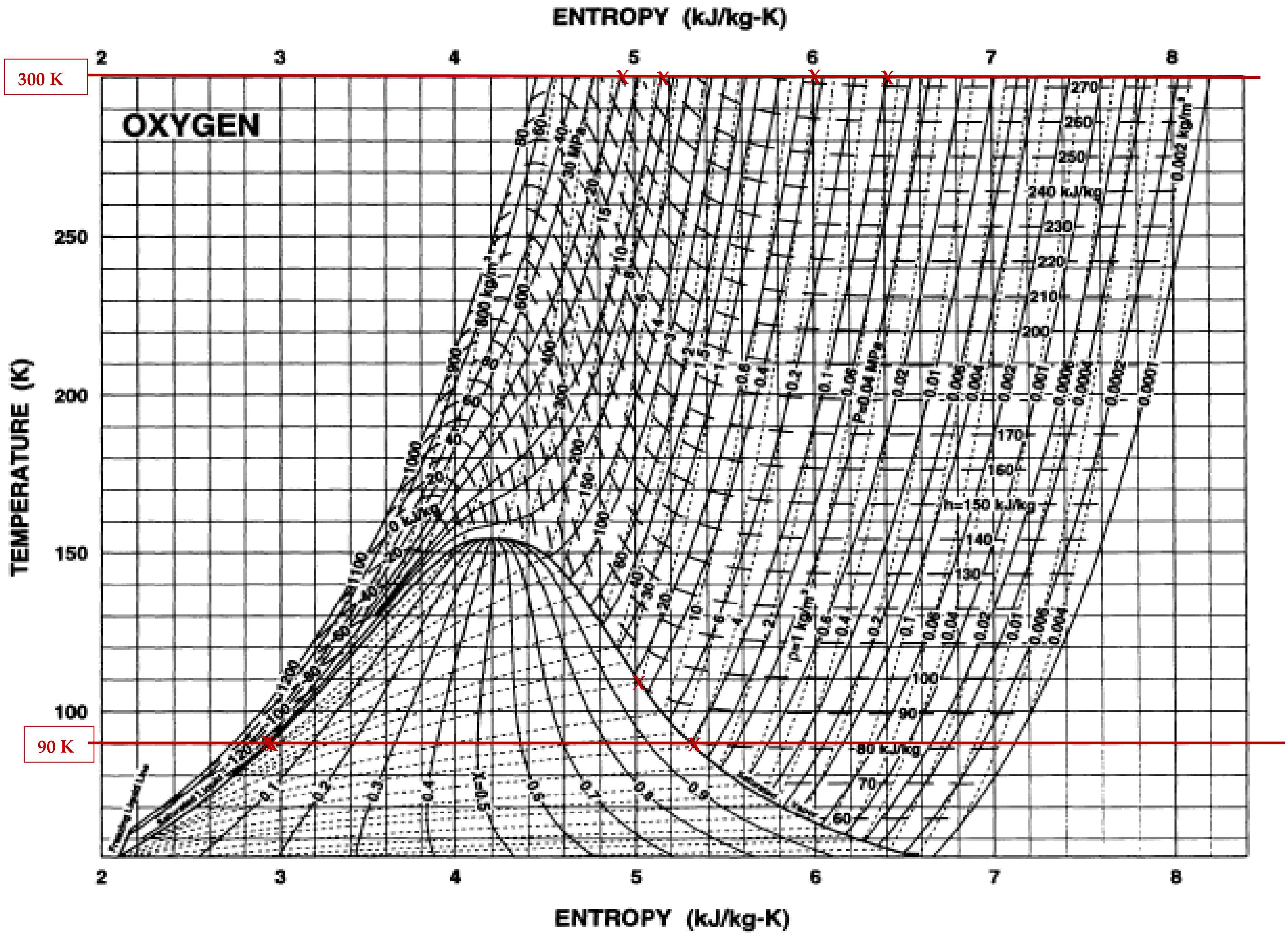


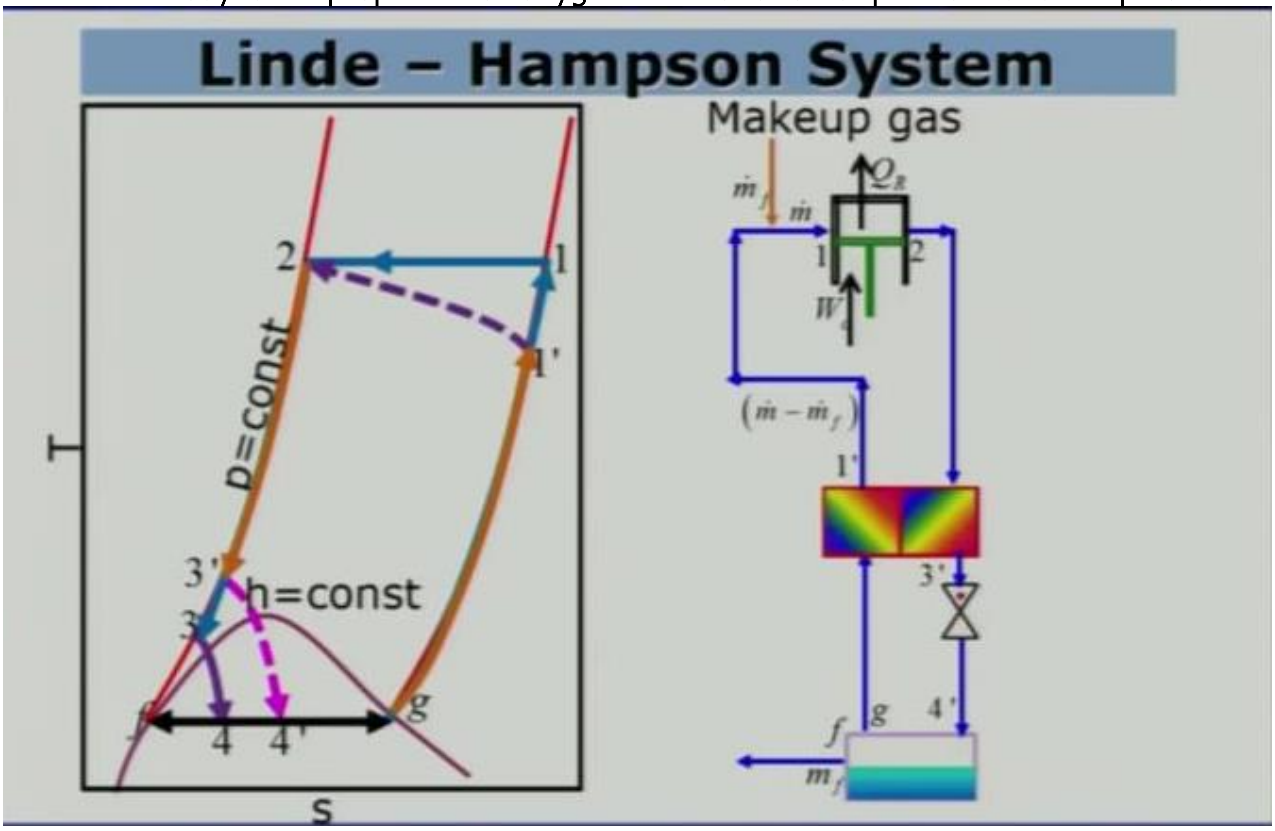
Fig. 5.30. $T-S$ diagram for oxygen ($T = 50-300$ K)

7.2 Drawing by FreeCad

Linde.FCStd

7.3 Detailes of calculation

- Thermodynamic properties of Oxygen with variation of pressure and temperature



1→2 isothermal compressor

3→4 Isenthalpic expansion

2→3' , g→1 isobaric heat exchange

2→3' , g→1' heat exchange (actual)

We choose 90 K as temperature of boiling point (see table above)

Thermodynamic Properties of Oxygen	Unit	P= 1 bar = 0.1 Mpa		P= 50 bar = 5 Mpa		P= 100 bar = 10 Mpa		P= 200 bar = 20 Mpa	
		T= 90 K	T= 300 K	T= 90 K	T= 300 K	T= 90 K	T= 300 K	T= 90 K	T= 300 K
Enthalpy	**kJ/Kg**	**-133.69**	**272.71**	**-131.04**	**260.88**	**-128.28**	**249.39**	**-122.61**	**229.99**
Entropy	**kJ/Kg.K**	**2.9383**	**6.4163**	**2.9202**	**5.3679**	**2.9029**	**5.1561**	**2.8712**	**4.9208**

Note: The mass flow $\dot{m}$=2.75 Kg/s is an approximated value, a change in this value will affect Q-dot as well as $\dot{m}$f and thus yield Y.

- In steady state conditions, the first Law around the compressor gives:
  $\dot{W}c - (Q\text{-dot})r + \dot{m}(h1 - h2) = 0$

The second Law around the compressor gives:

(Q-dot)r = ṁ T1 (S1 – S2)

Combining, we have:

Ẇc = ṁ [T1 (S1 –S2) – (h1 – h2)]

= (Q-dot)r - ṁ (h1 – h2)

Or (Q-dot)c = ṁ (h1 –h2)

- Applying the 1st Law around everything except the compressor gives:
  ṁ (h1 – h2) = ṁf (h1 – hf)
  $$\rightarrow \dot{m}f = \frac{\dot{m}\,(h1-h2\,)}{h1-hf}$$
- Defining yield, $y = \frac{\dot{m}f}{\dot{m}} = \frac{h1-h2}{h1-hf}$
- $\text{FOM} = \frac{(\,h1-h2\,)(T1-Tc)}{[T1\,(S1-S2)-(\,h1-h2)]\,Tc}$

Thus, the table below contains the results of calculation with variation of pressure

Pesure P	Unit	1 bar → 50 bar	1 bar → 100 bar	1 bar → 200 bar
Gas mass flow rate ṁ	**Kg/sec**	**2.75**	**2.75**	**2.75**
Heat transfer of compressor Qr	kJ/sec	864.93	1039.665	1233.7875
Heat transfert of evaporator Qc	kJ/sec	32.5325	64.13	115.995
Work transfert compressor W-dot	kJ/sec	832.3975	975.535	1117.7925
Liquid mass flow rate ṁf	**Kg/sec**	**0.08005**	**0.1578**	**0.28542**
Yield Y		0.02911	0.0573	0.10379
FOM		**0.09111**	**0.15324**	**0.241903**

7.4 Heat exchanger

- **Heat Exchanger Design Process**
  1. Identify application – Temperature, heat loads, mass flow rates,etc.
  2. Decide on construction type.
  3. Evaluate LMTD, q and F
  4. Determine dimensions.
  5. Evaluate heat transfert coefficient on hot side
  6. Evaluate heat transfer coefficient on cold side
  7. Determine overall heat transfer coefficient.
  8. Determine dimensions – iterate
  9. Check power consumpltion

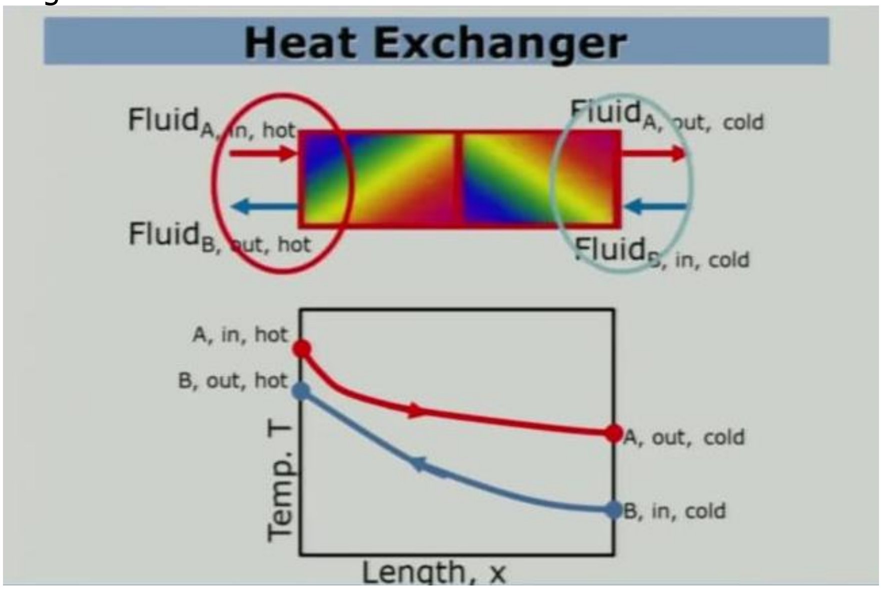
7.4.1 Calculation of heat exchanger 5

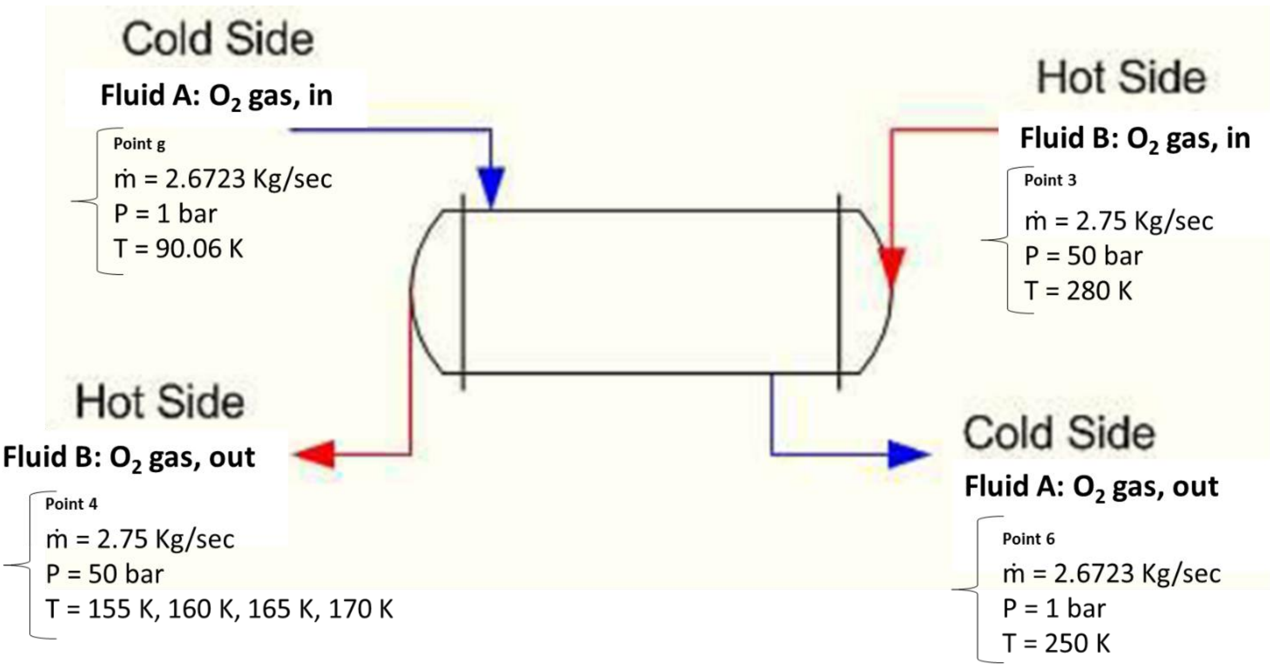
✍ **Notes :**

1- U value is taken approximate (40 W/m^2.K)

5 https://checalc.com/solved/LMTD_Chart.html & https://checalc.com/calc/ShortExch.html

2- A base of inlet and outlet temperature (hot & cold), the appropriate type of heat exchanger is 2 shells and 4 tubes





Static Analysis

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Heat Duty
318.56 kW

U Value
40 W/m^2.°K

Hot Side

Temperature In
280.00 °K

Temperature Out
160.00 °K

Cold Side

Temperature In
90.06 °K

Temperature Out
220 °K

Result

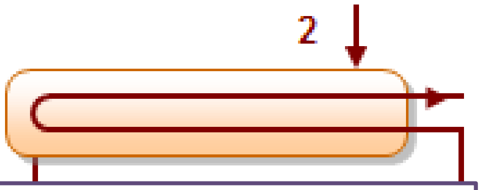
Tube Pitch	106.3500	mm
LMTD	64.84	°K
Correction Factor (F)	0.8195	
LMTD (Corrected)	53.14	°K
Shell in Series	2	
Total Area	149.86	m^2
Area per Shell	74.93	m^2
Tubes per Shell	48	
Shell ID (Estimate)	0.91	m

Geometry

Tube Pass
Multiple

Tube Length

•



Geometry

Tube Pass
Multiple

Tube Length
5 m

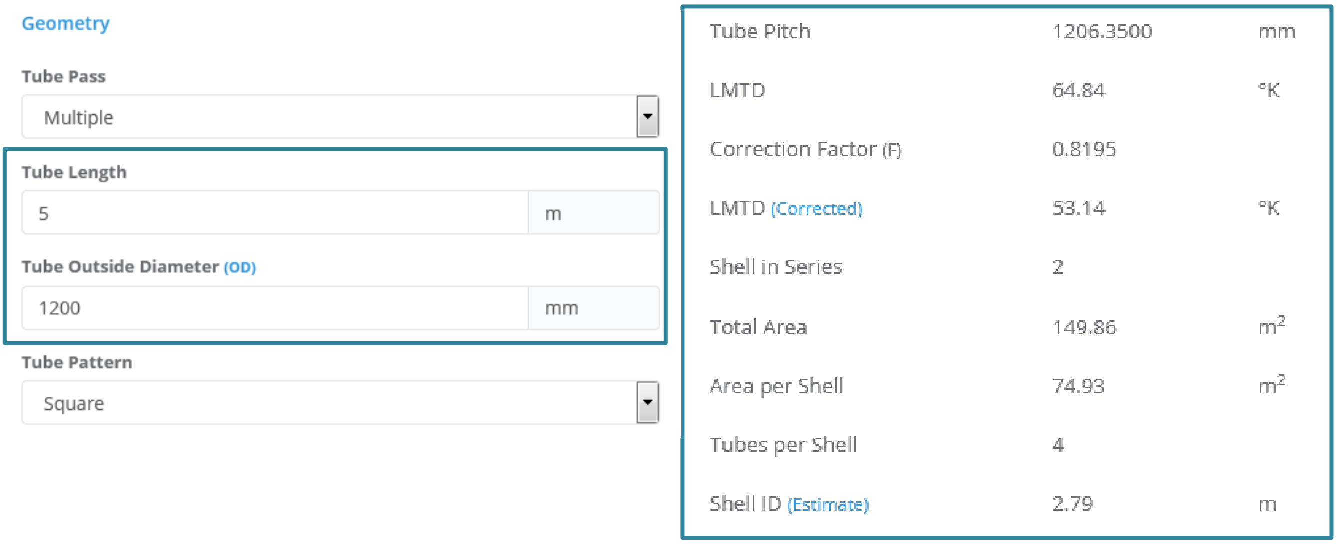
Tube Outside Diameter (OD)
400 mm

Tube Pattern
Square

Tube Pitch	406.3500	mm
LMTD	64.84	°K
Correction Factor (F)	0.8195	
LMTD (Corrected)	53.14	°K
Shell in Series	2	
Total Area	149.86	m^2
Area per Shell	74.93	m^2
Tubes per Shell	12	
Shell ID (Estimate)	1.66	m

1

•



7.5 Calculation of compressor

	Stage 1	Stage 2	Stage 3	Total
Mass flow rate (Kg/s)	1.12E-03	1.12E-03	1.12E-03	
Pessure ratio	3	4	3.6	43.5
Pump efficiency	0.6	0.6	0.6	
Input pressure (bar)	1.18	3.56	14.25	
Outlet pressure (bar)	3.56	14.25	51.67	51.67
Intel density (Kg/m3)	1.7	5.0	20.4	
Pump input power (W)	265	397	344	1005

- **Compressor choice :**

Choice 1:

https://toplongcompressor.en.made-in-china.com/product/IvVmtGBbhyhA/China-5nm3-3stage-High-Pressure-Oil-Free-Oxygen-Compressor-Nitrogen-Compressor.html

5nm3 3stage High Pressure Oil Free Oxygen Compressor Nitrogen Compressor

Get Latest Price >   Leave a message.

Min. Order / Reference FOB Price	
1 Piece	US $6,500-8,000/ Piece

Port:	Shanghai, China
Production Capacity:	200PCS/Month
Payment Terms:	L/C, T/T, D/P, Western Union, Paypal, Money Gram
Lubrication Style:	Oil-free
Cooling System:	Air Cooling
Cylinder Arrangement:	Balanced Opposed Arrangement
Cylinder Position:	Vertical
Structure Type:	Closed Type
Compress Level:	Multistage

Product Description
Oil-free Special Gas Compressor

Oil-free special gas compressor booster is the kind of semi-hermetic compressor, it adopts hermetic construction for its motor without pollution to the medium to be compressed and without leakage. This series compressor has numerous advantage of reliable performance, simple operation, compact construction, quick connection and so on. It can be applied in the compression and recovery of toxic, rare and precious gas such as SF6, helium, methane, ammonia, Freon, carbon dioxide and so on.

Performance Characteristics

Oil free high pressure oxygen nitrogen helium Co2 gas compressor
Principle 1: Oil-free type reciprocating piston
2 Cooling Type: Air-cooled or water-cooled
(3) Power consumption: ≤ 110kw4 Speed: . 300-560rpm
5 Flow: . ≤ 2000Nm3 / h6
Suction pressure: . 0-5Mpa7
Exhaust pressure: . ≤ 16.5Mpa8 Compression Level: 1-4Winds oil-free compressors
Product Features: No oil lubrication with clean and non-polluting.
High efficiency, low energy consumption. High reliability, continuous 24-hour operation. The unit uses air-cooled or water-cooled, compact structure, operation and low maintenance cost

All our models can be customized. For more information, pleaes do not hesitate to contact.

Model	gas	inlet .barg	outlet .barg	flow rate NM3/hr	power.KW	voltage/frequency	inlet/outlet.mm	cooling way	net eight.kg	dimension.mm	pressure riato stage
GOWW-4-10/4-150	oxygen	3-4	150	4-10	3	220/380 /440/50/60/3	DN15/M16X1.5	air cooling	380	1300X750X1000	3stage
GOWW-11-20/4-150	oxygen	3-4	150	11-20	4-7.5	220/380 /440/50/60/3	DN15/M16X1.5	air cooling	420	1300X750X1000	3stage

Choice 2:

https://www.alibaba.com/product-detail/BROTIE-oxygen-compressor_1600122723363.html?spm=a2700.galleryofferlist.topad_classic.d_image.35d821fd7VGM2u

BROTIE oxygen compressor

FOB **Reference** Price: Get Latest Price

$6,500.00 - $10,000.00 / Set | 1 Set/Sets (Min. Order)

Power: 3-22kw

Warranty: **1 Year** for machinery warranty | **1 Year** for Core Components

Shipping: Support Express · Sea freight · Land freight · Air freight

Lead Time:

Quantity(Sets)	1 - 100	>100
Est. Time(days)	30	Negotiable

Overview

Quick Details

Applicable Industri...	Garment Shops, Building Material Shops, Manufacturing Plant...	After Warranty Serv...	Video technical support, Online support, Spare parts, Field ma...
Local Service Locat...	United Kingdom, United States, Germany, Viet Nam, Philippine...	Showroom Location:	Turkey, United Kingdom, United States, Viet Nam, Philippines, ...
Condition:	New, New	Type:	PISTON
Configuration:	PORTABLE	Power Source:	AC POWER
Lubrication Style:	Oil-free	Mute:	yes
Place of Origin:	China	Brand Name:	BROTIE
Model Number:	O2-3/4-150, O2-5/4-150, O2-10/4-150, O2-15/4-150, O2-20/4-...	Voltage:	customized
Dimension(L*W*H):	customized	Weight:	300-650kg
Certification:	ISO	Warranty:	1 Year
After-sales Service ...	Field installation, commissioning and training	Working Pressure:	150bar, 200bar
Air capacity:	3-75Nm3/h	Machinery Test Re...	Provided
Video outgoing-ins...	Provided	Marketing Type:	New Product 2020
Warranty of core co...	1 Year	Core Components:	Motor, compressor block
Gas Type:	oxygen	Model:	O2-3,5,10,15,20,25,30,40,50,75/4-150
Flow Capacity:	3,5,10,15,20,25,30,40,50,75Nm3/h	Compressing Stage:	3Stages
Inlet Pressure:	4bar	Outlet Pressure:	150, 200bar
Outlet Temperature:	50C	Inlet Size:	DN20-DN32
Outlet Size:	8-15mm	Cooling System:	Wind cooling/Water cooling
Lubrication:	no oil lubricated		

BROTIE Totally Oil-free Oxygen Compressor Specifications

Item	Specification	Remarks
Model	O2-3,5,10,15,20,25,30,40,50,75/4-150	
Flow Capacity	3,5,10,15,20,25,30,40,50,75Nm3/h	
Compressing Stage	3Stages	
Inlet Pressure	4bar	
Outlet Pressure	150bar	
Outlet Temperature	≤50°C	
Inlet Size	DN20-DN32	Due to the model
Outlet Size	8mm-15mm	Due to the model
Ambient Temperature	Normal temperature	
Cooling System	Wind cooling/Water cooling	Due to the model
Lubrication	No Lubrication	
Rotating Speed	350-730rpm	Due to the model
Power Consumption	3-22Kw	Due to the model
Weight	300-620kg	Due to the model

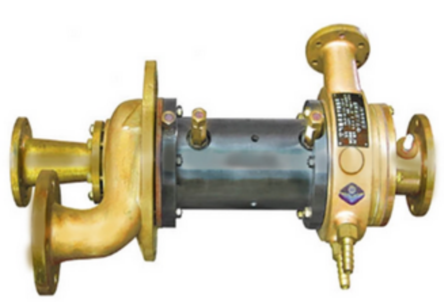
Totally oil-free model, no oil lubricated in the whole compressor.
All parts which contact with O2 gas are made of stainless steel.
Please confirm your power supply of 3phase before order.

7.6 Expansion valve :

Catalogue :
https://www.parker.com/literature/Instrumentation%20Products%20Division/Catalogs/Cryogenic%20Valves%20for%20Industrial%20Gas%20Applications.pdf

Choice 1 :

https://www.alibaba.com/product-detail/Cryogenic-Turbo-Expander-China-Made-PLPK_60832517222.html?spm=a2700.7735675.normal_offer.d_title.1e6742e1VyAiHQ&s=p



China made PLPK-8.33/18.6-4.9 cryogenic turbo expander for air separation turbo expander

>=1 Units
$1,000.00

Model Number: PLPK-8.33/18.6-4.9

Warranty: **1 Year** for machinery warranty

Shipping: Support Sea freight

Alibaba.com Freight | Compare Rates | Learn more

Payments: VISA T/T Online Transfe Pay WesternUnion WU

Parameters of turbo expander for air separation

Models	technical parameter					matching air separation	remark
	output (Nm³/h)	intake pressure (MPa，G)	discharge pressure (MPa，G)	intake temperature (K)	efficiency (%)		
PLPK-6/6-0.42	360	0.6	0.042	130	76	180m³/h oxygen generating	
PLPK-8.33/18.6-4.9	500	1.86	0.49	173	76	medium-pressure 150 m³/h oxygen generating	
PLPK-7.1/3.6-0.3	425	0.36	0.03	118.3	77	oxygen producing truck	military
PLPK-10/8-0.47	600	0.8	0.047	150	76	350~750 m³ /h oxygen generating	booster turbine
PLPK-18.33/7.7-0.38	1100	[illegible]	[illegible]	[illegible]	78	oxygen generating plant	booster turbine
PLPK-25/6.25-0.45	1500	0.625	0.045	153	78	1500m³/h oxygen generating	booster turbine
PLPK-30/5.5-0.4	1800	0.55	0.04	150	80	1600 m³/h oxygen generating	adjustable nozzle
PLPK-40/13.7-0.2	2400	1.37	0.02	150	78	pure nitrogen plants	booster turbine
PLPK-46.17/13.4-0.19	2770	1.34	0.019	148	78	pure nitrogen plants	booster turbine
PLPK-43.3/4.6-0.4	2600	0.46	0.04	110	81	pure nitrogen plants	adjustable nozzle
PLPK-80/9.5-5.2	4800	0.95	0.52	112	81	pure nitrogen plants	adjustable nozzle
PLPK-83.67/3.2-0.3	5020	0.32	0.03	116	81	pure nitrogen plants	

7.7 Materials suitable for cryogenic heat exchanger

Material link: 6

7.7.1 Materials suitable down to -45 °C

This first threshold is important because, besides being typically the lower limit of the temperatures naturally reached on the planet, it is also the temperature at which some industrial operations and some chemical processes are carried out.

Unfortunately, common construction steels are no longer usable at this level, either because of their intrinsic characteristics or because they are not usually tested for hardness and resistance to low temperatures. Some steelworks, however, have special carbon steels for these applications. These are mainly quenched and tempered low alloy steels.

Almost all aluminium alloys can be used at temperatures down to -45 °C, except series such as 7075-T6 and 7178-T6, and titanium alloys 13V-11Cr-3Al or 8Mn. Copper and nickel alloys can generally all be used at these temperatures. PH stainless steels, i.e. precipitation hardening stainless steels, are not suitable for temperatures below -20 °C because of embrittlement and cracks.

7.7.2 Materials suitable down to -75 °C

Some steels can be used at these temperatures, such as low alloy, quenched and tempered steels or ferritic nickel steels. Most low carbon (0.20-0.35%) martensitic steels can be used with sufficient reliability. Many of these alloys contain manganese, nickel, chromium, molybdenum and vanadium, and some zirconium and boron.

7.7.3 Materials suitable down to -100 °C

Low carbon, 3.5%-nickel steels are often used in liquid gas storage tanks at temperatures down to -100°C. Many aluminium, nickel, and titanium alloys are also suitable for these temperatures. Aluminium 7076-T6 can also be used up to -128 °C, but not for critical applications.

7.7.4 Materials suitable down to -196 °C

The austenitic stainless steels of the 300 series are all suitable for working in this temperature range. Maraging steels with nickel content between 20% and 25% and the addition of cobalt, molybdenum, titanium, aluminium, and niobium are also suitable. Maraging steels have excellent malleability, toughness and hardness characteristics, and must be hardened at a temperature of just 400 °C.

Many aluminium alloys, such as 2024-T6, 7039-T6 and 5456-H343 have excellent fracture resistance at -196 °C; also 2014-T6 but with the exception of welds. Other alloys resistant to even lower temperatures are the 5000 series aluminium-magnesium alloys, the 2219-T87 and the 6061-T6.

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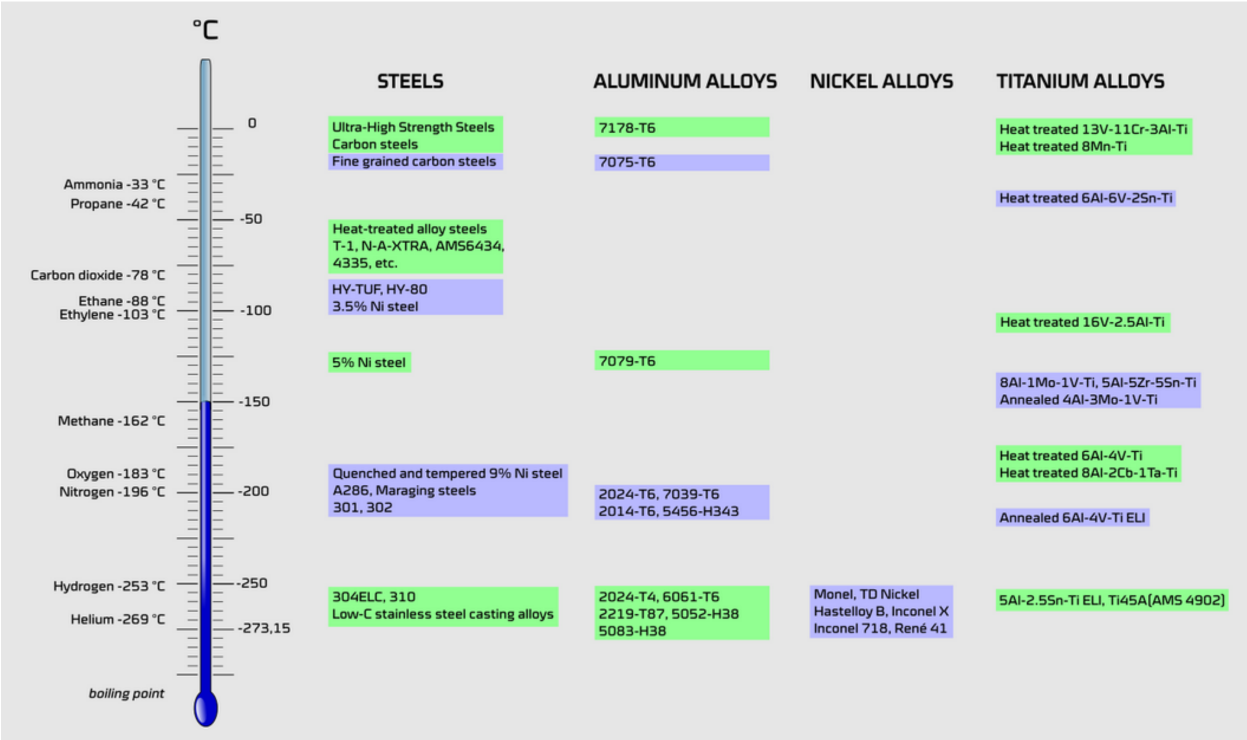
6 https://www.gasparini.com/en/blog/metals-and-materials-for-low-temperatures/

The nickel-based materials are almost all resistant to -196 °C. Titanium alloys such as 5Al-2.5Sn-Ti, 6A1-4V-Ti and 8Al-2Cb-1Ta-TiY are also suitable, but should be kept free of impurities such as oxygen, nitrogen, carbon and iron as they cause embrittlement.

The aluminium alloys that can be used at the temperatures involved are typically in the 2000 and 5000 series, or the 6061-T6 alloy. In particular, welds on 2219-T87 have demonstrated excellent fracture resistance, while 5052-H38 and 5083-1138 have high crack resistance. The same applies to Monel, K-Monel, electroformed nickel, hardened nickel for thorium dispersion, and nickel alloys such as Inconel X, Inconel 718, René 41, and Hastelloy B. At these temperatures, only Ti45A and 5Al-2.5Sn-Ti titanium alloys can be used, both as base metal and welded.

Copper alloys are generally also used in contact with liquid hydrogen and helium, such as 70-30 brass, copper-beryllium, iron-silicon and aluminium bronzes. Magnesium alloys, on the other hand, tend to become brittle but can be used in low stress applications with careful design.



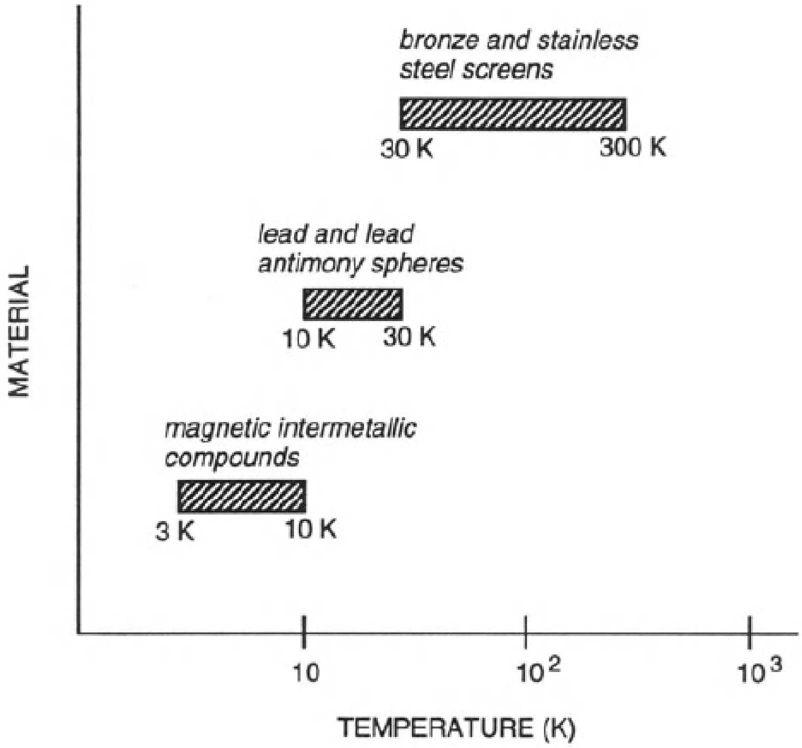


Fig. 2.16. Temperature range for commonly used regenerator materials in cryogenic refrigerators. 7

7 https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.468.3966&rep=rep1&type=pdf

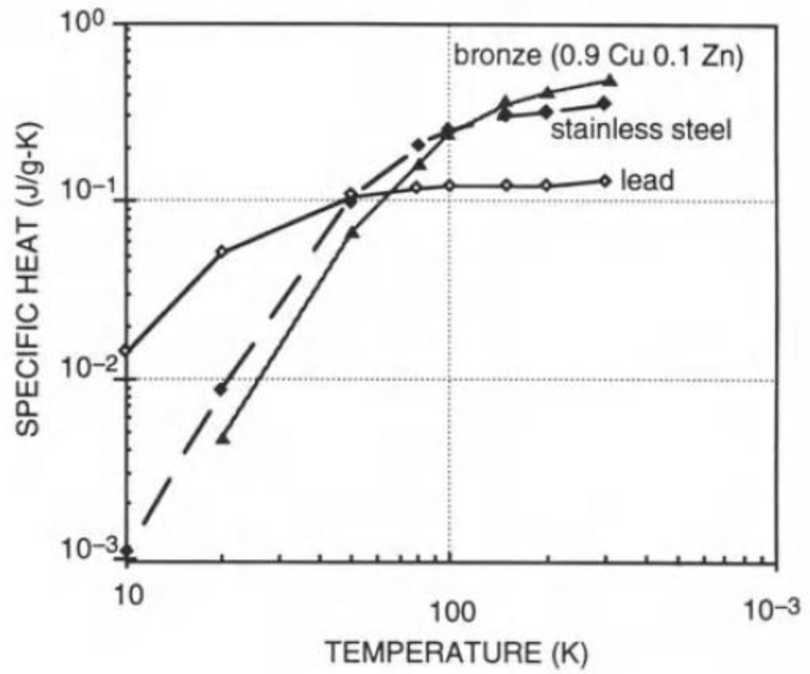


Fig. 2.17. Comparison of the specific heats for three commonly used regenerator materials. 6

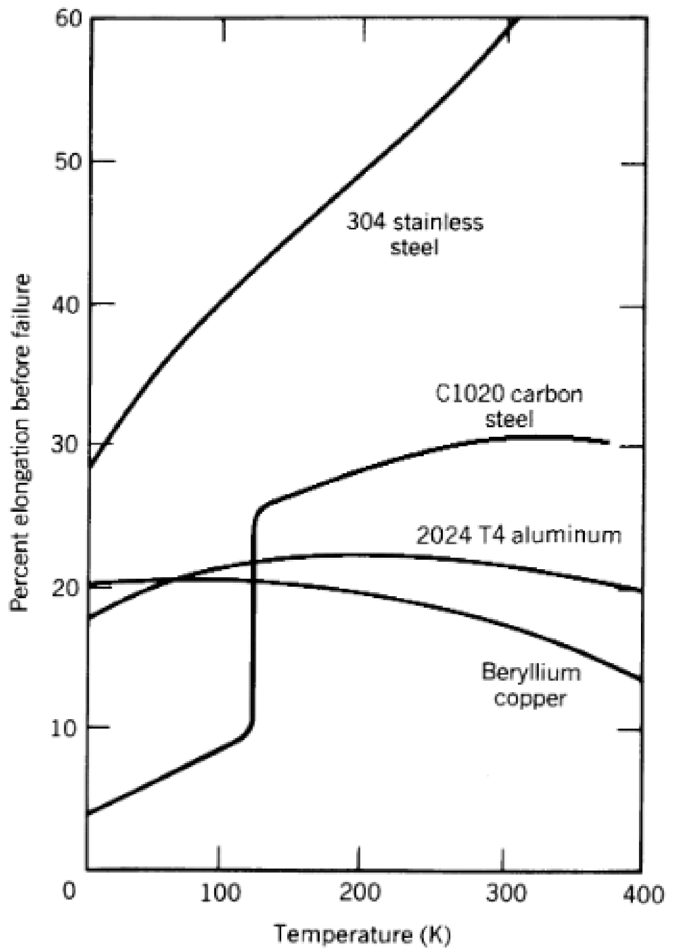


Figure 33 Percent elongation before rupture of some materials used in cryogenic service. 6

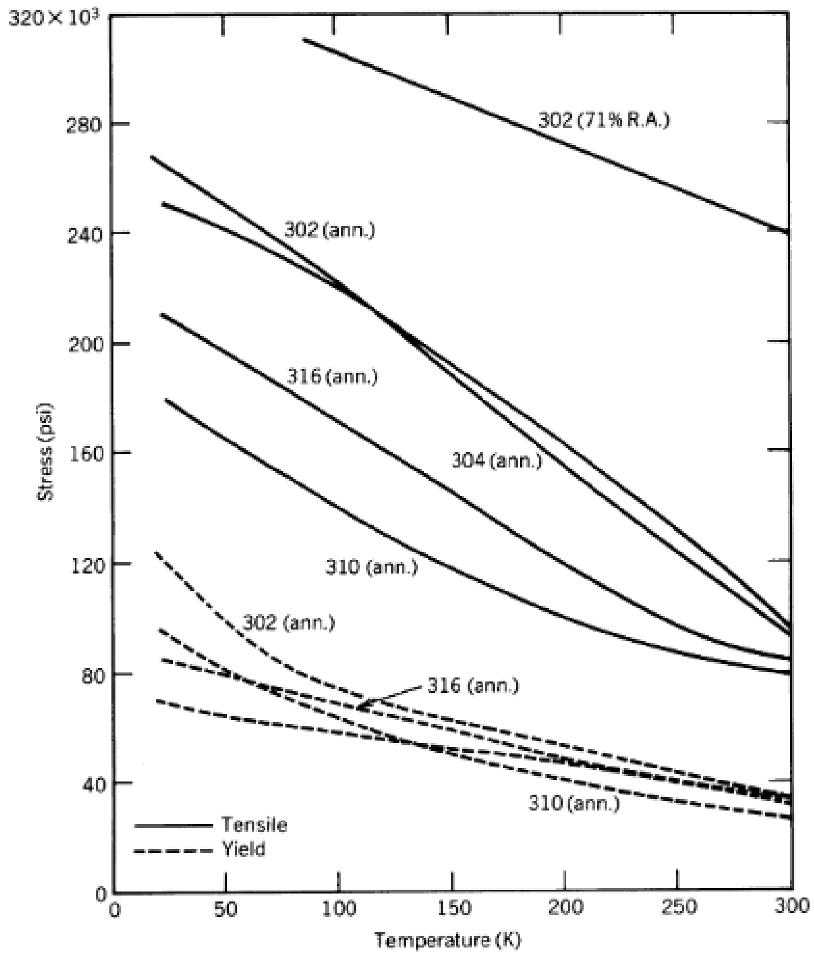


Figure 34 Yield and tensile strength of several AISI 300 series stainless steels.[33] (Courtesy American Iron and Steel Institute.) 6

Table 6 Properties of Various Multilayer Insulations (Warm Wall at 300 K)

Sample Thickness (cm)	Shields per Centimeter	Density (g/cm^3)	Cold Wall T (K)	Conductivity ($\mu W/cm \cdot K$)	Material[a]
3.7	26	0.12	76	0.7	1
3.7	26	0.12	20	0.5	1
2.5	24	0.09	76	2.3	2
1.5	76	0.76	76	5.2	3
4.5	6	0.03	76	3.9	4
2.2	6	0.03	76	3.0	5
3.2	24	0.045	76	0.85	5
1.3	47	0.09	76	1.8	5

[a] 1, Al foil with glass fiber mat separator; 2, Al foil with nylon net spacer; 3, Al foil with glass fabric spacer; 4, Al foil with glass fiber, unbonded spacer; 5, aluminized Mylar, no spacer.

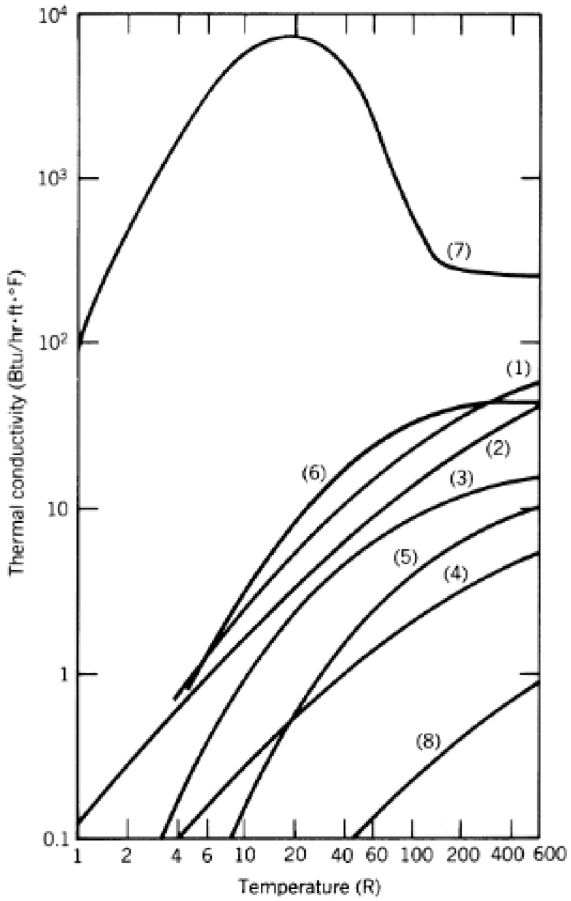


Figure 36 Thermal conductivity of materials useful in low-temperature service. (1) 2024TA aluminum; (2) beryllium copper; (3) K-Monel; (4) titanium; (5) 304 stainless steel; (6) C1020 carbon steel; (7) pure copper; (8) Teflon.[35] 6

Table 3.5. Specific Heat of Regenerator Materials c_p (J/kg-K)

Temp. (K)	Al	Cu	In	Pb	18-8 stainless steel	Bronze	Sn
10	1.5	2.8	15.5	13.8	1.6	—	8
20 (H_2 bpt)	9	7.5	51	51	4.6	4.5	40
50	141	98	160	103	67	64	130
77 (N_2 bpt)	341	197	190	118	159	140	170
90 (O_2 bpt)	427	232	200	119	209	200	180
100	485.6	254	205	120	238.6	220	187
150	686.5	324	210	125	356	340	203
200	799.5	357.5	220	128	414.4	400	205
300	900	387	220	130	477	490	210

7.8 Liquid oxygen tank

The liquid oxygen tank is an insulated vertical tank with double layer cover for storing liquid oxygen. The material used for inner tank is s30408 stainless steel.

The liquid oxygen tank is an insulated vertical tank with double layer cover for storing liquid oxygen. The material used for inner tank is S30408 stainless steel; The outer container materials are chosen as Q235-B, Q245R or 345R according to the national regulations according to the user's area. The inner and outer container sandwiches are filled with sand pearl thermal insulation materials, insulated and broomed.

The liquid oxygen tank has the features of high air tightness, low thermal conductivity, good thermal insulation performance, small evaporation loss and long service life, it is widely used in the pharmaceutical, chemical, manufacturing and other industries.

The structure of the liquid oxygen tank8

Liquid oxygen tank (LO2 tank) consists of tank body, tools, tubes, valves, etc.

1. Relief device
2. Inner container
3. Insulation layer (sand pearl)
4. Shell
5. Instrument

(Differential pressure gauge, oxygen pressure gauge, combination valve)

6. Pump port and vacuum valve
7. Pipeline valve

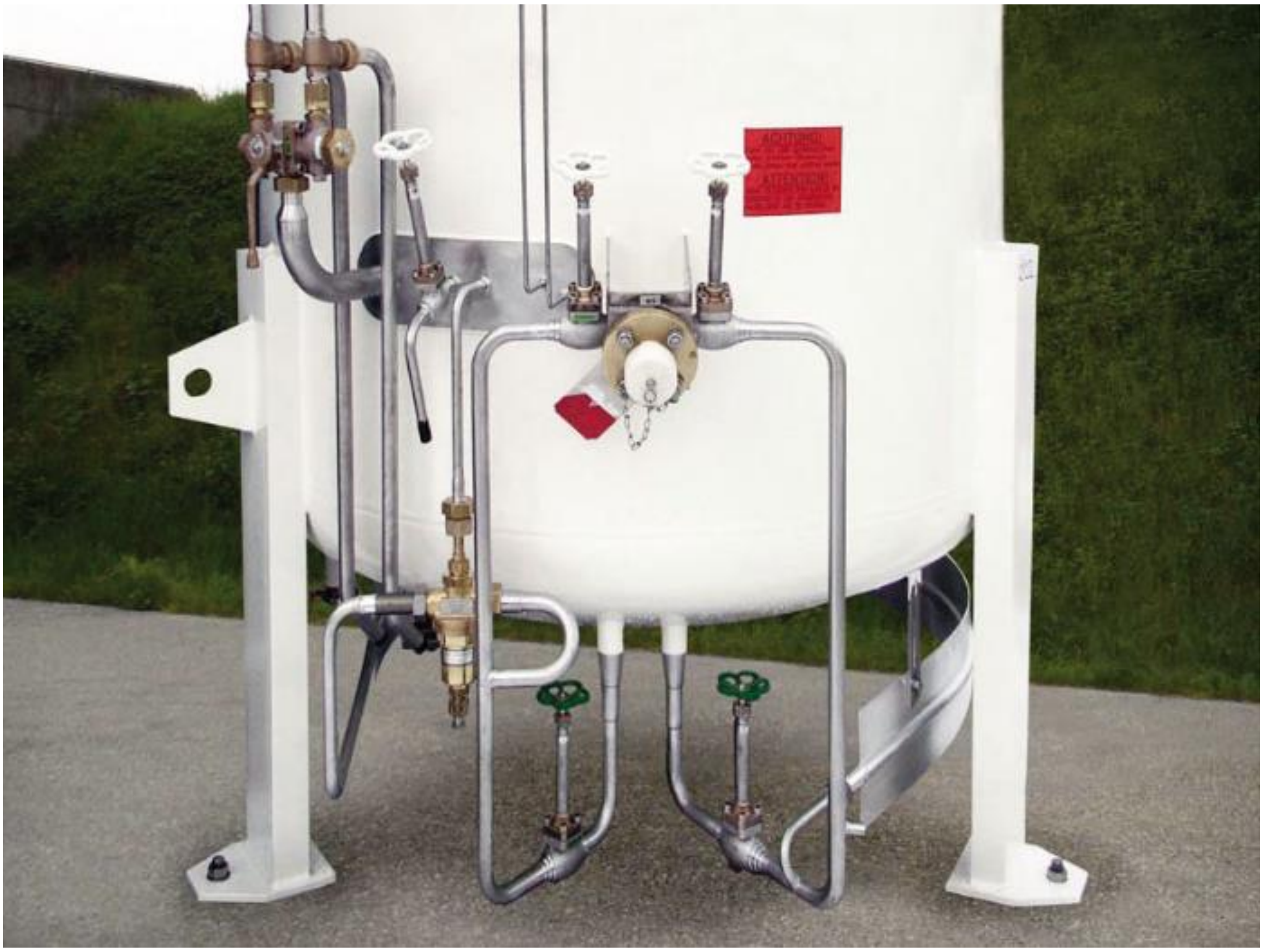
Describe:

(1) The liquid oxygen tank drive system is mostly centered on the bottom of the tank, and the instrument system and the built-in valve are arranged on the tank wall for easy monitoring and operation.

8 http://m.zhongjie-se.com/cryogenic-tank/cryogenic-storage-tank/liquid-oxygen-tank.html

(2) Cryogenic storage tank contains booster and boost regulator to increase the tank pressure to the pressure required by the user.

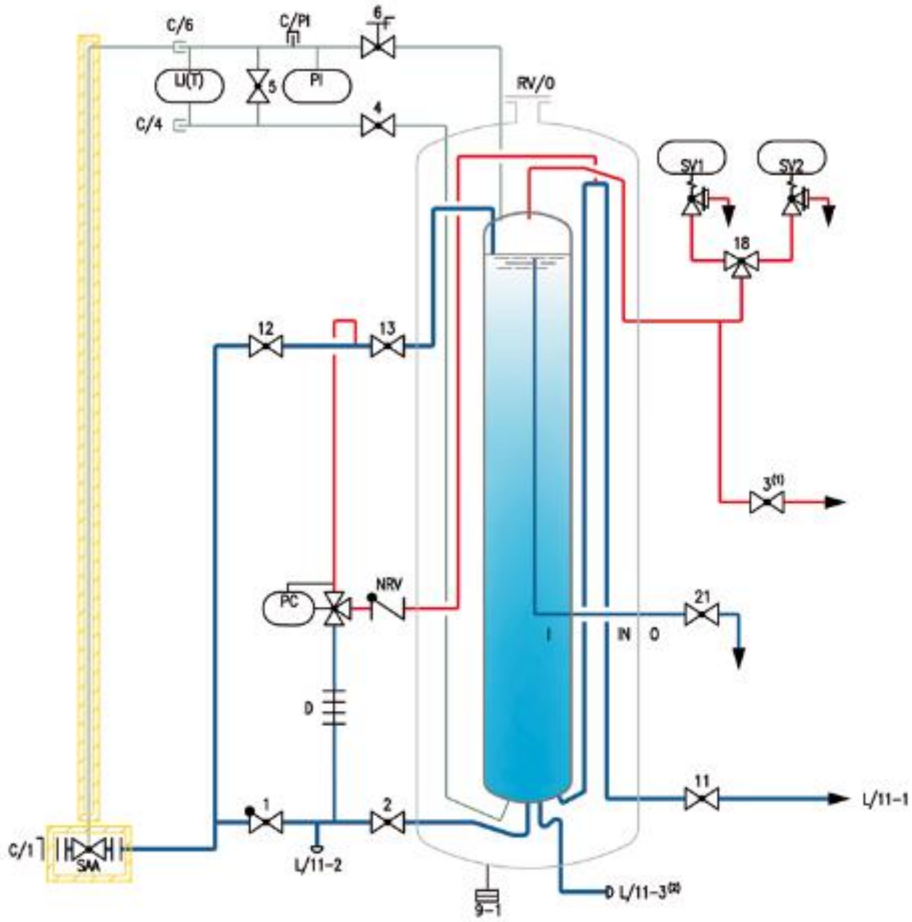
(3) The inner container for liquid oxygen storage tanks is equipped with two safety valves, two rupture discs, a tube safety valve, an intermediate pressure relief device.



LOX tanks are stationary, vacuum-insulated pressure vessels and consist of an inner and an outer pressure vessel. The inner vessel, designed for the storage of low-temperature, liquefied gas, is manufactured out of cold-stretched material (stainless steel 1.4311 or 1.4301). The outer vessel is manufactured out of carbon steel. The space between the inner and outer vessel is filled with perlite, a grained insulation material and is evacuated up to a pressure of below 50 microns in a warm state (20°C). In addition, a molecular sieve ensures, by means of absorption, the long-term stability of the vacuum during the operation of the tank. An automatic regulation system helps maintain the working pressure and minimizes losses in case of lower withdrawal rates. The quality of the welded seams is checked by a leak test with helium, which also ensures long-term durability of the vacuum.9

To improve the efficiency of the cold converter, the tank is equipped with an additional pressure reducing system. This system works with a pressure reducing regulator which is installed in a connecting line between the gas phase and the highest point of the product withdrawal line. If, due to a prolonged standstill, the pressure in the tank is above the adjusted opening pressure of the regulator, and if valve is open, the economizer will open and opens the connection between gas phase and liquid phase. In case of product withdrawal through valve, it will now be taken out of the gas reserve of thetank and this measure will result in a rapid reduction of pressure. If the tank pressure is now below the opening pressure of the regulator, the economizer will close andwithdrawal will be done out of the liquid phase, consequently with a smaller pressure drop. The standard opening pressure is set 1 bar above the closing pressure of the pressure reducing regulator.

9 https://acprodbponlinebcc5.blob.core.windows.net/bp-public-files/bp_editor_div_mgs/TechnicalInformation/PMGS_LOX_Storage_Tanks_HTM_Instruction_Book_EN_8102341086.pdf



[10]

Flow diagram - tanks for nitrogen, oxygen, argon.

Instrumentation and equipment, standard

C/1	Fill coupling
C/4, C/6	Connection add. transmitter
C/PI	Test connection pressure indicator
D	Pressure building coil
I	Inner vessel
IN	Insulation
LI	Level indicator
L/11-1	Pipeline discharge
L/11-2	Pipeline discharge (plugged)
L/11-3	Pipeline discharge (plugged)
NRV	Non return valve
O	Outer vessel
PC	Pressure controller
PI	Pressure indicator
RV/O	Relief valve-outer vessel
SV1, SV2	Safety valve
(1)	only T ... V110 - T ... V800
(2)	only T18 V200 - T18 V800

Valves, standard

1	Filling
2	Pressure building valve
3	Vent valve
4	Bottom gauge (+)
5	Gauge bypass
6	Top gauge (-)
9-1	Evacuation connection
11	Discharge
12	Top filling
13	Gas shut-off
18	Change over
21	Trycock

Options

SAA	Safety shut-off valve, control line for SAA
LI(T)	Level indicator Samson Media 6 incl. instrument panel and standard programming, extra programming of Samson Media 6 acc. to customer requirements
LI(T)	Level indicator WIKA with transmitter output 4 - 20 mA

10 https://www.linde-engineering.com/en/images/P_3_3_e_12_150dpi_tcm19-5774.pdf

Patents - 6,782,339 • 6,944,570

Interchangeable gauge systems with digital telemetry capable gauge and flexible stainless steel interconnection lines.

Combination pressure building/economizer regulator for easy in-field adjustments.

Long-life extended stem packing pressure builder and economizer isolating valves are standard on the VS-01 series.

Liquefied gases are store at ultra-cold temperatures in a vacuum insulated tank. Controls on the tank keep the pressure at optimum levels to assure proper liquid delivery to the application.Vacuum insulated pipe connects the tank’s liquid withdrawal to the application equipment. The pipe is the foundation for the system’s heat-loss efficiency and long-term integrity. It must be engineered to work with the associated controls and accessories.

Modular Piping Design Advantages 11

- Reduces your life-cycle costs by reducing the number of external piping joints, minimizing the risk of external piping leaks and the cost to repair.

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11 Bulk Storage Product Catalog

- Simple by design yet robust and able to support a broad range of customer applications.
- Combination pressure building/economizer regulator for easy pressure adjustment and extended bonnet bronze control valves for ease of operation.
- Piping modules designed for ease-of-access to all operational control valves with stainless steel inter- connecting piping for improved durability.

High performance safety system with dual relief valves and rupture disks supplied as standard

New, innovative vertical fin pressure building system improves performance, while reducing frost and ice build up to further reduce your maintenance costs

Dual regulator economizer and pressure builder supplied as standard.

Full-trycock and economizer valves come standard with non-extended packing

Densities at Various Saturation Pressures

	OXYGEN		NITROGEN		ARGON	
Saturation Pressure PSIG	Liquid Density Lbs/Ft^3	Gas Density SCF/Gal	Liquid Density Lbs/Ft^3	Gas Density SCF/Gal	Liquid Density Lbs/Ft^3	Gas Density SCF/Gal
0	71.17	115.10	50.44	93.11	87.51	112.50
5	70.42	113.72	49.62	91.55	85.77	110.89
10	69.80	112.73	49.00	90.40	84.77	109.60
25	67.86	109.59	47.50	87.63	82.46	106.61
50	65.55	105.86	45.69	84.18	79.90	103.31
75	63.76	102.97	44.19	81.53	77.90	100.71
100	62.43	100.82	42.88	79.12	76.15	98.45
150	59.80	96.57	40.70	75.08	73.16	94.59
200	57.62	93.05	38.76	71.51	70.28	90.87
250	55.60	89.79	36.83	67.95	67.79	87.65

Note: Density of water at 60°F = 62.30 lbs/cu ft

Conversion Data

Oxygen

	Weight		Gas		Liquid	
	Pounds (Lb)	Kilograms (Kg)	Cubic Feet (SCF)	Cubic Meters (Nm^3)	Gallons (Gal)	Liters (L)
1 Pound	1.0	0.4536	12.076	0.3174	0.1050	0.3977
1 Kilogram	2.205	1.0	26.62	0.6998	0.2316	0.8767
1 SCF Gas	0.08281	0.03756	1.0	0.02628	0.008691	0.0329
1 Nm^3 Gas	3.151	1.4291	38.04	1.0	0.3310	1.2528
1 Gal Liquid	9.527	4.322	115.1	3.025	1.0	3.785
1 L Liquid	2.517	1.1417	30.38	0.7983	0.2642	1.0

SCF (Standard Cubic Foot) gas measured at 1 atmosphere and 70°F. Nm^3 (normal cubic meter) measured at 1 atmosphere and 0°C.
Liquid measured at 1 atmosphere and boiling temperature.

مواصفات خزان الأوكسجين السائل كما يلي:

لا.	نموذج	متوسط	البعد (مم)	الوزن (كلغ)
1	CFL-5 / 0.8	LO2	Φ1916 * 5262	3940
2	CFL-10 / 0.8	LO2	Φ2316 * 5981	5970
3	CFL-15 / 0.8	LO2	Φ2316 * 8035	8045
4	CFL 20 / 0.8	LO2	Φ2716 * 7377	9855
5	CFL-30 / 0.8	LO2	Φ2920 * 8904	14025
6	CFL-50 / 0.8	LO2	Φ3220 * 11204	21570
7	CFL-100 / 0.8	LO2	Φ3424 * 18466	38300
8	CFL-150 / 0.8	LO2	Φ3728 * 22128	54700

- Choice 1:

https://www.alibaba.com/product-detail/5m3-8-bar-new-vertical-liquid_62150227966.html?spm=a2700.galleryofferlist.normal_offer.d_title.7011710cmDfcd2

5m3 8 bar new vertical liquid oxygen tank Manufacturer

FOB **Reference** Price: Get Latest Price

$10,000.00 - $20,000.00 / Set | 1 Set/Sets (Min. Order)

Model Number: CFL-5/0.8mpa

Warranty: **1 Year** for machinery warranty

Lead Time:

Quantity(Sets)	1 - 1	>1
Est. Time(days)	45	Negotiable

Customization: Customized logo (Min. Order: 1 Sets)
Customized packaging (Min. Order: 1 Sets) More

Overview

Quick Details

Capacity:	5~120 M3	Condition:	New
Applicable Industri...	Manufacturing Plant, Food & Beverage Factory, Energy & Mining	Place of Origin:	Henan, China
Brand Name:	Chengde	Dimension(L*W*H):	5130*2000*2000
Weight:	3412	Certification:	CE,ASME,ISO9001
Warranty:	1 Year	After-sales Service ...	Field installation, commissioning and training, Online support
Working Pressure:	0.8MPa	Effective Capacity:	5m3
Inner Material:	S30408	Outer Material:	Q345R
Loading medium:	LIN,LO2,LN2,LAr	Standard:	as your requirement
Filling Rate:	0.95	Color:	White or Customer's Request
Type:	Vertical		

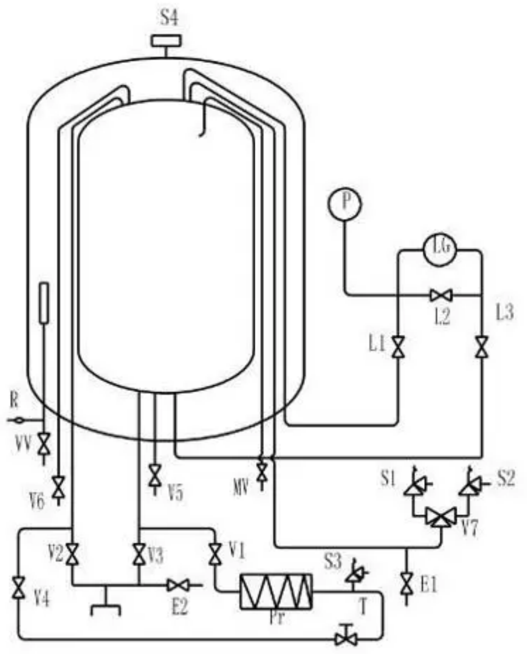
Specification

Item	Effective Volume (m3)	Max Working Pressure (Mpa)	Working medium	Size (mm)	Weight (KGS)
CFL-5/0.8	5	0.8	Liquid oxygen Liquid argon Liquid nitrogen LNG	Φ2000×5130	~3412
CFL-5/1.6		1.6		Φ2000×5130	~3945
CFL-5/0.2		0.2		Φ2000×5130	~3461
CFL-10/0.8	10	0.8	Liquid oxygen Liquid argon Liquid nitrogen LNG	Φ2100×7170	~5378
CFL-10/1.6		1.6		Φ2000×7895	~6787
CFL-10/0.2		0.2		Φ2100×7130	~5895
CFL-15/0.8	15	0.8	Liquid oxygen Liquid argon Liquid nitrogen LNG	Φ2500×6950	~6415
CFL-15/1.6		1.6		Φ2400×7552	~8628
CFL-15/0.2		0.2		Φ2500×6950	~7876
CFL-20/0.8	20	0.8	Liquid oxygen Liquid argon Liquid nitrogen LNG	Φ2500×8756	~8255
CFL-20/1.6		1.6		Φ2400×9371	~10744
CFL-20/0.2		0.2		Φ2500×8756	~9284
CFL-30/0.8	30	0.8	Liquid oxygen Liquid argon Liquid nitrogen LNG	Φ2900×8870	~12899
CFL-30/1.6		1.6		Φ2700×8960	~20392
CFL-30/0.2		0.2		Φ2900×8900	~16093
CFL-50/0.8	50	0.8	Liquid oxygen Liquid argon Liquid nitrogen LNG	Φ3100×12058	~18960
CFL-50/1.6		1.6		Φ3000×12760	~21590
CFL-50/0.2		0.2		Φ3100×12060	~19662
CFL-100/0.8	100	0.8	Liquid oxygen Liquid argon Liquid nitrogen LNG	Φ3600×17250	~45218
CFL-100/1.6		1.6		Φ3600×17250	~57258
CFL-100/0.2		0.2		Φ3600×17250	~38655

المسافات الآمنة لتعرض صهاريج الأكسجين المُسال لإحتمالات التسريب أو الإنسكاب	حتى 20 طن (متر)	أكبر من 20 طن (متر)
عن الأماكن المسموح فيها بالتدخين أو إشعال النيران	5	8
عن أماكن التجمعات العامة	10	15
عن المكاتب، و المقاصف، و الأماكن المشغولة بالأشخاص	5	8
عن الحفر، و القنوات، و مصارف المياه السطحية (غير المستغلة)	5	8
عن الفتحات المؤدية إلى الأنظمة الموجودة تحت الأرض	5	8
عن حدود الملكية	5	8
عن الطريق العام	5	8

15	10	عن السكك الحديدية
8	5	عن أماكن إنتظار السيارات (غير المُرَخَّصَة)
15	15	عن الإنشاءات الخشبية الضخمة
8	5	عن المخزونات الصغيرة من المواد القابلة للإشتعال، و كرافانات المواقع، و ما إلى ذلك
8	5	عن معدات التشغيل (التي ليست جزء من منظومة شبكة الغازات الطبية)
3	3	عن خطوط الغازات القابلة للإشتعال
15	15	عن فلانشات خطوط الغازات القابلة للإشتعال (المقاسات التي تتعدى 50 mm)
8	5	عن مواسير تنفيس الوقود الغازي
8	5	عن مآخذ هواء الكباسات و أجهزة التنفس الصناعي
5	5	عن إسطوانات الوقود الغازي (التي تصل إلى 70 m^3)
7.5	7.5	عن صهاريج تخزين وقود الغاز المُسال (التي تصل إلى 4 أطنان)
15	15	عن صهاريج تخزين وقود الغاز المُسال (التي تصل إلى 60 طن)
7.5	7.5	عن صهاريج تخزين الوقود السائل (التي تصل إلى 7.8 m^3)
15	15	عن صهاريج تخزين الوقود السائل (التي تصل إلى 117 m^3)
8	5	عن محطات الجهد العالي HV و الجهد المتوسط MV الفرعية

Cryogenic Liquid Storage Tank Flow Chart (B)



V1	Pressure building valve	V2	Upper inlet valve	V3	Lower inlet valve	V4	Gas passing valve
V5	Liquid Outlet valve	V6	Gas return valve	V7	3-way switch valve	R	Vacuum tube
VV	Vacuum Valve	MV	Full measuring valve	E1	Vent valve	E2	Raffinate vent valve
Pr	Turbo charger	T	Pressure regulating valve	S1	Inner tank safety valve	S2	Inner tank safety valve
S3	Inner tank safety valve	S4	Outer tank safety device	L1	Liquid gauge upper valve	L2	Balancing valve
L3	Liquid gauge lower valve	P	Pressure Gauge	LG	Liquid Level Gauge		

Xinxiang Chengde Energy Technology Equipment Co., Ltd

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CNCD 新乡市诚德能源科技装备有限公司
Xinxiang Chengde Energy Technology Equipment Co.,Ltd.

1. Loading medium: LN2, LO2, LAr, LNG, LPG, etc.
2. Effective Volume: 20m^3
3. Working pressure: 0.8 MPa
4. Overall dimension: Φ3000*6100mm
5. Cylinder design temperature: -196℃
6. Shell material:Outer jacket: Q245-R; Inner: S30408.
7. Insulation: Vacuum powder insulation
8. Filling rate: 0.95
9. Relief Valve: All valves are high grade Chinese valves.
10. Delivery date: Within 60 days after received pre-payment,or more shorter time.
11. Payment model: We can negotiate,we suggest TT,LC.
12. Documents: Bill of Loading, Invoice, Packing list, Contract (3 originals).

الطرف أ: معلمات المنتجات

15CBM 0.8Mpaعموديخزان مبرد

1.وسيط التحميل: LAr ، Ln2 ، Lo2

2.إجمالي الحجم: 15.789 م³الحجم الفعال: 15.0 م³

3. ضغط التصميم: 0.8 ميجا باسكالضغط العمل: 0.8 ميجا باسكال

4. البعد الكلي: 002500 × 6912 مم

5.درجة حرارة تصميم الاسطوانة الخارجية: 60 °Cدرجة حرارة تصميم الاسطوانة الداخلية: -196 °C

6. قذيفة المواد: سترة الخارجي: Q245-R ، الداخلية: S30408.

7.عزل: فراغ مسحوق العزل

8.الوزن الفارغ: حوالي 6415 كجم

9. معدل التعبئة: 0.95

10.صمام الإغاثة: جميع الصمامات عبارة عن صمامات صينية عالية الجودة. 12

Cryogenic Liquid Storage Tank							
Model	**Volume(M3)**	**Pressure(MPa)**	**Size(mm)**	**Weight(kg)**	**Material**	**Medium**	**Filling rate**
CFL-5/0.8	5		φ2000*5130	3412			
CFL-10/0.8	10		φ2100*7170	5378			
CFL-15/0.8	15		φ2500*6912	6415			
CFL-20/0.8	20	0.8	φ3000*6100	8673			
CFL-30/0.8	30		φ2900*8870	12899			
CFL-50/0.8	50		φ3100*12058	18960			
CFL-100/0.8	100		φ3600*15947	34480	Outer:Q245-R Inner:S30408	LO2/LAR/LN2	
CFL-5/1.6	5		φ2000*5130	3945			
CFL-10/1.6	10		φ2000*7895	6787			
CFL-15/1.6	15	1.6	φ2400*7552	8628			95%
CFL-20/1.6	20		φ2400*9371	10744			
CFL-30/1.6	30		φ2700*10310	14640			
CFL-50/1.6	50		φ3100*12058	23370			

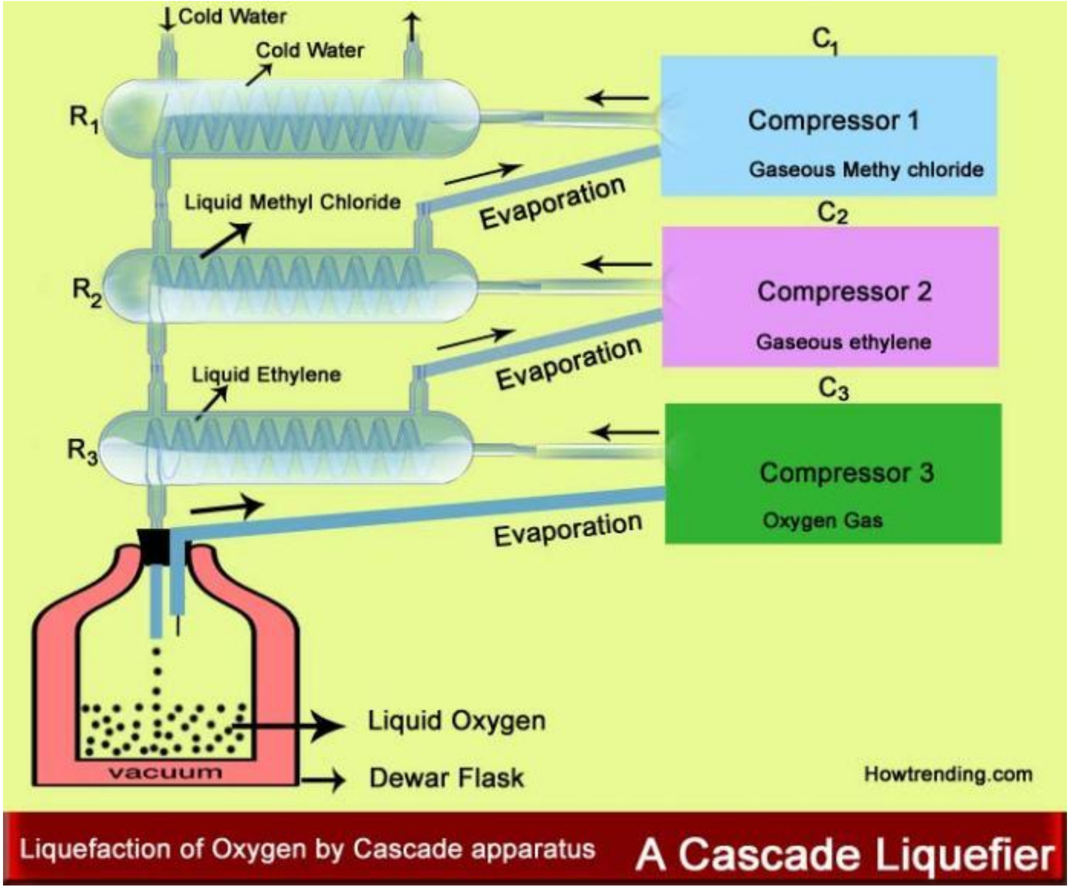
13

- Another method of Oxygen liquefaction

12 http://ar.cncdtank.com/cryogenic-tank/5000l-oxygen-liquid-tank.html

13 http://ar.cncdtank.com/news/safety-use-standards-that-liquid-oxygen-storag-26472706.html

Cascade system for Liquefaction of Oxygen Gas or Cascade Liquefier or Apparatus for Liquefaction of Oxygen Gas.14



As you can see in the above figure that, before getting liquid oxygen many stages of liquefaction are used. That's why we called it a cascade system or a Cascade liquefier, which is used to liquefy Oxygen or air.

As you know this process is first used by **Pictet** after sometime **K Onnes (Kamerlingh Onnes**) used this apparatus.

7.8.1 About the Apparatus

1. In this apparatus, three compressors C_1, C_2, C_3 are used to fulfill the requirement of sufficient pressure. Also, the C_1, C_2, and C_3 have a suction side which is used during the process.
2. Three condensers R_1, R_2, R_3 are used, into which three refrigerants cold water, Methyl chloride, and ethylene are used to get the desired result.
3. The Liquid oxygen is collected in the last, into a Dewar flask.

14 https://www.howtrending.com/liquefaction-of-gases/

7.8.2 Principles

This apparatus work on two principles.

1. The first, Principle, compression of gases below its critical temperature resulting in a change to liquid.
2. Second is, producing cooling by the principle of evaporation of liquids.

7.8.3 How does it work?

First, the gaseous methyl chloride (CH_3Cl) is pumped by the compressor C_1 into the spiral tube. The refrigerant in condenser R_1 surrounding this tube starts liquefying the methyl chloride.

This is because the critical temperature of methyl chloride is 143°C, which is more than room temperature as well.

Now the liquid methyl chloride comes in Condensor R_2 through the tube. Here one portion of condenser R_2 is connected with the suction side of compressor C_1.

Here due to the evaporation of liquid methyl chloride in reduced pressure, more cooling as a result produced, and the temperature of condenser R_2 decreases more.

The evaporated methyl chloride return back to the compressor C_1 through the suction side of the compressor.

Now the gaseous ethylene (C_2H_4) pumped by the compressor C_2 into the next spiral tube.

Here the refrigerant, liquid methyl chloride which is achieved in the previous stage, surrounding the tube which contains gaseous ethylene, starts to convert this gas into liquid ethylene.

This is because the critical temperature of ethylene is around 9.2°C.

Now, this liquid ethylene comes in Condensor $R_{3,}$ and one portion of R_3 condenser connected with the suction side of compressor C_2.

Here evaporation of liquid ethylene takes place in reduced pressure like in the previous stage, and the evaporated ethylene return back to the compressor C_2 through the suction side of the compressor.

Therefore, due to the evaporation process more cooling produced into the condenser R_3, which is more than the cooling that we achieved in Condenser R_2.

This cooling has a temperature of around −160°C.

Now, the oxygen (which is in gaseous form) is pumped by the compressor C_3 into the next spiral tube.

Here, due to the very low temperature inside the Condenser R_3 the oxygen gas into the spiral tube starts converting into liquid and later collected into a Dewar flask.

This is because the critical temperature of oxygen gas is around −118°C.

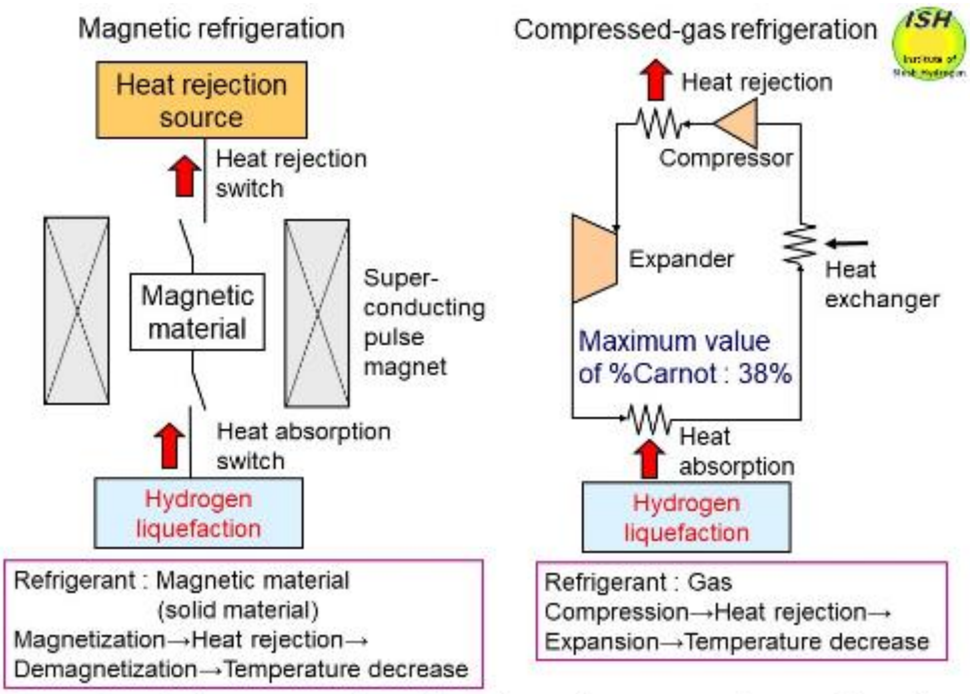
Here, likewise the previous stages, the evaporated oxygen return back to the compressor C_3 through the suction side of the compressor.

If we continue this cascade system, we can liquefy air and other gases like Nitrogen, etc.

Note: But by this system, we cannot liquefy the gases that have very low critical temperatures, such as Hydrogen (T_c around −240 °C) and Helium (T_c around −267.8 °C).

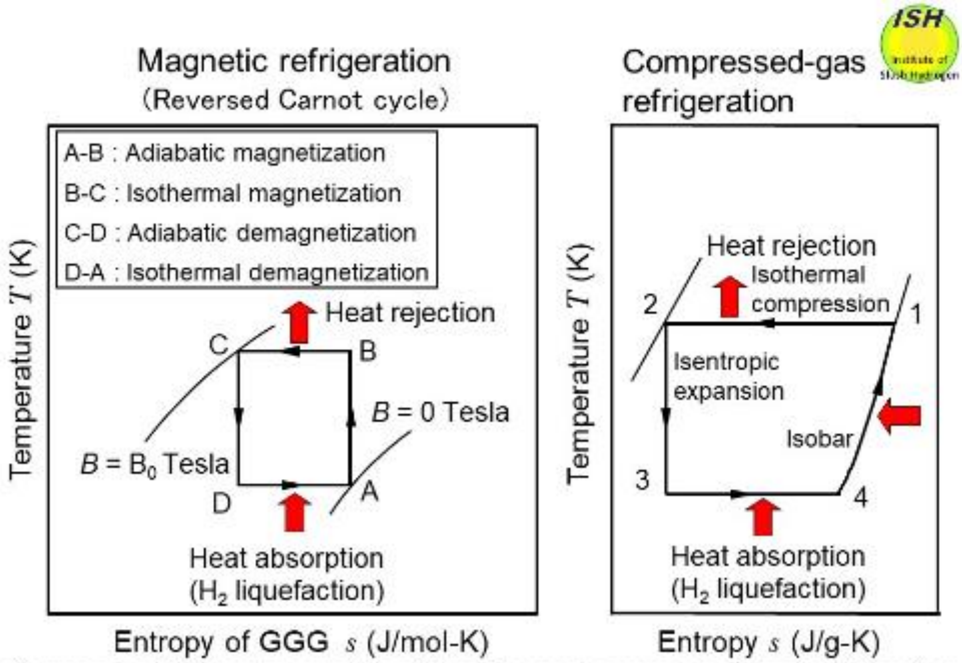
- Liquefaction of hydrogen

The principles of magnetic refrigeration and compressed-gas refrigeration are presented in the below figure. The temperature-entropy diagrams of magnetic material and gas as a refrigerant in liquefaction cycle are respectively shown in the below figure. The magnetic refrigeration for hydrogen liquefaction uses an external magnetic field to magnetize and demagnetize a magnetic material in repeated cycles, thus producing low temperatures through the magnetocaloric effect.

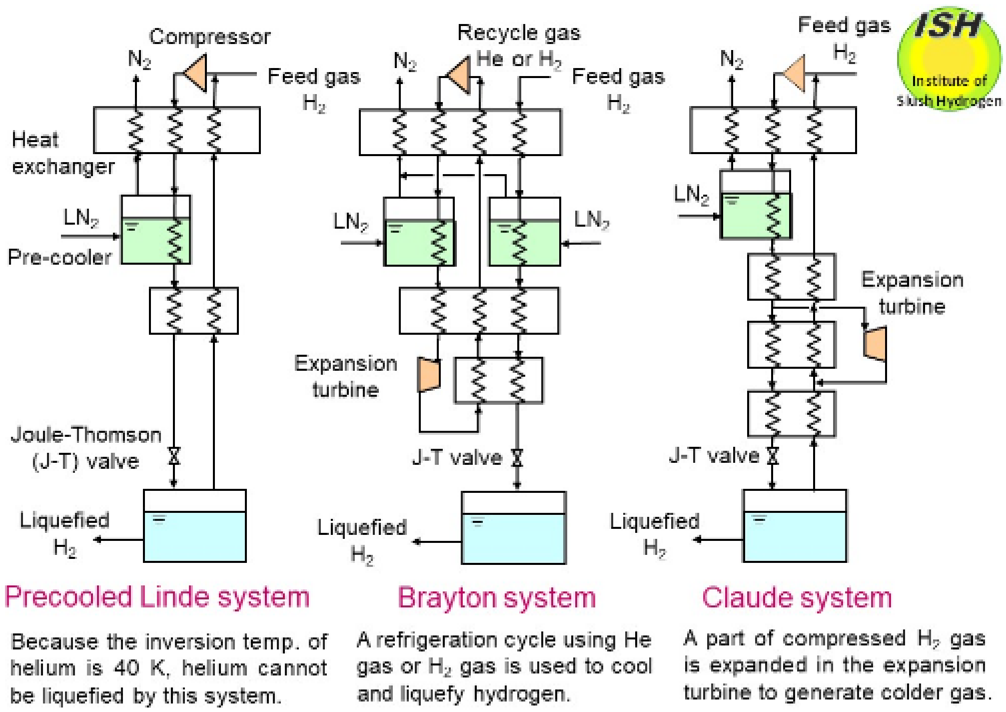


Comparison between magnetic refrigeration and compressed-gas refrigeration. [15]

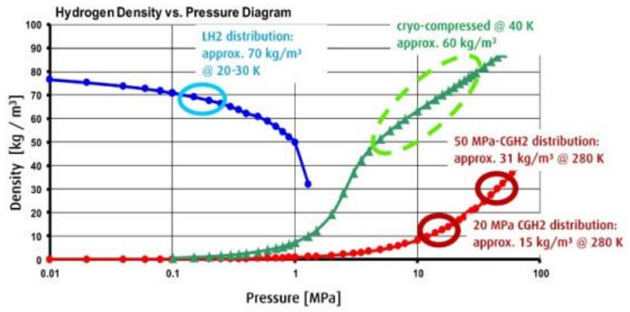
15 https://slush-ish-mag-english.com/technology2.html



Comparison between magnetic refrigeration and compressed-gas refrigeration (temperature-entropy diagram).



Simplified typical hydrogen liquefaction systems.

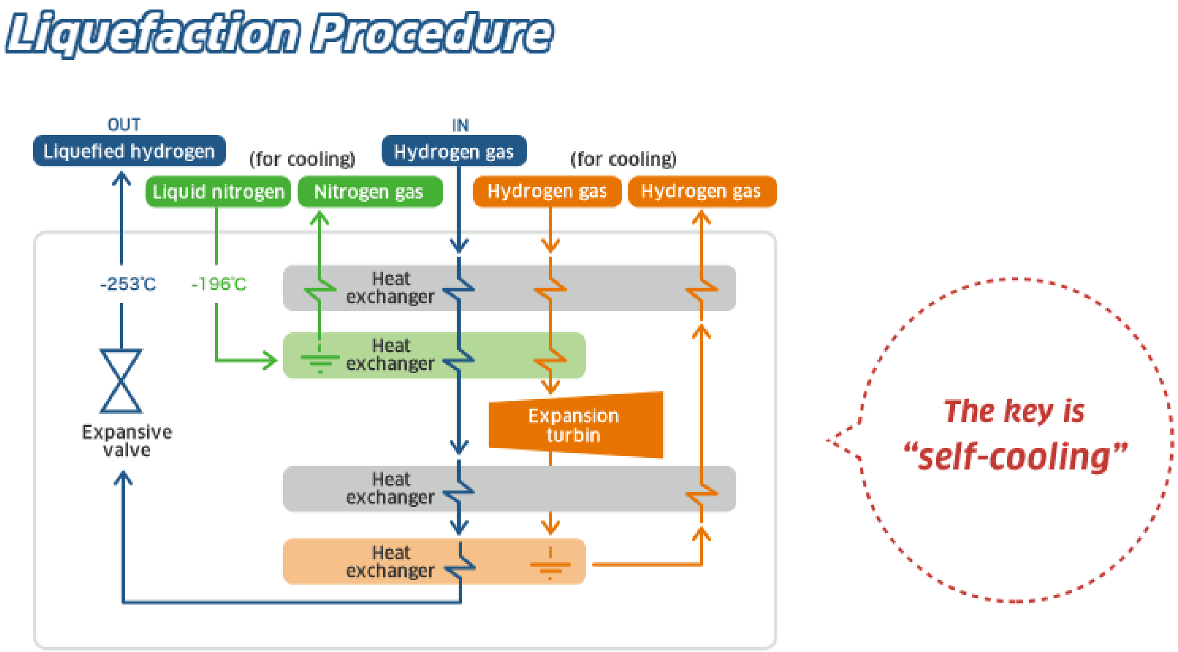


Comparison of hydrogen density in storage form of hydrogen 16

- Liquefaction of hydrogen by compressed-gas

http://sadanaresearch.com/liquid-helium-generator-overview/ !

https://vorbuchner.com/en/helium-liquefaction/



17

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16 https://www.jstra.jp/seminar/PDF/English_Report%20of%20The%202nd%20International%20Workshop%20on%20Liquefied%20Hydrogen%20Technology.pdf

17 https://global.kawasaki.com/en/stories/articles/vol57/

Compounds	T_c , K	P_c, atm	Z_c	Compounds	T_c , K	P_c, atm	Z_c
ميثانMethane	191	45.8	0.290	الكحول الميثيليMethyl Alcohol	513	78.5	0.220
إيثانEthane	306	48.2	0.284	كلوريد الميثيلMethyl Chloride	416	65.9	0.276
بروبانPropane	370	42.0	0.276	Methyl Ethyl Ketone	533	39.5	0.26
بيوتانn-Butane	425	37.5	0.274	التولوينToluene	594	41.6	0.270
أيزوبيوتانIso-butane	408	36.0	0.282	Tri-Chloro Fluoro Methane (11فريون)	471	43.2	0.277
بنتانPentane	470	33.3	0.268	Tri-Chloro Trifluoro Ethane(13 فريون)	487	33.7	0.274
أيزوبنتانIso-pentane	461	32.9	0.268	بروم Bromine (Br_2)	584	102	0.307
Neo-pentane	434	31.6	0.260	كلورChlorine, Cl_2	417	76.1	0.276
هكسانHexane	508	29.9	0.264	هيليومHelium (He)	5.3	2.26	0.300
هبتانHeptane	540	27.0	0.260	هيدروجينHydrogen (H_2)	33.3	12.8	0.304
أوكتانOctane	569	24.6	0.258	نيونNeon (Ne)	44.5	26.9	0.307
إيثيلينEthylene	282	50.0	0.268	نيتروجينNitrogen (N_2)	126.0	33.5	0.291
بروبيلينPropylene	365	45.6	0.276	أكسجينOxygen (O_2)	155	50.1	0.29
بيوتين1- Butene	420	39.7	0.276	نشادر (أمونيا) Ammonia (NH_3)	406	111	0.242
١- بنتين1-Pentene	474	40.0	-	ثاني أكسيد الكربون Carbon Dioxide (CO_2)	304	72.9	0.276
حامض الخليك Acetic Acid	595	57.1	0.200	أول أكسيد الكربون Carbon Monoxide (CO)	133	34.5	0.294
أسيتونAcetone	509	46.6	0.237	هيدرازينHydrazine	653	145	-
أسيتيلينAcetylene	309	61.6	0.274	كلوريد الهيدروجين Hydrogen Chloride (HCl)	325	81.5	0.266
بنزينBenzene	562	48.6	0.274	كبريتيد الهيدروجين Hydrogen Sulfide (H_2S)	374	88.9	0.284
1,3-Butadiene	425	42.7	0.270	أكسيد النيتريكNitric Oxide (NO)	180.0	64	0.25
هكسان حلقي Cyclohexane	553	40.0	0.271	أكسيد النيتروزNitrous Oxide (N_2O)	310	71.7	0.271
Dichloro-difluoro methane	385	39.6	0.273	كبريتSulfur (S)	1313	116	-
إيثيلينEthylene	282	50.0	0.268	ثاني أكسيد الكبريت Sulfur Dioxide (SO_2)	431	77.8	0.268
ثنائي إيثيل إيثر Diethyle Ether	467	35.6	0.261	ثالث أكسيد الكبريت Sulfur Trioxide (SO_3)	491	83.8	0.262
كحول إيثيلي Ethyl Alcohol	516	63.0	0.249	ماءWater (H_2O)	647	218	0.320
Ethylene أكسيد الإيثيلينOxide	468	71.0	0.25				

- Methane liquefaction
    - Characteristics of Methane

Table 1 Properties of Principal Cryogens

P=1bar =100 KPa

Name	Normal Boiling Point T (K)	Liquid Density (kg/m³)	Latent Heat (J/kg·mole)	Critical Point T (K)	Critical Point P (kPa)	Triple Point T (K)	Triple Point P (kPa)	Reference
Helium	4.22	123.9	91,860	5.28	227			1
Hydrogen	20.39	70.40	902,300	33.28	1296	14.00	7.20	2, 3
Deuterium	23.56	170.0	1,253,000	38.28	1648	18.72	17.10	4
Neon	27.22	1188.7	1,737,000	44.44	2723	26.28	43.23	5
Nitrogen	77.33	800.9	5,579,000	126.17	3385	63.22	12.55	6
Air	78.78	867.7	5,929,000					7, 8
Carbon monoxide	82.11	783.5	6,024,000	132.9	3502	68.11	15.38	9
Fluorine	85.06	1490.6	6,530,000	144.2	5571			10
Argon	87.28	1390.5	6,504,000	151.2	4861	83.78		11, 12, 13
Oxygen	90.22	1131.5	6,801,000	154.8	5081	54.39	0.14	6
Methane	111.72	421.1	8,163,000	190.61	4619	90.67	11.65	14
Krypton	119.83	2145.4	9,009,000	209.4	5488	116.00	73.22	15
Nitric oxide	121.50	1260.2	13,809,000	179.2	6516	108.94		
Nitrogen trifluoride	144.72	1525.6	11,561,000	233.9	4530			
Refrigerant-14	145.11	1945.1	11,969,000	227.7	3737	89.17	0.12	16
Ozone	161.28	1617.8	14,321,000	261.1	5454			
Xenon	164.83	3035.3	12,609,000	289.8	5840	161.39	81.50	17
Ethylene	169.39	559.4	13,514,000	282.7	5068	104.00	0.12	18

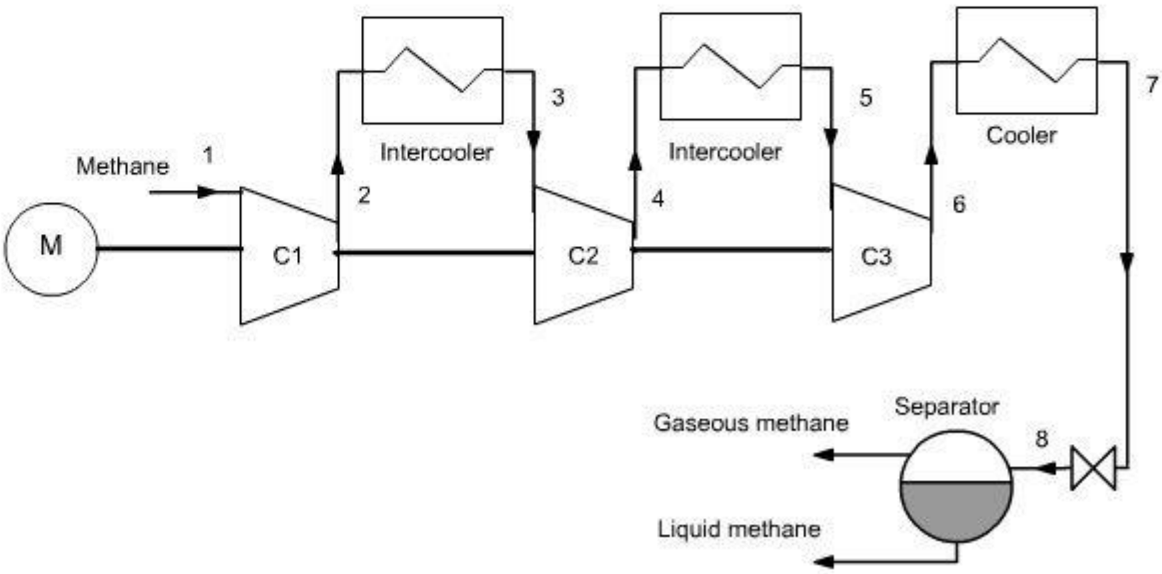
- Methane liquefaction basic cycle18

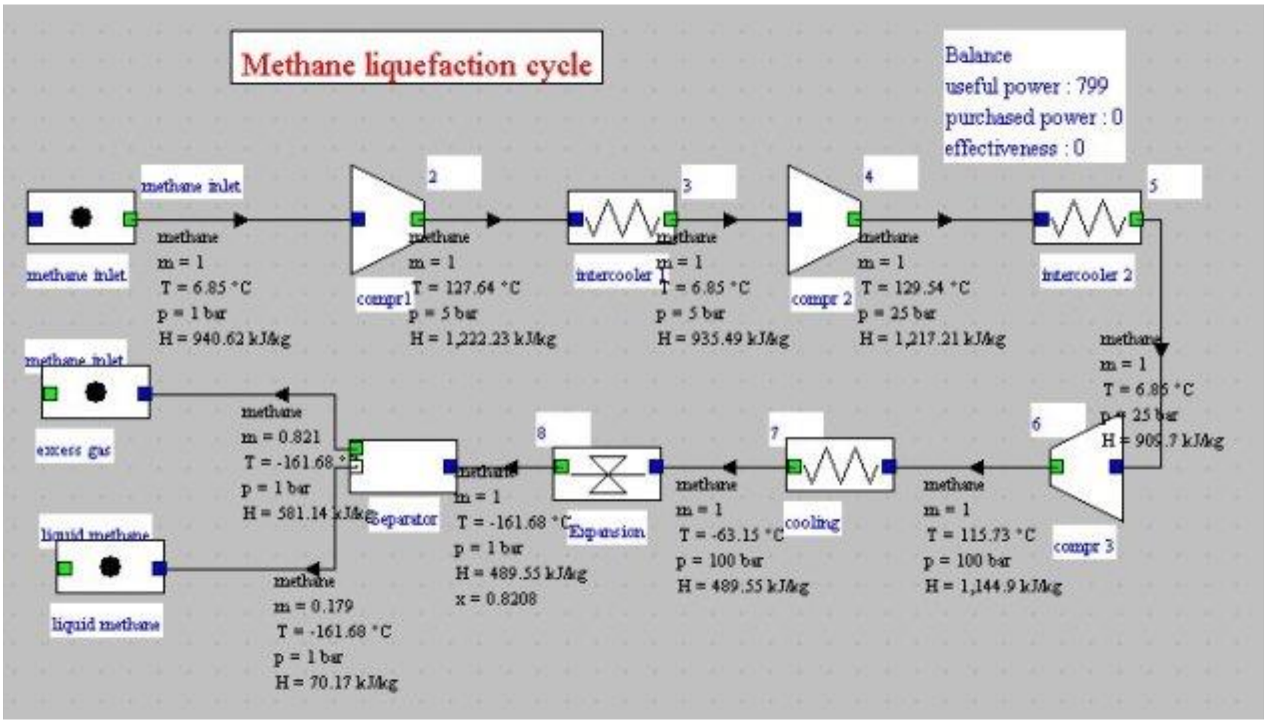
To liquefy natural gas methane taken at 1 bar and 280 K is compressed to 100 bar and then cooled to 210 K (it is assumed in this example that a refrigeration cycle is available for that).

Isentropic compression is assumed, but the very high compression ratio requires the use of several compressors (3 in this example) with intermediate cooling at 280 K. Intermediate pressures are equal to 5 and 25 bar.

The gas cooled at 210 K is isenthalpically expanded from 100 bar to 1 bar, and gas and liquid phases separated. As shown in the diagram in Figure below, the methane enters in the upper left, and liquid and gaseous fractions exit in the bottom right.

18 https://direns.mines-paristech.fr/Sites/Thopt/en/co/cryogenie.html



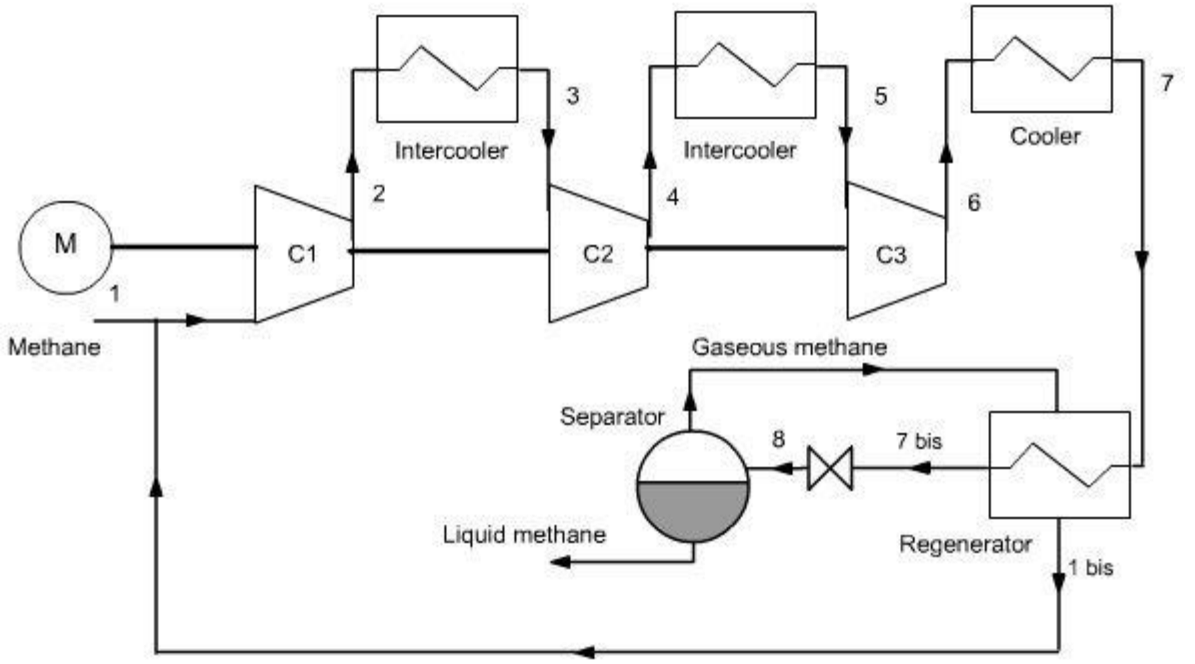


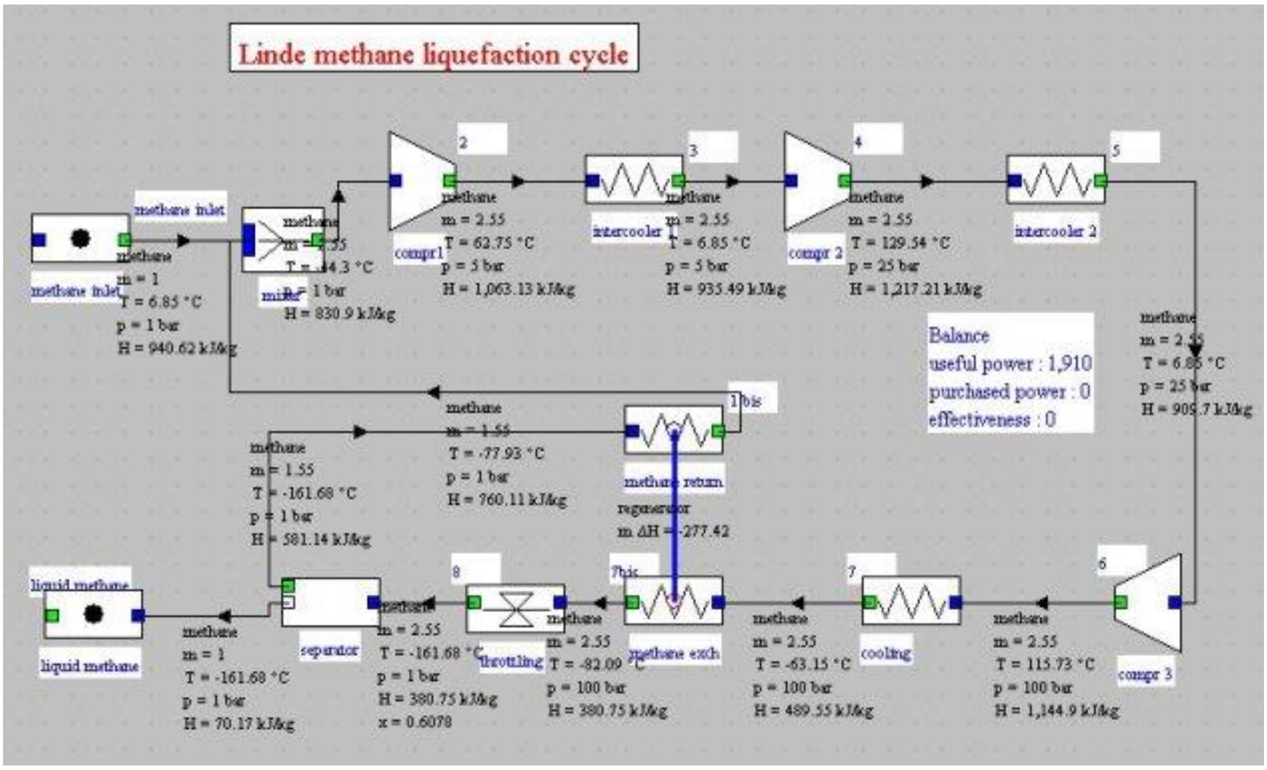
The compression work required per kilogram of methane sucked is 798.5 kJ, and 0.179 kg of liquid methane is produced, which corresponds to a work of 4.46 MJ per kilogram of liquefied methane.

- <u>Linde cycle</u>

The Linde cycle (Figure below) improves the previous on two points:

- gaseous methane is recycled after isenthalpic expansion;
- we introduce a heat exchanger between the gaseous methane and methane out of the cooler in order to cool the compressed gas not at 210 K but at 191 K.





- Conclusion related to methane liquefaction:

Each gas has a temperature it cannot be flushed over whatever the pressure. This temperature is known as critical temperature, and critical pressure is the pressure needed to liquefy the gas at the critical temperature of the gas.

Linde cycle can be applied to hydrogen gas, methane as well as oxygen, with consideration given to the critical point of each. Oxygen gas needs a temperature of 90 K (1 bar) to be in the liquid state, or it needs a pressure higher than 51 bar and a temperature of 154 K.

As for hydrogen gas, it needs a temperature of 20 K (atm pressure 1 bar) to become in the liquid state, or it needs a pressure higher than 13 bar and a temperature of 33 K.

Finally, for gas, methane needs 110 K (1 bar air pressure) to become in the liquid state, or it needs a pressure higher than 46.2 bar and a temperature of 190 K.

8 COMPRESSORS

Various types of compressors are used in the oil and gas industry and the same can be said about the medical, dental and pharmaceutical industries.

Their variety ensures that each is specifically tailored to serve a particular purpose and to the best of its ability.

That being the case, the review of main types of compressors and their applications will give you a good knowledge of the best out there whose level of performance is on par with what you’re out to get.[19]

19 https://kbdelta.com/blog/main-types-of-compressors.html

8.1 WHAT IS A COMPRESSOR?

A compressor is also known as a Heating, Ventilation & Air-Conditioning (HVACR) machine.

It is a mechanical device that reduces the volume of a fluid such as gas or liquid while at the same time increasing its temperature and pressure.

A compressor features two major components and these are the power source and a compressing mechanism (for example piston and vanes).

What's more, these machines are similar to gas pumps because they transport compressed gas through pipes.

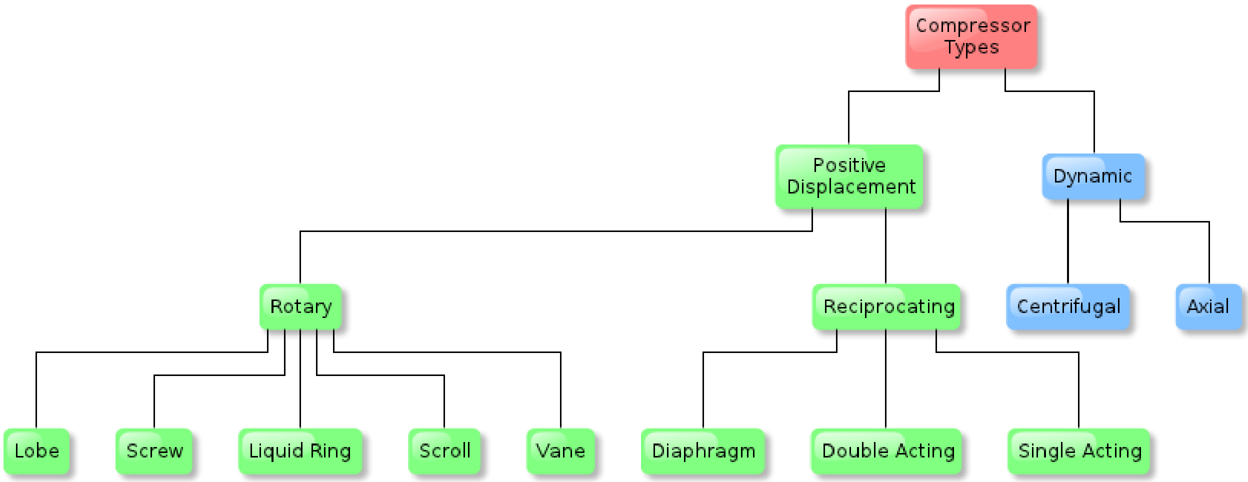
The latter has aided in the compression of natural gas in the oil and gas industry where the gas is pressurized in order to meet with the standards of certain jurisdictions that require at least 95 percent of the gas in petroleum to be compressed.

It is also worthy to note that certain factors influence a compressor's performance and these are:

- Speed of rotation
- Pressure at suction
- Pressure at discharge
- Type of refrigerant used

8.1. THE BASIC TYPES OF COMPRESSORS

A list of the major types of compressors by mechanical design has been outlined below and the feature of each, aids in its functionality.



Now, the best way to get a good idea of these devices is to compare them side by side and as such, a comparison between different types of compressors, how they work, and when to use them has also been given in this section.

Therefore, the two basic types of compressors are:

1. Positive displacement compressors
2. Dynamic compressors

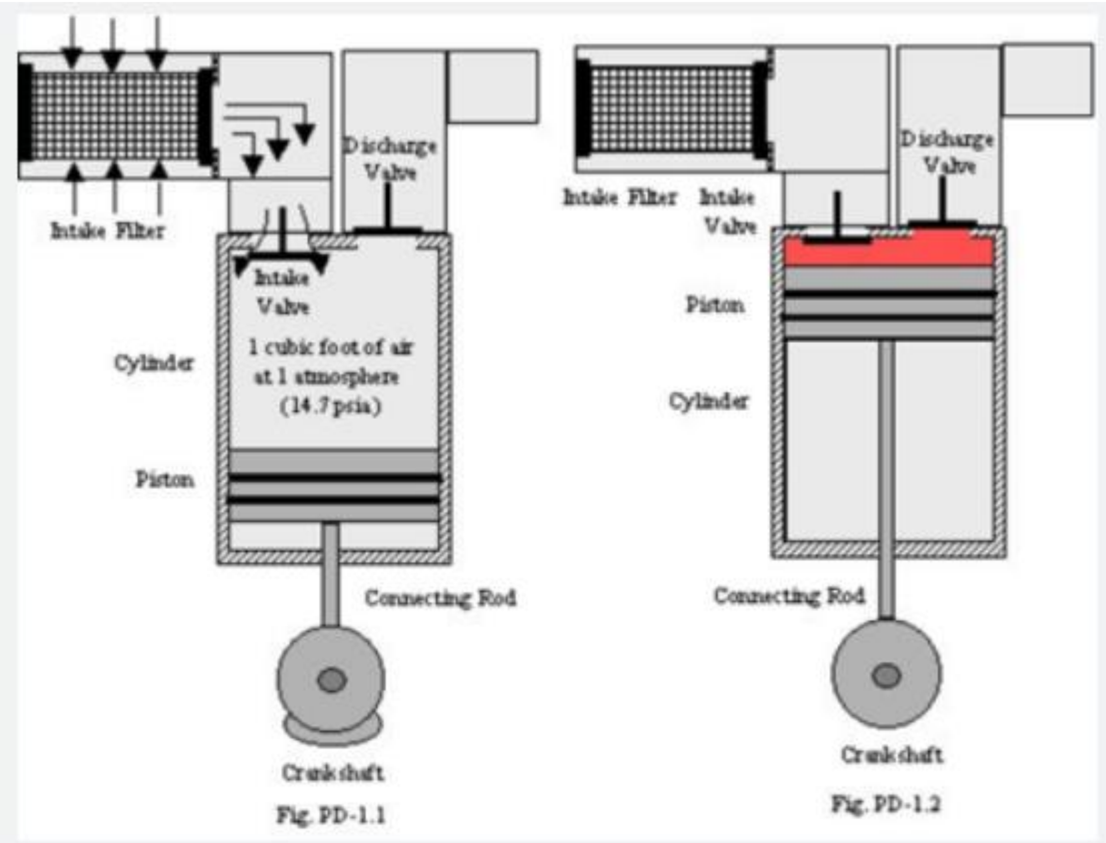
8.1.1. POSITIVE DISPLACEMENT COMPRESSORS

In positive displacement compressors, gases are compressed due to the displacement of a mechanical linkage which reduces its volume.

First off, a certain amount of gas is passed into a confined space and the volume or space is subsequently reduced which helps to boost the gas' pressure levels.

The gas is then released into a discharge piping or vessel system once the pressure has been raised.

If you're wondering why this displacement is called positive in the first place, then reference can be made to thermodynamics where a displacement caused by the movement of a piston (as is the case of a reciprocating compressor) is known to be positive.



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The movement can also be caused by rotation as is the case of a twin helical screw-rotating machine.

Consequently, the types of positive displacement compressors are:

A) Reciprocating compressors
B) Rotary compressors

8.2.1.A) RECIPROCATING COMPRESSORS

Reciprocating compressors or piston compressors feature one or more pistons which are driven by a crankshaft; a component that also drives the piston rod, and connecting rod.

As the piston within the cylinder moves back and forth, the pressure of the gas is increased. This, in turn, helps in its compression. The compressed gas is then discharged into high pressure receiving tanks.

On the other hand, this positive displacement compressor can also be driven by electric motors or internal combustion engines.

They can be fixed to a particular location or portable enough to be moved around.
In terms of their horsepower, small compressors operate within the range of 5 to 30 horsepower (hp) and they are mostly used in the automobile sector of the economy.

Large compressors, on the contrary, have a horsepower above 1,000 hp (750 kW). They are available in the oil and gas industry and generally in large industrial applications.

- TYPES OF RECIPROCATING COMPRESSORS

The various types of Reciprocating compressors are:

- Single-cylinder: A single cylinder reciprocating compressor features a suction, discharge area and compression. A double cylinder comes with dual suction, discharge areas, and compression, and it helps to achieve higher gas pressures.
- Multi-cylinder: While double cylinders are prevalent, there are instances where compressors are designed with as many as six cylinders.

20 https://cascousa.com/compressed-air-101/types-of-compressors/positive-displacement-compressors/

- Multi-stage design: As the name implies, more stages are incorporated to arrive at the final processed gas. Here, the gas is compressed multiple times in several compression cylinders to increase pressure levels.
- Diaphragm compressor: This differs from the conventional reciprocating compressor since the compression of gas is brought about by the to and fro movement of a flexible membrane. The movement is facilitated by a rod and the crankshaft.

8.2.1.B) ROTARY COMPRESSORS

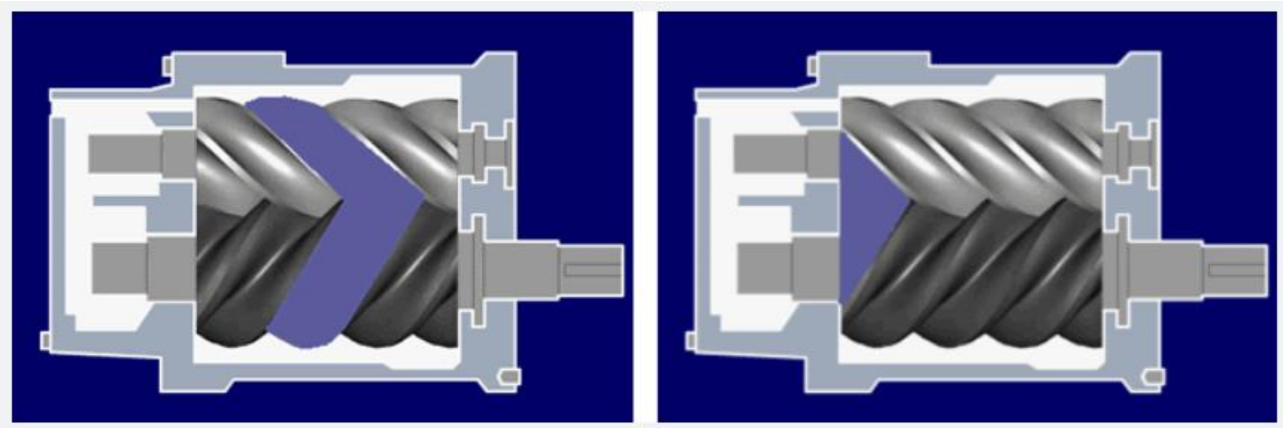
Rotary compressors also have a positive displacement. These low capacity types of equipment have applications in home freezers and refrigerators.

They can either have a single vane that is located within the cylinder and kept away from the rotor, or multiple vanes located in the rotor.

The various types of rotary compressors include:

- ROTARY SCREW COMPRESSORS

It uses two meshed helical screws in rotation to force the gas into a smaller space.

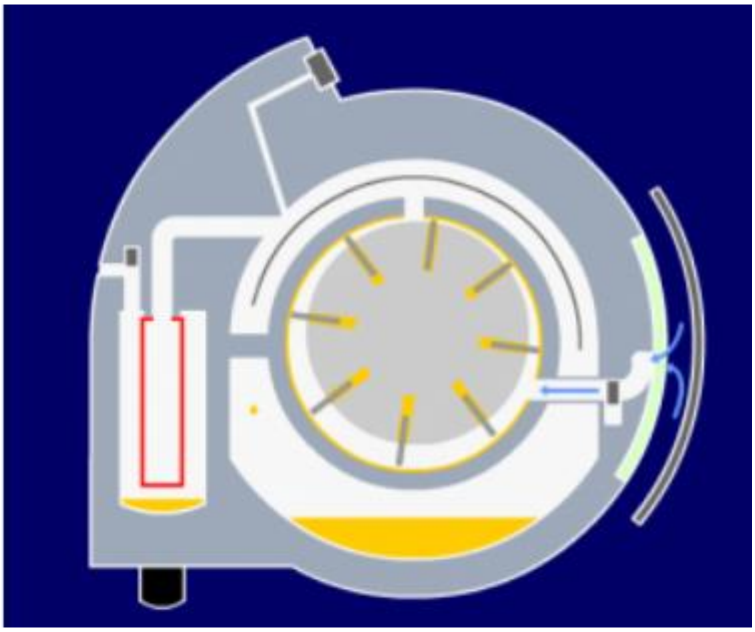


They can be employed in industrial and commercial purposes and their application can range between 3 horsepower (2.2 kW) to about 1,200 horsepower (890 kW).

Likewise, the discharge pressure can range between low to moderately high pressure (>1,200 psi or 8.3 MPa).

- ROTARY VANE COMPRESSORS

These machines feature a rotor that is mounted in a larger housing which has either a circular or complex shape.



The rotor also has several blades which are inserted in radial slots within the rotor.

As the rotor moves, the blades move in and out of the slots. This increases and decreases the volume of the gas.

In comparison with a piston compressor, a rotary vane compressor operates more quietly and is best suited to the electric motor drive.

Like piston compressors, they can also be single or multi-staged, as well as stationary or portable.

Their discharge range can be between 29 psi as is the case of dry vane machines and 190 psi for oil-injected machines.

- SCROLL COMPRESSORS

These are also known as scroll pump or scroll vacuum pump and they feature two spiral vanes that are interwoven.

While one of the vanes is fixed, the other moves around it which help in compressing the gas.

Scroll compressors also operate even more quietly and smoothly than other types of compressors in the lower volume range.

8.1.2. DYNAMIC COMPRESSORS

Dynamic compressors are also known as turbo compressors and they depend on a fluid's inertia and momentum to bring about its increased pressure levels.

In their mode of operation, velocity energy is impacted to a stream of gas and this energy is then converted to pressure energy.

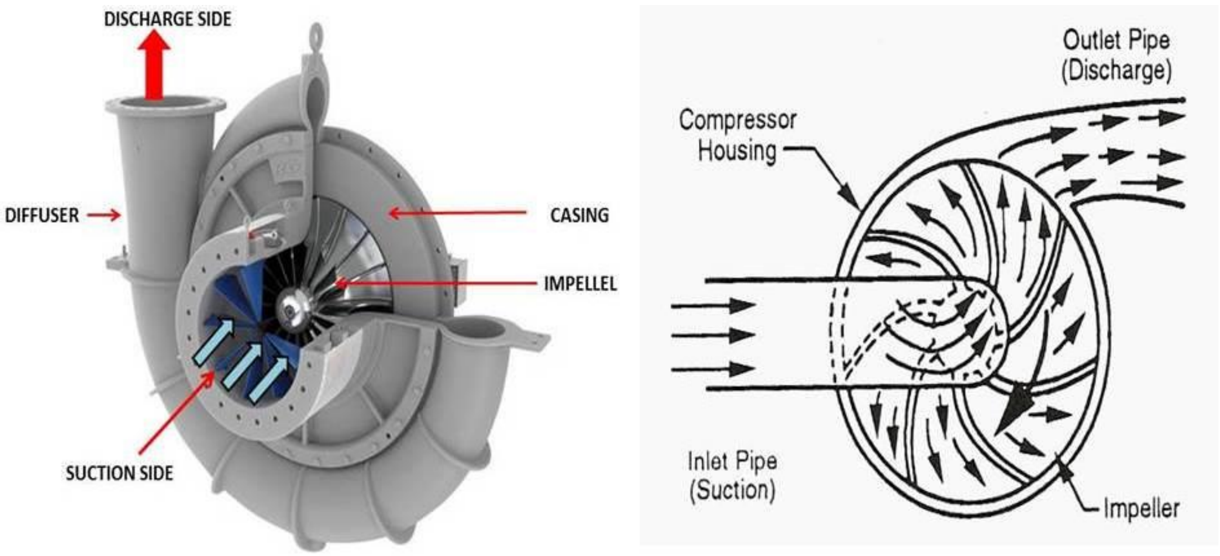
There are two basic types of dynamic compressors and these are:

A. Centrifugal compressors
B. Axial compressors

8.2.2.A) CENTRIFUGAL COMPRESSORS

Centrifugal compressors make up about 80 percent of the entire dynamic processors, therefore, leaving 20 percent to axial compressors.

That being the case, they are widely used in oil refineries, natural gas processing plants, chemical and petrochemical plants.



CENTRIFUGAL COMPRESSOR

21

Due to their high output pressures of over 1,000 psi (6.9 MPa) and horsepower range of a 100 to 1000, these machines can be used in:

- Snowmaking operations
- Refrigeration
- Air conditioning systems

21 https://www.mech4study.com/2017/11/centrifugal-compressor.html

For their mode of operation, compression is made possible by exerting inertial force on the gas with the use of high-speed rotating impellers

The gas is forced to the rim of the impeller which helps to increase its velocity. This velocity is then converted to pressure energy by a diffuser.

The process can also be carried out in a single stage or multi-stage where each stage takes advantage of an impeller (a rotating disk) and diffuser (a stationary element).

Both single and multistage machines are generally made up of standardized components. However, the multistage helps in improving the compression ratio since centrifugal compressors generally have lower compression ratios in comparison to displacement compressors.

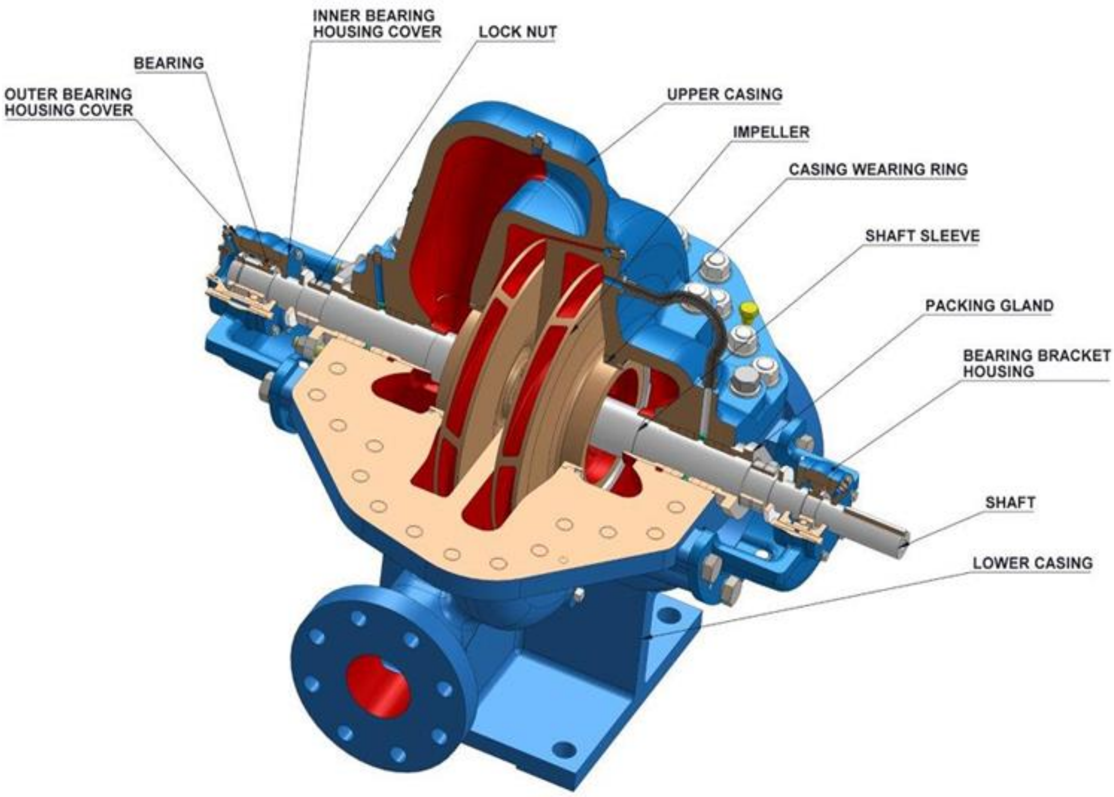
Centrifugal compressor also features two casing designs and these are:

- HORIZONTALLY SPLIT CASING DESIGN

This compressor has an outer casing which can be split horizontally to aid in the maintenance of its internal component.

Within the compressor, the rotating disk or impellers are connected to one rotating shaft to form a multi-stage structure.

As the gas passes through the intake nozzle, a centrifugal force created by the high-speed movement of the impellers causes it to be compressed and pressurized before it is sent out to an ejection nozzle.



- VERTICALLY SPLIT CASING DESIGN

While the internal components of this machine have a similar design to that of the horizontal split type casing, its outer design differs.

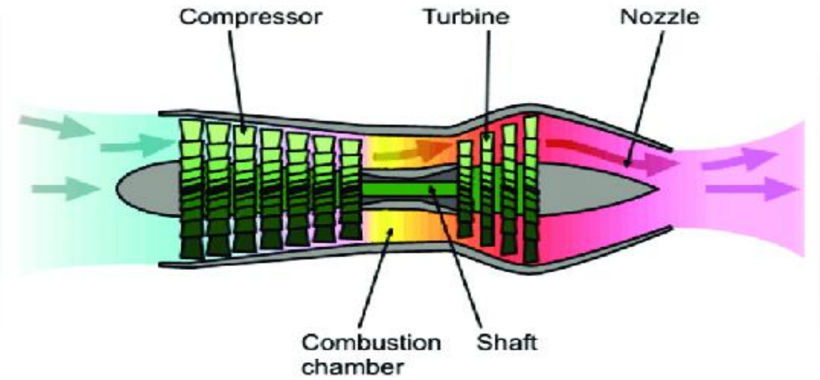
Here, the rotor bundle and the diaphragm seals are axially arranged in a steel barrel casing.

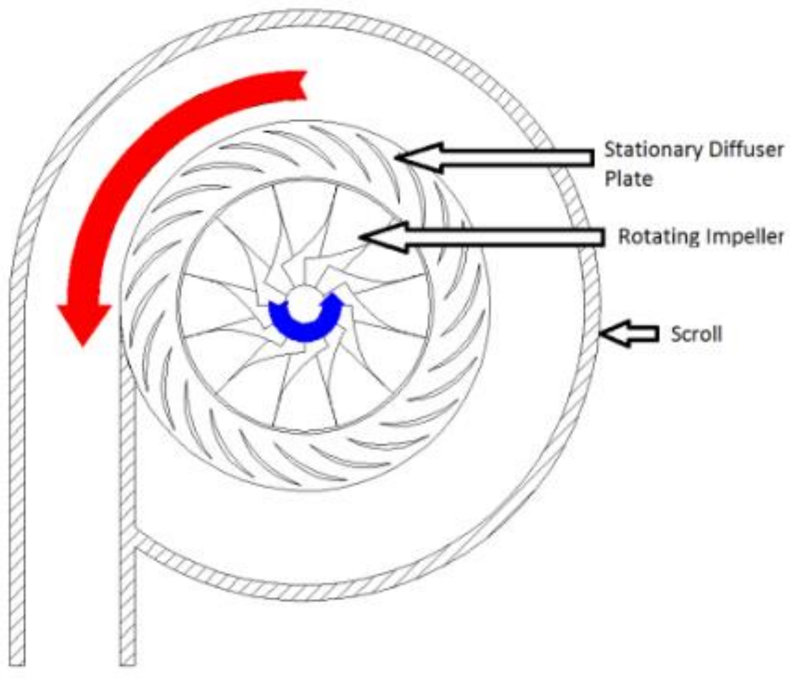
Generally, this design depends on the working pressure and the type of gas that is to be compressed.

8.2.2.B) AXIAL-FLOW COMPRESSORS

Another type of dynamic rotating compressors is the axial-flow compressor. They are mostly employed where compact design or high flow rates (large flow volumes) is desired.

These compressors have a pressure range between low to medium and you'll find their application in jet engines, natural gas pumping stations, chemical plants, and large gas turbine engines. 23





Axial Compressors-Centrifugal Compressors24

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22 https://www.flowmorepumps.com/product/horizontal-split-casing-pumps.html

23 https://www.researchgate.net/figure/Axial-flow-compressor-engine_fig4_261477455

24 https://cascousa.com/compressed-air-101/types-of-compressors/dynamic-displacement-compressors/

When it comes to how this compressor works, gas is compressed with the use of an array of airfoils which are arranged in rows.
The airfoils can exist as pairs, where one of the set is a rotating airfoil known as the blade or rotor and the other is a stationary airfoil also known as stators or vanes.

While the rotating airfoil accelerates the fluid; the stationary airfoil decelerates and also redirects its direction in preparation for the rotor blades of the next stage.

- PROS AND CONS

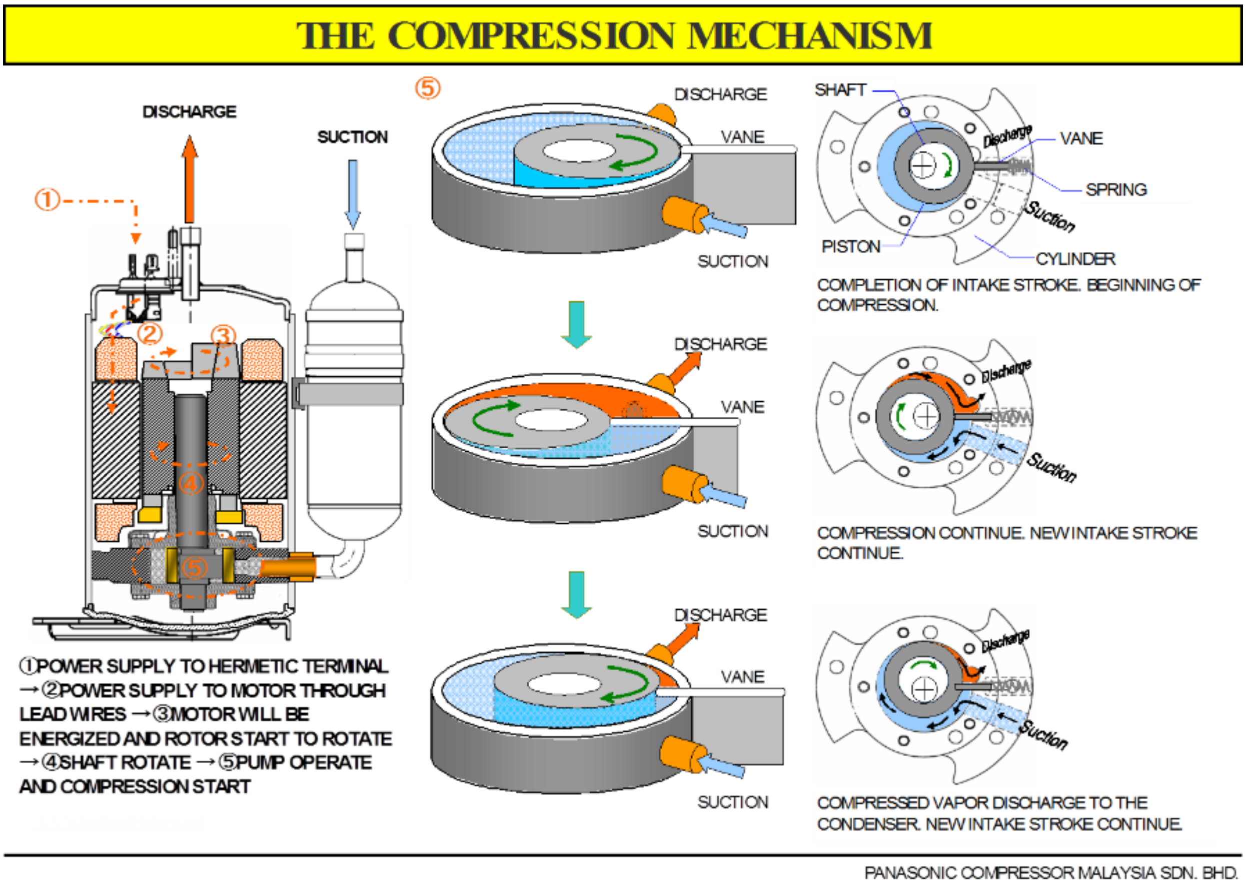
What this means is that the velocity of the gas is first increased before it is slowed down and passed through the blades which help to increase the gas pressure.

In comparison with other compressors, axial machines are relatively expensive since they require more parts and materials of high quality. They, however, have high efficiencies and employ multi-stages where the cross-sectional area of the gas passing along the compressor diminishes to give an optimum axial Mach number.

8.2.2.C) HERMETICALLY SEALED, OPEN, OR SEMI-HERMETIC

There are also compressors that are specifically designed for refrigerators. These types can either be classified as hermetically open, sealed, or semi-hectic.

Each description refers to the way the motor drive is positioned in relation to the gas that is being compressed.



[25]

Design of Oil-Less Compressors and Vacuum Pumps (pdf)

https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1017&context=icec

https://oaktrust.library.tamu.edu/bitstream/handle/1969.1/188625/TT02.pdf?sequence=1

Denair compressor to inquire about:

http://www.denair.net/Gas_Compressor/Gas_Compressor.html (#8)

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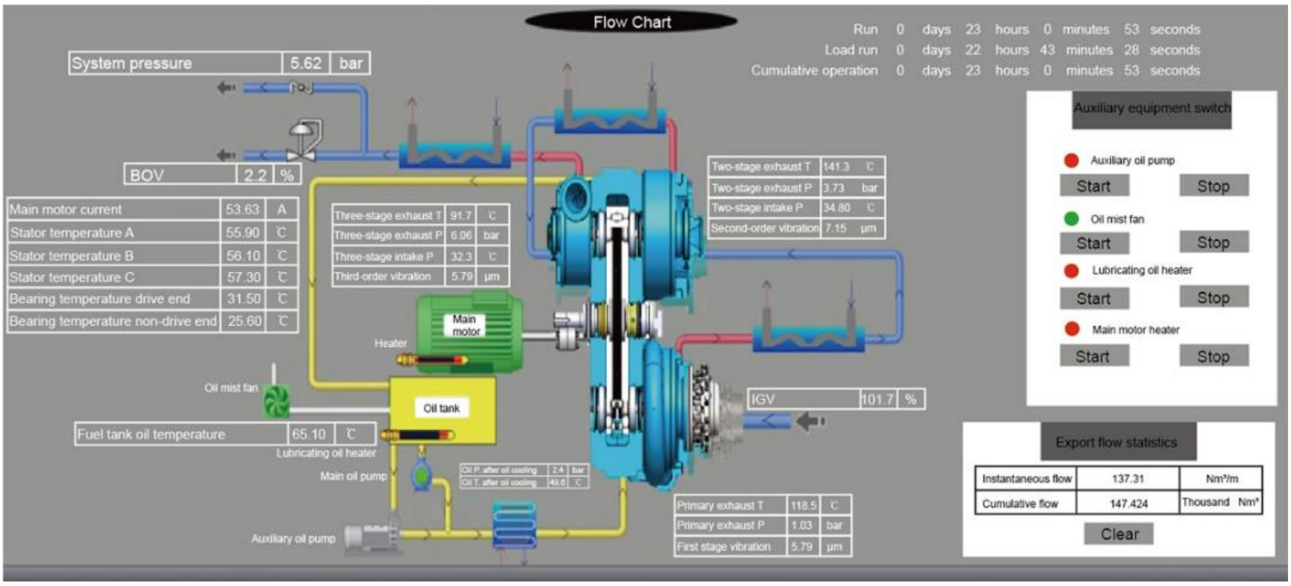
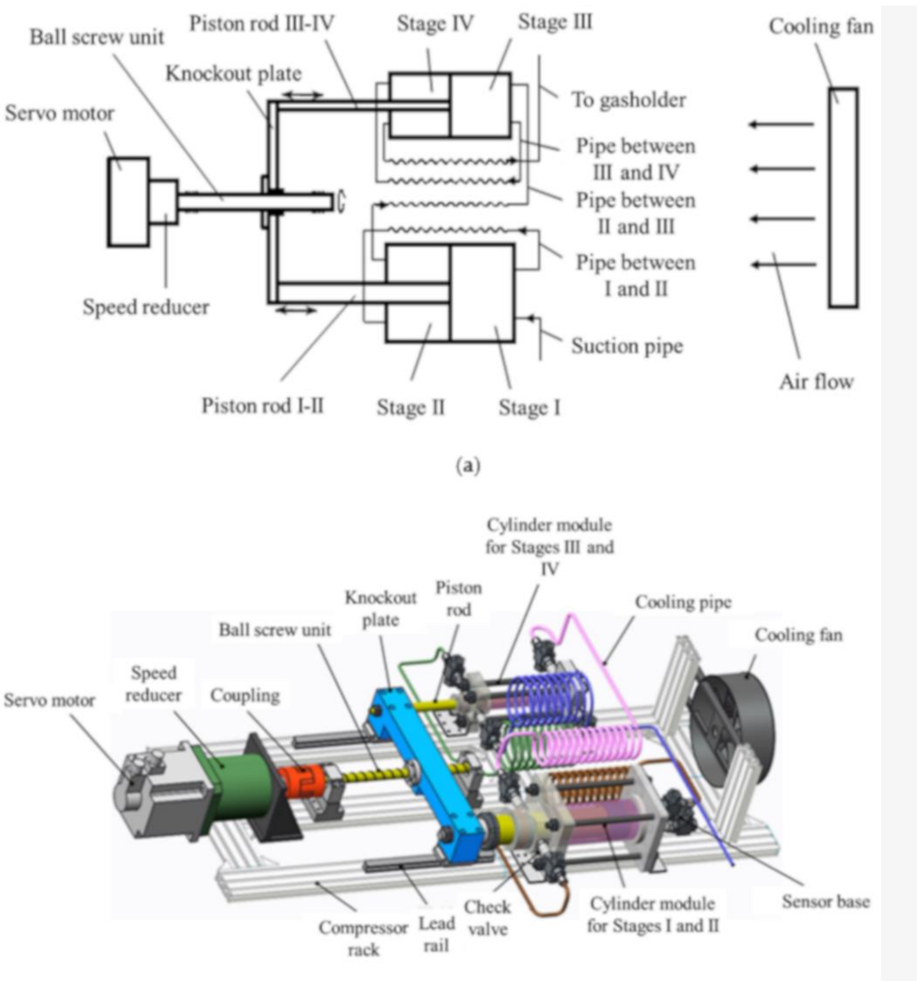
25 https://na.industrial.panasonic.com/complete-guide-rotary-compressors





[26]

*(**a**) Structural diagram and (**b**) 3D model of the multistage compressor unit.*

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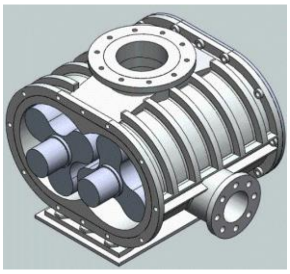
26 https://www.mdpi.com/1996-1073/13/1/112/htm

8.2. Gas compressors [27]

8.2.1. Positive displacement rotary blower

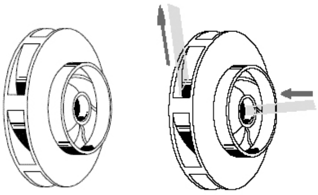


Two profiled rotors turn in a figure of eight shaped housing. They are geared together so that they run very close to each other, but cannot touch. There is no compression within the machine, it simply pushes gas into the system to which it is connected. Machines with semi-screw profile rotors are also available, which reduces noise and vibration.

Typical Performance Envelope

	Imperial	Metric
Minimum swept volume	50 cfm	85 m^3/h
Maximum swept flow	70,000 cfm	120,000 m^3/h
Maximum casing pressure	30 psi	2 bar
Maximum pressure ratio	2	

8.1.1 Centrifugal blower



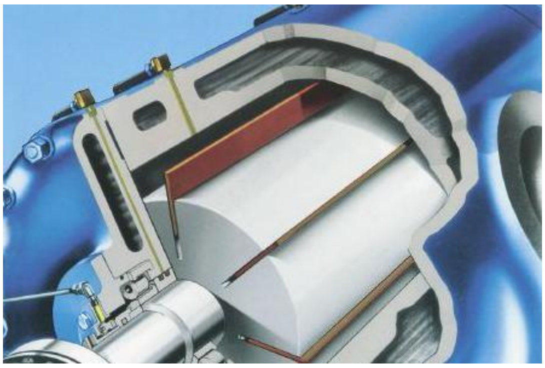
An impeller is attached to a rotating shaft within a cylindrical housing. Gas drawn into the housing near the centre, is then thrown towards the perimeter. The imparted velocity of the gas causes a pressure rise and flow. Multi-stage machines direct the gas back to the centre of the next stage.

Typical Performance Envelope

	Imperial	Metric
Minimum swept volume	100 cfm	170 m^3/h
Maximum swept flow	40,000 cfm	70,000 m^3/h
Maximum casing pressure	30 psi	2 bar
Maximum pressure ratio	2.2	

27 http://www.gascompressors.co.uk/tech-osc.php

8.1.2 Rotary vane compressor

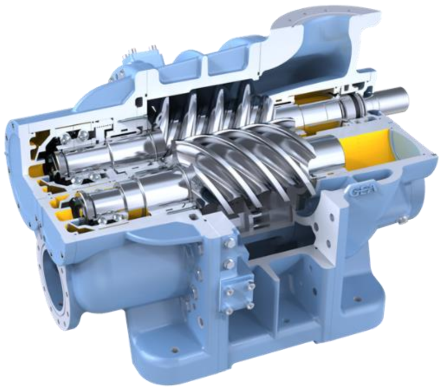


A single rotor is mounted offset in a cylindrical housing. Slots in the rotor contain vanes, which are thrown against the wall of the housing as it rotates. Oil is injected into the compression space to lubricate the bearings and vanes. As the rotor is offset, the segments that are created by the vanes vary in size through the cycle, causing the trapped gas to be compressed. Ports in the housing wall are positioned to let the gas in and out at the points of minimum and maximum pressure. Fully oil flooded versions are also available, with no oil loss to process.

Typical Performance Envelope

	Imperial	Metric
Minimum swept volume	5 cfm	8 m^3/h
Maximum swept flow	3,500 cfm	6,000 m^3/h
Maximum casing pressure	250 psi	17 bar
Maximum pressure ratio per stage	3.5	

8.1.3 Oil flooded screw compressor



Twin screw shaped meshing rotors are mounted in a figure of eight shaped housing, which has suction and discharge ports at either end. As the rotors turn they form a space that traps gas, the space travels down the length of the housing, and because of the profile of the screws, is compressed as it goes. Oil is flood injected into the compression space to lubricate the bearings and screws, and to absorb the heat of compression. The oil and compressed gas mixture subsequently passes into a de-oiling vessel. The oil is then cooled and filtered and goes back round the cycle once again.

Typical Performance Envelope

	Imperial	Metric
Minimum swept volume	150 cfm	250 m^3/h
Maximum swept flow	10,000 cfm	17,000 m^3/h
Maximum casing pressure	500 psi	40 bar
Maximum pressure ratio	20	
Minimum pressure ratio	2	

8.1.4 Oil free screw compressor

Twin screw shaped meshing rotors are mounted in a figure of eight shaped housing, which has suction and discharge ports at either end. As the rotors turn they form a space that traps gas, the space travels down the length of the housing, and because of the profile of the screws, is compressed as it goes. Due to no lubricant in the compression space, timing gears are employed to ensure that the two rotors do not touch.

Typical Performance Envelope

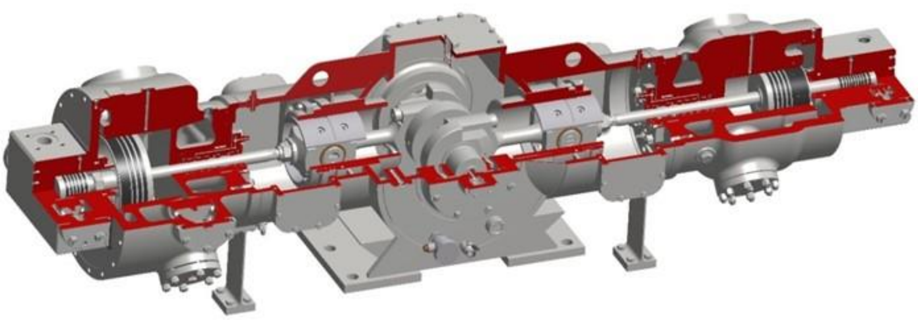
	Imperial	Metric
Minimum swept volume	120 cfm	200 m^3/h
Maximum swept flow	60,000 cfm	100,000 m^3/h
Maximum casing pressure	750 psi	52 bar
Maximum pressure ratio	4	

- **Advantages**
  - Flow controllable by speed variation.
  - Vibration free operation.
  - No special foundation required, lowering civil costs.
  - Pulsation free gas discharge.
  - Valve less porting means no drop off in efficiency between overhauls, and no valves to maintain or break in service.
  - No oil in contact with gas.
  - Resistant to damage by particulate.

- **Disadvantages**
  - High capital cost.
  - Low pressure ratio per stage, but can be mounted in series.

- **Common applications**
  - Refinery service.
  - Flare gas recovery.

8.1.5 Reciprocating compressor



Similar to an automotive combustion engine, except passive non return valves replace actuated valves. A piston travels up and down inside a cylinder, and is connected to a crank shaft by a connecting rod. On the intake stroke, the discharge valves are forced shut, and gas is therefore sucked into the cylinder.

On the compression stroke the suction valves are forced shut, and gas is expelled into the discharge port. On multi-stage machines, the gas must be cooled before entering the next stage.

Typical Performance Envelope

	Imperial	Metric
Minimum swept volume	10 cfm	17 m^3/h
Maximum swept flow	15,000 cfm	25,000 m^3/h
Maximum casing pressure	5,800 psi	400 bar
Maximum pressure ratio per stage	3.5	

8.2.2. Diaphragm compressor

Based on a reciprocating compressor frame. In place of conventional cylinders, is a saucer shaped stainless steel head, inside of which is a thin stainless steel diaphragm. The diaphragm oscillates up and down, powered by oil that is in turn pushed up and down by the piston. Gas is drawn in to the top of the head, and pushed out, in a similar manner to a reciprocating compressor, by passive poppet valves. The diaphragm totally insulates the gas stream from the mechanics and lubrication system, and so is often specified for hazardous or poisonous gas applications.

Typical Performance Envelope

	Imperial	Metric
Minimum swept volume	6 cfm	10 m^3/h
Maximum swept flow	1,800 cfm	3,000 m^3/h
Maximum casing pressure	15,000 psi	1,000 bar
Maximum pressure ratio per stage	20	

8.1.6 Centrifugal compressor

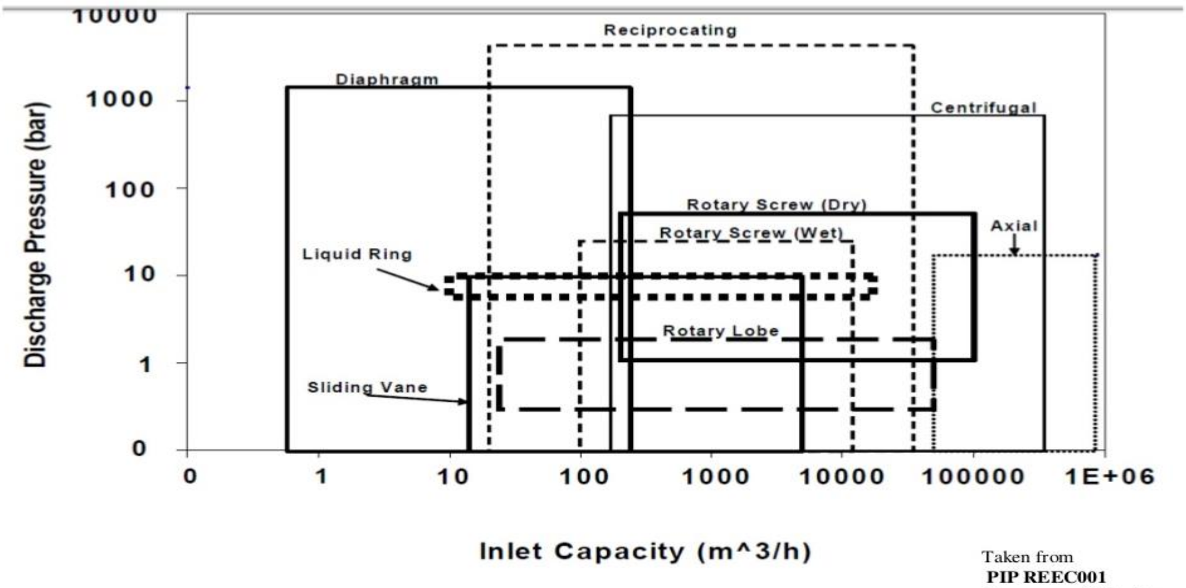
An impeller is attached to a rotating shaft within a cylindrical housing. Gas drawn into the housing near the centre, is then thrown towards the perimeter. The imparted velocity of the gas causes a pressure rise and flow. Multi-stage machines direct the gas back to the centre of the next stage. Differs from centrifugal blower in that pressure containment housing is much stronger. Two main layouts are Integrally Geared type, where several stages are mounted radially on a central speed increaser gearbox, and Barrel type, where stages are all mounted on a single shaft.

Typical Performance Envelope

	Imperial	Metric
Minimum swept volume	10,000 cfm	17,000 m^3/h
Maximum swept flow	180,000 cfm	300,000 m^3/h
Maximum casing pressure	2,200 psi	150 bar
Maximum pressure ratio	4	

8.3. ---

Graph showing operating regions of various compressors



Taken from
PIP REEC001
Compressor Selection

Table showing operating conditions of various compressors

Table 1b. Summary of Typical Operating Characteristics of Compressors (US Units)

	Inlet Capacity (acfm)	Maximum Discharge Pressure (psig)	Efficiency (%)	Operating Speed (rpm)	Maximum Power (HP)	Application
Dynamic Compressors						
Centrifugal	100 - 200,000	10,000	70 – 87	1,800 - 50,000	50,000+	Process gas & air
Axial	30,000 - 500,000	250	87 - 90+	1,500 - 10,000	100,000	Mainly air
Positive Displacement Compressors						
Reciprocating (Piston)	10 - 20,000	60,000	80 – 95	200 - 900	20,000	Air & process gas
Diaphragm	0.5 – 150	20,000	60 – 70	300 - 500	2,000	Corrosive & hazardous process gas
Rotary Screw (Wet)	50 - 7,000	350	65 – 70	1,500 - 3,600	2000	Air, refrigeration & process gas
Rotary Screw (Dry)	120 – 58,000	15 – 700	55 – 70	1,000 - 20,000	8,000	Air & dirty process gas
Rotary Lobe	15 - 30,000	5 - 25	55 – 65	300 - 4,000	500	Pneumatic conveying, process gas & vacuum
Sliding Vane	10 - 3,000	150	40 – 70	400 - 1,800	450	Vacuum service & process gas
Liquid Ring	5 - 10,000	80 - 150	25 – 50	200 - 3,600	400	Vacuum service & corrosive process gas

Capacity and Pressure Range of various compressors

Type of compressor	capacity range (m^3/h)	Working pressure (bar)
Roots blower compressor		
Single stage	100 – 30000	0.1 – 1
Reciprocating compressor		
Single stage	100 – 12000	0.8 – 12
Multi stage	100 – 12000	12 – 700
Screw compressor		
Single stage	100 – 2400	0.8 – 13
Multi stage	100 – 2200	0.8 – 24
Centrifugal	600 – 300000	0.1 – 450

Advantages and disadvantages of positive displacement type compressor

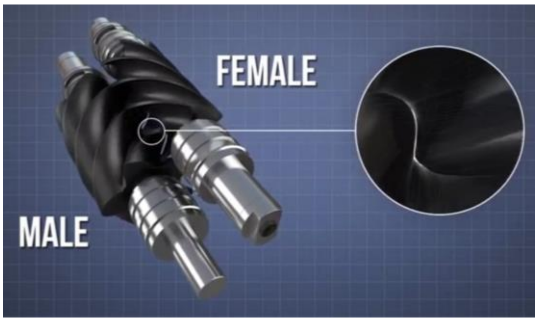
	Advantages	Disadvantages
Positive displacement compressor		
Reciprocating	•Wide pressure ratios •High efficiency	•Heavy foundation required •Flow pulsation •High maintenance
Diaphragm	•Very high pressure •Low flow •No moving seal	•Limited capacity range •Periodic replacement of diaphragm
Screw	•Wide application •High efficiency •High pressure ratio	•Expensive •Unsuitable for corrosive or dirty gases

selection of compressor lubricants

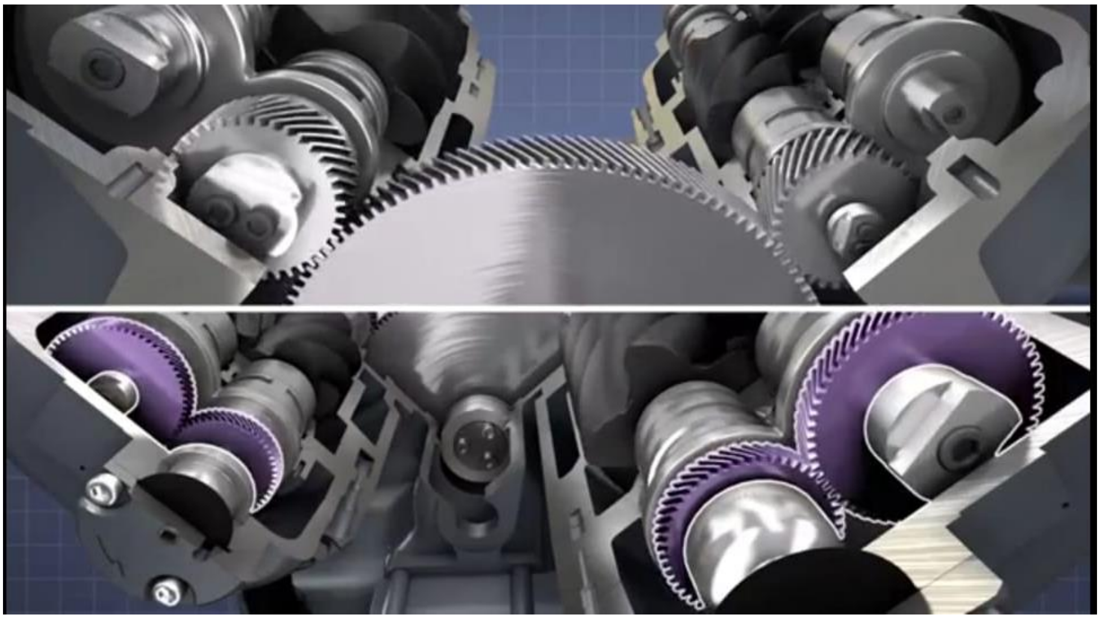
The major factors involved in the selection of compressor lubricants include:

- Type, size and speed of compressor
- Gas being compressed
- Number of stages
- Pressure and temperature at each stage
- Environment
- Type of lubrication system

8.4. Oil-free screw air compressor process

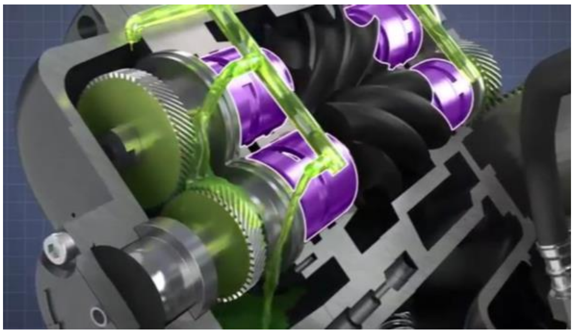


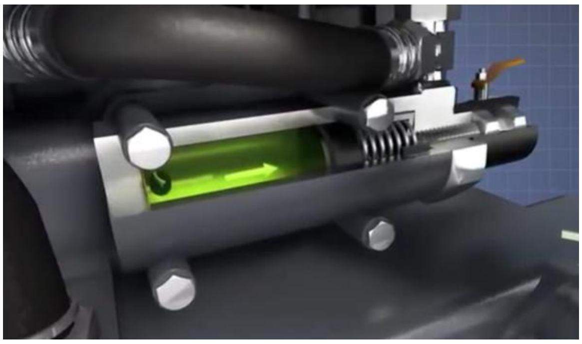
The oil-free industrial air compressor is a two-stage oil-free compressor unit. both compression stages comprise male and female rotors, with special protective coating. there's no physical contact either between the matched rotor pairs or the rotors and the air and casing. everything is separated by a precisely engineered air gap. The male rotors of both the first and second stages are driven by a single main gear at the back of the air end.



Helical timing gears at the front of both sets of rotors ensure perfect synchronization is kept between the rotor pairs at all times. This means no oil is needed to seal the compression process, making this air end a perfect solution wear oil-free compressed air is a critical requirement. Oil never enters the compression chambers, but is used to keep gears and bearings lubricated and cool. Special seals between the rotors and bearings prevent air passing into the oil system and oil passing into the compression chambers.

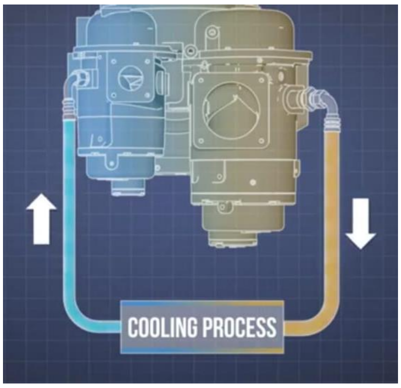
Hot oil drains to an oil reservoir located below the air and via to oil returned pipes. The hot oil is then pumped to a cooler and returns to the air environ oil filter. A pressure relief valve fitted to the front of the air and ensures that oil pressure doesn't exceed 2.5 bar or 36 psi.





Oil is topped up via a fillip pipe at the front to the air end. The compression process is kept cool by a constant flow of water passing through channels that surround the air end rotors. Heat transfers to the water which is then pumped through an external cooler before returning to the air end.

Air enters the third stage via the air intake valve and is trapped between the lobes and flutes on the underside of the compression rotors. As the rotors turn the volume of the trapped air reduces compressing the air and driving it towards the delivery port at the back of the air end. After leaving the first stage the compressed air passes through a pulsation damper, then on to a first stage or inter stage cooler. This can either be air or water cooled depending on the model of compressor. It's important to cool the air before it enters the second stage as hot air will have expanded.



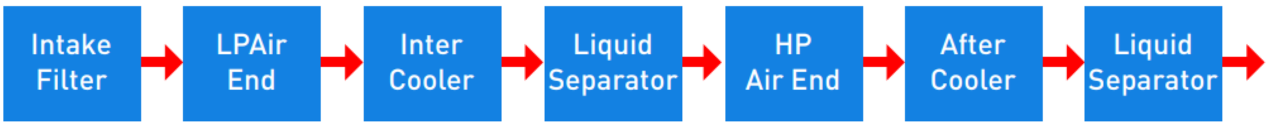
When cooled, the air contract providing a greater number of air molecules in the same volume, this results in more efficient second stage compression. The cooled compressed air passes through a moisture separator, then on to the inlet port of the second stage. The volume of the air is greatly reduced after first stage compression, which means that the size of the second stage rotors can be smaller. The second stage further compresses the air to the required pressure in the same manner as the first stage. However, this time, the compression process takes place on the upper side of the rotors. the compressed air exits the air and fire a delivery silencer then through a non-return valve.

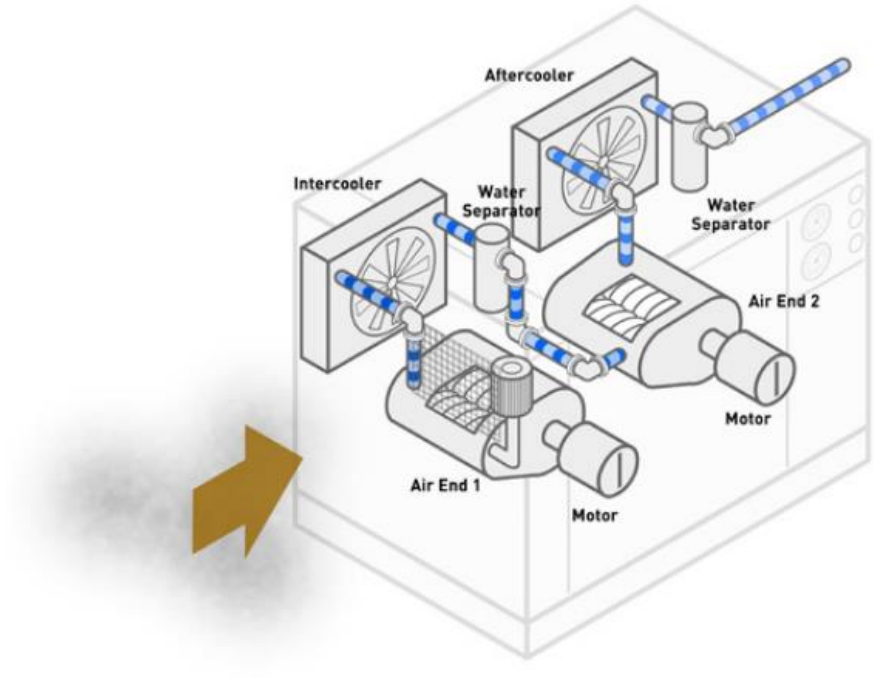
The air then passes through a final second stage air or water cooling process to ensure the delivery air is at the right temperature. Then after a final journey through a moisture separator, the air is ready to exit the compressor at the delivery port.

8.5. Overview of Screw Compressor Operation Oil Free

The obvious thought is that the term 'Oil free compressor' describes a compressor containing no oil. Unfortunately, that is not the case for most oil free compressors. An oil free compressor is the term used to describe a compressor that does not use oil in its compression stage.

Basic Operation – Oil Free Rotary Screw Compressor





Drive

Oil free rotary screw compressors are typically multi stage, driven by a single drive motor. This motor will drive a gear which in turn distributes the power to each air end. Some oil free screw compressors are now available where each compression stage driven by an individual motor

Compression

Unlike the oil injected screw compressor which uses oil to seal the gaps between the rotors and provide compression, oil free variants achieve compression in an alternative way.

Rotor elements are manufactured in pairs with extremely tight tolerances to decrease the gap between them. During operation, rotors are spun at much higher speeds than an equivalent oil injected ompressor. Specialist coatings are often applied to the rotors to give some of the protection from water and heat usually provided by oil.

The rotors operate extremely close to each other, however as there is no oil in the compression stage to prevent the rotors from touching, the distance between each rotor is maintained by additional gearing.

Cooling

As there is no oil in the compression chamber to provide direct cooling, indirect cooling is used. The air end housings of oil free compression stages typically contain gelleries in which cooling water (on water cooled machines) or oil (on air cooled machines) can be circulated. This process is not as efficient as direct cooling as it only cools the casing and not the compressed air or the rotors.

Due to the lack of direct cooling in an oil free compressor, the compressed air and rotors reach much higher temperatures. Oil-free compressors therefore obtain their final discharge pressure in stages (as opposed to oil injected machines which typically use only 1 stage). Between stages they will cool the compressed air with an inter-cooler. This keeps typical air end temperatures between 180°C & 200°C.

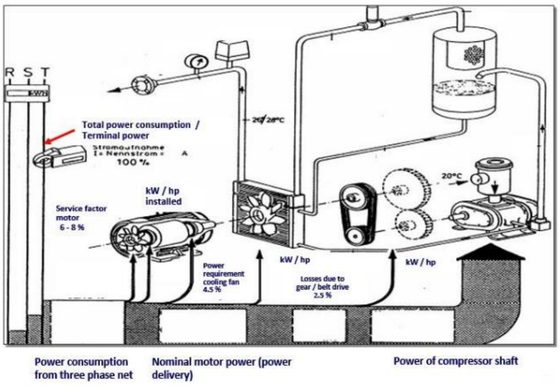
For example, on a typical oil free rotary screw compressor with 2 compression stages, an intercooler and aftercooler. Stage 1 will typically compress the air up to a pressure around 3.5 bar g, stage 2 will then compress the air to the discharge pressure of 7 bar g.

Lubrication

On an oil free screw compressor, it is not only important that the individual rotors in each air end are synchronised with gears, with only one drive motor, additional gearing is also required to drive each of the air ends. All of the gearing and bearings require lubrication. So although the name implies that an oil free compressor is “oil less”, for most oil free compressors sold, this is not the case. Oil is not used in the compression stages; however, oil is still required for lubrication and cooling of other components. This oil is pumped around the compressor forming a closed loop system which lubricates bearings and gears, is filtered, cooled and recirculated.

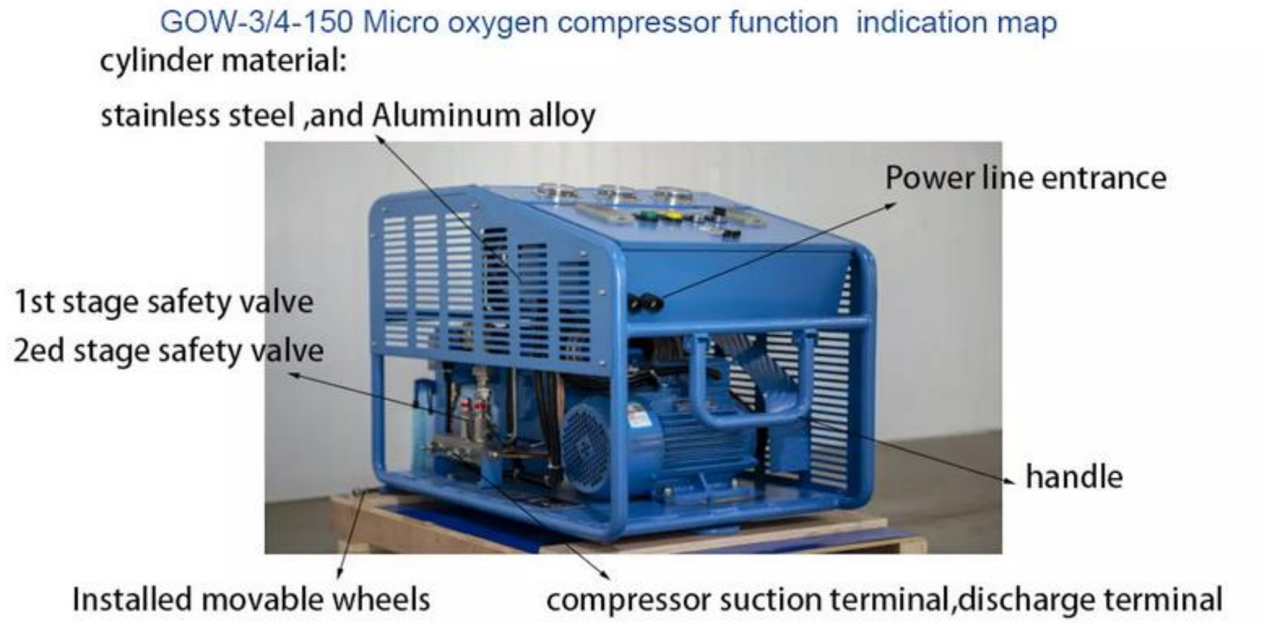
Oil Reclamation (Air / Oil Separator)

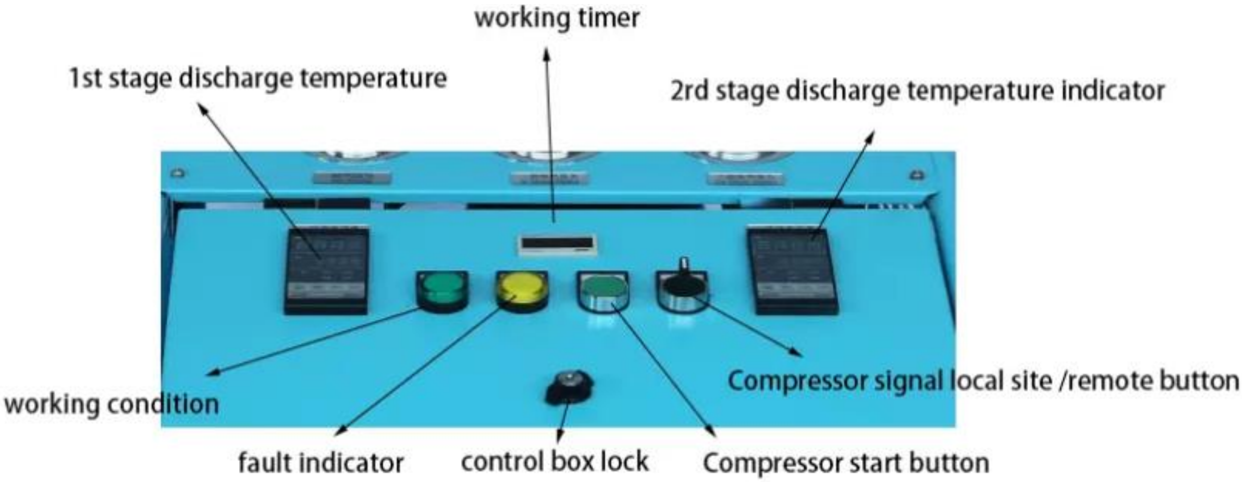
As there is no oil used in the compression stage, there is no requirement for an air / oil separator on an oil free compressor.



Compressor #1: (info completed)

https://www.oxygen-compressors.com/2m3-High-Pressure-Industrial-Booster-Oxygen-Compressor-pd46014866.html





suction pressure

1st stage discharge pressure

discharge pressure

suction pressure switch

discharge pressure switch

Model 型号	Working medium	suction pressure (Mpa,Psig)	Discharge pressure (Mpa,Psig)	Motor.KW	Flow rate Nm3/hr	Voltage	Cooling way	weight	dimension
GOW-1.8/1-150	oxygen	0.1，14.3	15,2150	1.5	1.8	220V/380V /415V/440V 50/60HZ	air cooling	150kgs	700×650×650
GOW-1.8/1-200	oxygen	0.1，14.3	20,2875	1.5	1.8	220V/380V /415V/440V 50/60HZ	air cooling	150kgs	700×650×650
GOW-2.7/1-150	oxygen	0.1，14.3	15,2150	2.2	2.7	220V/380V /415V/440V 50/60HZ	air cooling	150kgs	700×650×650
GOW-3/4-150	oxygen	0.3-0.4,40-60	15,2150	3	3	220V/380V /415V/440V 50/60HZ	air cooling	150kgs	700×650×650

1. The above parameters are for reference only, and is subject to our technical quotation
2. More displacement, higher filling pressure, such 20Mpa,23Mpa,30Mpa,please feel free consult us

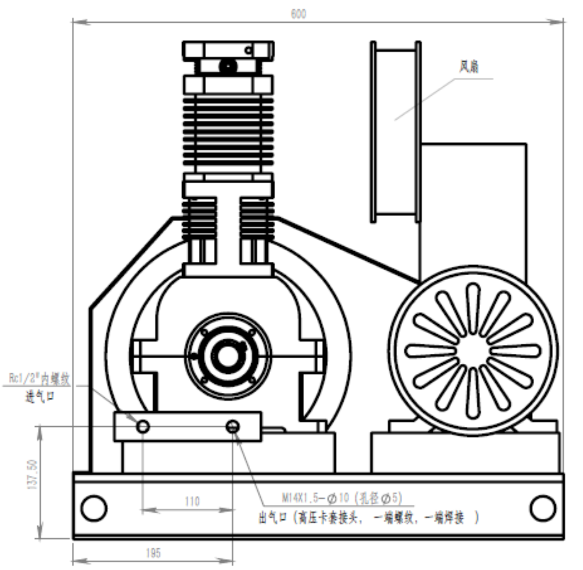
NOTICE: THE OXYGEN MUST BE OIL FREE

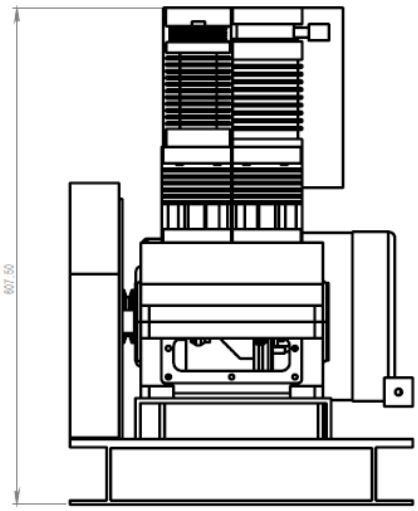
TOTALLY OIL FREE OXYGEN COMPRESSOR

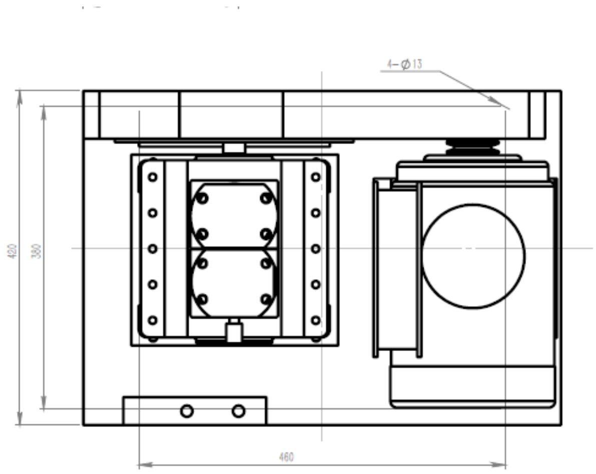
TECHNICAL DATA

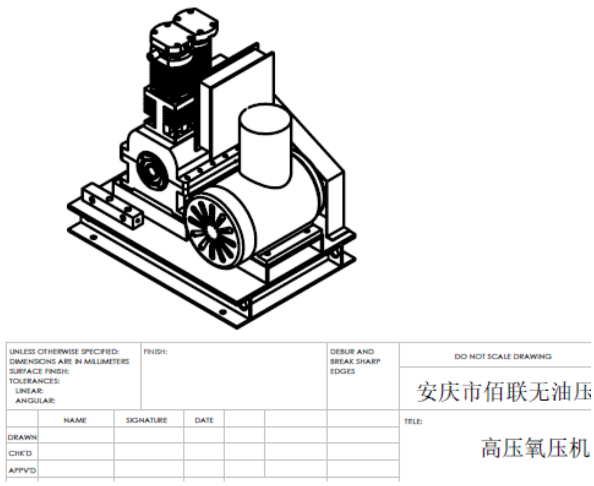
S/N	ITEMS		PARAMETER
1	WORKING MEDIUM		OXYGEN O2
2	MODEL		GOW-3/4-150
3	STRUCTURE		100% OIL FREE RECIPROCATING COMPRESSOR
4	PRESSURE STAGE		2
	Cylinder		2
5	OXYGEN CAPACITY(STANDARD CONDITION)Nm³/h		3
6	RATE INPUT MPa(G)		0.3-0.4
7	RATED OUTPUT MPa(G)		15.0
8	INLET TEMPERATURE℃		≤40
9	DISCHARGE TEMPERATURE℃		≤50
10	TRANSMIT TEMPERATURE℃		≤50
11	PUMP SPEED r/min		400 ※
12	COOLING WAY		AIR COOLING
13	LUBRICATE WAY	CRANK SHAFT 、CONNECT ROD	SEAL GREASE
		CYLINDER	OIL FREE LUBRICATE
14	MOTOR POWER Kw		3 ※
15	TRANSMIT WAY		BELT DRIVEN
16	INSTALLATION WAY		HAS BASEMENT
17	Automatic control items		Pressure over loading
18	Dimension L×W×H mm		700×650×650 ※
19	Inlet and outlet mm		15
20	Weight Kg		150KGS ※
21	GW		190KGS
22	Motor		220V 60HZ 3PHASE
23	Working model		6-8hours per day

GOW-3/4-150 FOB SHANGHAI USD8000/PC









Compressor #2: (info uncompleted)

https://toplongcompressor.en.made-in-china.com/product/IvVmtGBbhyhA/China-5nm3-3stage-High-Pressure-Oil-Free-Oxygen-Compressor-Nitrogen-Compressor.html

5nm3 3stage High Pressure Oil Free Oxygen Compressor Nitrogen Compressor

Get Latest Price >   Chat with Supplier.

Min. Order / Reference FOB Price	
1 Piece	US $6,500-8,000/ Piece

Port:	Shanghai, China
Production Capacity:	200PCS/Month
Payment Terms:	L/C, T/T, D/P, Western Union, Paypal, Money Gram
Lubrication Style:	Oil-free
Cooling System:	Air Cooling
Cylinder Arrangement:	Balanced Opposed Arrangement
Cylinder Position:	Vertical
Structure Type:	Closed Type
Compress Level:	Multistage

Product Description
Oil-free Special Gas Compressor

Oil-free special gas compressor booster is the kind of semi-hermetic compressor, it adopts hermetic construction for its motor without pollution to the medium to be compressed and without leakage. This series compressor has numerous advantage of reliable performance, simple operation, compact construction, quick connection and so on. It can be applied in the compression and recovery of toxic, rare and precious gas such as SF6, helium, methane, ammonia, Freon, carbon dioxide and so on.

Performance Characteristics

Oil free high pressure oxygen nitrogen helium Co2 gas compressor
Principle 1: Oil-free type reciprocating piston
2 Cooling Type: Air-cooled or water-cooled
(3) Power consumption: ≤ 110kw4 Speed: . 300-560rpm
5 Flow: . ≤ 2000Nm3 / h6
Suction pressure: . 0-5Mpa7
Exhaust pressure: . ≤ 16.5Mpa8 Compression Level: 1-4Winds oil-free compressors
Product Features: No oil lubrication with clean and non-polluting.
High efficiency, low energy consumption. High reliability, continuous 24-hour operation. The unit uses air-cooled or water-cooled, compact structure, operation and low maintenance cost

4-20m3 3 stage pressure high pressure bottle compressor oxygen concentrator
3stage pressure filling pressure 15mpa
capacity from 4nm3 to 20nm3 per hour

All our models can be customized. For more information, pleaes do not hesitate to contact.

Model	gas	inlet .barg	outlet .barg	flow rate NM3/hr	power.KW	voltage/frequency	inlet/outlet.mm	cooling way	net eight.kg	dimension.mm	pressure riato stage
GOWW-4-10/4-150	oxygen	3-4	150	4-10	3	220/380 /440/50/60/3	DN15/M16X1.5	air cooling	380	1300X750X1000	3stage
GOWW-11-20/4-150	oxygen	3-4	150	11-20	4-7.5	220/380 /440/50/60/3	DN15/M16X1.5	air cooling	420	1300X750X1000	3stage

Compressor #3: (info uncompleted)

https://toplongcompressor.en.made-in-china.com/product/oXcQMuqdpshw/China-Totally-Oil-Free-Oxygen-Argon-Hydrogen-Compressor.html

Totally Oil Free Oxygen Argon Hydrogen Compressor

Get Latest Price >　　Chat with Supplier.

Purchase Qty. / Reference FOB Price

1-9 Pieces	US $10,000
10+ Pieces	US $7,000

Production Capacity:	200PCS/Month
Transport Package:	Carton/Plywood
Payment Terms:	L/C, T/T, Money Gram, Western Union
Lubrication Style:	Oil-free
Cooling System:	Air Cooling
Cylinder Arrangement:	Balanced Opposed Arrangement
Cylinder Position:	Vertical
Structure Type:	Closed Type
Compress Level:	Double-Stage

Model NO.	Gow-3/4-150	Refrigerant Type	Oxygen ,Nitrogen,Helium,Hydrogen
Configuration	Portable	Power Source	AC Power
Type	Piston	Application	Intermediate Back Pressure Type
Mute	Mute	HS	8414809090
Noise	Silent	Delivery	Stock
Name	Totally Oil Free Oxygen Compressor	Packing Material	Plywood
Trademark	Toplong compressors	Specification	CE
Origin	China	HS Code	8414809090

Product Description
Oil-free Special Gas Compressor

Oil-free special gas compressor booster is the kind of semi-hermetic compressor, it adopts hermetic construction for its motor without pollution to the medium to be compressed and without leakage. This series compressor has numerous advantage of reliable performance, simple operation, compact construction, quick connection and so on. It can be applied in the compression and recovery of toxic, rare and precious gas such as SF6, helium, methane, ammonia, Freon, carbon dioxide and so on.

Performance Characteristics

Oil free high pressure oxygen nitrogen helium Co2 gas compressor
Principle 1: Oil-free type reciprocating piston
2 Cooling Type: Air-cooled or water-cooled
(3) Power consumption: ≤ 110kw4 Speed: . 300-560rpm
5 Flow: . ≤ 2000Nm3 / h6
Suction pressure: . 0-5Mpa7
Exhaust pressure: . ≤ 16.5Mpa8 Compression Level: 1-4Winds oil-free compressors
Product Features: No oil lubrication with clean and non-polluting.
High efficiency, low energy consumption. High reliability, continuous 24-hour operation. The unit uses air-cooled or water-cooled, compact structure, operation and low maintenance cost

All our models can be customized. For more information, pleaes do not hesitate to contact.

Model	GOW-3/4-150
Medium	O2,N2,argon,helium,hydrogen,biogas etc
Power(Hp,Kw)	2.2KW
Working Pressure(Bar,Psi)	150,2160
Air Delivery(L/min,CFM)	3 Nm3/Hr
Inlet pressure ,outlet pressure	0.2-0.4Mpa, <16.5Mpa
Speed(r.p.m)	200-400
pressure stage	2
Net Weight(Kgs)	110
Cooling way	Air cooling
dimension	830*600*640mm

Compressor #4: (same family of compressor #1)

http://www.cnsouair.com/compressor/CompAirsGasCompressor/1326.html

https://souair.en.alibaba.com/

email: ironcai@cnsouair.com

WhatsApp:008618121319076

Oil-Free Lubricating Oxygen O2 Gas Compressor

Technical data sheet:

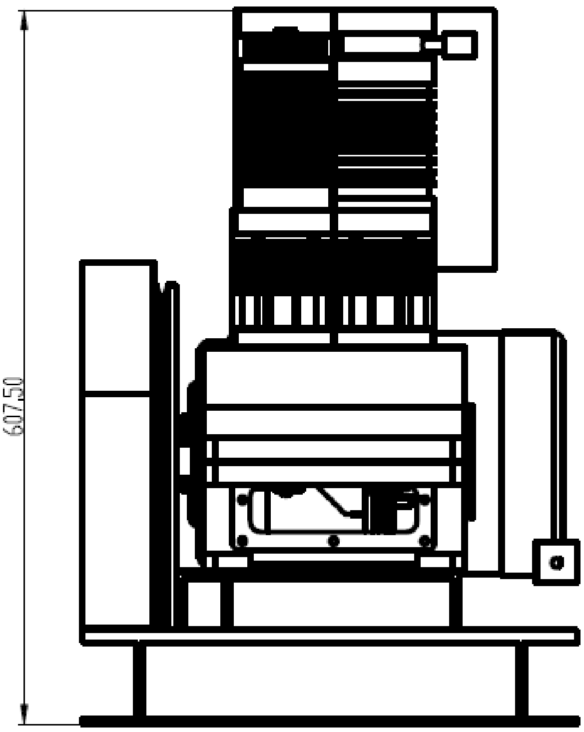
Must keep the complete oil free for the gas(O2 before get into compressor

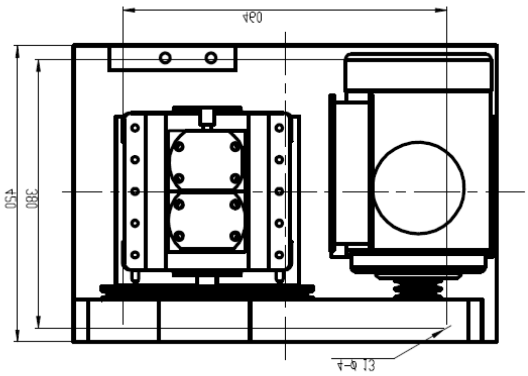
SN.	Items	Unit	Performance parameters
1	Model		GOW-3/3-150
			Oil Free Reciprocating compressor
2	Structure		Vertical four stage compressed
2	Compressed stage		4
3	Compressed media		Oxygen O2
4	Suction pressure	MPa (g)	0.3-0.5
5	Discharge pressure	MPa (g)	15.0
6	Flow capacity	Nm^3/h	3@ suction Pressure=0.3MPa (g)
7	Running speed	rpm	400 ※
8	Motor Power	kw	2.2 ※
9	Cooling type		air cooled
10	Driven type		V-Belt
11	Lubricating	Cylinder: Oil-Free; crankcase、connection rod: sealing grease	
12	Inlet temperature	℃	≤45
13	Outlet temperature	℃	≤130
13	Gas Transport temperature	℃	≤50
14	Inlet size		M14*1.5
15	Outlet size		M14*1.5
16	Control module		Automatic
17	Net weight	KG	200 ※
18	Dimension(L*W*H)	mm	900×800×1000 ※
19	Installation		Fixed base
20	Unit price USD/SET	USD	7100(FOB Shanghai, China)
21	Lead Time	Days	30
22	Power source		380V/50Hz/3PH

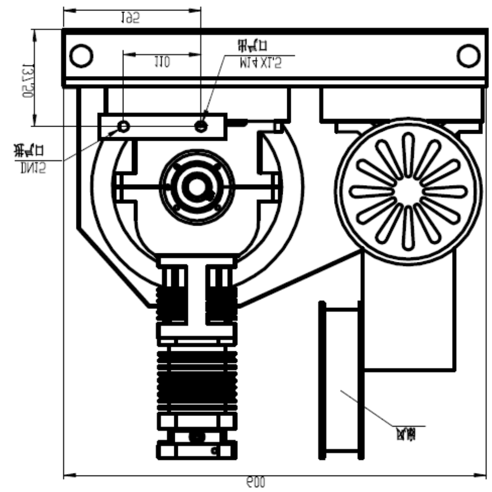
※ some parameter will be changed according to design.

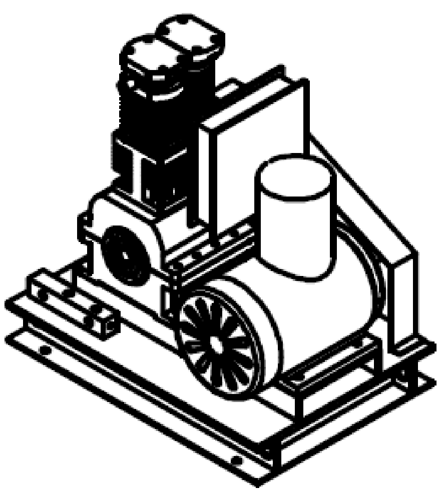
Pipeline system, Cooler system, Valve system, Cylinder is all Stainless steel material.

GOW-3/4-150









Bidder: Shanghai Souair International Trade Co., Ltd

Add: R1403 A-Bld No.1370Zhennan Road,Shanghai,China.

Buyer: NLAP (North Lebanon Alternative Porwer) Corporation,

Address: Harba Building, next to Hospital Albert Haykal, Ras Masqa, Lebanon

Commercial Quotation

Name of Vendor ： Shanghai Souair International Trade Ltd			FCA Shanghai, China		
				Currency:	**USD**
No.	**Description**	**Model / Main Parameters**	**Qty**	**Unit Price**	**Total Price**
1	Oil Free Reciprocating Oxygen gas compressor	Model GOW-3/3-150, Inlet pressure 3-5Barg,Discharge pressure 150Barg,3Nm3/hr Flow capacity,2.2KW 380V 50HZ 3PH IP55,V-Belt Driven,Air Cooled Type,4stage compressed	1	7,100.00	7,100.00
	Shipping charge from shanghai,china to Beirut seaport, Lebanon by sea				**400.00**
	CNF Beirut,Lebanon(USD)				**7,500.00**
	Shipping time to Beirut,Lebanon by sea: 25 Days				

Manufacturer of Compressor: souair
Country Of Origin: China
Lead Time: usual 30-40 Days upon order, confirmed by the order.
Payment term: 40%TT in advance, then 60%TT before delivery.
Price: USD Based on CNF Beirut,Lebanon.
Warranty: 12Month after commission or 18month after the shipping.
Validity: one month

Compressor #5:

https://www.oxywise.com/en/products/oxygen-hp-compressor?gclid=EAIaIQobChMI84-M8euo7wIVQe7tCh2CnAb-EAAYASAAEgLM3vD_BwE

I am looking for an oxygen compressor (oil-free) taht has the following specifications:
inlet pressure : 1 bar - 5 bar
outlet pressure : 100 bar
flow rate: more than 800 L/hr

Oxywise Answer: (Monday 15.3.2021)
I'm sorry we don't have a RIX unit that small.
I can offer an unbranded CE marked Oxygen compressor?
Price is circa €8k. Leadtime 5 weeks.

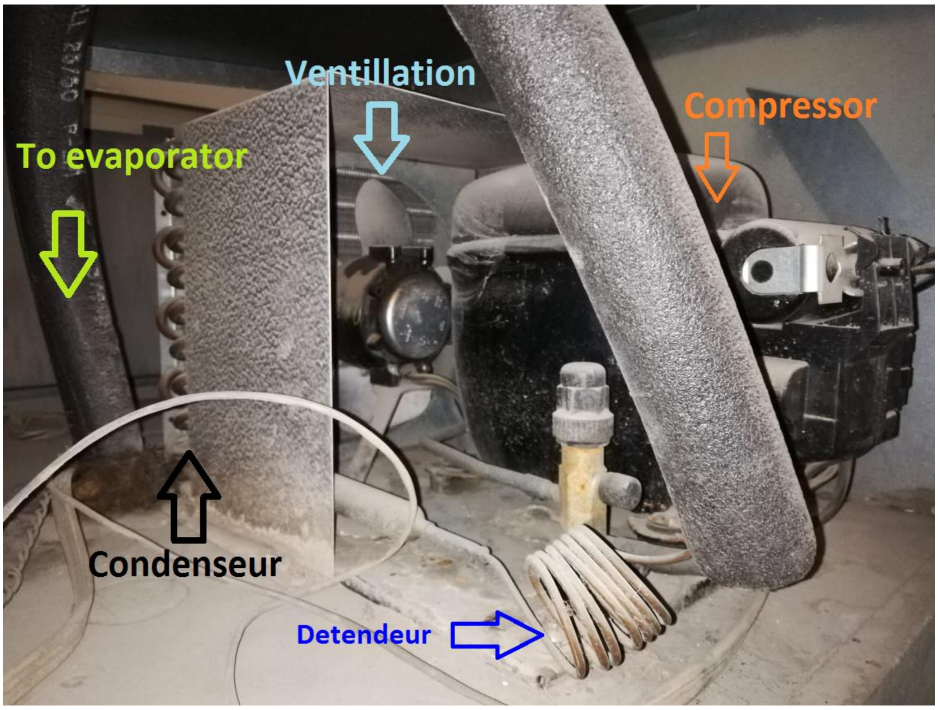
9. Calculation of Oxygen flow rate outlet by electrolysis:

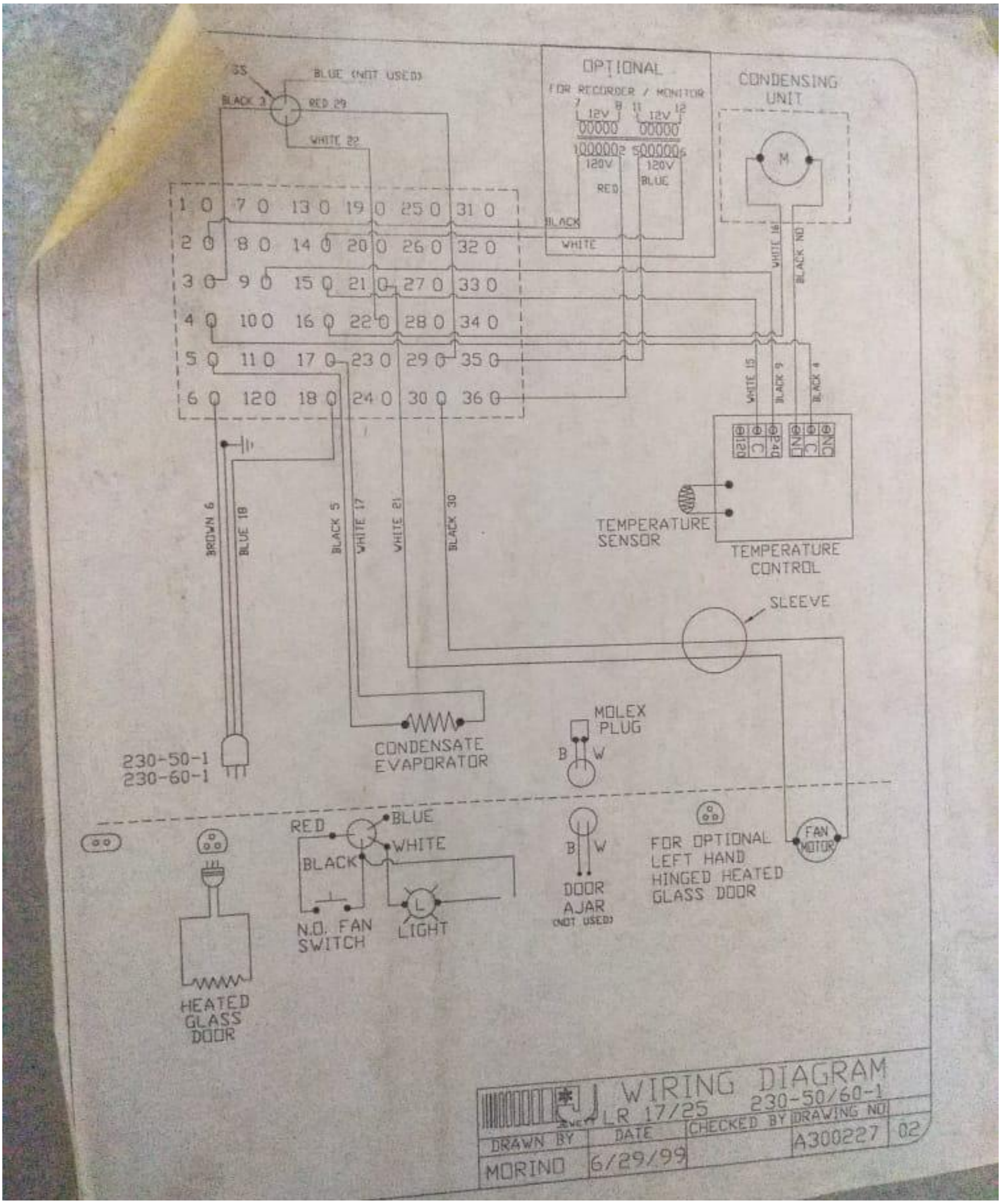
- Power :2.4 kW (voltage =4V; current = 150 A)

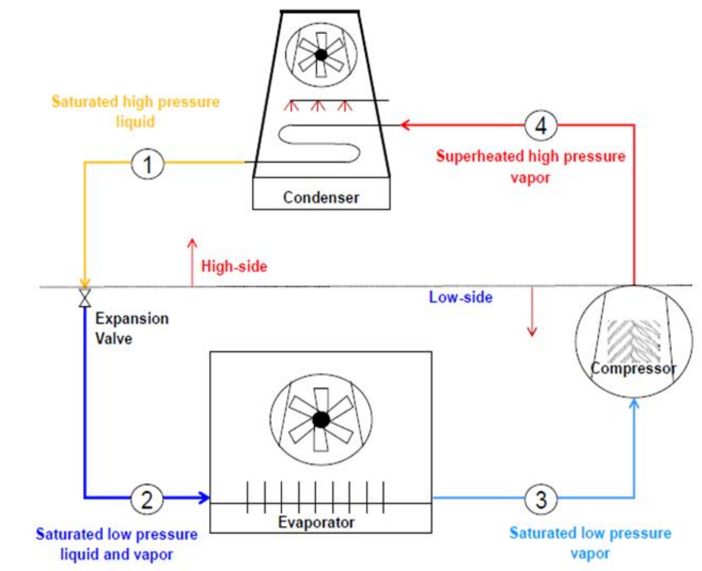
  - Gas flow rate Hydrogen all stacks = 2.27 L/min =136.2 L/hr
  - **Gas flow rate Oxygen all stacks = 1.13 L/min = 67.8 L/hr**
- Power : 25 kW
  - Gas flow rate Hydrogen all stacks = 23.65 L/min = 1418.75 L/hr
  - **Gas flow rate Oxygen all stacks = 11.77L/min = 706.25 L/hr**

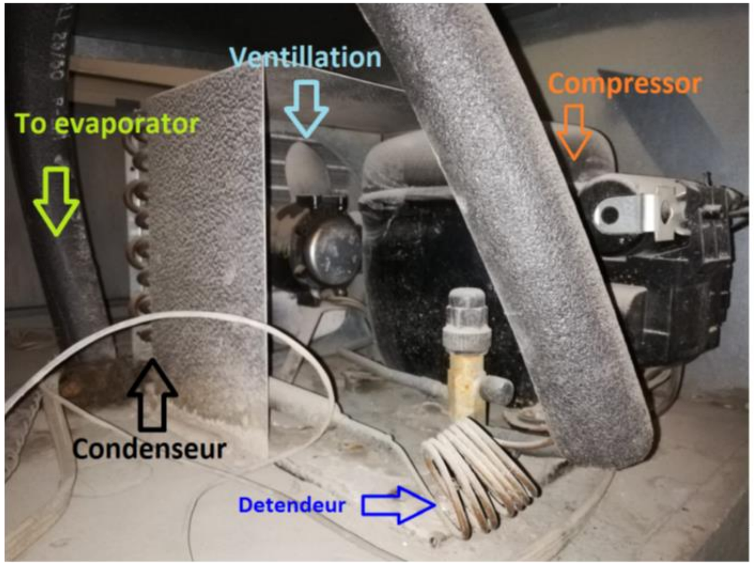
10. Prototype of refrigerator

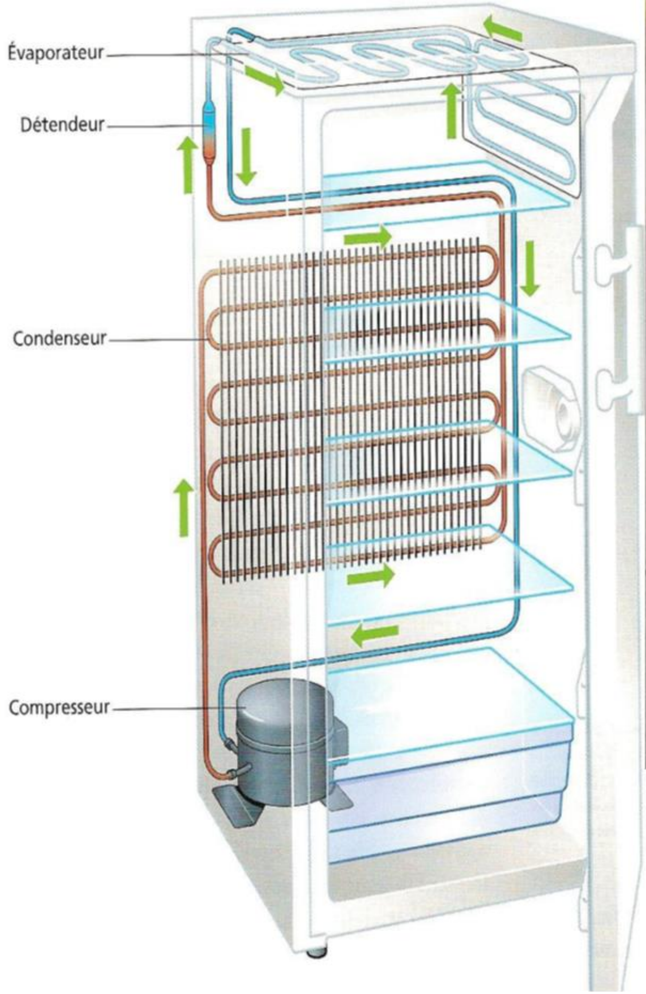
10.1. Prototype 1 : Laboratory fridge

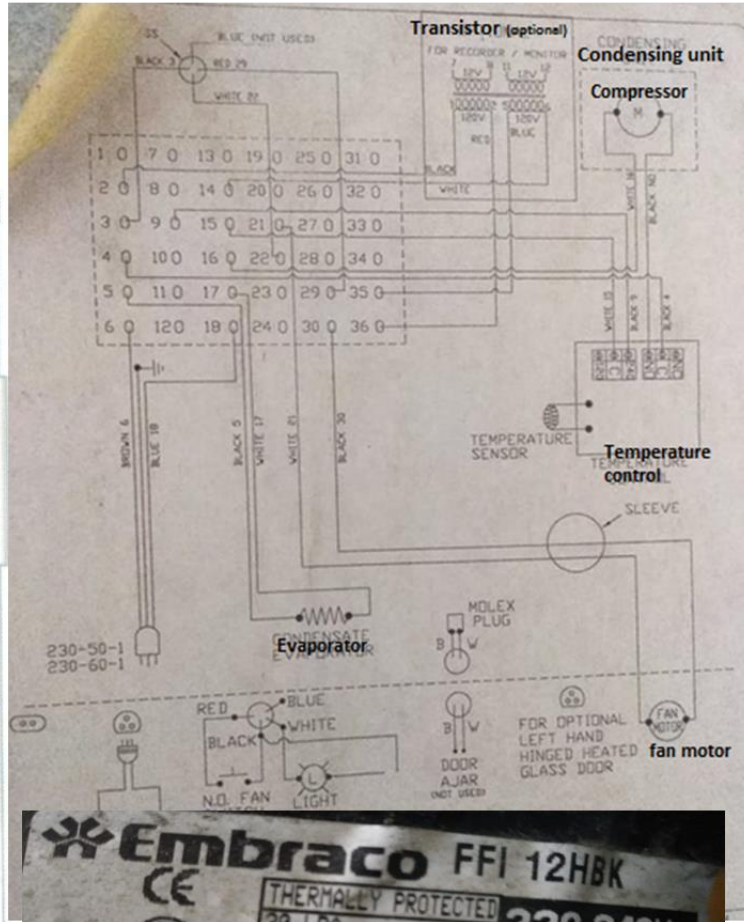


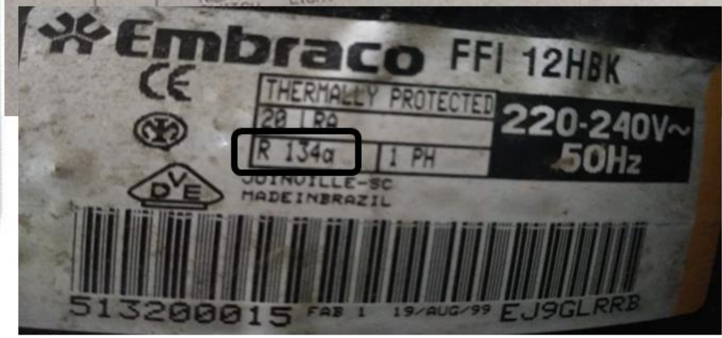

OPTIONAL
FOR RECORDER / MONITOR
CONDENSING UNIT
BLUE (NOT USED)
BLACK 3
RED 29
WHITE 22
BROWN 6
BLUE 18
BLACK 5
WHITE 17
WHITE 21
BLACK 30
WHITE 15
BLACK 9
BLACK 4
WHITE 16
BLACK NO
TEMPERATURE SENSOR
TEMPERATURE CONTROL
SLEEVE
MOLEX PLUG
CONDENSATE EVAPORATOR
230-50-1
230-60-1
FAN MOTOR
RED
BLUE
WHITE
BLACK
N.O. FAN SWITCH
LIGHT
DOOR AJAR (NOT USED)
FOR OPTIONAL LEFT HAND HINGED HEATED GLASS DOOR
HEATED GLASS DOOR
WIRING DIAGRAM
LR 17/25
230-50/60-1
DRAWN BY
DATE
CHECKED BY
DRAWING NO
MORINO
6/29/99
A300227
02

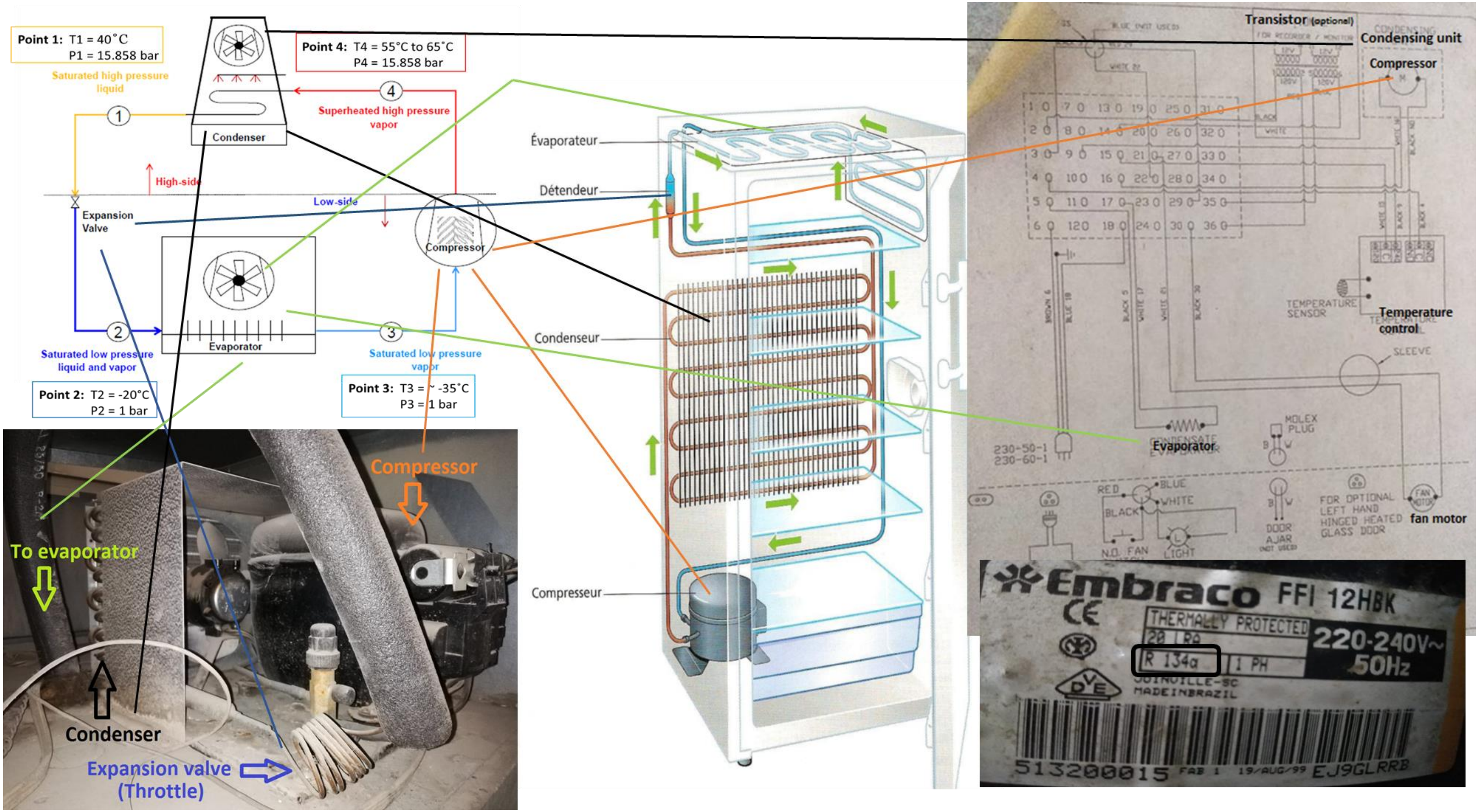

Saturated high pressure liquid
Condenser
4
Superheated high pressure vapor
1
High-side
Low-side
Expansion Valve
Compressor
Evaporator
2
3
Saturated low pressure liquid and vapor
Saturated low pressure vapor


Ventillation
Compressor
To evaporator
Condenseur
Detendeur


Évaporateur
Détendeur
Condenseur
Compresseur


Transistor (optional)
Condensing unit
Compressor
TEMPERATURE SENSOR
Temperature control
SLEEVE
Evaporator
MOLEX PLUG
230-50-1
230-60-1
RED
BLUE
WHITE
BLACK
N.O. FAN
LIGHT
DOOR AJAR
FOR OPTIONAL LEFT HAND HINGED HEATED GLASS DOOR
fan motor


Embraco FFI 12HBK
CE
THERMALLY PROTECTED
R 134a
1 PH
220-240V~
50Hz
MADEINBRAZIL
513200015
19/AUG/99
EJ9GLRRB


Point 1: T1 = 40°C
P1 = 15.858 bar
Saturated high pressure liquid
Condenser
Point 4: T4 = 55°C to 65°C
P4 = 15.858 bar
Superheated high pressure vapor
High-side
Low-side
Expansion Valve
Compressor
Evaporator
Saturated low pressure liquid and vapor
Saturated low pressure vapor
Point 2: T2 = -20°C
P2 = 1 bar
Point 3: T3 = ~ -35°C
P3 = 1 bar
Compressor
To evaporator
Condenser
Expansion valve
(Throttle)
Évaporateur
Détendeur
Condenseur
Compresseur
Transistor (optional)
Condensing unit
Compressor
TEMPERATURE SENSOR
Temperature control
SLEEVE
Evaporator
MOLEX PLUG
230-50-1
230-60-1
RED
BLUE
WHITE
BLACK
N.O. FAN
LIGHT
DOOR AJAR
FOR OPTIONAL LEFT HAND HINGED HEATED GLASS DOOR
fan motor
Embraco FFI 12HBK
THERMALLY PROTECTED
R 134a
1 PH
220-240V~
50Hz
MADE IN BRAZIL
513200015
19/AUG/99
EJ9GLRRB

reforgerator compressor R134A Fridge compressor

Parameters

Specification

Production Facility	Brazil
Brand	Embraco
Compressor Type	Hermetic Reciprocating
Application	HBP (+7,2°C / +54,4°C)
H.Power	3/8
Power Supply	220-240V
Refrigerant	R134a
Cooling Capacity (Watt)	1.316
Motor Type	1 Phase - RSIR
BOM.	513200015962A
Compressor Model	FFI 12HBK
Diplacement (cm3/rev)	11,14
Frequency (Hz)	50
Suction Line	5/16"
Discharge Line	1/4"

embraco

COMPRESSOR TECHNICAL DATA

COMPRESSOR DEFINITION

Designation	**F FI12HBK**
Nominal Voltage/Frequency	**220-240 V 50 Hz**
Engineering Number	**513200015**

A - APPLICATION / LIMIT WORKING CONDITIONS

1 Type	Hermetic reciprocating compressor		
2 Refrigerant	R-134a		
3 Nominal voltage and frequency	220-240 / 50	[V / Hz]	
4 Application type	Low-Medium-High Back Pressure		
4.1 Evaporating temperature range	-35°C to 15°C	(-31°F to 59°F)	
5 Motor type	RSIR/CSIR		
6 Starting torque	LST - Low Starting Torque		
7 Expantion device	Capillary tube		
8 Compressor cooling		Operating voltage range	
		50 Hz	60 Hz
8.1 LBP (32ºC Ambient temperature)	Fan	198 to 255 V	-
8.2 LBP (43ºC Ambient temperature)	Fan	198 to 255 V	-
8.3 HBP (32ºC Ambient temperature)	Fan	198 to 255 V	-
8.4 HBP (43ºC Ambient temperature)	Fan	198 to 255 V	-
9 Maximum condensing pressures/temperature			
9.1 Operating (gauge)	16.2	[kgf/cm²] (230 psig)	/ ºC - ºF
9.2 Peak (gauge)	20.6	[kgf/cm²] (293 psig)	/ ºC - ºF
10 Maximum winding temperature	130	[°C]	

B - MECHANICAL DATA

1 Commercial designation	1/3+	[hp]
2 Displacement	11.14	[cm³] (0.680 cu.in)
2.1 Bore [mm]	26.000	
2.2 Stroke [mm]	21.000	
3 Lubricant charge	280	[ml] (9.47 fl.oz.)
3.1 Lubricants approved		
3.2 Lubricants type/viscosity	ESTER / ISO22	
4 Weight (with oil charge)	10.9	[kg] (24.03 lb.)
5 Nitrogen charge	0.2 to 0.3	[kgf/cm²] (2.84 to 4.27 psig)

C - ELETRICAL DATA

1 Nominal Voltage/Frequency/Number of Phases	220-240 V 50 Hz 1 ~ (Single phase)	
2 Starting device type	Current Relay	
2.1 Starting device	213516035/213516043	
3 Start capacitor	88-108(220)	[µF(VAC minimum)]
4 Run capacitor	-	[µF(VAC minimum)]
5 Motor protection	CP4TMF210N52A2	
6 Start winding resistance	29.90	[Ω at 25ºC (77ºF)] +/- 8%
7 Run winding resistance	5.70	[Ω at 25ºC (77ºF)] +/- 8%
8 LRA - Locked rotor amperage (50 Hz)	20.00	[A] - Measured according to UL 984
9 FLA - Full load amperage L/MBP (50 Hz)	2.50	[A] - Measured according to UL 984
10 FLA - Full Load Amperage HBP (50 Hz)	3.00	[A] - Measured according to UL 984
11 Approval boards certification	CCC - IRAM - UL - VDE	

D - PERFORMANCE - CHECK POINT DATA

TEST CONDITIONS: @220V50Hz			ASHRAEHBP32 Fan			Evaporating temperature (Condensing temperature	7.2°C (44.96°F) 54.4°C (129.92°F))	
Cooling capacity +/- 5%			Power consumption +/- 5%	Current consumption +/- 5%	Gas flow rate +/- 5%	EFFICIENCY RATE +/- 7%		
[Btu/h]	[kcal/h]	[W]	[W]	[A]	[kg/h]	[Btu/Wh]	[kcal/Wh]	[W/W]
4492	1132	1316	504	2.79		8.91	2.25	2.61

TEST CONDITIONS: @220V50Hz			ASHRAELBP32 Fan			Evaporating temperature (Condensing temperature	-23.3°C (-9.94°F) 54.4°C (129.92°F))	
Cooling capacity +/- 5%			Power consumption +/- 5%	Current consumption +/- 5%	Gas flow rate +/- 5%	EFFICIENCY RATE +/- 7%		
[Btu/h]	[kcal/h]	[W]	[W]	[A]	[kg/h]	[Btu/Wh]	[kcal/Wh]	[W/W]
1090	275	319	256	1.96	6.19	4.26	1.07	1.25

E - PERFORMANCE - CURVES

TEST CONDITIONS: @220V50Hz		ASHRAE32 Fan						(Condensing temperature 45°C (+113°F))		
Evaporating temperature		Cooling capacity +/- 5%			Power consumption +/- 5%	Current consumption +/- 5%	Gas flow rate +/- 5%	EFFICIENCY RATE +/- 7%		
°C	(°F)	[Btu/h]	[kcal/h]	[W]	[W]	[A]	[kg/h]	[Btu/Wh]	[kcal/Wh]	[W/W]
-35	(-31)	553	139	162	187	1.87	3.13	2.94	0.74	0.86
-30	(-22)	762	192	223	214	1.91	4.33	3.62	0.91	1.06
-25	(-13)	1038	262	304	242	1.97	5.90	4.35	1.10	1.27
-20	(- 4)	1383	348	405	272	2.05	7.87	5.12	1.29	1.50
-15	(+ 5)	1799	453	527	303	2.13	10.26	5.94	1.50	1.74
-10	(+14)	2289	577	671	336	2.23	13.10	6.80	1.71	1.99
-5	(+23)	2853	719	836	370	2.35	16.41	7.69	1.94	2.25
0	(+32)	3495	881	1024	406	2.47	20.21	8.60	2.17	2.52
+5	(+41)	4217	1063	1236	442	2.60	24.54	9.52	2.40	2.79
+10	(+50)	5019	1265	1471	480	2.75	29.41	10.46	2.64	3.07
+15	(+59)	5905	1488	1730	518	2.90	34.86	11.40	2.87	3.34

TEST CONDITIONS: @220V50Hz		ASHRAE32 Fan						(Condensing temperature 55°C (+131°F))		
Evaporating temperature		Cooling capacity +/- 5%			Power consumption +/- 5%	Current consumption +/- 5%	Gas flow rate +/- 5%	EFFICIENCY RATE +/- 7%		
°C	(°F)	[Btu/h]	[kcal/h]	[W]	[W]	[A]	[kg/h]	[Btu/Wh]	[kcal/Wh]	[W/W]
-35	(-31)	514	130	151	184	1.89	2.91	2.71	0.68	0.79
-30	(-22)	713	180	209	215	1.93	4.05	3.31	0.83	0.97
-25	(-13)	974	245	285	247	2.00	5.54	3.95	1.00	1.16
-20	(- 4)	1300	328	381	282	2.08	7.40	4.62	1.16	1.35
-15	(+ 5)	1693	427	496	319	2.18	9.65	5.32	1.34	1.56
-10	(+14)	2155	543	631	357	2.30	12.33	6.03	1.52	1.77
-5	(+23)	2687	677	787	398	2.44	15.44	6.76	1.70	1.98
0	(+32)	3292	830	965	440	2.59	19.03	7.50	1.89	2.20
+5	(+41)	3972	1001	1164	483	2.75	23.11	8.23	2.08	2.41
+10	(+50)	4729	1192	1386	528	2.93	27.71	8.97	2.26	2.63
+15	(+59)	5565	1402	1631	575	3.12	32.85	9.69	2.44	2.84

E - PERFORMANCE - CURVES

TEST CONDITIONS: @220V50Hz		ASHRAE32 Fan					(Condensing temperature **65ºC (+149ºF)**)			
Evaporating temperature		Cooling capacity +/- 5%			Power consumption +/- 5%	Current consumption +/- 5%	Gas flow rate +/- 5%	EFFICIENCY RATE +/- 7%		
°C	(°F)	[Btu/h]	[kcal/h]	[W]	[W]	[A]	[kg/h]	[Btu/Wh]	[kcal/Wh]	[W/W]
-35	**(-31)**	395	100	116	175	1.87	2.22	2.32	0.58	0.68
-30	**(-22)**	608	153	178	211	1.92	3.46	2.91	0.73	0.85
-25	**(-13)**	880	222	258	249	2.00	5.01	3.53	0.89	1.03
-20	**(- 4)**	1212	305	355	289	2.10	6.90	4.16	1.05	1.22
-15	**(+ 5)**	1606	405	471	332	2.22	9.16	4.81	1.21	1.41
-10	**(+14)**	2065	520	605	377	2.37	11.82	5.45	1.37	1.60
-5	**(+23)**	2590	653	759	424	2.53	14.89	6.09	1.54	1.79
0	**(+32)**	3183	802	933	474	2.71	18.40	6.73	1.70	1.97
+5	**(+41)**	3847	970	1127	525	2.91	22.38	7.34	1.85	2.15
+10	**(+50)**	4583	1155	1343	578	3.13	26.85	7.94	2.00	2.33
+15	**(+59)**	5394	1359	1581	633	3.36	31.84	8.51	2.14	2.49

F - EXTERNAL CHARACTERISTICS

1 Base plate	Universal EG/F/AMEM version 2		
2 Tray holder	No		
3 Connectors			
3.1 SUCTION	8.2 +0.12/-0.08	[mm]	(0.323" +0.005"/-0.003")
3.1.1 Material	Copper		
3.1.2 Shape	Straight		
3.2 DISCHARGE	6.5 +0.12/-0.08	[mm]	(0.256" +0.005"/-0.003")
3.2.1 Material	Copper		
3.2.2 Shape	Straight		
3.3 PROCESS	6.5 +0.12/-0.08	[mm]	(0.256" +0.005"/-0.003")
3.3.1 Material	Copper		
3.3.2 Shape	Straight		
3.4 Oil cooler (Copper)	No	[mm]	
3.5 Connector sealing	Rubber Plugs		

- R134a refrigerant:

R134a is also known as Tetrafluoroethane (CF3CH2F) from the family of HFC refrigerant. With the discovery of the damaging effect of CFCs and HCFCs refrigerants to the ozone layer, the HFC family of refrigerant has been widely used as their replacement.

It is now being used as a replacement for R-12 CFC refrigerant in the area of centrifugal, rotary screw, scroll and reciprocating compresssors. It is safe for normal handling as it is non-toxic, non-flammable and non-corrosive.

Currently it is also being widely used in the air conditioning system in newer automotive vehicles. The manufacturing industry use it in plastic foam blowing. Pharmaceuticals industry use it as a propellant.

It exists in gas form when expose to the environment as the boiling temperature is -14.9°F or -26.1°C.

This refrigerant is not 100% compatible with the lubricants and mineral-based refrigerant currently used in R-12. Design changes to the condenser and evaporator need to be done to use this refrigerant. The use of smaller hoses and 30% increase in control pressure regulations also have to be done to the system.

Properties of R-134a

No	Properties	R-134a
1	Boiling Point	-14.9°F or -26.1°C
2	Auto-Ignition Temperature	1418°F or 770°C
3	Ozone Depletion Level	0
4	Solubility In Water	0.11% by weight at 77°F or 25°C
5	Critical Temperature	252°F or 122°C
6	Cylinder Color Code	Light Blue
7	Global Warming Potential (GWP)	1200

Features and uses of R-134a

The refrigerant gas R-134a is a HFC replacing R-12 in new installations. As all HFC refrigerants not damage the ozone layer. It has a great chemical and thermal stability, low toxicity and is non-flammable, besides having an excellent compatibility with most materials. Its classification is **A1 group L1.**

Immiscible with traditional oils of R-12 (mineral and alkyl benzene), whereas its miscibility with oils polyesters (POE) is complete, so it should always be used with these oils.

R-134a is an alternative refrigerant to R-12 for the facility retrofitting or for new installations. It is widely used in automobile air conditioners and household refrigerators. It is also widely used in the industrial and commercial chillers in addition to transport in positive temperatures.

Toxicity and storage

R-134a is a substance with very low toxicity. The index LCL0 inhalation in rats during 4 hours is less than 500,000 ppm and NOEL in relation to heart problems is about 75,000 ppm. In exposure for 104 weeks at a concentration of 10,000 ppm was observed no effect. R-134a containers should be stored in a cool and ventilated area away from heat sources. R-134a vapors are heavier than air and tend to accumulate near the ground.

Security

R-134a is not toxic, not flammable, high security.
It has been classified as **A1 / group L1.**

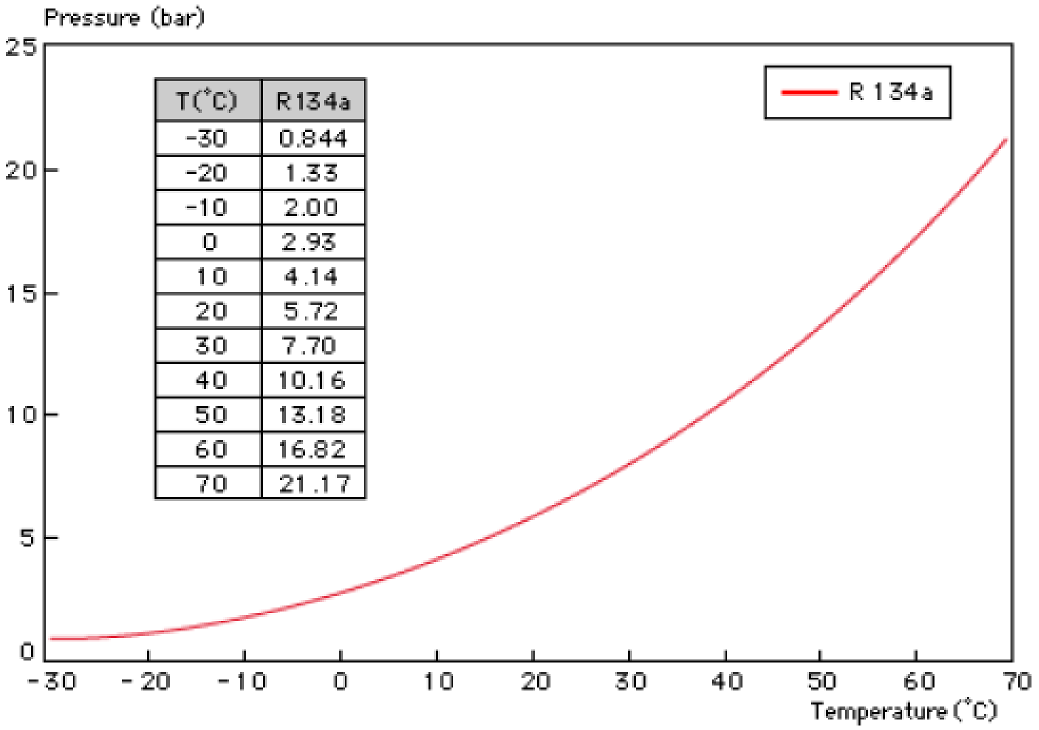
Components

Chemical Name	% By weight	CAS N °	EC N °
1,1,1,2- Tetrafluoroethane (R-134a)	100	811-97-2	212-377-0

[28]

28 https://gas-servei.com/shop/docs/technical-data-sheet-r-134a-gas-servei.pdf

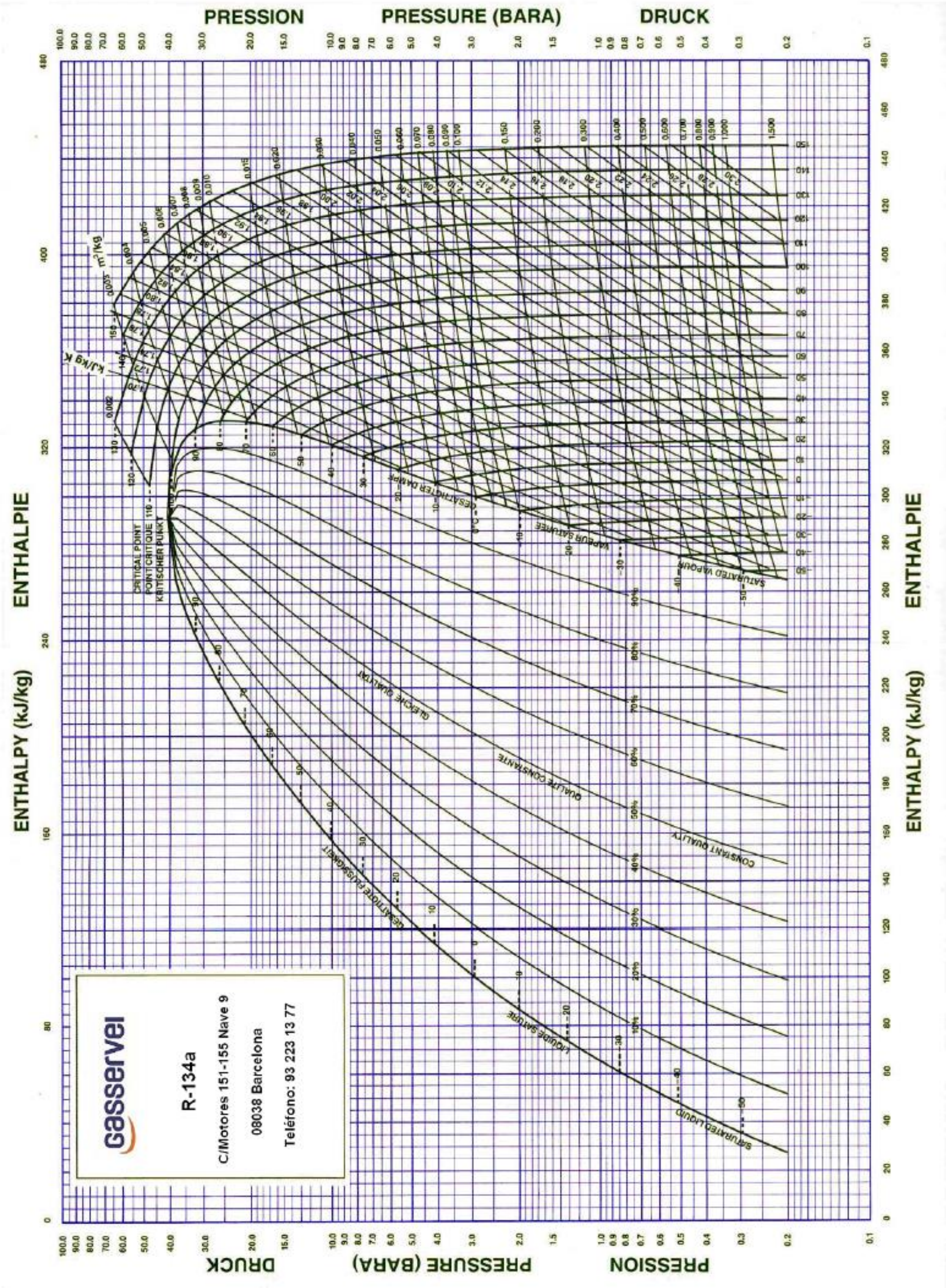
Chart Pressure / Temperature



Thermodynamic properties

TEMP. (°C)	ABSOLUTE PRESSURE (bar)		DENSITY (Kg/m³)		ENTHALPY (kJ/Kg)		ENTROPY (kJ/Kg.K)	
	BUBBLE	DEW	BUBBLE	DEW	BUBBLE	DEW	BUBBLE	BUBBLE
-40	0.51	0.51	1413.94	2.76	149.45	375.65	0.8008	1.7710
-35	0.66	0.66	1399.95	3.50	155.53	378.93	0.8266	1.7646
-30	0.84	0.84	1385.72	4.39	161.67	382.20	0.8521	1.7590
-25	1.06	1.06	1371.24	5.45	167.88	385.45	0.8773	1.7540
-20	1.32	1.32	1356.46	6.71	174.16	388.69	0.9023	1.7497
-15	1.63	1.63	1341.36	8.19	180.51	391.90	0.9270	1.7458
-10	2.00	2.00	1325.92	9.92	186.93	395.07	0.9515	1.7425
-5	2.42	2.42	1310.10	11.92	193.43	398.20	0.9759	1.7395
0	2.92	2.92	1293.86	14.23	200.00	401.28	1.0000	1.7369
5	3.49	3.49	1277.17	16.89	206.65	404.30	1.0240	1.7346
10	4.14	4.14	1259.99	19.93	213.38	407.25	1.0478	1.7325
15	4.88	4.88	1242.27	23.40	220.20	410.13	1.0714	1.7306
20	5.71	5.71	1223.96	27.34	227.11	412.92	1.0950	1.7288
25	6.65	6.65	1205.00	31.81	234.11	415.62	1.1184	1.7272
30	7.70	7.70	1185.33	36.88	241.21	418.20	1.1417	1.7256
35	8.88	8.88	1164.89	42.61	248.42	420.67	1.1650	1.7240
40	10.18	10.18	1143.58	49.08	255.74	423.01	1.1882	1.7223
45	11.62	11.62	1121.32	56.40	263.19	425.20	1.2114	1.7206
50	13.20	13.20	1197.98	64.66	270.77	427.23	1.2346	1.7187

Mollier Diagram



- Expansion valve:

R134a refrigerant gas pressure – temperature chart

Refrigerant Temperature / Pressure Chart

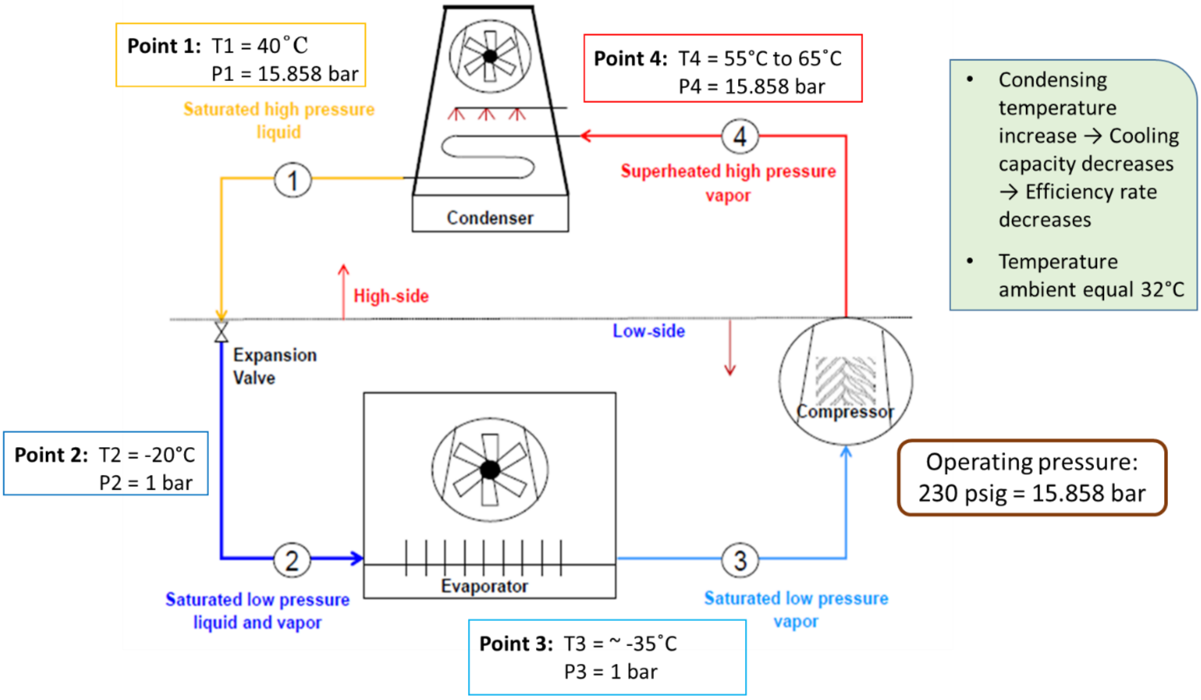
Red numbers = inches Hg Black numbers = psig

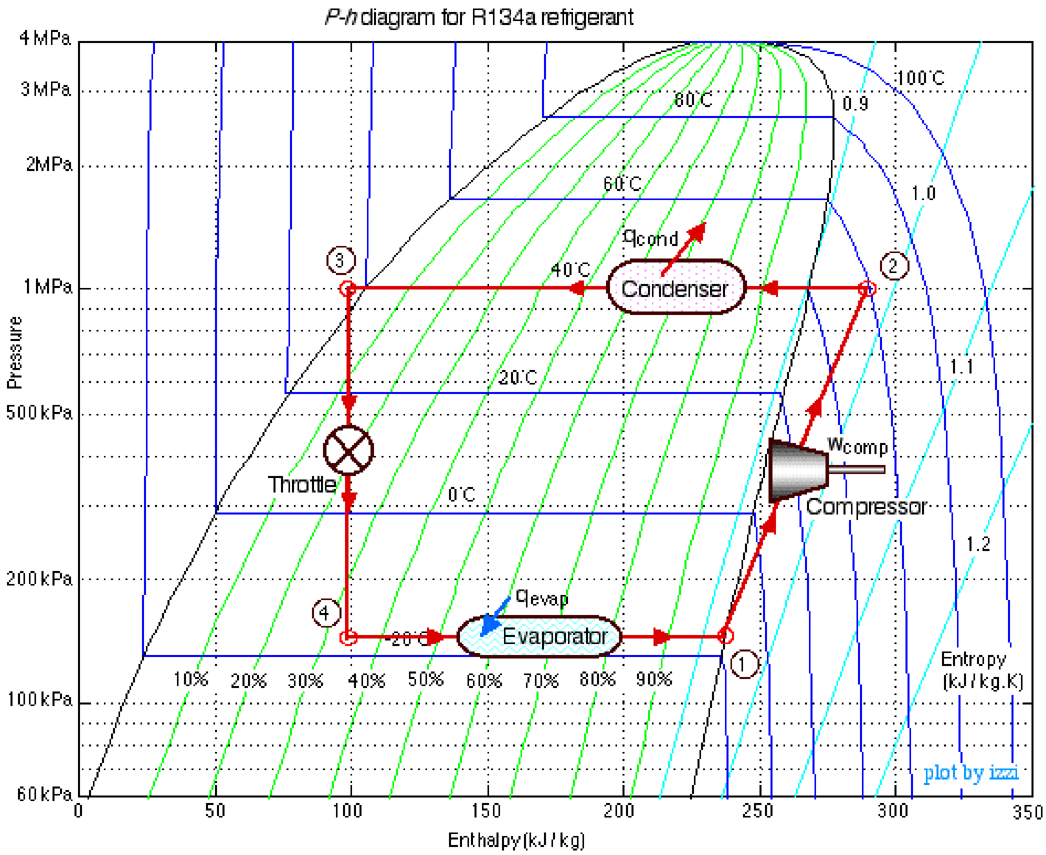
Temp	Pressure PSI						
(°F)	R-11	R-12	R-22	R-123	R-134A	R-500	R-502
-100	29.8	27.0	25.0	29.9	27.8	26.4	25.3
-90	29.7	25.7	23.0	29.8	26.9	24.9	20.6
-80	29.6	24.1	20.2	29.7	25.6	22.9	17.2
-70	29.4	21.8	16.6	29.6	23.8	20.3	12.8
-60	29.2	19.0	12.0	29.5	21.5	17.0	7.2
-50	28.9	15.4	6.2	29.2	18.5	12.8	0.2
-40	28.4	11.0	0.5	28.9	14.7	7.6	4.1
-30	27.8	5.4	4.9	28.5	9.8	1.2	9.2
-20	27.0	0.6	10.2	27.8	3.8	3.2	15.3
-10	26.0	4.4	16.4	27.0	1.8	7.8	22.6
0	24.7	9.2	24.0	26.0	6.3	13.3	31.1
10	23.1	14.6	32.8	24.7	11.6	19.7	41.0
20	21.1	21.0	43.0	23.0	18.0	27.2	52.4
30	18.6	28.4	54.9	20.8	25.6	36.0	65.6
40	15.6	37.0	68.5	18.2	34.5	46.0	80.5
50	12.0	46.7	84.0	15.0	44.9	57.5	97.4
60	7.8	57.7	101.3	11.2	56.9	70.6	116.4
70	2.8	70.2	121.4	6.6	70.7	85.3	137.6
80	1.5	84.2	143.6	1.1	86.4	101.9	161.2
90	4.9	99.8	168.4	2.6	104.2	120.4	187.4
100	8.8	117.2	195.9	6.3	124.3	141.1	216.2
110	13.1	136.4	226.4	10.5	146.3	164.0	247.9
120	18.3	157.7	259.9	15.4	171.9	189.2	282.7
130	24.0	181.0	296.8	21.0	199.4	217.0	320.8
140	30.4	206.6	337.2	27.3	230.5	247.4	362.6
150	37.7	234.4	381.5	34.5	264.4	280.7	408.4

[29]

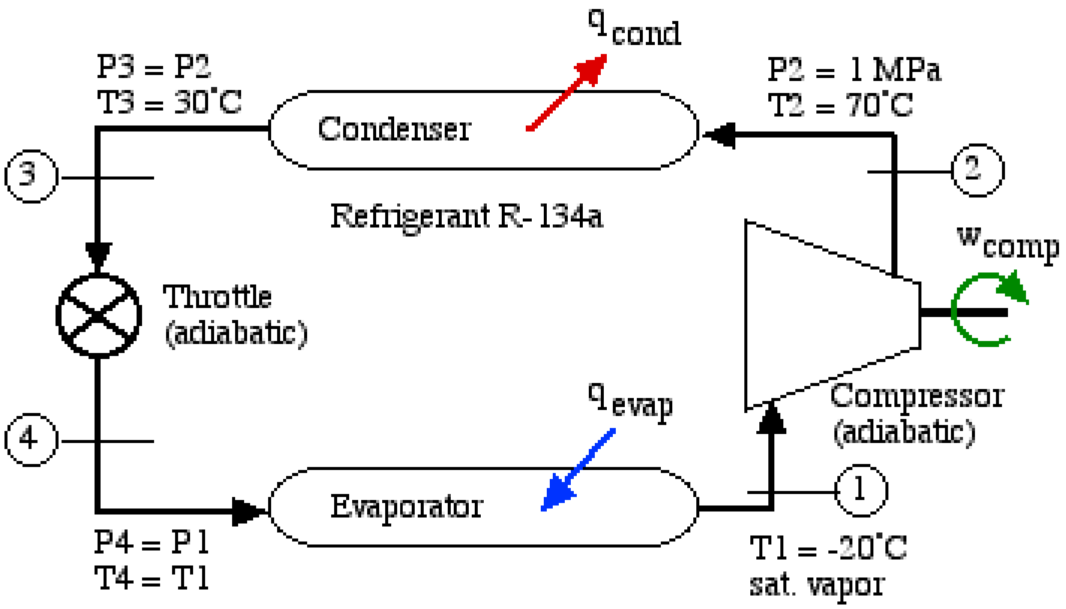
R134a				
Temperature		Pressure		
°F	°C	Bar	Inches Hg	psig
-40	-40	0.498	14.7	
-31	-35	0.3241		
-30	-34.44	0.3048	9.8	
-20	-28.89	0.1016	3.8	
-10	-23.33	0.1241		1.8
0	-17.78	0.4344		6.3
10	-12.22	0.7998		11.6
20	-6.67	1.2411		18
30	-1.11	1.7651		25.6
40	4.44	2.3787		34.5
50	10	3.0957		44.9
59	15	3.8404		
60	15.56	3.9231		56.9
70	21.11	4.8746		70.7
80	26.67	5.9571		86.4
90	32.22	7.1843		104.2
100	37.78	8.5702		124.3
110	43.33	10.087		146.3
120	48.89	11.8521		171.9
130	54.44	13.7481		199.4
140	60	15.8924		230.5
149	65	17.996		
150	65.56	18.2297		264.4

29 https://www.pinterest.com/pin/333829391133607747/

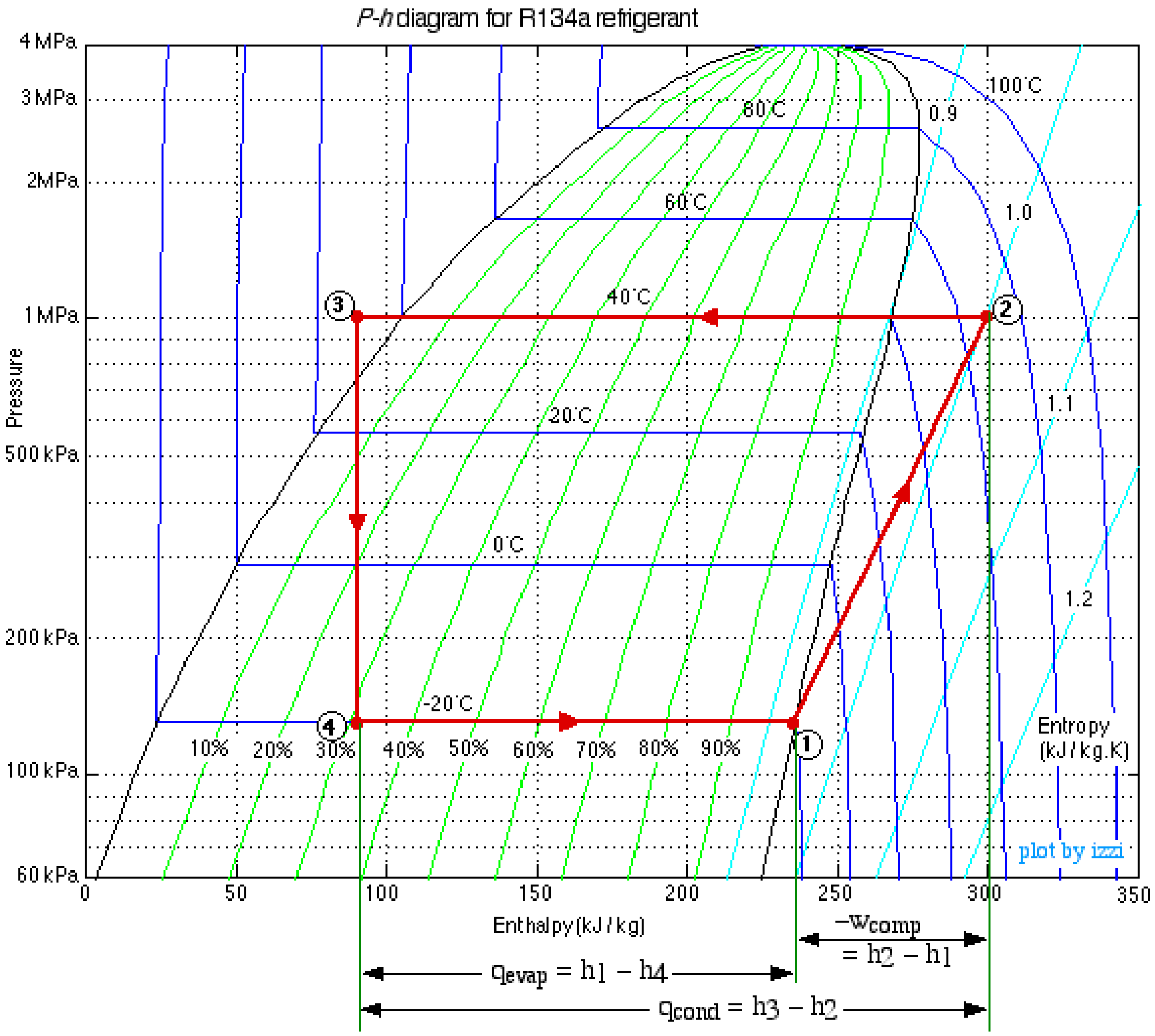

Point 1: T1 = 40˚C
P1 = 15.858 bar
Saturated high pressure liquid
Condenser
Point 4: T4 = 55°C to 65˚C
P4 = 15.858 bar
Superheated high pressure vapor
4
1
High-side
Low-side
Expansion Valve
Compressor
Point 2: T2 = -20°C
P2 = 1 bar
2
Evaporator
3
Saturated low pressure liquid and vapor
Saturated low pressure vapor
Point 3: T3 = ~ -35˚C
P3 = 1 bar
• Condensing temperature increase → Cooling capacity decreases → Efficiency rate decreases
• Temperature ambient equal 32°C
Operating pressure: 230 psig = 15.858 bar



[30]

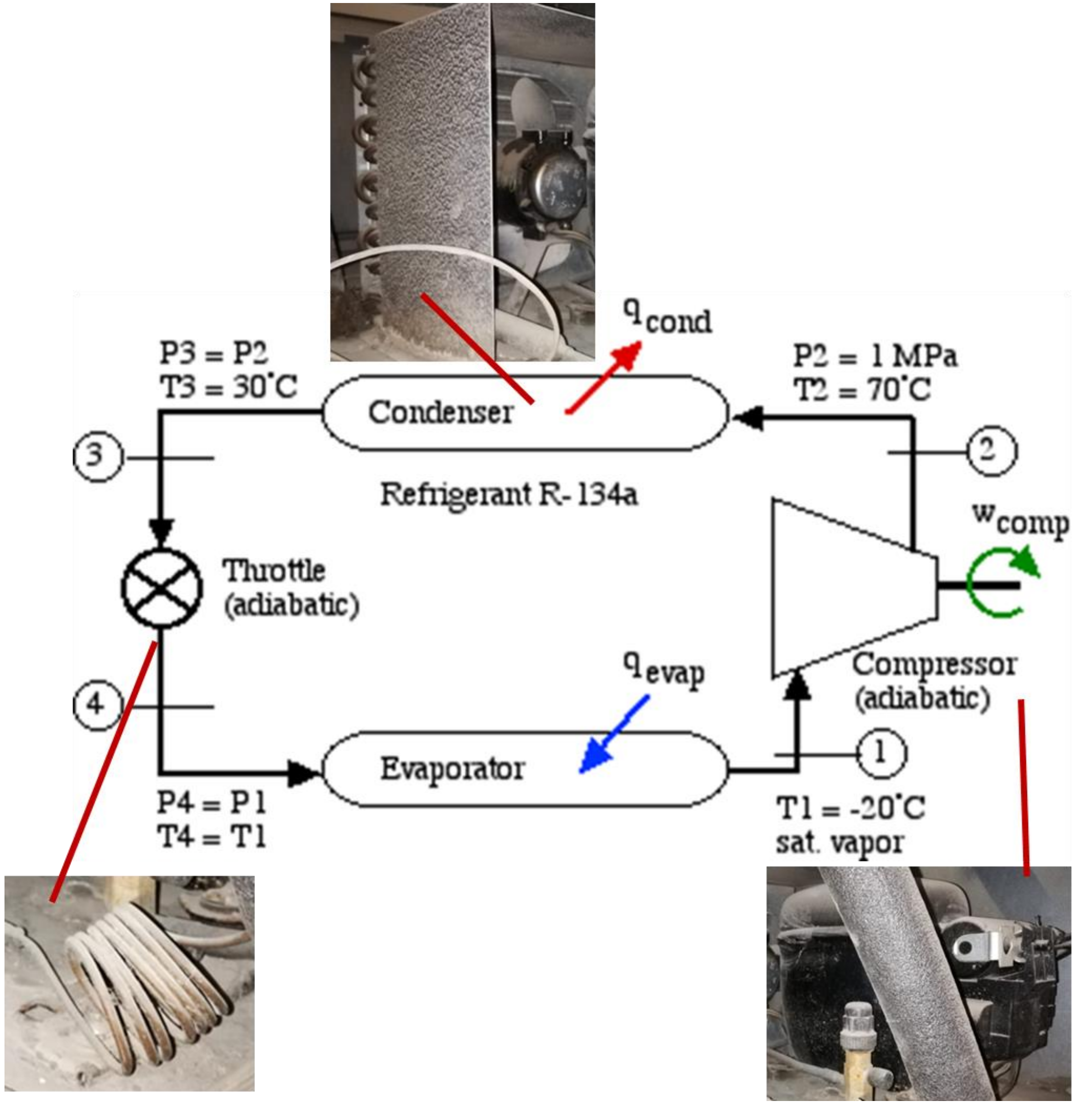


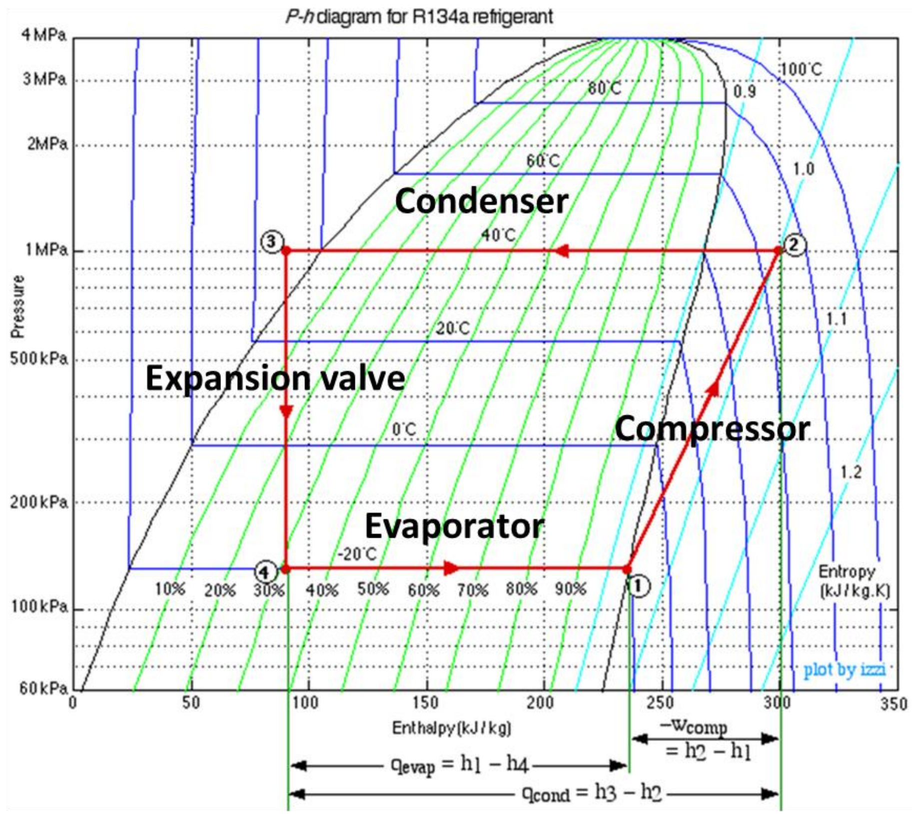
30 https://www.ohio.edu/mechanical/thermo/Intro/Chapt.1_6/refrigerator/refrig_problems.html



[31]

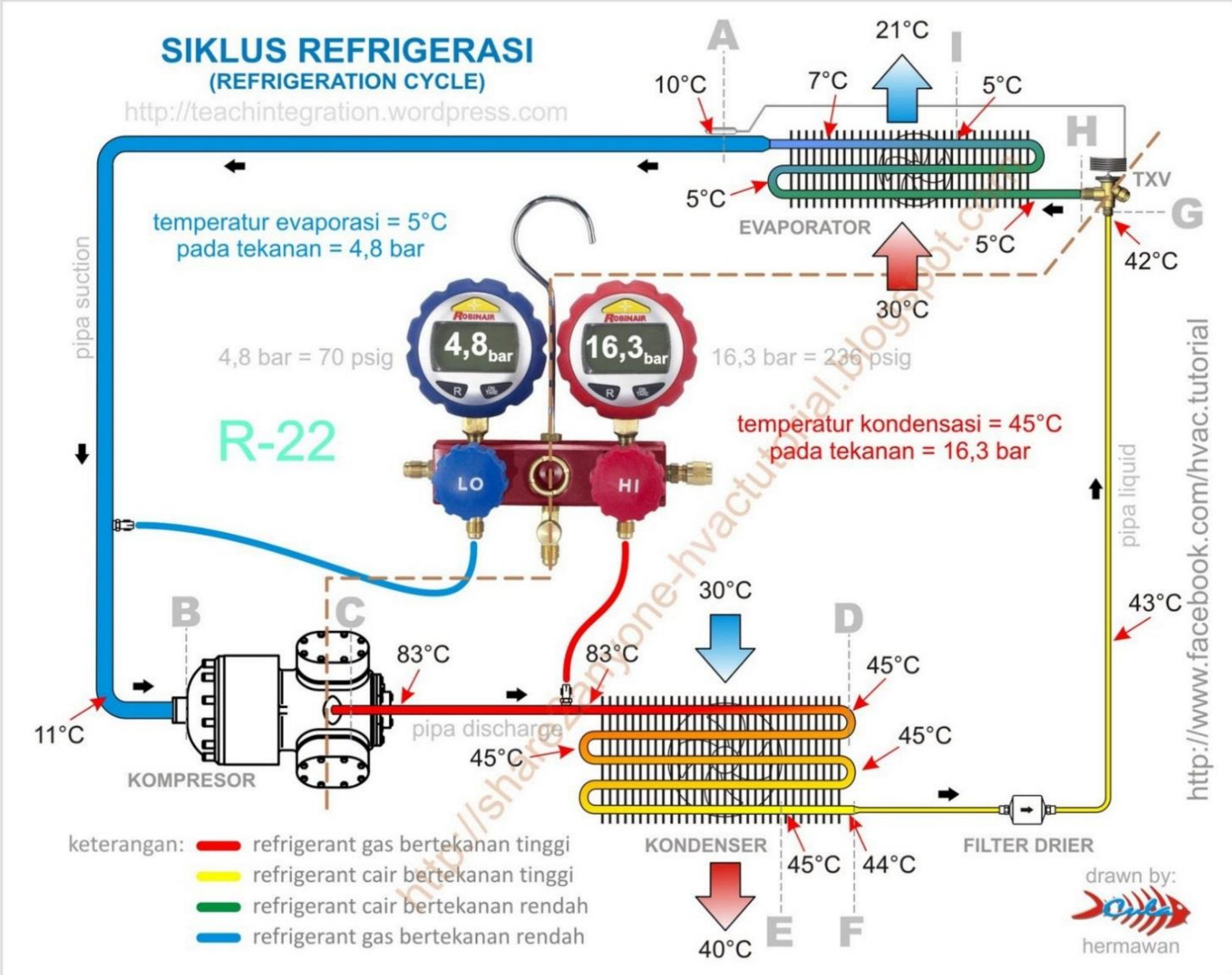
31 https://www.ohio.edu/mechanical/thermo/Intro/Chapt.1_6/Chapter4c.html


q cond
P3 = P2
T3 = 30˚C
Condenser
P2 = 1 MPa
T2 = 70˚C
3
2
Refrigerant R-134a
w comp
Throttle
(adiabatic)
q evap
Compressor
(adiabatic)
4
1
Evaporator
P4 = P1
T4 = T1
T1 = -20˚C
sat. vapor


P-h diagram for R134a refrigerant
4 MPa
3 MPa
2MPa
1 MPa
500 kPa
200 kPa
100 kPa
60 kPa
Pressure
Condenser
Expansion valve
Compressor
Evaporator
100˚C
80˚C
60˚C
40˚C
20˚C
0˚C
-20˚C
0.9
1.0
1.1
1.2
10%
20%
30%
40%
50%
60%
70%
80%
90%
Entropy
(kJ / kg.K)
plot by izzi
0
50
100
150
200
250
300
350
Enthalpy (kJ / kg)
−wcomp
= h2 − h1
qevap = h1 − h4
qcond = h3 − h2

10.2. Prototype 2: Carrier Air conditioner

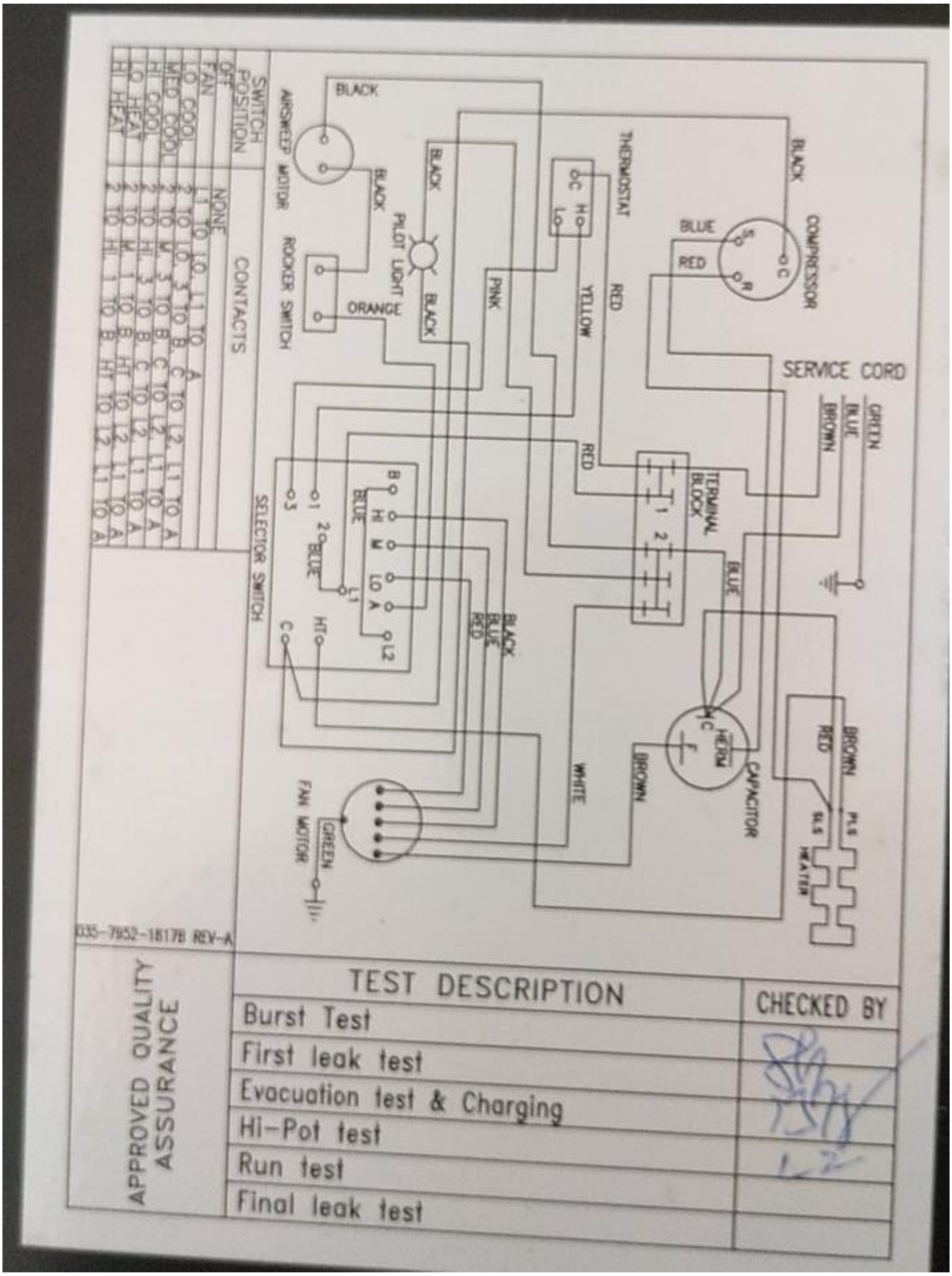

CARRIER
Model: CRVD243M-0B
Cooling Capacity:
24000 BTU/hr
Cooling Capacity (SASO):
5420 W
Heating Capacity: 5.0 KW
Electrical:
220V / 1Ph / 60Hz
Power (Cool)
2880W - 13.5A
Power (SASO)
3250W - 15A
Power (Heat)
5220W - 24A
Refrigerant: R22 - 946g
DESIGN PSIG HI 400 LO 150
Class 1 - IPX4
Serial Number:
DB722201390
SASO
Made in Saudi Arabia



Filter dryer: 32

So the refrigerant enters through the inlet, it passes across the spring, then surrounds the outside of the solid core. The refrigerant then passes through the solid core and as it does so the dirt, moisture and acids are absorbed, the refrigerant then collects in the groove at the centre of the core and then pass through the screen. It then passes through the perforated plate and exits the unit having been filtered and dried, it then continues to the expansion valve.

32 https://theengineeringmindset.com/filter-driers-how-do-they-work/


COMPRESSOR
THERMOSTAT
SERVICE CORD
GREEN
BLUE
BROWN
TERMINAL BLOCK
CAPACITOR
HEATER
FAN MOTOR
SELECTOR SWITCH
ROCKER SWITCH
PILOT LIGHT
AIRSWEEP MOTOR
SWITCH POSITION
CONTACTS
035-7952-1817B REV-A
TEST DESCRIPTION
CHECKED BY
Burst Test
First leak test
Evacuation test & Charging
Hi-Pot test
Run test
Final leak test
APPROVED QUALITY ASSURANCE

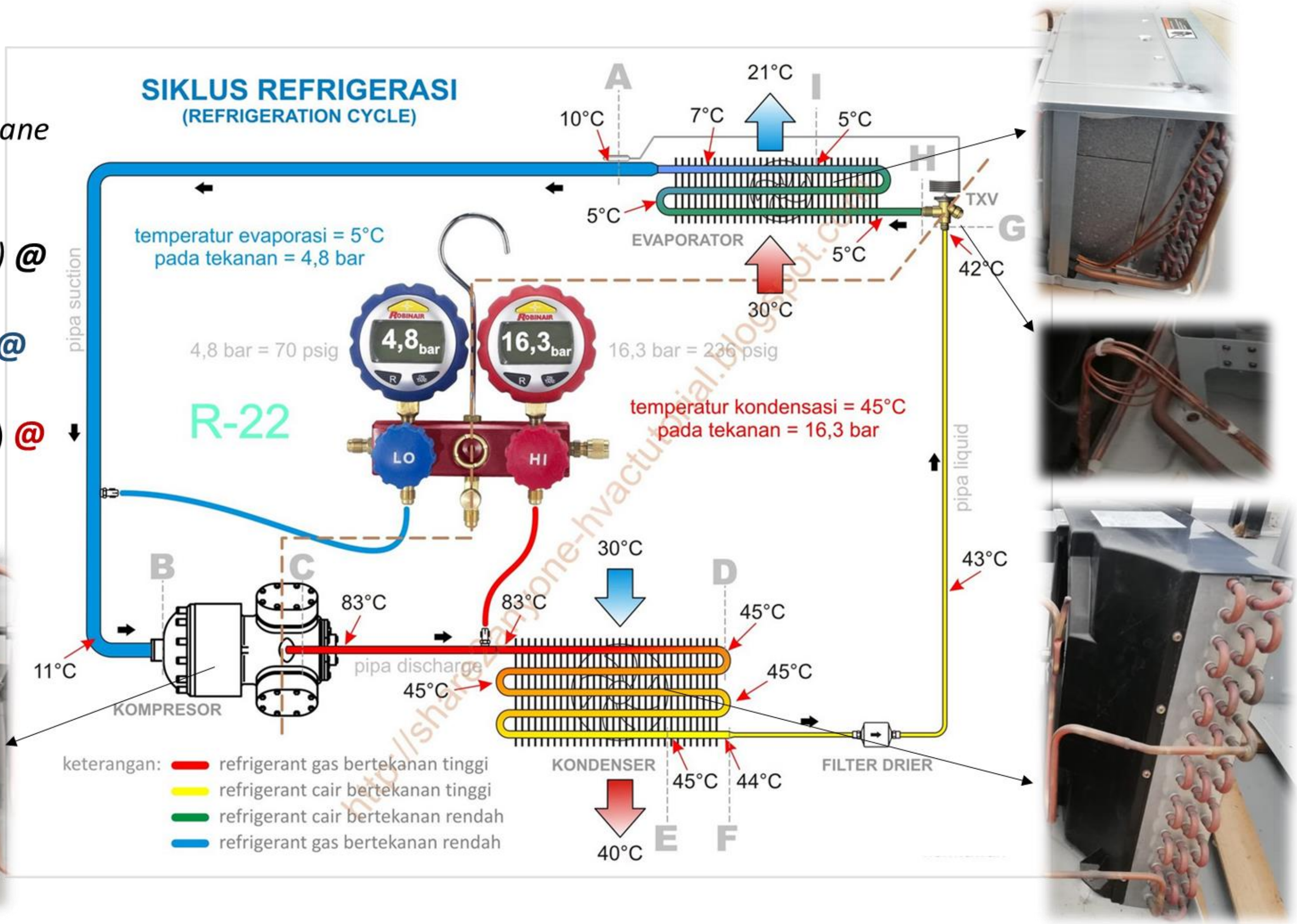
R-22

- **Nomenclature:** *Chlorodifluoromethane*
- **Symbol:** *$CHClF_2$*
- **Boiling point :**

T= - *40.7°C* *(232.5 K)* ***@ 1 bar***

T= *4.9°C* (278.05 K) **@ 4.8 bar**

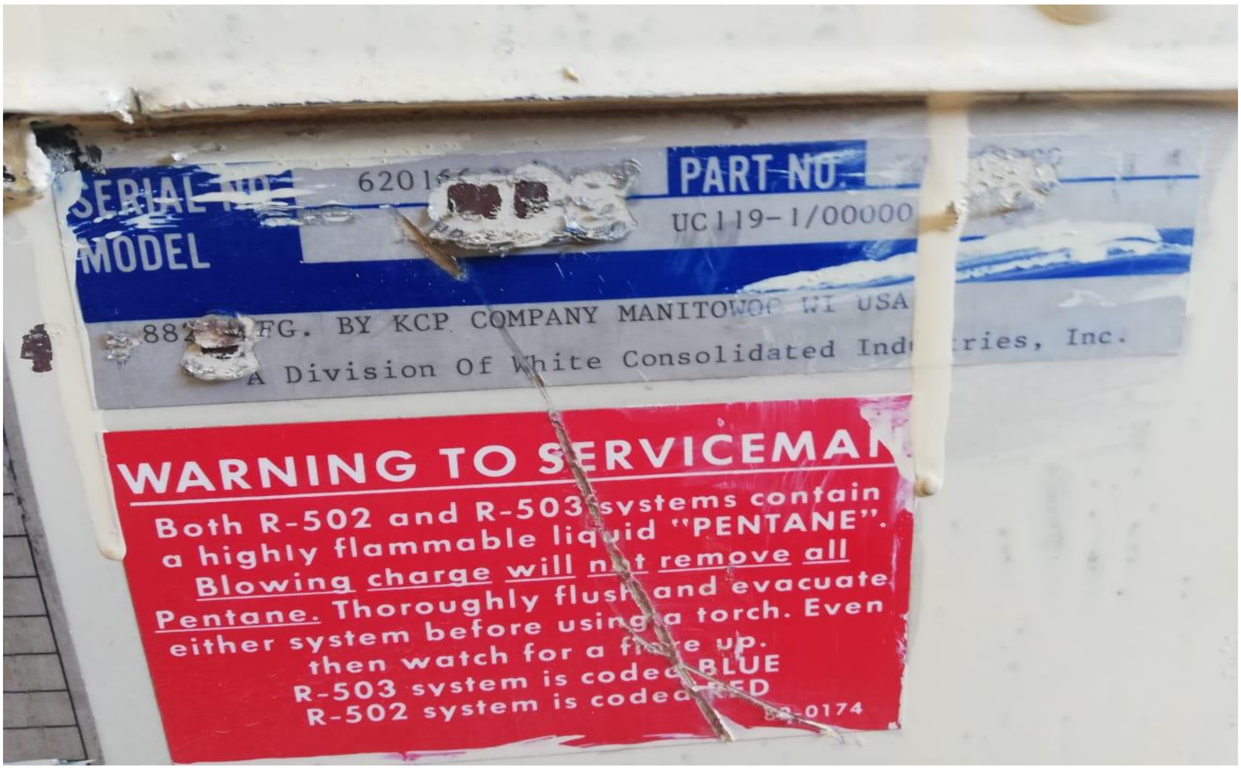
T= 45.6°C (318.75 K) **@ 16.3 bar**



33

33 https://refrigerants.com/product/r22/

10.3. Fridge 2 : Kelvinator fridge



Number	Ozone Friendly	Uses	Chemical Components	Alternatives	Notes
R410A HFC	Yes	Designed for new R22 applications, but can also be used to retrofit R13b1 systems.	HFC 125 - 50% HFC 32 -50%		Long term ozone friendly replacement for R502 / R22 Low GWP
R500 CFC	No; banned under Montreal protocol	Low temperature R12 CFC.	CFC 12 -CFC 115 -	R401b; R407d	
R502 CFC	No; banned under Montreal protocol	Widely used low temperature refrigerant in the United Kingdom.	HCFC 22 -48% CFC 115 -52%		
R503 CFC	No; banned under Montreal protocol	Low temperature refrigerant -80 to -100°C.		R95, R508a, R508b	

CFCs: Chlorofluorocarbons. These products have ceased production within the RSA for internal consumption with effect from 1996.
HCFCs: Hydrochlorofluorocarbons. Full availability within the RSA, and the present production phase out date is 2015. There is a widespread belief that this will be reduced to 2005 within the next 2-3 years.
HFCs: Hydrofluorocarbons. At the moment there is no production phase out date for HFCs and there is unrestricted use on their applications.
HCs & NH3: This product group mainly used in industrial equipment due to flammability concerns.

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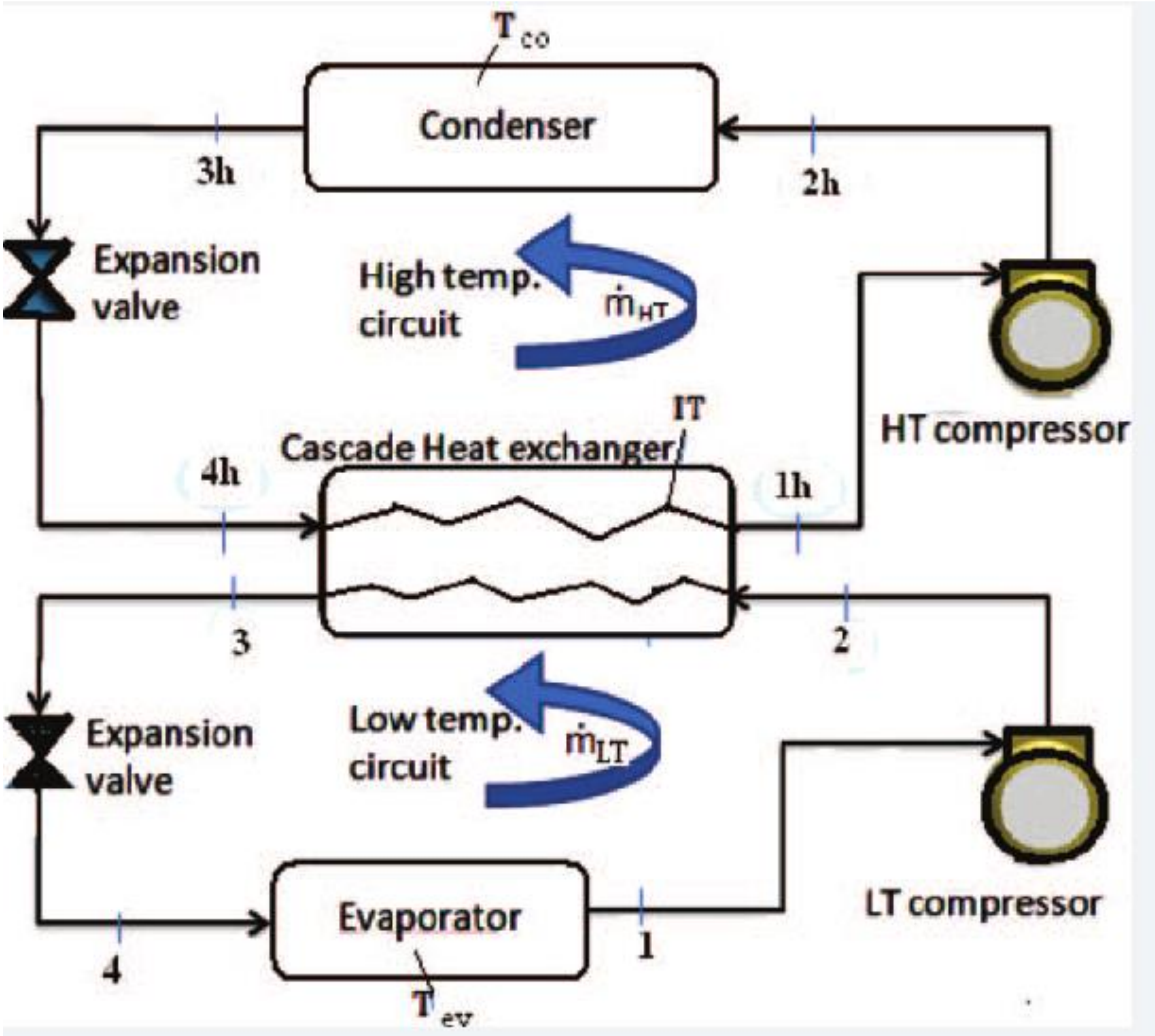
34 http://www.proairlda.com/gases.htm



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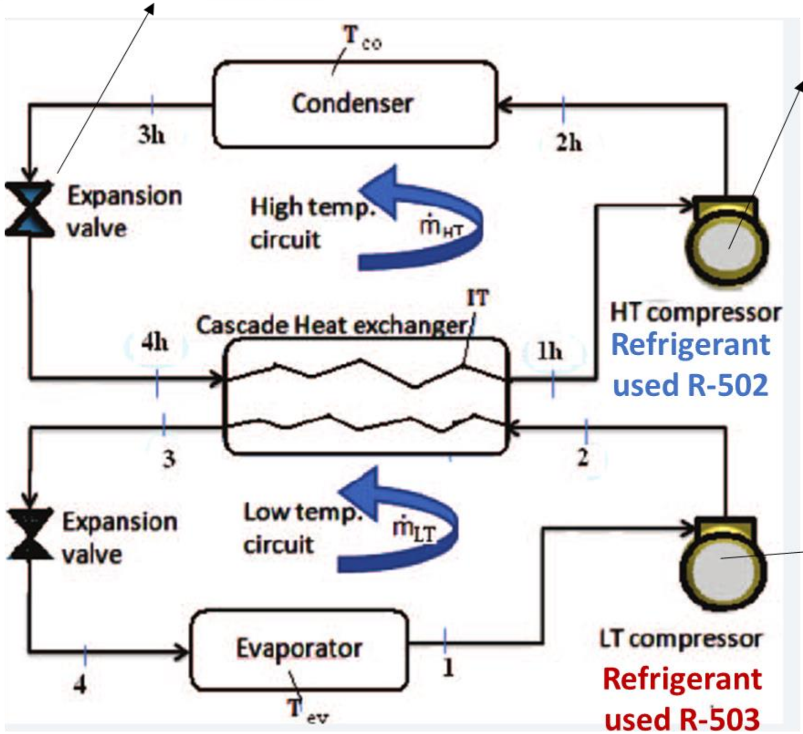
35 https://www.eevblog.com/forum/chat/refrigerator-with-two-compressors-how-do-they-do-it/

R-502 (High stage)

- **Nomenclature:** Chlorodifluoromethane, Chloropentafluoroethane
- **Symbol:** CHC1F2, CC1F2CF3
- **Compress:** 375 psi = 25.85 bar
- **Boiling point :**

T= - *45.6°C* *(227.4 K)* **@ 1 bar**

T= 61.5°*C* (334.7 K) **@ 25.85 bar**



R-503 (Low stage)

- **Nomenclature:** Azeotropic Blend
- **Symbol:** CHF3
- **Compress:** 375 psi = 25.85 bar
- **Boiling point :**

T= - *88.9°C* *(184.1 K)* **@ 1 bar**

T= - 20°*C* (253.2 K) **@ 25.85 bar**

36 37 38

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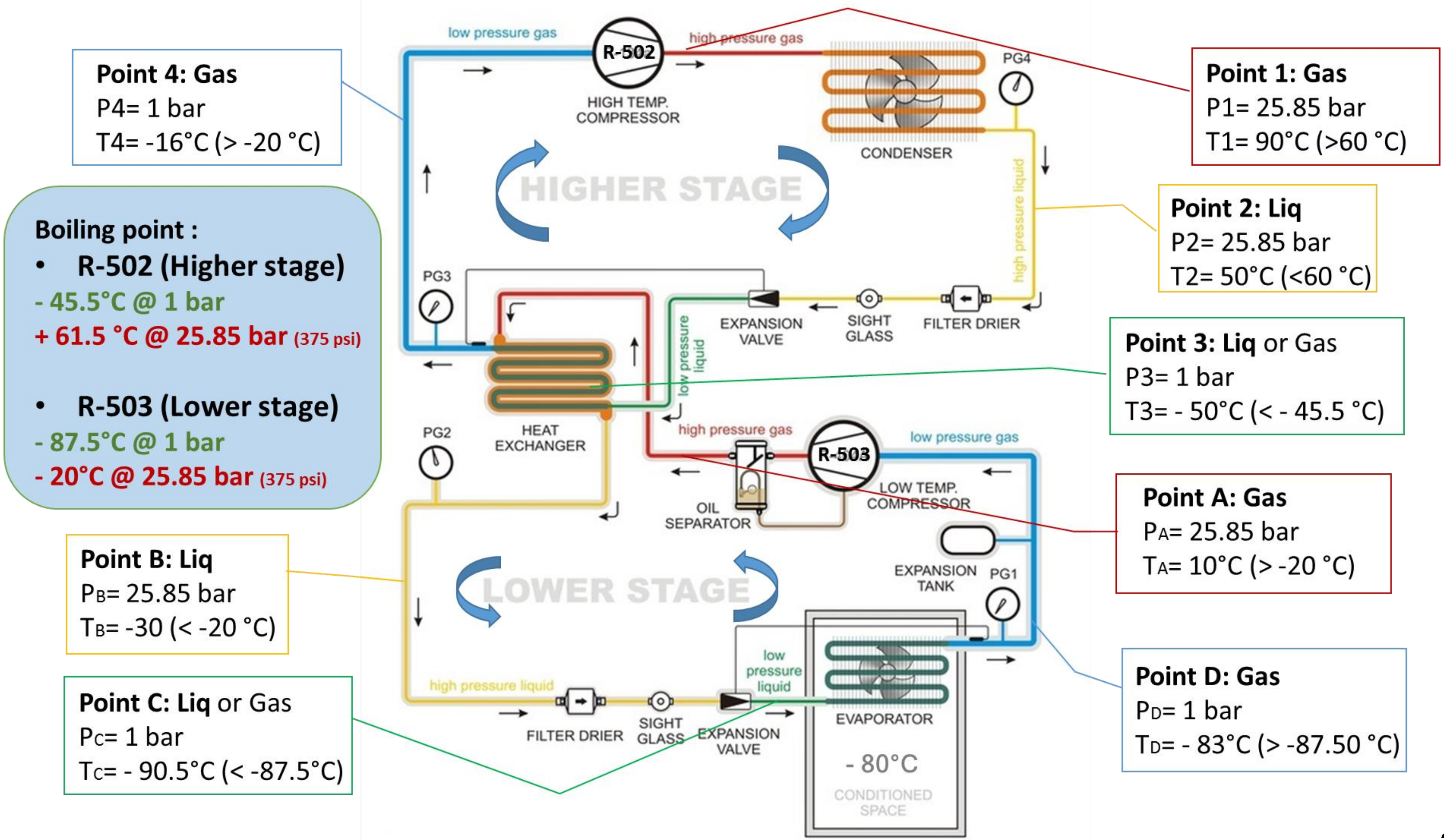
36 https://secureservercdn.net/198.71.233.179/m9v.7b6.myftpupload.com/wp-content/uploads/2019/12/SDS-R22.pdf?time=1618519493

37 https://www.cc.kyushu-u.ac.jp/scp/system/library/PROPATH/manuals/p-propath/r503.pdf

38 https://www.arma.org.au/wp-content/uploads/2017/02/SDS-R503.pdf



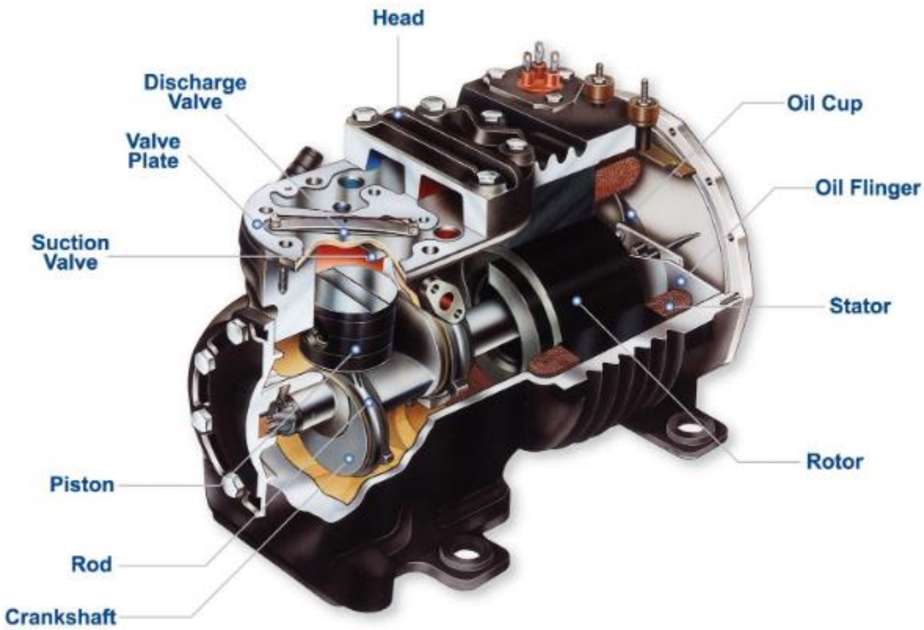
39

39 https://www.quora.com/What-is-a-cascade-refrigeration-system

The cascade refrigeration system consists of a low-temperature loop (Low stage) and a high-temperature loop (high stage).
Each stage consists of a compressor, condenser, expansion valve and evaporator
The high stage condenser is cooled by air cooled, while the low stage condenser is cooled by the high stage evaporator.
So the high stage evaporator acts as a coolant for the pressurized refrigerant in the low stage.
Advantages of a cascade cooling system:

- Repair is easy
- The Cascade refrigeration allows to low-temperature operation.
- You can reduce the use of power up to 10% with the help of cascade refrigeration.

Basic Components



N.B. (process):

1- Pressure Controls

With the exception of a reverse acting control, the pressure controls will be standard, and used in the normal way. A high pressure control will usually be found on all second and third stages, and in some cases on the first stage. This protects the system against excessive pressures during pull-down, or if there is a failure of the first stage system. The control may cycle a few times at the start. A high pressure control with a 100 pound differential (to allow pressures to equalize) is sometimes used rather than a back pressure regulator.

Where continuous operation at the lowest temperature is desired, the high pressure control only is used on the low stage. Where control of the low side or fixture temperature is desired, a thermostat, connected in series with the high pressure control, is used. In special applications and on older units, a liquid line solenoid may be used with a low pressure control on the low stage. (A solenoid for such an application requires a waterproof coil in a well sealed housing.)

The addition of a reverse acting pressure control provides automatic operation even when starting warm. With the interstage condenser at room temperature, a pressure of 700 pounds or more would be required to condense the low temperature refrigerant, therefore the low stage compressor cannot be allowed to start until the high stage has lowered the temperature in the interstage condenser to operating temperatures. This has been accomplished in several ways, such as a thermostat sensing the temperature of the heat exchanger, or pressure controls with reverse acting contacts which open on pressure increase and close on a decrease. This control would be connected to the low side of the high stage.

2-Control Of High Pressure Equipment

Up until a few years ago, most cascade equipment used expansion valves and a low temperature refrigerant charge of at least 3 to 5 pounds which necessitated an interstage condenser receiver capable of holding the refrigerant pressure at 500 to 700 psi so that the charge could be contained there. To put the system in operation, the high stage had to be started and the inlet and outlet valves of the interstage condenser receiver opened when it was down to the working temperature. Any power failure or loss of refrigeration due to any failure in the high stage meant the loss of the low temperature refrigerant charge through the relief valve or rupture disc. The system could not be shut down until the low stage was pumped down and the charge locked in the interstage condenser receiver.

Small self-contained systems using less than 2 pounds of the low temperature refrigerants can be made completely automatic, if space is available to provide expansion tanks of sufficient volume to store the refrigerant in the vapor stage at or below 200 pounds pressure. Some of the small chest type units for temperatures down to -130°F using capillary tubes and hermetic compressors can hold the charge in the low side, oil separators, heat exchangers, etc., plus the dome or shell of the unit. As the size of the low side is increased and more refrigerant is required, one or more expansion tanks are required for automatic operation. Good practice limits the maximum pressure to 150 or 200 pounds.

In some cases, the connection to the expansion tank may be a capillary tube. When the unit is shut down, the rise in pressure is slow and most of the charge is stored in the tank. This capillary tube is sized so that the charge in the tank is fed slowly into the system during a pull-down from room temperature. In larger installations where a pull-down imposes a severe load on the motor and compressor, the charge may be admitted to the expansion tanks through a check valve and returned through a pressure reducing valve which can be adjusted to the capacity of the unit during such periods.

3- Water Cooling Circuitry

The condenser of a high stage does not always receive the incoming water first.

Water is used to remove superheat from the compressed low stage refrigerant before entering the interstage condenser and is also used in some motor cooling jackets. If it were also used on the compressor heads, the flow would be inadequate when the water regulator reduced the flow according to the demand of the high stage. By feeding the condenser last, an adequate flow is maintained at all times.

4- Frost Suppressors

While not so common today, these will be found on some units in the form of a heat exchanger between the low temperature suction line and the low temperature hot gas line before it enters the interstage condenser.

5- Liquid Line Accumulator

On some small units using capillary tubes in both systems, a small liquid accumulator may be found in the liquid line of the high stage. This is required, as the capillary tube is sized for continuous operation at low temperature, and during a start-up it can not pass the volume of refrigerant condensed by the unit at high temperatures, thus filling the condenser and causing excessively high pressures. The accumulator or reservoir prevents this pressure during the few minutes required to cool the interstage condenser.

6- SYSTEM CLEANUP

Cleanup is required any time a system has to be opened, for whatever reason, excluding the addition of refrigerant. Recover the charge according to EPA-approved procedures, and remove the dryer, disconnect the suction line from the compressor, and backflush the entire system with solvent to remove any contaminants or oil from the system. This is most important when replacing a compressor.

✍ **Connecting 2 compressors to get combined pressure and volume.**

In order to achieve the desired pressure and volume for our pneumatic equipment, I need to inter-connect 2 compressors.

I need advice on how to go about doing it and need a couple of questions answered:

1) Is it necessary that both compressors share the same specs ?

2) Will the resultant pressure and volume be a sum of both compressors?

Both good questions, and both covered extensively on the pages of this site already.

Answer to question #1 – no.

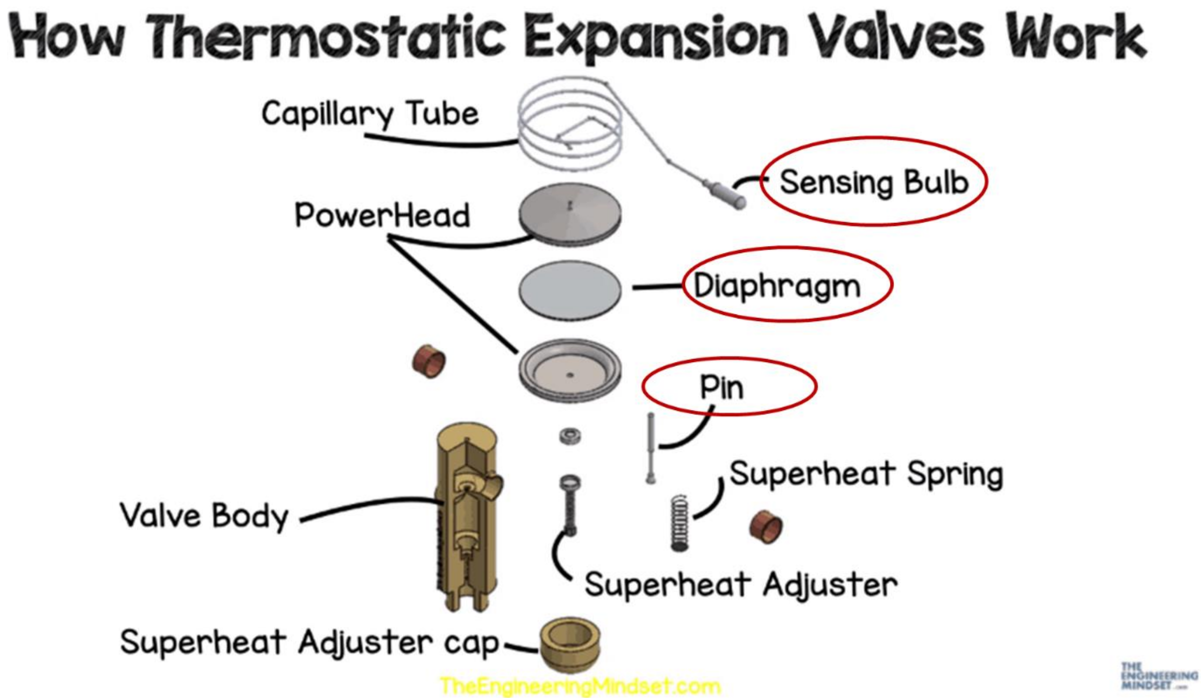
Answer to #2 – no. If each compressor puts out 100 PSI, your downstream air line will not see 200 PSI. What you will do is increase the available compressed air flow at the pressure the system needs.

Both compressors will plumb to the same air main to your plant.

Both air compressors will have a one-way or check valve in their lines before the two lines connect to the single main.

In order for one compressor not to be the one that's always on first, undergoing greater wear, periodically change the pressure switch settings so that the alternate compressor comes on first.

- **Expansion valve**



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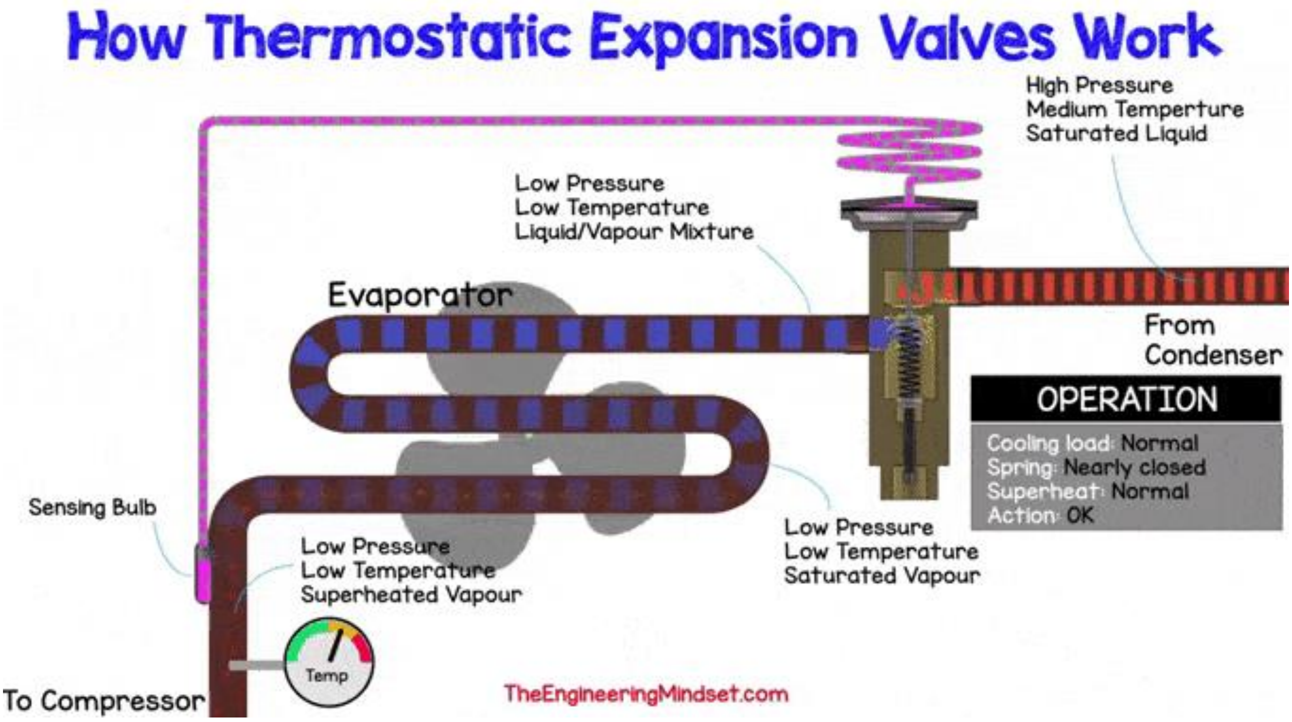
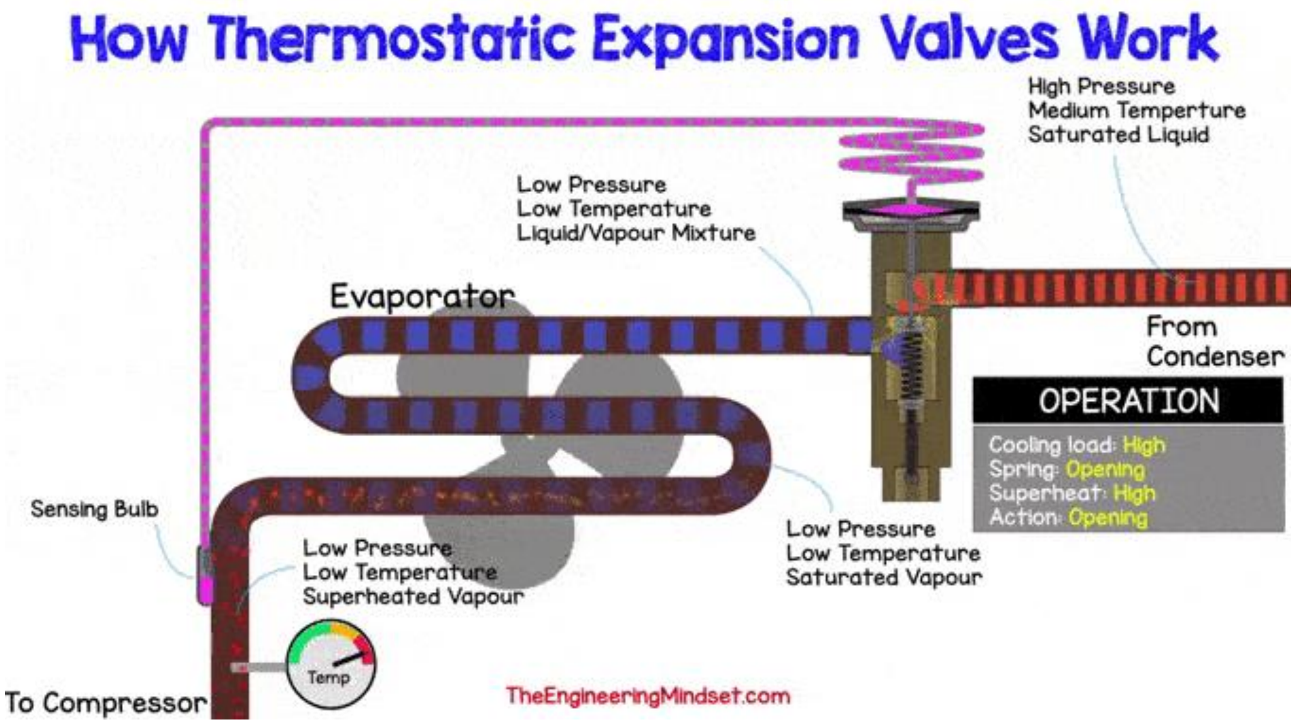


40 https://theengineeringmindset.com/thermostatic-expansion-valves-work/



The TXV is used in many refrigeration systems, they can be found in the same location which is just before the evaporator.

The valve decreases the pressure to allow the refrigerant to boil at lower temperatures. The boiling is essential as the refrigerant will absorb the heat from the ambient air and carry this away to the compressor. Just remember that refrigerants have a much lower boiling point than water.

The high pressure liquid refrigerant is forced through a small orifice which causes a pressure reduction as it passes through. During this pressure reduction, some of the refrigerant will vaporise and the rest will remain as liquid.

- Types of bulbs

There are **three different types of bulbs**:

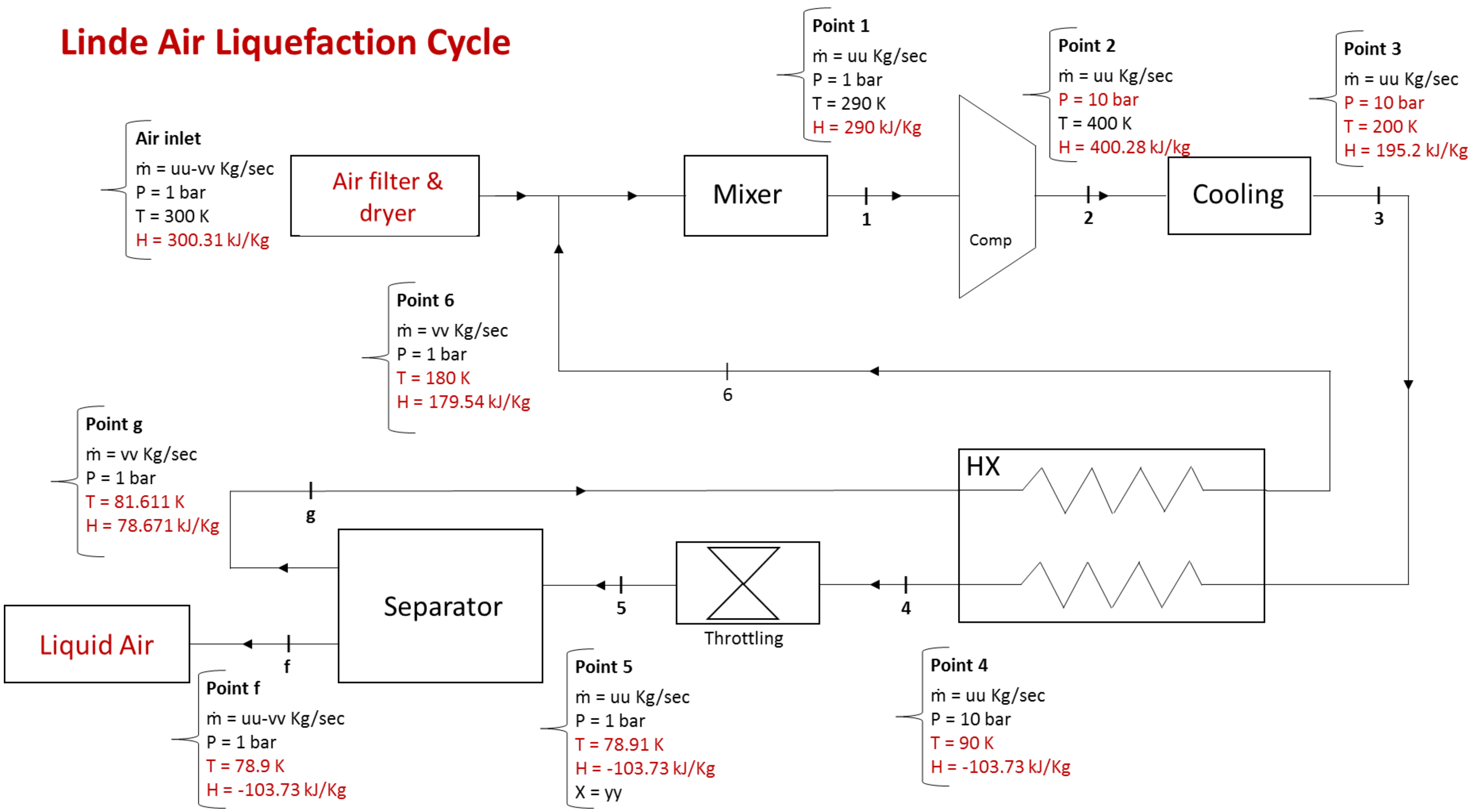
- **Liquid-charged bulbs**
- MOP (Maximum Operating Pressure) bulbs – also called gas-charged bulbs
- Adsorption-filled bulbs

A **liquid-charged bulb** has a large charge of refrigerant and will never "run dry". It will always contain both liquid and gaseous refrigerant. The pressure inside the bulb increases as the superheating increases, due to additional evaporation. Historically, the refrigerant in the bulb was the same as the working refrigerant in the system (parallel-charged). However, better characteristics have been achieved by using different refrigerants (cross-charged), which is now the most common arrangement.

An **MOP bulb**, also called gas-charged, has a much smaller quantity of refrigerant mixture inside the bulb than a liquid-charged bulb. As the evaporation pressure increases, the suction pipe will become increasingly warm as a result. A limited refrigerant charge in an MOP bulb will be totally evaporated at a predefined pressure, the MOP pressure. When the liquid refrigerant mixture has boiled off, the pressure inside the bulb will not increase greatly even if the evaporating pressure does. The needle valve will not open further, thus limiting the maximum mass flow through the valve. The reason for this is to protect the compressor from electrical overload, especially during start-up when the evaporation pressure can be much higher than under normal operating conditions. A disadvantage of the MOP valve is that the bulb always has to be colder than the valve housing to prevent the limited refrigerant charge from migrating and condensing at the membrane surface. If the MOP bulb were instead warmer than the valve housing, the MOP valve would close even if the operating pressure were well below the maximum operating pressure.

TEVs may also have **an adsorption** charge, where the bulb also contains a solid adsorbent such as charcoal or silica gel. The adsorbed refrigerant reacts more slowly to temperature changes than direct-charged bulbs, and gives a slower response. This can sometimes help to stabilize oscillation tendencies. However, adsorption-filled bulbs work best over a limited range, which is why they are often specially designed for the operating conditions.

Linde Air Liquefaction Cycle



In this project (Liquefaction of air), We need to cool the air from 27 °C (300 K) to -194.35 °C (78.8 K), and to achieve this we will use an air compressor (10 bar). The compressor will compress ambient air from 1 bar (27 °C, 300 K) to 10 bar (126.85 °C, 400 K).

To cool the air from 400 K to 90 K, two heat exchangers will be used, the first will be a heat exchanger to cool the compressed air from (126.85 °C, 400 K) up to (-73.15 °C, 200 K) due to the cascade refrigeration cycle (R-502 and R-503 (Kelvinator fridge)) and a second heat exchanger to cool the compressed air from 200 K to 90 K, this exchanger will work with the temperature of the non-liquefied cold air (about -195 °C, 78.8 K).

After the cooling process, the compressed air will pass into the expansion valve, where the air will be subjected to a sudden pressure drop, causing a similar temperature drop, from 10 bar (-183.15 °C, 90 K) to 1 bar (-194.24 °C, 78.91 K).).

After expanding, the liquefied air (air liquid) will be separated from the non-liquefied air (air in gas state). Where the liquid will be stored in special containers, while the non-liquefied cold air will be used to cool the compressed air as mentioned earlier (in the second heat exchanger).

Therefore, to obtain liquefied air with a 10 bar compressor, the air must be cooled to 90 K (-183 ° C).

# of	Point 3	Point 4 (10 bar, 1 MPa)		Point 5 (1 bar, 0.1 MPa)	Point g	Point 6
cycle	T (K)	T (K)	H (kJ/Kg)	T (K)	T (K)	T (K)
1	200	200	195.2	195.54	300	300
2	200	249.06	246.092	246.11	246.11	249.49
3	200	222.17	218.32	218.5	218.5	223.97
4	200	208.79	204.39	204.66	204.66	209.45
5	200	202.2	197.5	197.82	197.82	202.4
6	200	198.98	194.13	194.47	194.47	198.88
7	200	197.41	192.48	192.46	192.46	197.14
8	200	196.47	191.49	191.48	191.48	196.1
9	200	196.01	191	190.99	190.99	195.59
10	200	195.78	190.76	190.75	190.75	195.33
11	200	195.67	190.64	190.64	190.64	195.21
12	200	195.62	190.59	190.58	190.58	195.15
13	200	195.59	190.56	190.55	190.55	195.12
14	200	195.58	190.55	190.54	190.54	195.11
15	200	195.57	190.54	190.53	190.53	195.1
|	|	|	|	|	|	|
|	|	|	|	|	|	|
~ 1000	200	90	-103.73	78.91	80	131.86

We notice that the temperatures in the first five stages were changing significantly as the heat exchanger was cooling down, then with the beginning of the sixth stage, the heat exchanger began to play its primary role, which is cooling the air entering the exchanger before passing through the expansion valve, but after several stages we notice that the heat difference between The stages due to the decrease in the temperature difference before and after the expansion valve (+ -5 degrees), which slows down the process of cooling the air and prevents it from reaching temperatures as low as 90 kelvin except after many many stages. Here the problem appears in practice, as in the event of any thermal leakage from the thermal insulating materials, this leakage will further delay the process of liquefying the air, and we may be vulnerable to not reaching the liquefaction temperature.

Literature

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