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بسم الله الرحمن الرحيم

مركز أبحاث تكنولوجيا العمليات الكيميائية
Institute for Chemical Process Technology (ICPT)
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Liquefaction of Oxygen

Simple refrigeration cycle

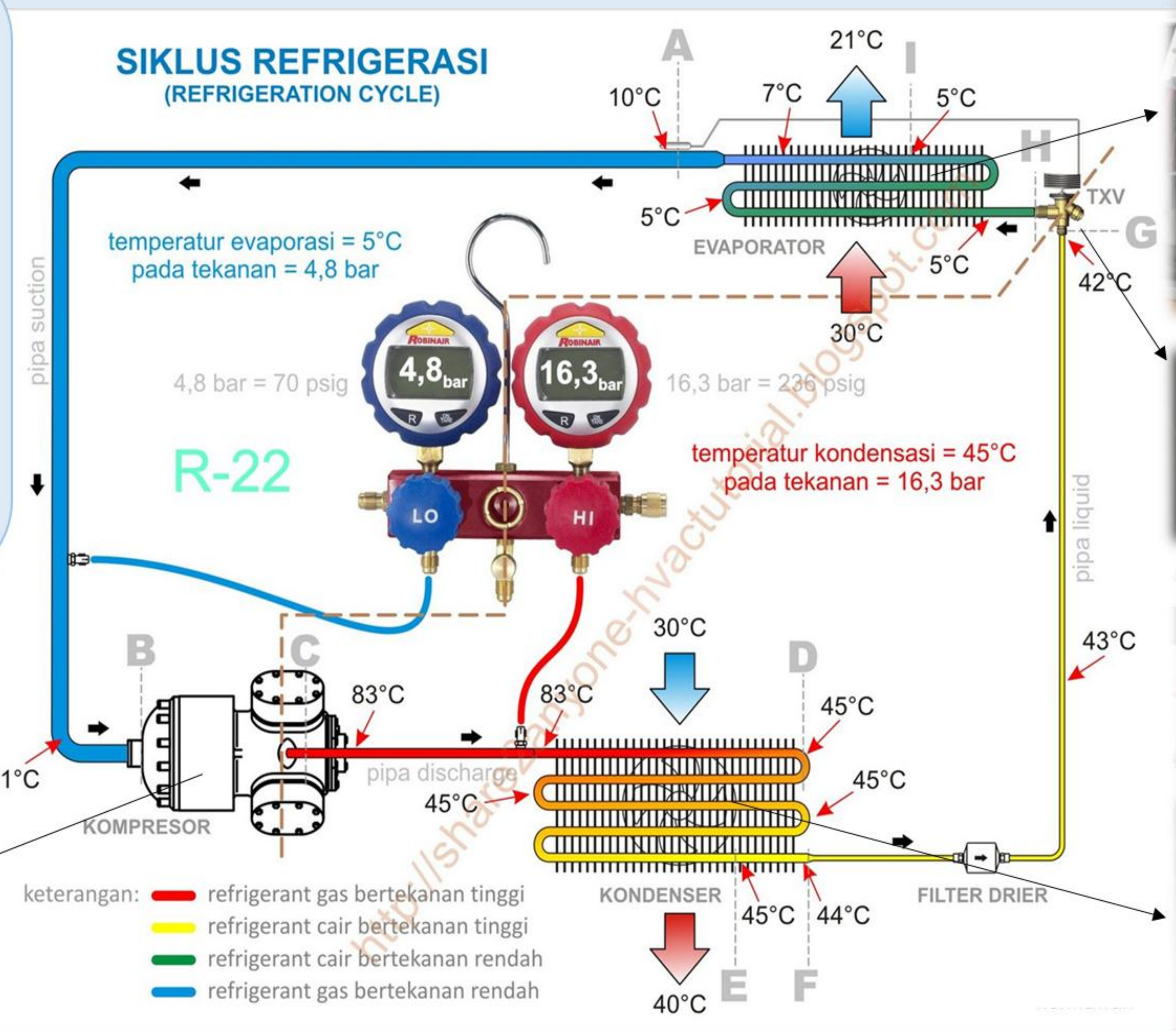
R-22

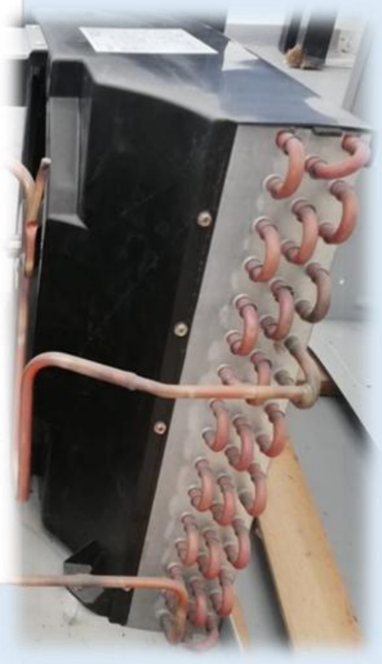
- **Nomenclature:** *Chlorodifluoromethane*
- **Symbol:** *$CHClF_2$*
- **Boiling point :**

T= - 40.7°C (232.5 K) **@ 1 bar**

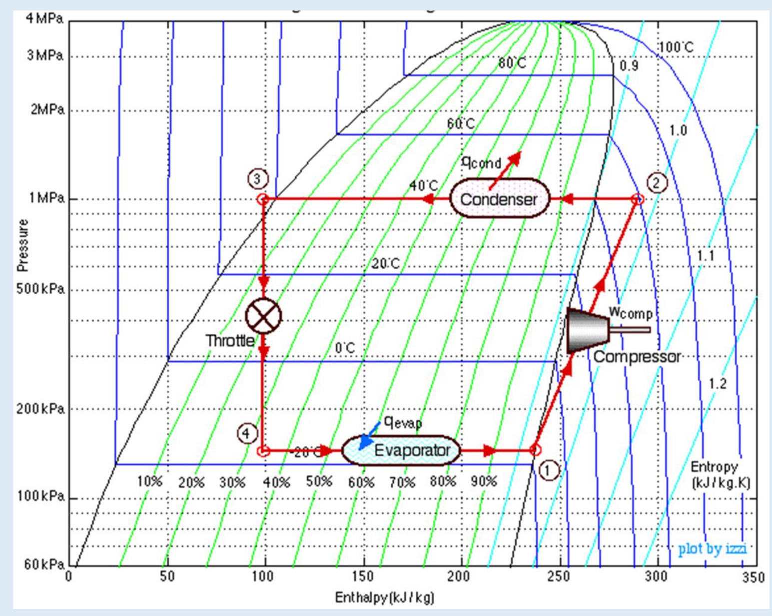
T= 4.9°C (278.05 K) **@ 4.8 bar**

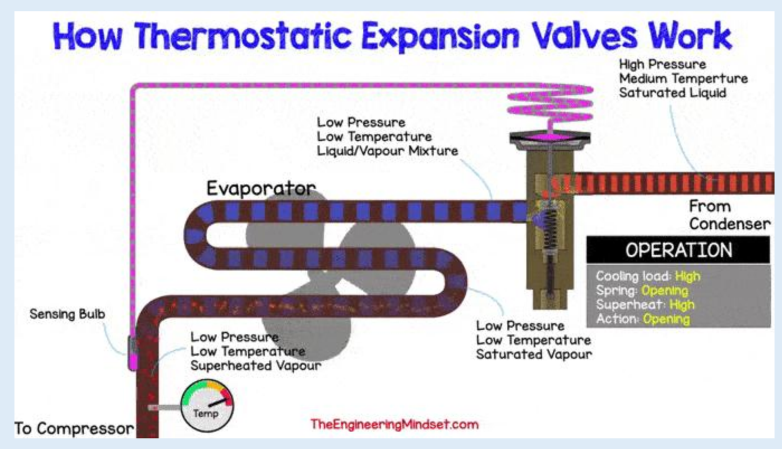
T= 45.6°C (318.75 K) **@ 16.3 bar**





Basic components of refrigeration are: Compressor, Condenser, expansion valve(throttle) and evaporator





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.

Based on the Ideal gas Law: **PV=nRT**
In a constant volume V, when P increases → T increases

The variation of pressure has influence on the degree of boiling point of a refrigerant

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.

Refrigeration with cascade to reaching a lower temperature

(kelvinator refrigerator)

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.

R-502 (Higher stage)

- **Chemical formula:** $C_3HCl_2F_7$
- **Boiling point:**

- 45.5°C @ 1 bar

+ 61.5 °C @ 25.85 bar (375 psi)

R-503 (Lower stage)

- **Chemical formula:** CC1F3,CHF3
- **Boiling point:**

- 87.5°C @ 1 bar

- 20°C @ 25.85 bar (375 psi)

Point 4: Gas
P4= 1 bar
T4= -16°C (> -20 °C)

Point 1: Gas
P1= 25.85 bar
T1= 90°C (>60 °C)

Point 2: Liq
P2= 25.85 bar
T2= 50°C (<60 °C)

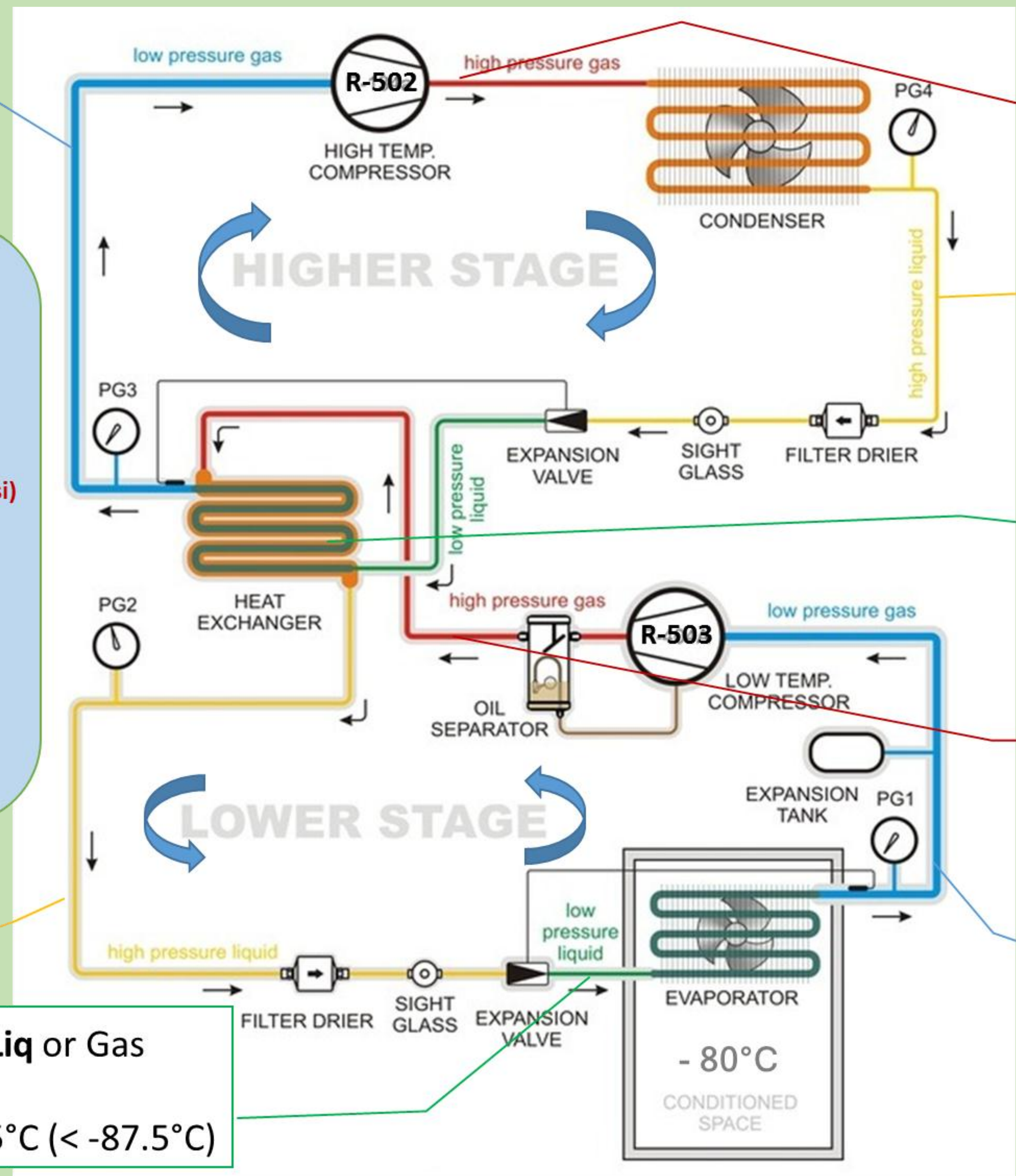
Point 3: Liq or Gas
P3= 1 bar
T3= - 50°C (< - 45.5 °C)

Point A: Gas
PA= 25.85 bar
TA= 10°C (> -20 °C)

Point B: Liq
PB= 25.85 bar
TB= -30 (< -20 °C)

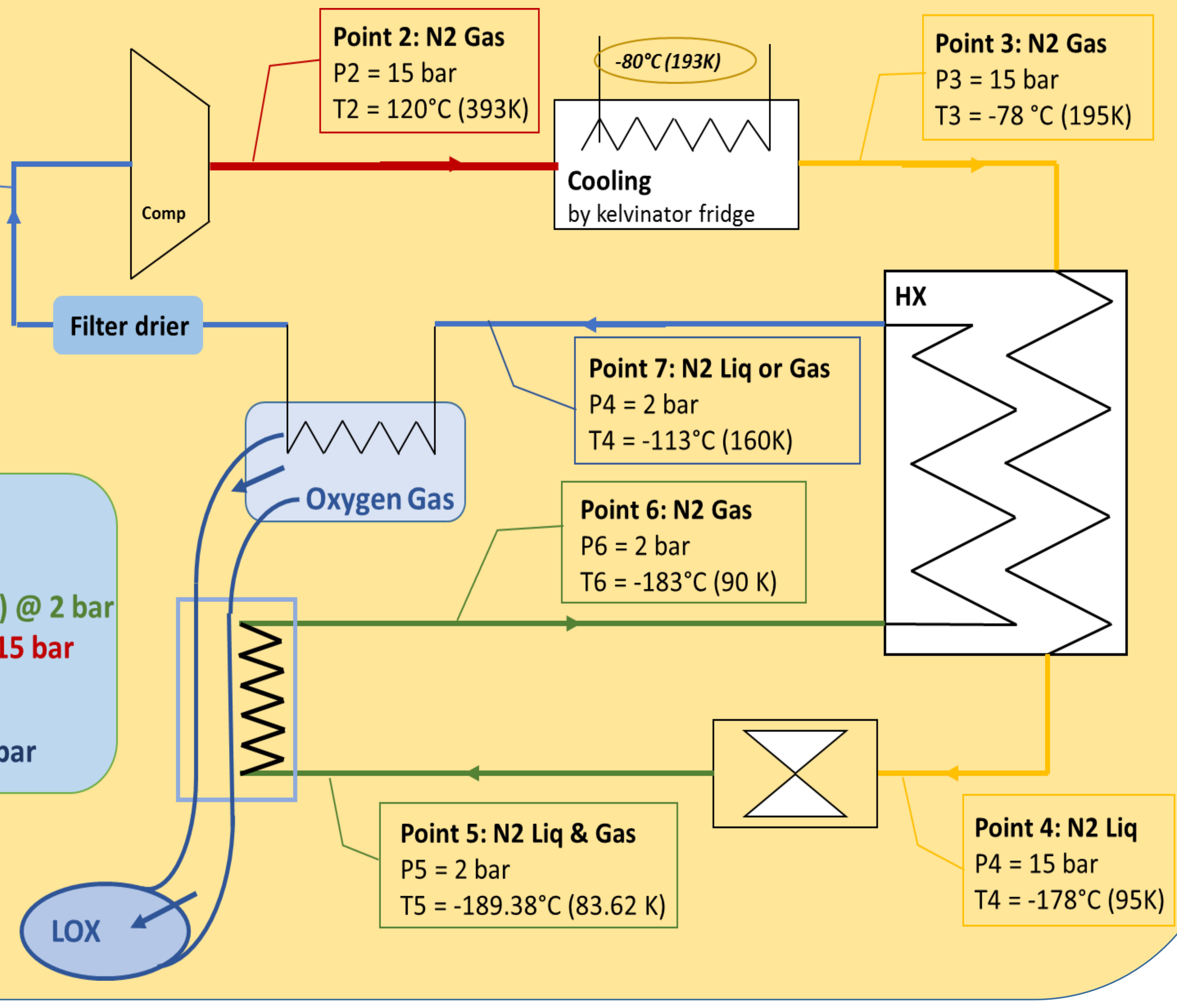
Point C: Liq or Gas
PC= 1 bar
TC= - 90.5°C (< -87.5°C)

Point D: Gas
PD= 1 bar
TD= - 83°C (> -87.50 °C)



Cryogenic

Liquefaction of Oxygen Prototype cycle



Point 1: N2 Gas
P1 = 2 bar
T1 = 7°C (280K)

Point 2: N2 Gas
P2 = 15 bar
T2 = 120°C (393K)

Point 3: N2 Gas
P3 = 15 bar
T3 = -78 °C (195K)

Point 4: N2 Liq
P4 = 15 bar
T4 = -178°C (95K)

Point 5: N2 Liq & Gas
P5 = 2 bar
T5 = -189.38°C (83.62 K)

Point 6: N2 Gas
P6 = 2 bar
T6 = -183°C (90 K)

Point 7: N2 Liq or Gas
P4 = 2 bar
T4 = -113°C (160K)

Boiling point :

- **Nitrogen N2**

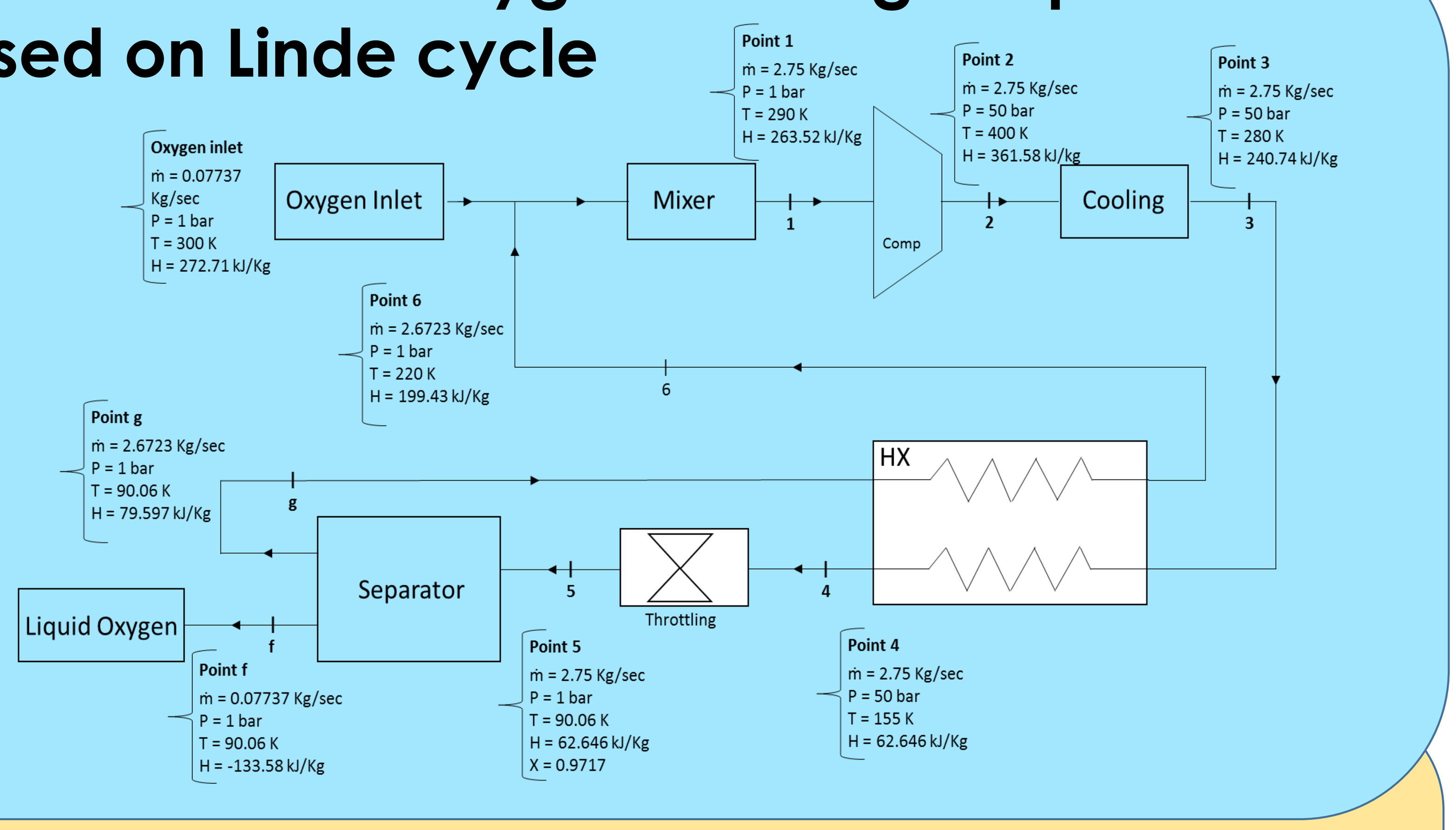
- 189.38°C (83.62K) @ 2 bar

- 163°C (110K) @ 15 bar

- **Oxygen O2**

- 183°C (90K) @ 1 bar

Liquefaction of Oxygen in a big shape based on Linde cycle



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

Then the nitrogen will be cooled to lower temperatures (83.6 K) using the expansion valve and heat exchanger.
This nitrogen temperature (<90 K) would be sufficient to liquefy the oxygen at 1atm.

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

Maryam EL-REZ @AECENAR/May 2021