PROTECTING THE ENVIRONMENT USING NATURAL REFRIGERANTS

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Ing. Roberto Ricardo Aguiló
President Asociación Argentina Del Frío
ASHRAE Fellow - DL

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INTRODUCTION

Refrigerants

- During the last decades the environment has suffered different negative impacts due to the action of synthetics refrigerants in the atmosphere.
- Some natural refrigerants have been used since the middle of XIX Century, but now they are much more important, due the very minor impact they have on the atmosphere.

Refrigeration Environmental Impact

- Refrigeration has two types of negative impact in the environment.
- These are :
  - Direct Impact
  - Indirect Impact

Refrigeration
Direct Impact

- Ozone Layer
- Global Warming

- These impacts can be measured by the ODP and the GWP of each refrigerant.
  - ODP: Ozone Depletion Potential
  - GWP: Global Warming Potential

Refrigerants Atmospheric Impact

- Refrigerant average life in the atmosphere impacts in the effects.
- A short live ensures a low ODP and GWP.
- This is a conflict between high chemical stability within the system and the need for the chemical breakdown of the molecule in the atmosphere.

ASHRAE Standard 34

- It classifies the refrigerant from the point of view of flammability (assigning a number between 1 and 3) and from toxicity (assigns a letter A or B).
- Defines the way of naming a refrigerant assigning a code number originated (mainly) in its chemical formula.

Refrigerants Environmental Properties

Refrigerant	ODP	GWP	
R12	1	10900	A1
R22	0,055	1810	A1
R134a	0	1430	A1
R407C	0	1800	A1
R410A	0	2100	A1
R404A	0	3900	A1
R1234yf	0	6	A2L

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Refrigeration
Indirect Impact

- Emission of pollutants originated for electrical production plants, for the energy used by refrigeration equipment.
- Some equipment also can be moved by explosion engines that burns fuel and produce contamination.

Refrigerants

- Sintetics
  - ~~CFC_s (R12 – R502)~~
  - ~~$HCFC_s$ (R22)~~
  - HFC_s (R134a -R404A- R507A - R407C – R410A)
  - HFO_s (R1234yz - R448A - R449A - R455A)
- Naturals
  - Ammonia
  - Hidrocarbons
  - CO_2

PFAs (PerFluorAlquils)

- HFC y HFO have fluorine.
- After some time in the atmosphere it can form trifluoroacetic acid (TFA) and finally PFAs.
- Recent investigations show PFAs high concentrations in underground waters.
- PFAs are not good for human health.

AMMONIA

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Ammonia Environmental Impact

- Ammonia is the best refrigerant about environmental impact.
  - ODP is equal to 0
  - GWP is les than 1

Ammonia Safety

- ASHRAE Standard 34 classifies ammonia as B2L.
- Combustion limits of ammonia in air are between 15% and 26%
- Harmful concentrations begin in 700 ppm, but at 200 ppm the odor is strongly high.

Ammonia Installations

- It is mainly used in large industrial plants.
- In ammonia plants, open type compressors are used, as ammonia is corrosive to copper, so semihermetic compressors do not work.
- The pipes are in iron or stainless steel.
- Condensation is usually by water.

Screw Compressors

- They are used in low and in medium temperature, and even can be used in low temperature applications in single stage, as the compression process can be cooled.
- They are usually driven with electric motors with an axle power of 120% of the power required by the compressor at full load.

Compressors with Economizer

- Compressors working with economizer port have an efficiency close to double stage systems.
- It is more efficient with high compression ratios.
- The problem of this cycle is that the unloaded compressor has the economizer port at the same pressure that the suction port.

Flow Control Methods

- There are three different methods to control the flow of refrigerant towards evaporators:
  - Direct Expansion Systems
  - Flooded Systems
  - Liquid Overfeed Systems

New Ammonia Equipment

- In the last years have appeared some ammonia equipment with low charges.
- Normally are using direct expansion.
- Also there are now semihermetic compressors with aluminium windings.
- They open a new brand of ammonia applications.

HIDROCARBONS

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Hydrocarbons

- Hidrocarbons have good refrigeration properties but their biggest disadvantage is that they are all explosive (classified as A3).
- The most commonly used in refrigeration are isobutane (R600a) and propane (R290).
- R600a are already used in refrigerators.
- R290 are used for long time in big installations in the petrochemical industry.

Hydrocarbons

- The environmental characteristics of hydrocarbons are good.
- Propane (R290) has an ODP of 0 and a GWP of 3 to 5 (according to different sources).
- Isobutane (R600a) also has an ODP of 0 and a GWP of approximately 10 to 20.

Hydrocarbons Equipment

- Isobutane is widely used in appliances.
- Currently more than 60 million refrigerators are manufactured per year with isobutane (R600a).
- The refrigerant charge is less than 150 gr.
- Sometimes hydrocarbons blends are used.
- They work well with mineral lubricants but also work well with AB and POE.

R600a
Evaporation Pressures -25°C

Refrigerant	Pressure Bar	Pressure Psig
R12	1,24	3,5
R134	1,07	1
R600a	0,58	- 6,1

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R290 - Propane

- The main use limitation is their security classification according to ASHRAE 34 of A3 (explosive).
- R290 has been used as refrigerant in the oil and petrochemical industry in large facilities for a long time.
- These types of installations works with very strong security standards.

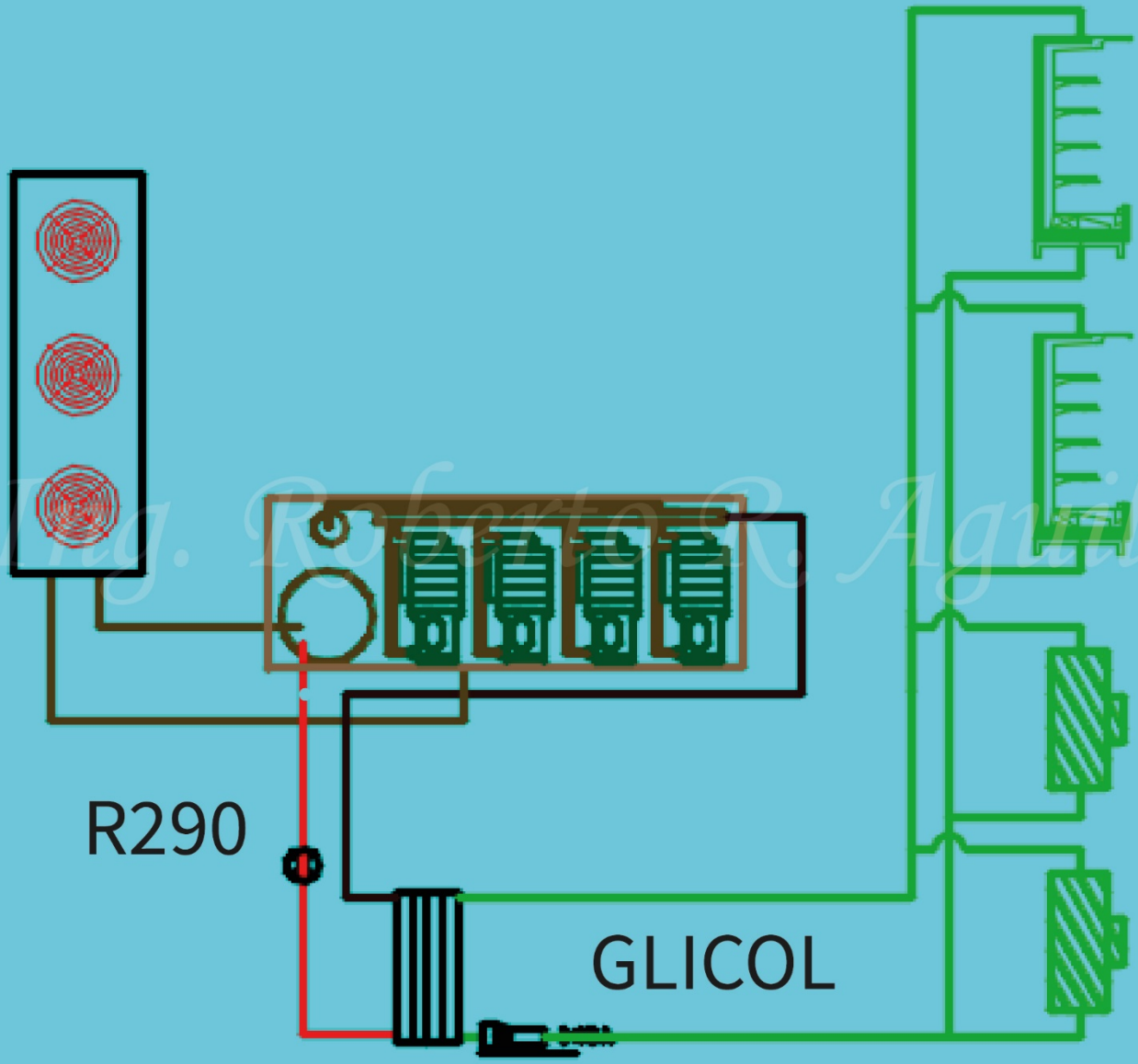
Central Facilities with R290

- Compressor racks have been used in commercial installations where R290 remains confined in the machinery room and only if high safety standards must be maintained there.
- They have a refrigerant charge that could exceed from 50 kg of R290.
- A secondary refrigerant is sent to all distributed loads.

Secondary Coolant

- Simple Technology
- Reduced refrigerant charge
- Very important reduction in lenght of refrigerant pipes, so it is possible to achieve less refrigerant leakages.
- Increase electric power demanded due to the pump.

Secondary Refrigerants



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CARBON DIOXIDE
CO_2

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R744 - CO_2

- It is a natural gas that is found in the atmosphere .
- The critical point has a temperature of 30,98ºC (87,9°F) and a pressure of 73,6 bars (1067psi).
- At atmospheric pressure it does not exist in liquid state, so it changes from solid state to gaseous state in a process of sublimation.

History

- CO_2 was used as refrigerant at the end of the XIX century and the beginning of the XX century.
- It was widely used, specially in naval refrigeration.
- In 1930, when halocarbon refrigerants appeared, practically CO_2 disappeared.

CO_2 Environmental Impact

- CO2 (R744) has a very low environmental impact.
  - ODP is equal to 0
  - GWP is just 1

Effects of CO_2 in Persons

Concentration (ppm)	Effects
350	Normal Value in air
1000	Maximum Value recommended for comfort
5000	TLV - TWA
20000	Breath afected 50% increased
30000	100 % increased
50000 (40000)	IDLH
100000	Minimum lethal concentration
300000	Immediately loss of conscious and convulsions

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- Availability for a variety of natural refrigerants including CO_2

CO_2 P & T

Temperat. ºC	Temperat. ºF	Pressure Bar	Pressure Psig
-30	-22	13,3	192
-10	14	25,5	370
-2	28,5	32	465
34	93	80,6	1168
45	111	109,2	1583

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Compression Index

Refrigerant	**ev-10C/cond 30C** ev 14F/cond 86F	**ev-30/cond 30C** ev -22F/cond 86F
R22	3,36	7,27
R134a	3,84	9,13
R404A	3,26	6,76
R717	4,01	9,77
R744	2,72	5,05

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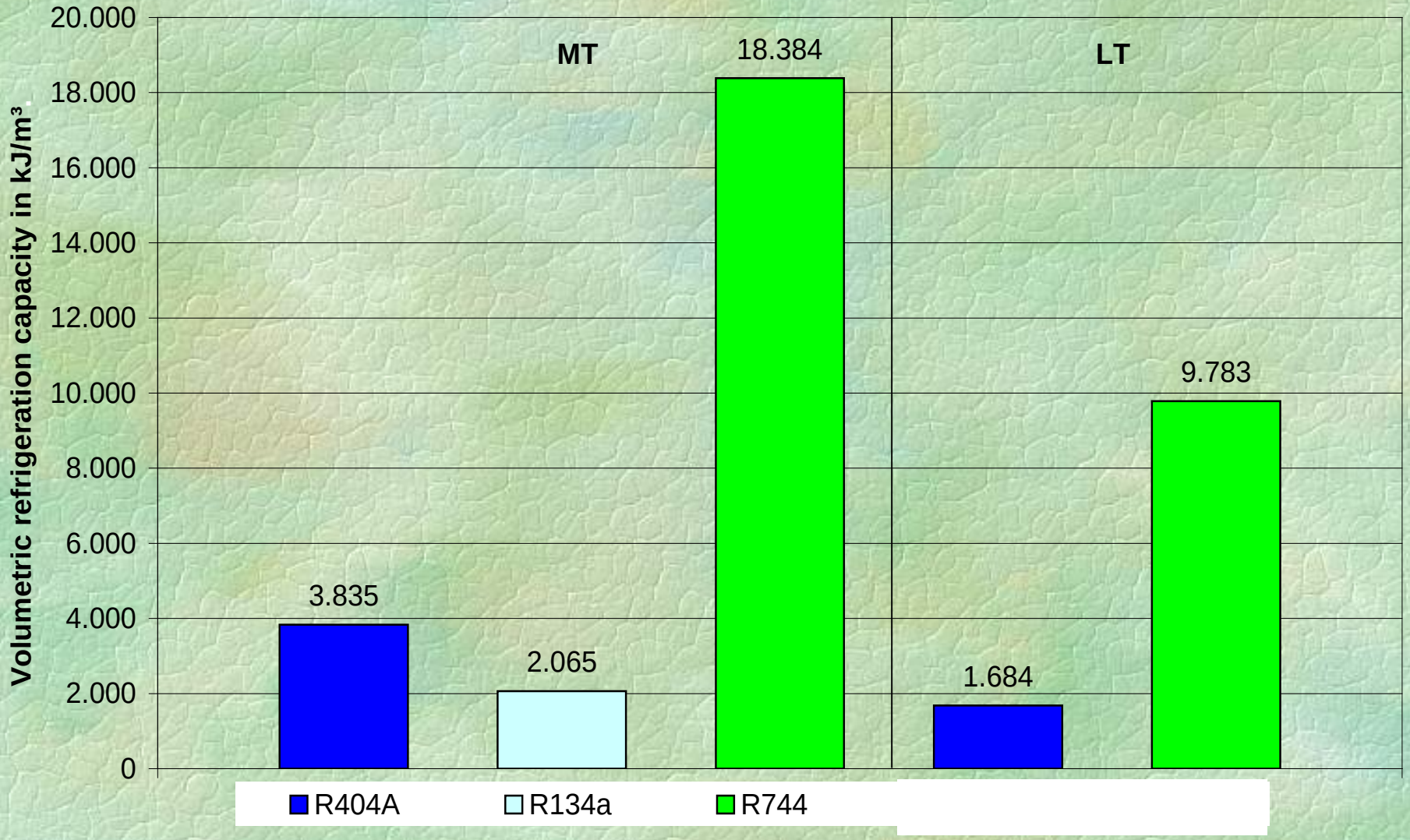
Volumetric Capacity



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Applications with CO_2

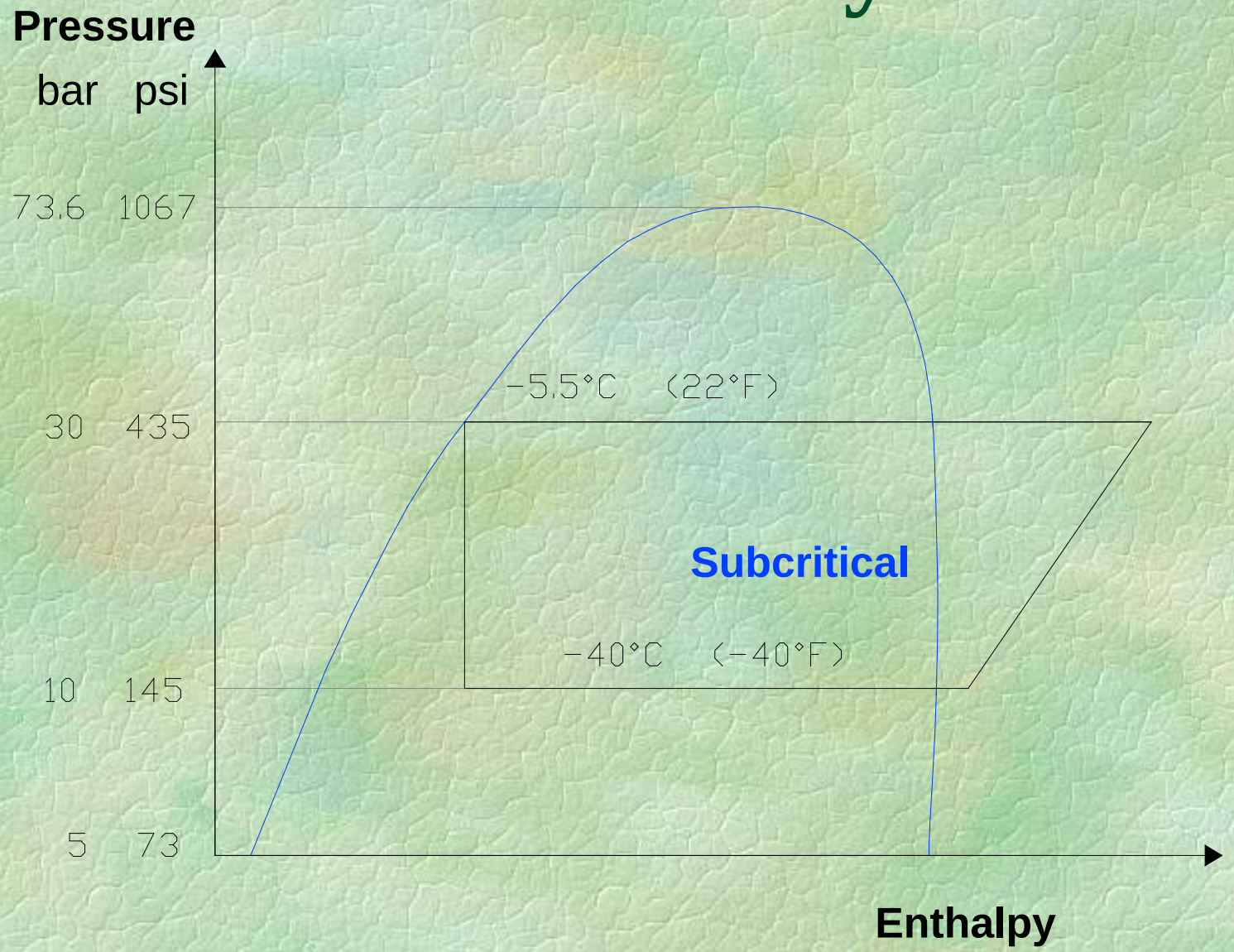
- Subcritical Cycle
- Transcritical Cycle
- Use as secondary refrigerant

- Double Stage Cycle
  - Cascade
  - Booster

Subcritical Cycle

- Normal refrigeration components can be used for temperatures between -50°C (-58°F) to 0°C (32°F).
- In these conditions working pressures will be between 6,7 and 35 bar (100 to 500 psi).
- Practically, the only way to work in these conditions is in a cascade system.

Subcritical Cycle



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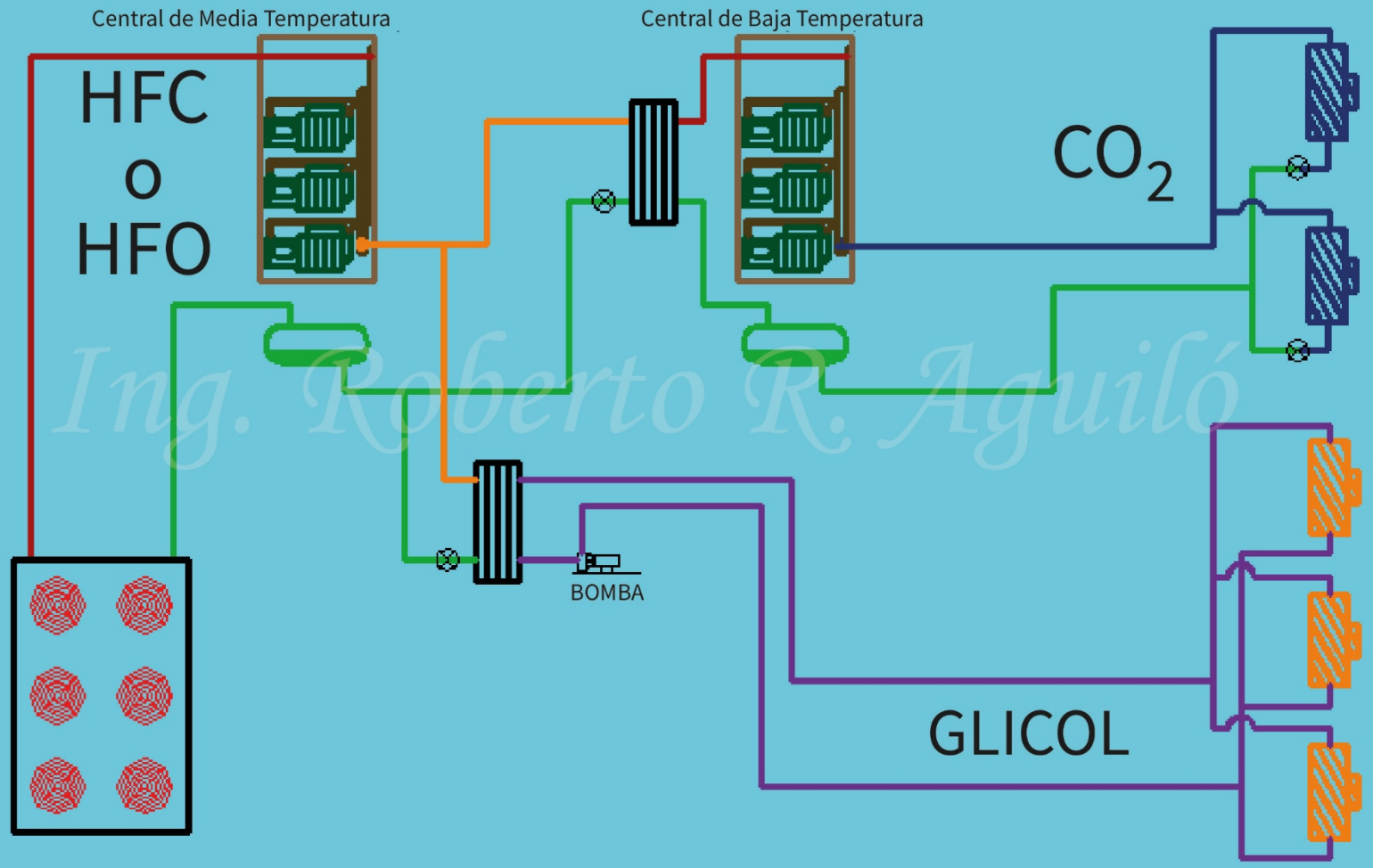
CO_2 Subcritical



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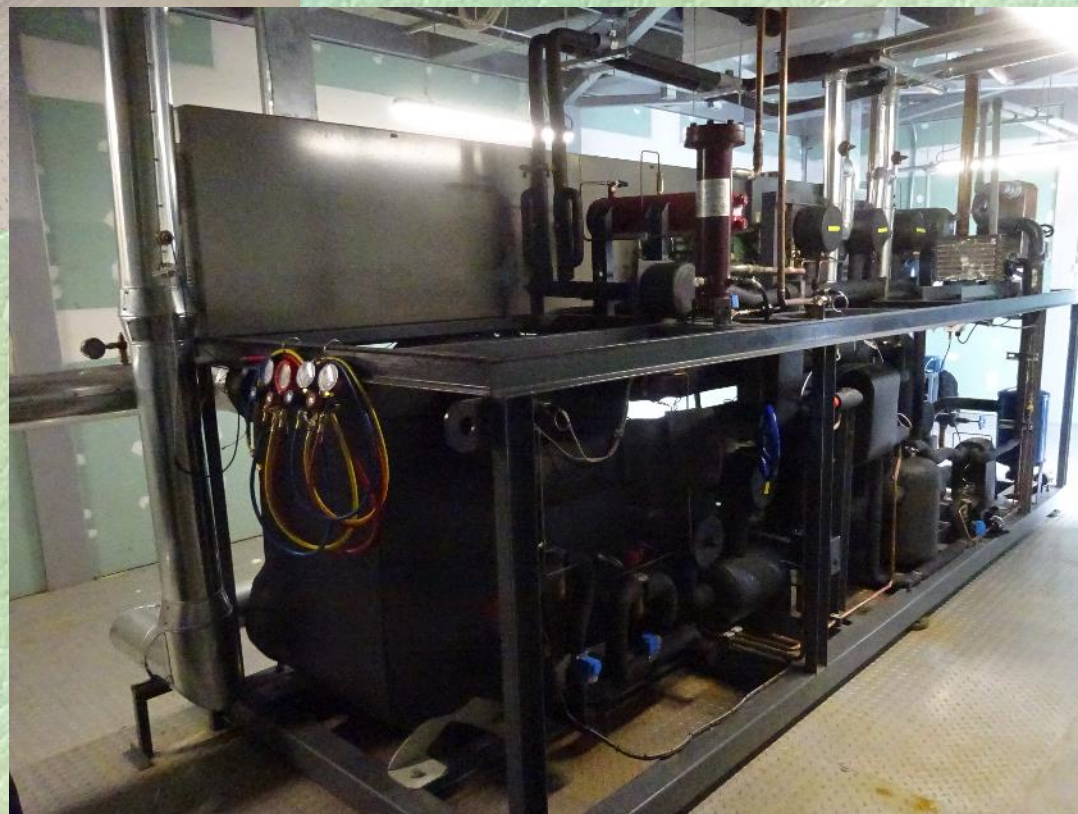
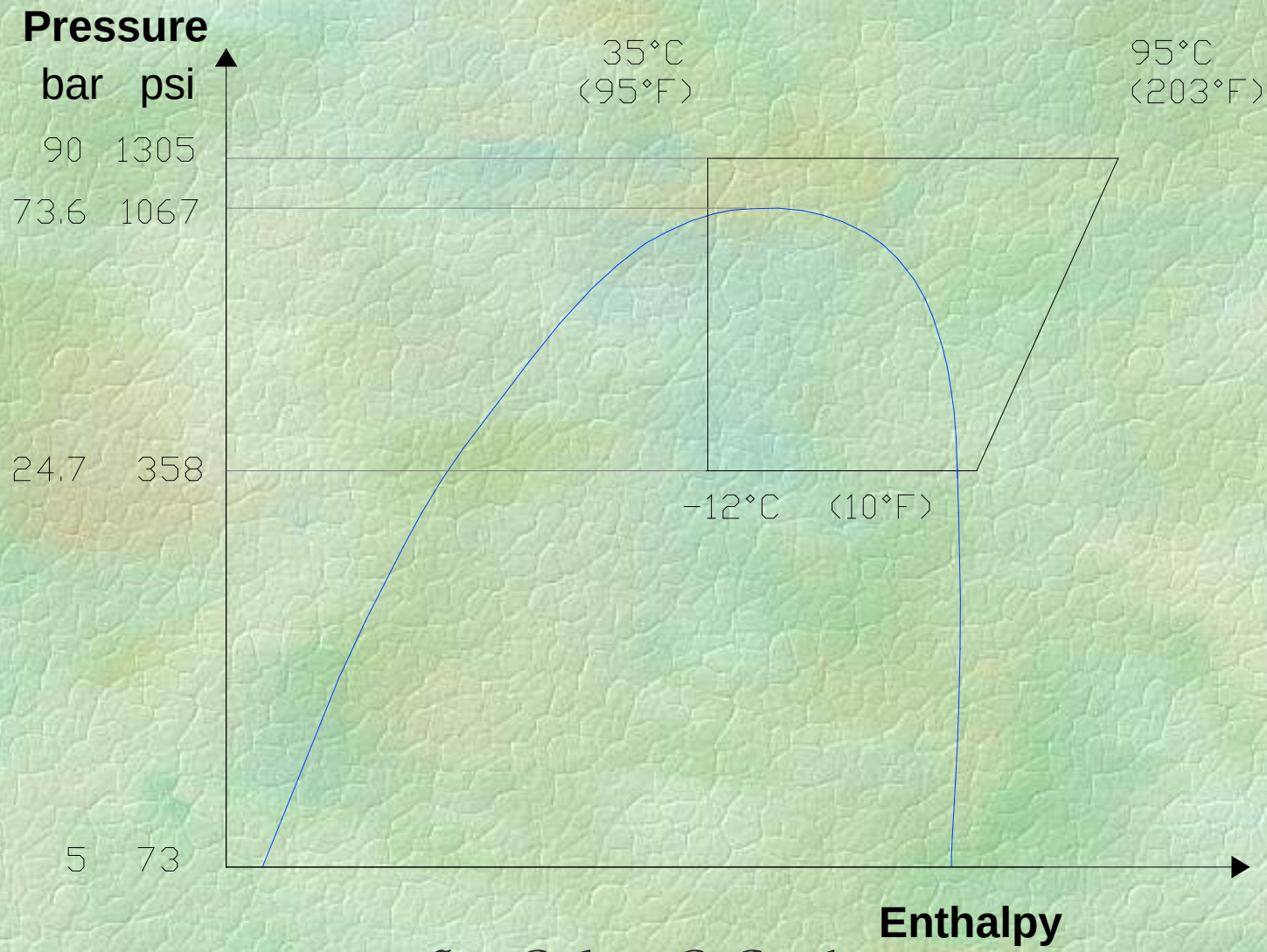
¡ATENCIÓN!
RIESGO
ELÉCTRICO



Transcritical Cycle

- In a transcritical cycle, refrigerant condensation not appear in the equipment where heat is rejected to the cooling media.
- It happens in this way because heat rejection occurs over the critical point and in this condition it is impossible to condense the refrigerant despite how much the pressure goes up.

Transcritical Cycle



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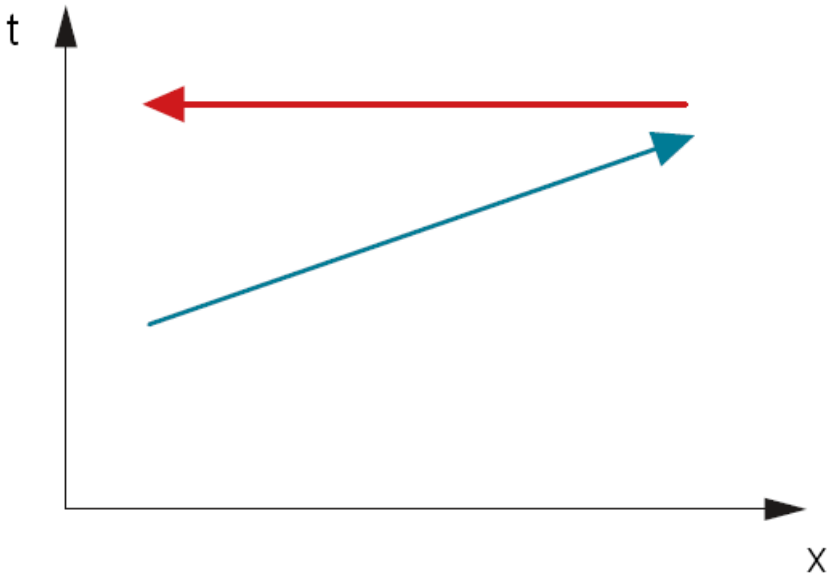
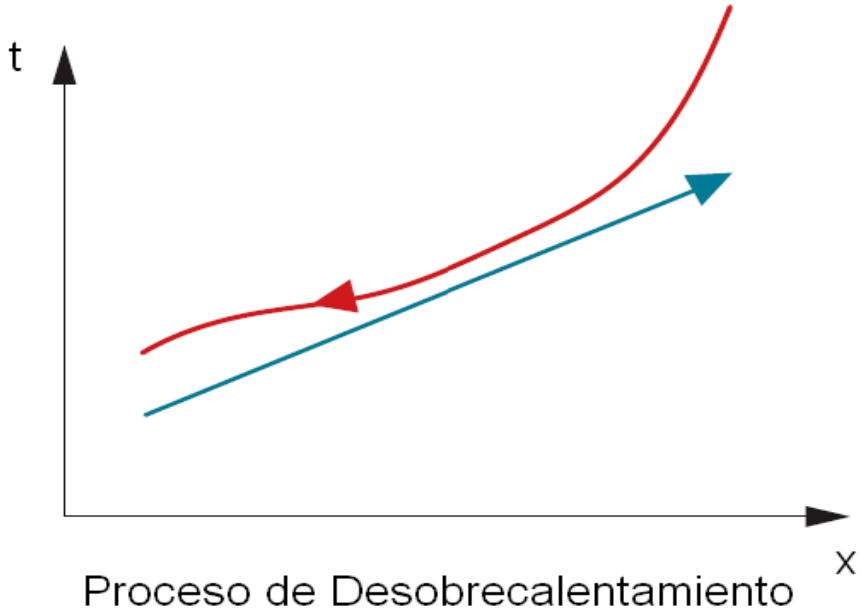
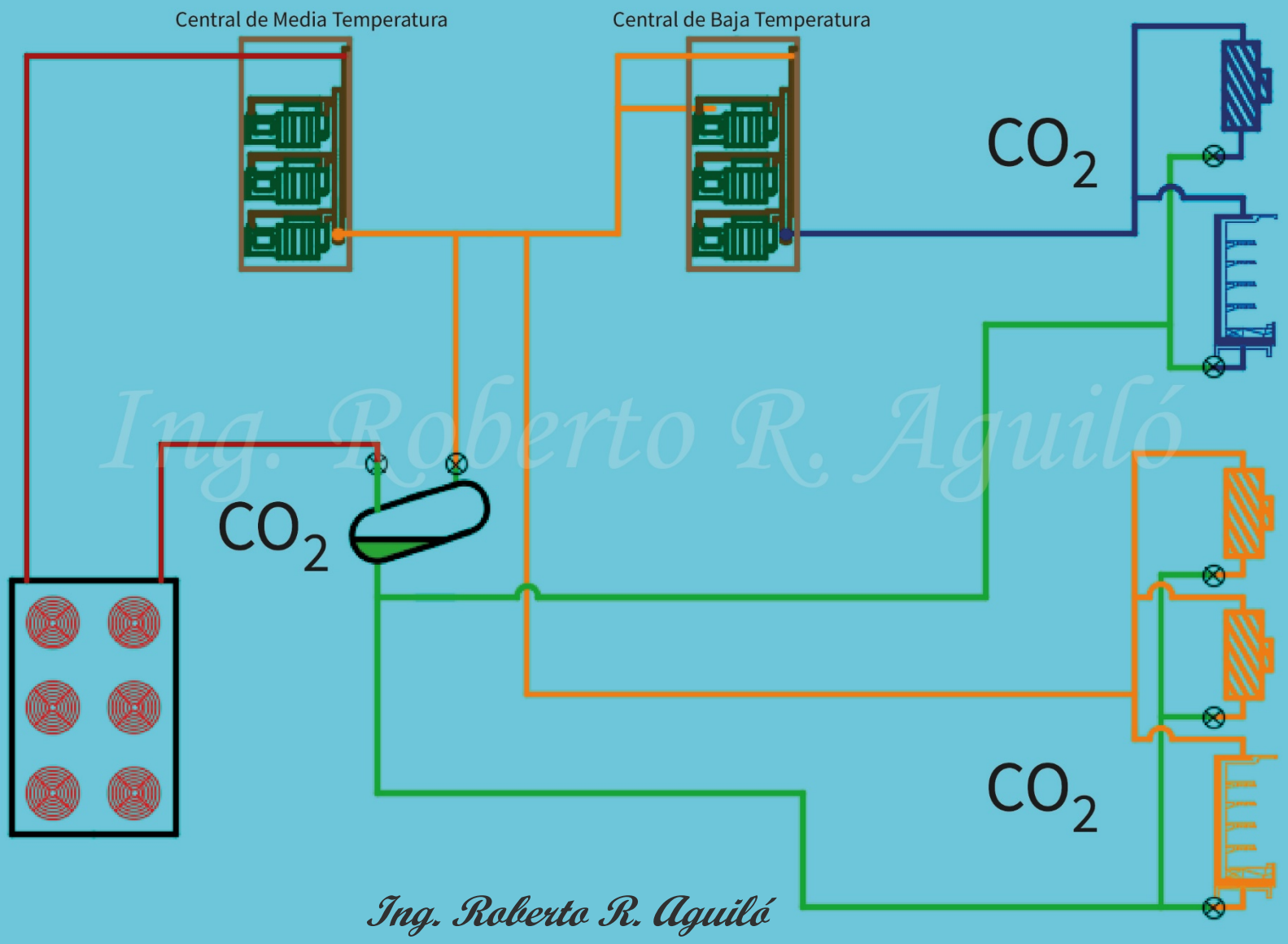


Proceso de Condensación



Proceso de Desobrecalentamiento

CO_2 Transcritical



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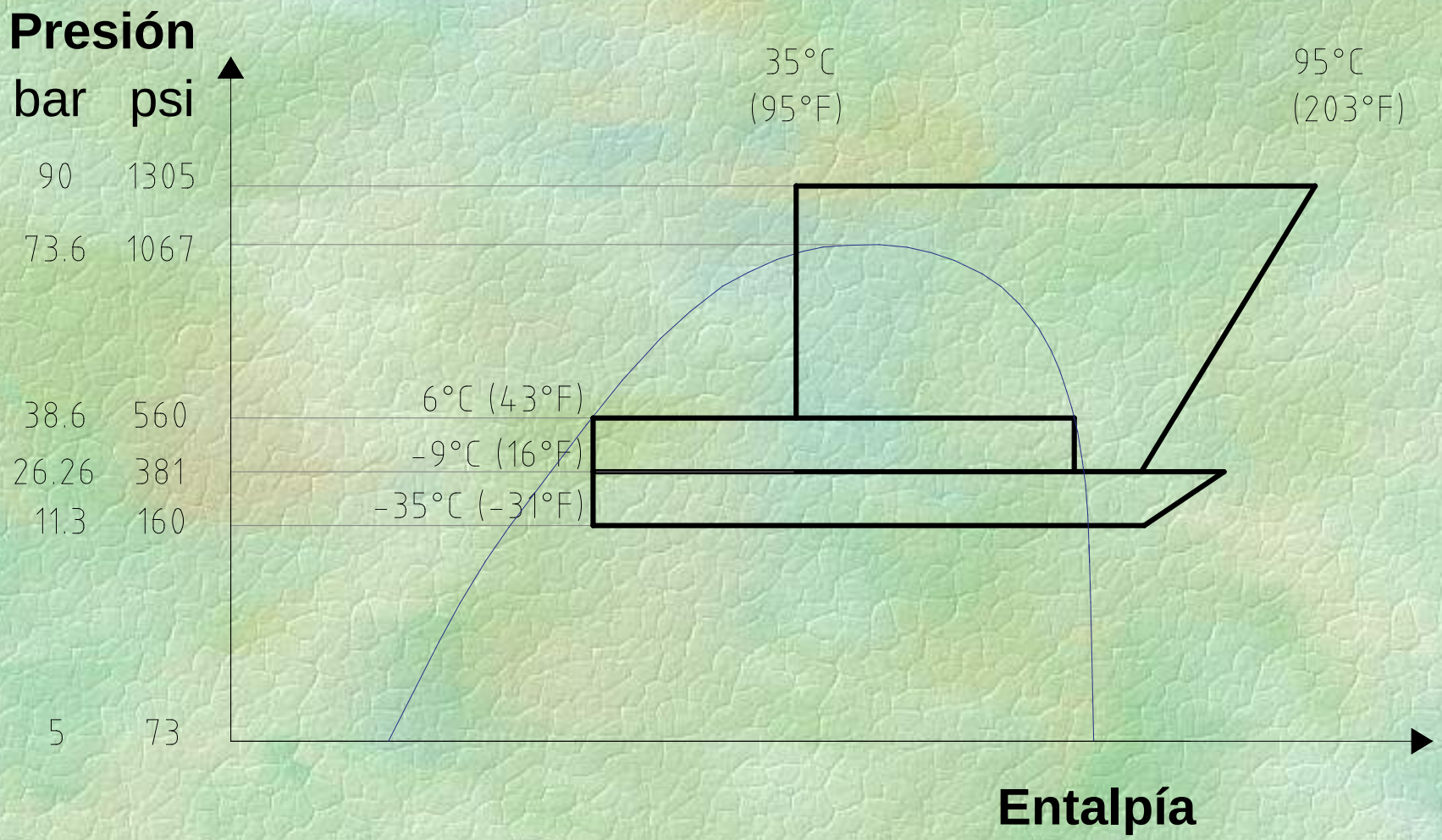
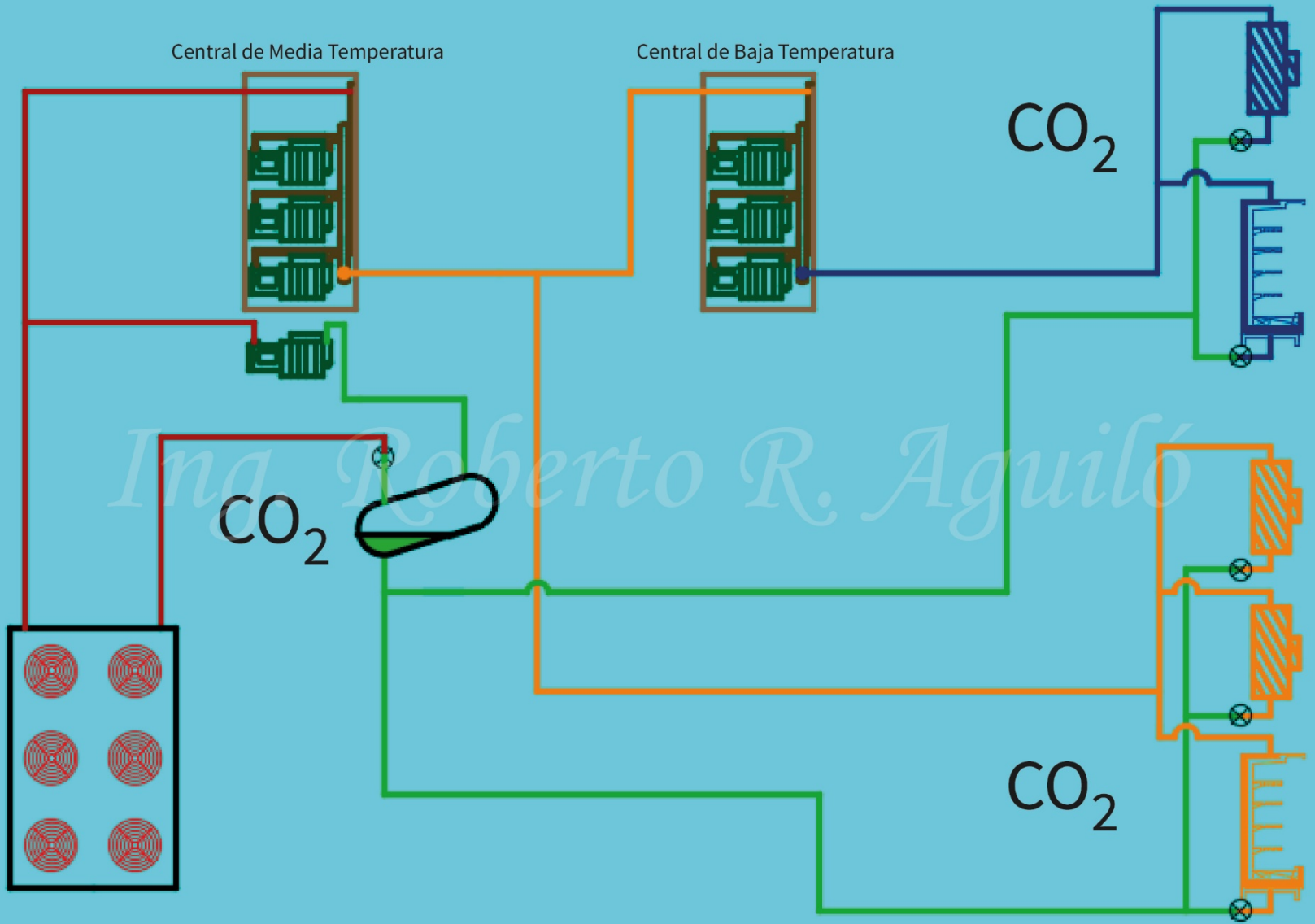

Presión
bar psi
90 1305
73.6 1067
38.6 560
26.26 381
11.3 160
5 73
35°C
(95°F)
95°C
(203°F)
6°C (43°F)
-9°C (16°F)
-35°C (-31°F)
Entalpía

Improving Efficiency

- Considering the same installation if we use a parallel compressor we can improve its efficiency between 8 and 12%.
- In the previous situation the entire refrigerant mass was suction @ –9C, and having a parallel or satellite compressor, about 50% mass will have a suction temperature of 4C.

CO_2 Transcritical w/parallel



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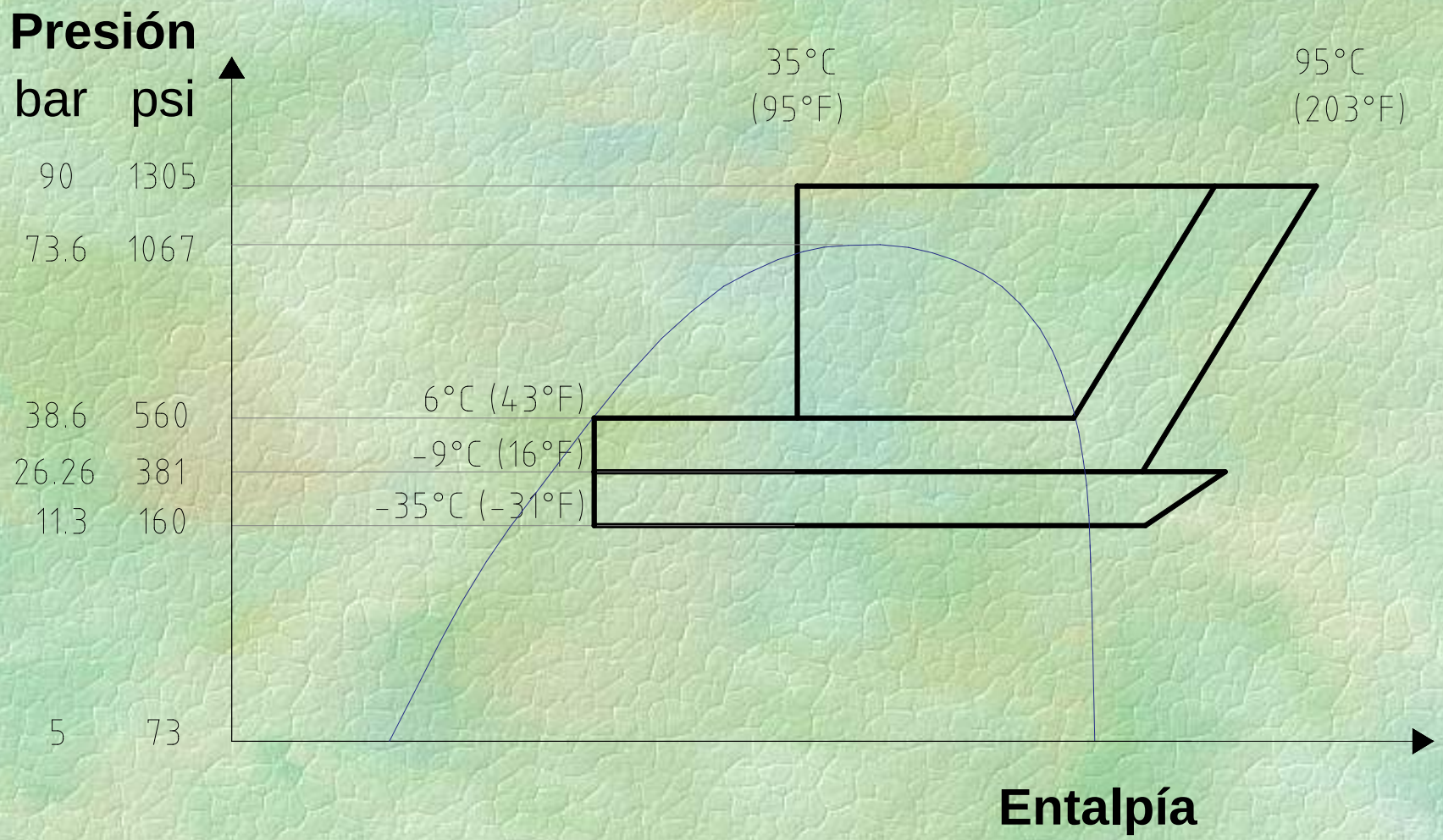
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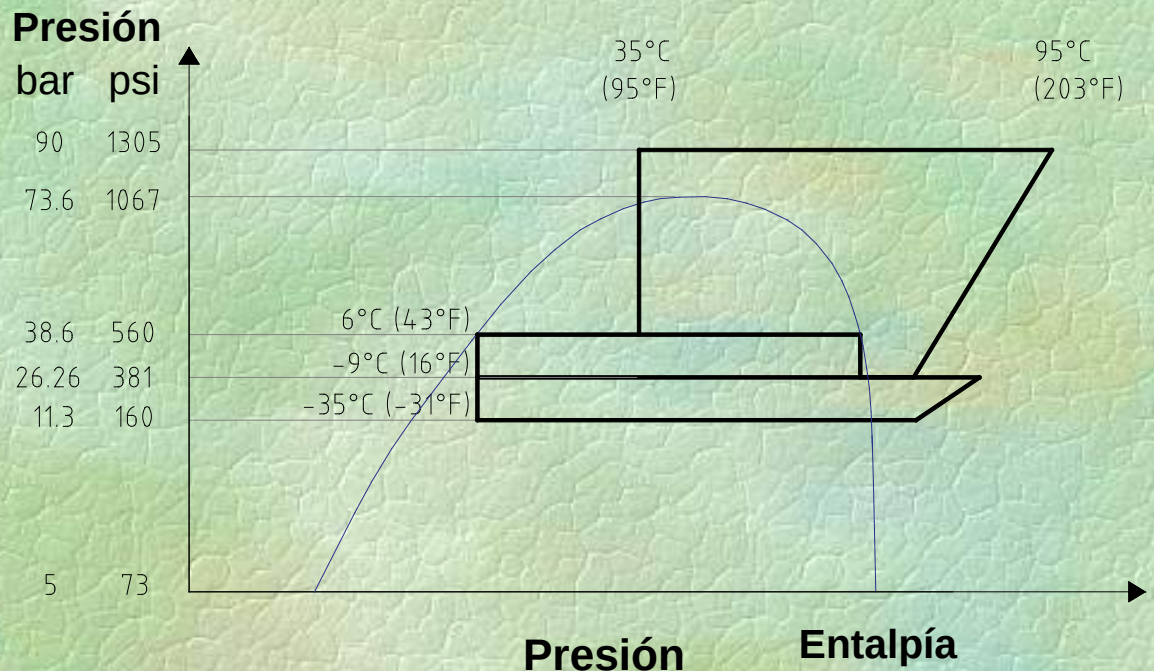
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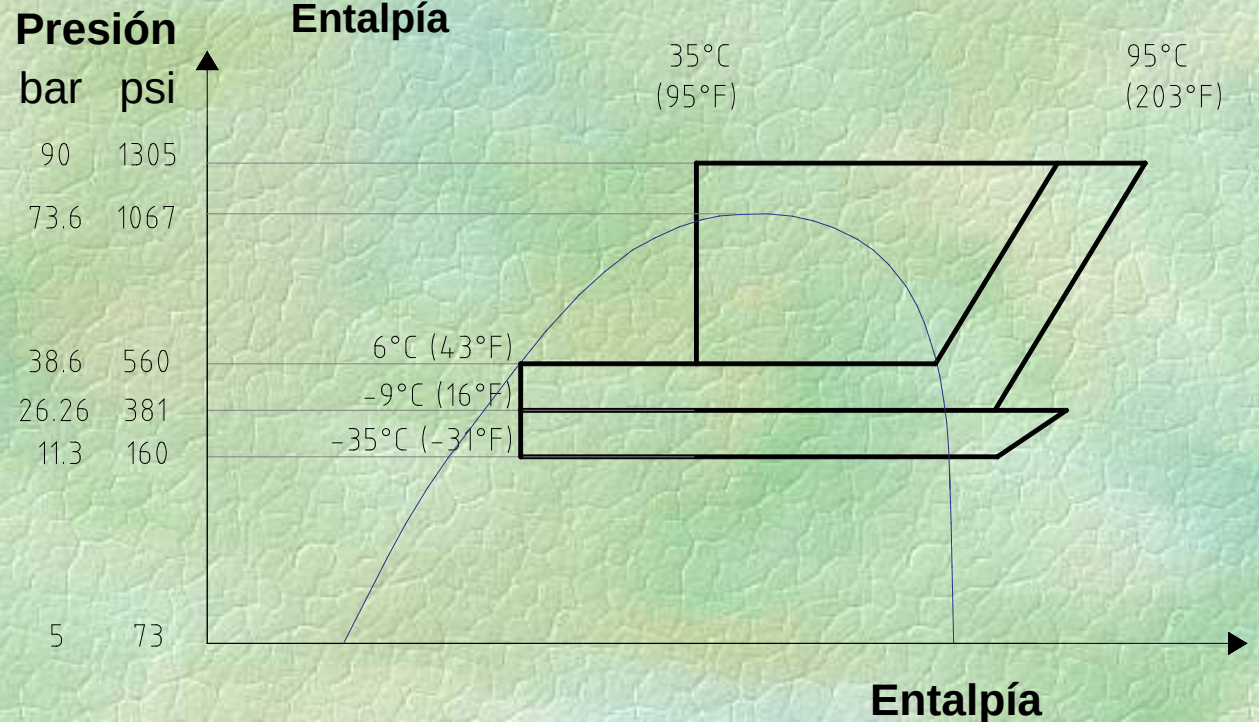
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95°C
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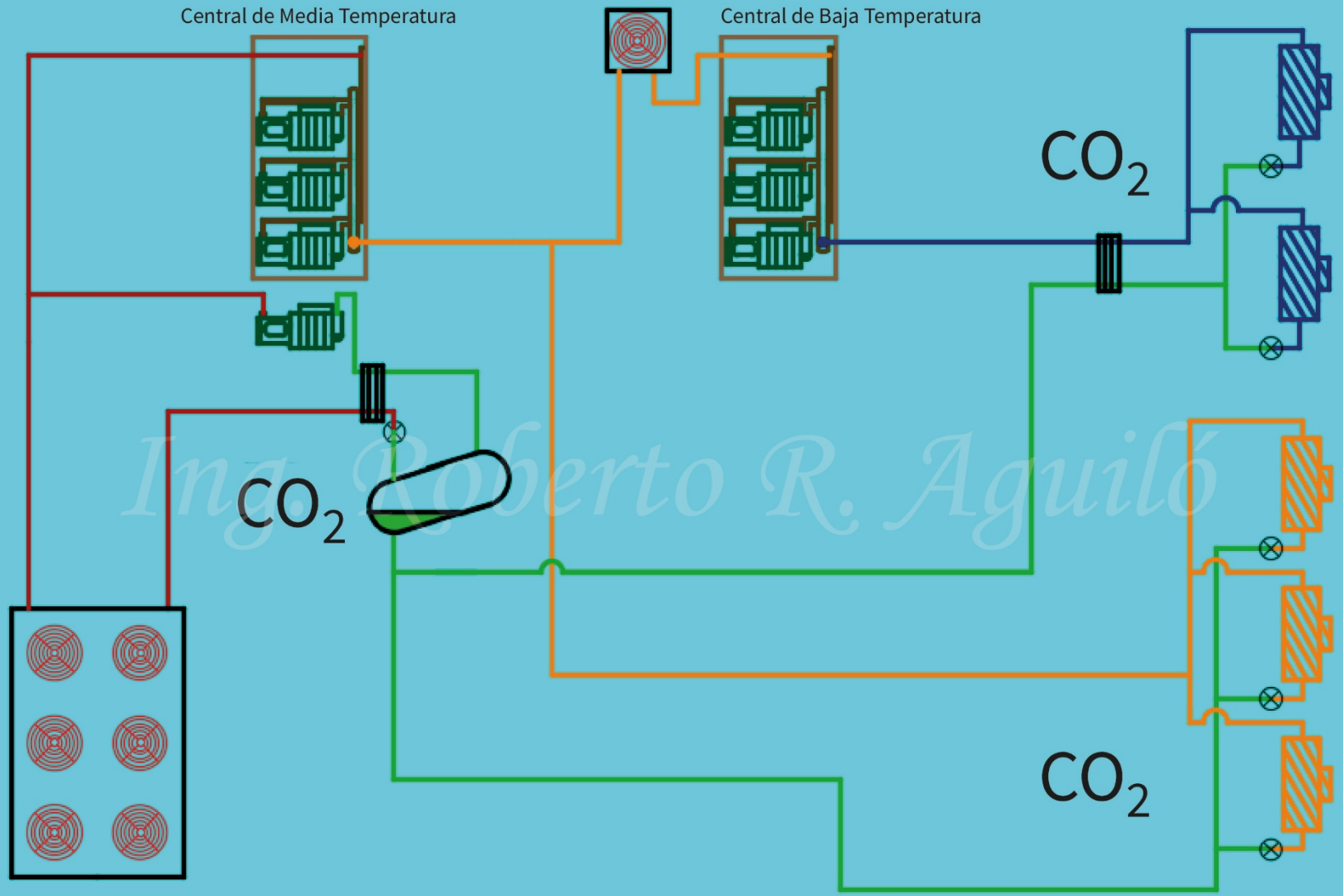
6°C (43°F)
-9°C (16°F)
-35°C (-31°F)
Entalpía

Improving Efficiency II

- We can improve the efficiency of the cycle just using some heat exchangers
- It is very common to install a gas cooler for the LT compressors discharge gas.
- Also some heat exchangers between gas and liquid masses in the system
- In this way we can improve efficiency between 5 and 8% depending on the weather condition.

CO_2 Transcritical w/parallel + Hx



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