Training Course

Carbon dioxide Refrigeration

R744/CO_2

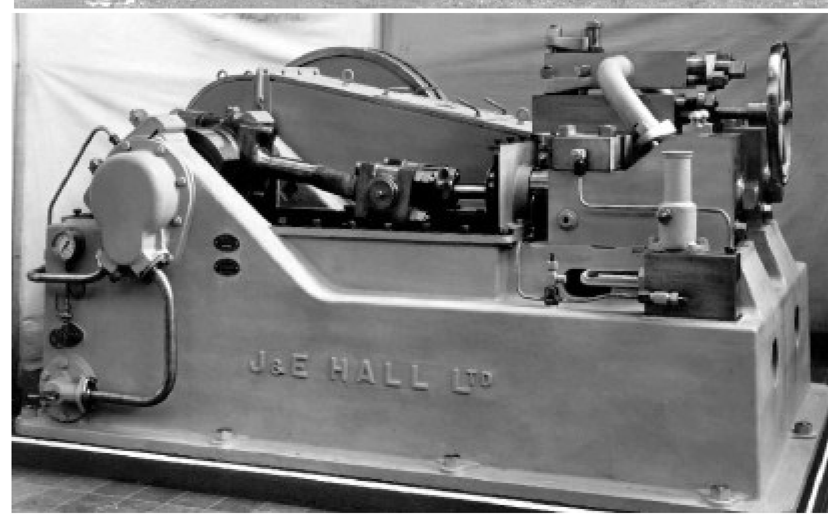
Overview: Modules and Sections

- History and importance of carbon dioxide
- Carbon dioxide (CO_2) refrigerant issues
- European standards and regulations
- CO_2 application potential
- Design, Construction, PPM
- Safety issues
- First Aid
- Review of tools and equipment
- Commissioning and maintenance
- Mechanical integrity

Ice and Refrigeration, 1886

It was reported in The Times in 1886 that J & E Hall's first cold air machines froze 30,000 mutton carcasses being shipped from The Falkland Islands to the UK

J & E Hall designed the first two stage carbon dioxide compressor in 1886 and, as early as 1910 supplied refrigeration equipment to the National Skating Palace.



J&E Hall International

Ice and Refrigeration, 1922

History and importance of CO_2

Beside refrigeration, CO_2 is widely used:

Inert gas: Carbon dioxide is used as an atmosphere for welding

Fire extinguisher: to extinguish flames by flooding the environment around the flame with the gas

As solvent: Liquid carbon dioxide is a good solvent , and is used to remove caffeine from coffee

Beverage industry: transferred into refreshing drinks for sparkling taste

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CO_2 refrigerant issues

CO_2 as refrigerant. Advantages and performance. Brief introduction.

- CO_2 is a natural refrigerant with very low global warming potential
- ODP = 0, GWP = 1
- Non-Toxic, Non-Flammable
- CO_2 is an inexpensive refrigerant compared with HCFCs and HFCs
- CO_2 has better heat transfer properties compared to conventional HCFCs and HFCs
- More than 50% reduction in HFC refrigerant charge possible (high volumetric cooling capacity)
- CO_2 lines are typically one to two sizes smaller than traditional DX piping systems
- Excellent material compatibility
- System energy performance equivalent or better than traditional HFC systems in cool climates

CO_2 refrigerant issues

CO_2 as refrigerant:

CO_2 is available in different degrees of purity.

It is recommended only to use refrigerant degree of 4.5 or higher.

Classification	CO_2 "KK"	CO_2 3.0			CO_2 4.5			R744 (CO_2 4.5)		
	915	918			925			690		
Purity	≥ 99,5	≥ 99,9			≥ 99,995			≥ 99,995		
	o. A.	$O_2 + N_2$	≤	500	O_2	≤	15	O_2	≤	15
		C_nH_m	≤	50	N_2	≤	30	N_2	≤	30
		H_2O	≤	250	C_nH_m	≤	2	C_nH_m	≤	2
					CO	≤	1	CO	≤	1
					H_2O	≤	5	H_2O	≤	5

General refrigerant classification

	Lower (chronic) toxicity		Higher (chronic) toxicity	
No flame propagation	**A1**	R22 R744 R134a R4010A R404	**B1**	R123 R245fa
Lower flammability	**A2L**	R32 R143a R1234yf R1234ze R444A/B	**B2L**	R717
Flammable	**A2**	R152a R142b R405A R411A R439A	**B2**	R30
Higher flammability	**A3**	R290 R600a R1270 R443A E170	**B3**	R1140

More onerous requirements

More onerous requirements

EN378-1 Annex E
AHRI 700
ISO817

Flammability and toxicity classification

Safety classification	Lower flammability level, % in air by volume	Heat of combustion J/kg	Flame propagation
A1	No flame propagation when tested at 60°C and 1013 mbar (101.3 kPa)		
A2 **lower flammability**	> 3.5	< 19,000	Exhibit flame propagation when tested at 60°C and 1013 mbar (101.3 kPa)
A2L **lower flammability**	> 3.5	< 19,000	Exhibit flame propagation when tested at 60°C and 1013 mbar (101.3 kPa) and have a maximum burning velocity of ≤ 10 cm/s when tested at 23°C and 1013 mbar
A3 **higher flammability**	≤ 3.5	≥ 19,000	Exhibit flame propagation when tested at 60°C and 1013 mbar

CO_2 refrigerant issues

Lower Flammability & Toxic

Very high pressure

Higher Flammability

REFRIGERANT	REFRIGERANT NUMBER	CHEMICAL FORMULA	GWP (100 YEARS)	ODP	NORMAL BOILING POINT (°C)	CRITICAL TEMPERATURE (°C)	CRITICAL PRESSURE (BAR)	SAFETY GROUP	MOLECULAR WEIGHT (G/MOL)
Ammonia	R717	NH_3	0	0	-33.3	132.4	114.2	B2L	17.03
Carbon dioxide	R744	CO_2	1	0	-78	31.4	73.8	A1	44.0
Propane	R290	C_3H_8	3.3	0	-42.1	96.7	42.5	A3	44.10
Isobutane	R600a	C_4H_{10}	4	0	-11.8	134.7	36.48	A3	58.12
Propylene	R1270	C_3H_6	1.8	0	-48	91	46.1	A3	42.08
Water	R718	H_2O	0	0	100	373.9	217.7	A1	18.0
Air	R729	-	0	0	-192.97	-	-	-	28.97

CO_2 refrigerant issues

Comparison of properties

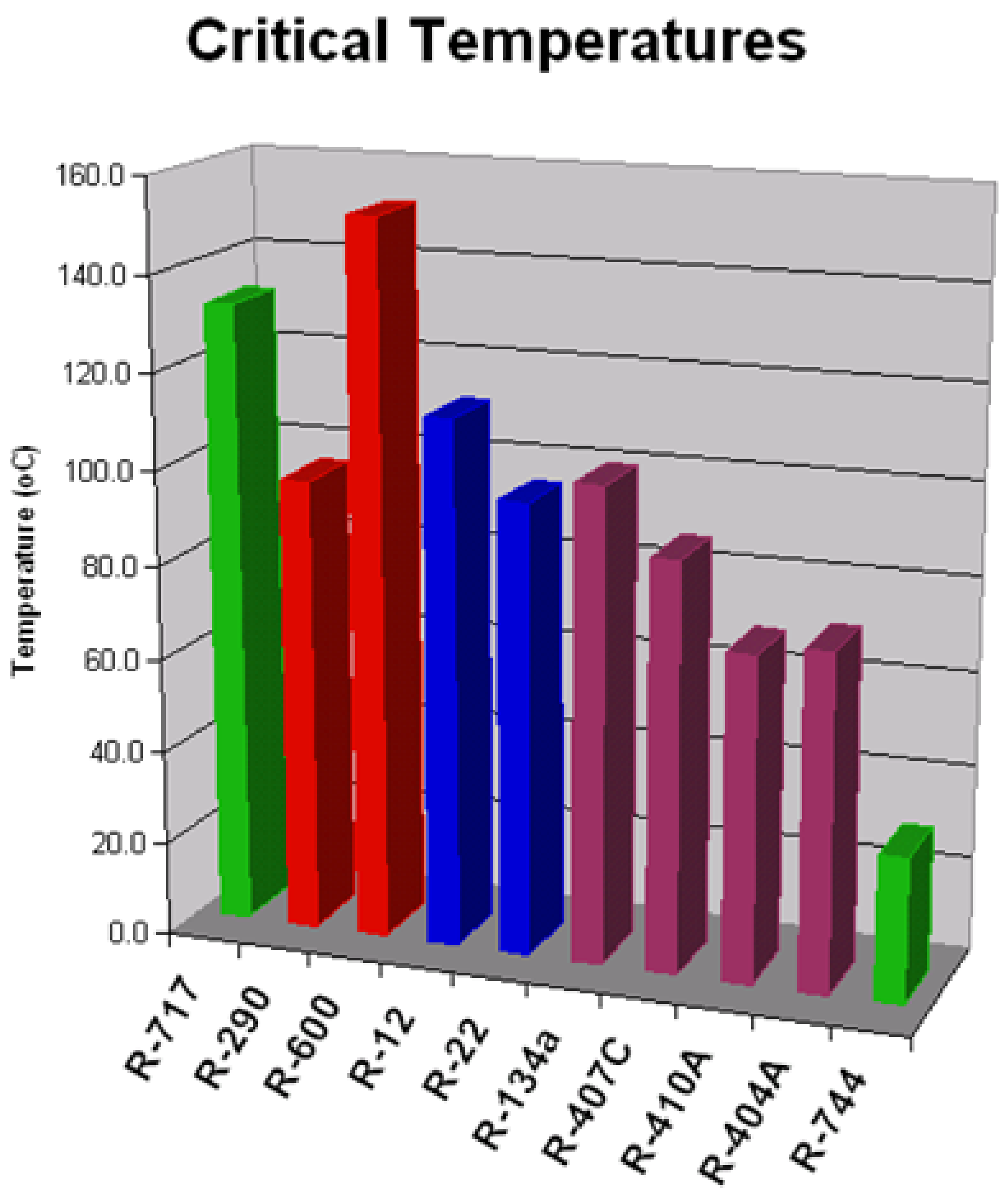
Refrigerant	R744	R404A	R134a	R407A	R407F
Temperature at atmospheric pressure	-109.3 °F (-78.5 °C) Temp. of dry ice	-50.8 °F (-46 °C) (Saturation temp.)	-14.8 °F (-26 °C) (Saturation temp.)	-41.8 °F (-41 °C) (Mid-point saturation temp.)	-45.5 °F (-43 °C) (Mid-point saturation temp.)
Critical temperature	87.8 °F (31 °C)	161.6 °F (72 °C)	213.8 °F (101 °C)	179.6 °F (82 °C)	181.4 °F (83 °C)
Critical pressure	1,056 psig (72.8 barg)	503 psig (34.7 barg)	590 psig (40.7 barg)	641 psig (44.2 barg)	674 psig (46.5 barg)
Triple point pressure	60.6 psig (4.2 bar abs)	0.44 psig (0.03 bar abs)	0.0734 psig (0.005 bar abs)	0.19 psig (0.013 bar abs)	---
Pressure at a saturated temperature of 20 °C (68 °F)	815 psig (56.2 barg)	144 psig (9.9 barg)	68 psig (4.7 barg)	133 psig (9.2 barg)	139 psig (9.6 barg)
Global warming potential	1	3922	1430	1990	1824

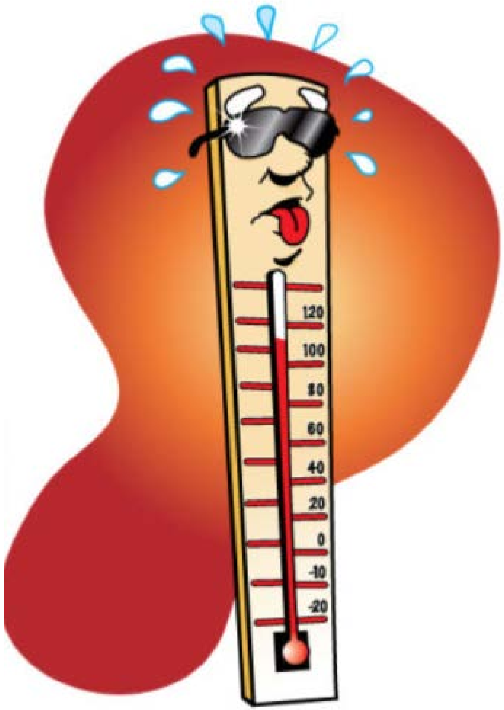
CO_2 refrigerant issues

Comparison of properties

Refrigerant	Critical temp. (°C)	Liquid viscosity (Pa s ×10^6)	Vapour viscosity (Pa s ×10^6)	Liquid sp. heat (kJ/kg K)	Liq thermal cond (W/m K)	Latent heat (kJ/kg)
R-22	96.1	216	11.4	1.17	0.095	205
R-134a	101.1	267	10.7	1.34	0.092	199
R-404A	72.0	179	11.0	1.39	0.073	166
R-407C	86.0	211	11.3	1.42	0.096	210
R-410A	71.4	161	12.2	1.52	0.103	221
R-717	132.3	170	9.1	4.62	0.559	1262
R-290	96.7	126	7.4	2.49	0.106	375
R-1270	92.4	121	7.8	2.44	0.126	378
R-744	31.0	99	14.8	2.54	0.110	231

CO_2 refrigerant issues





CO_2 refrigerant issues

Critical Pressure

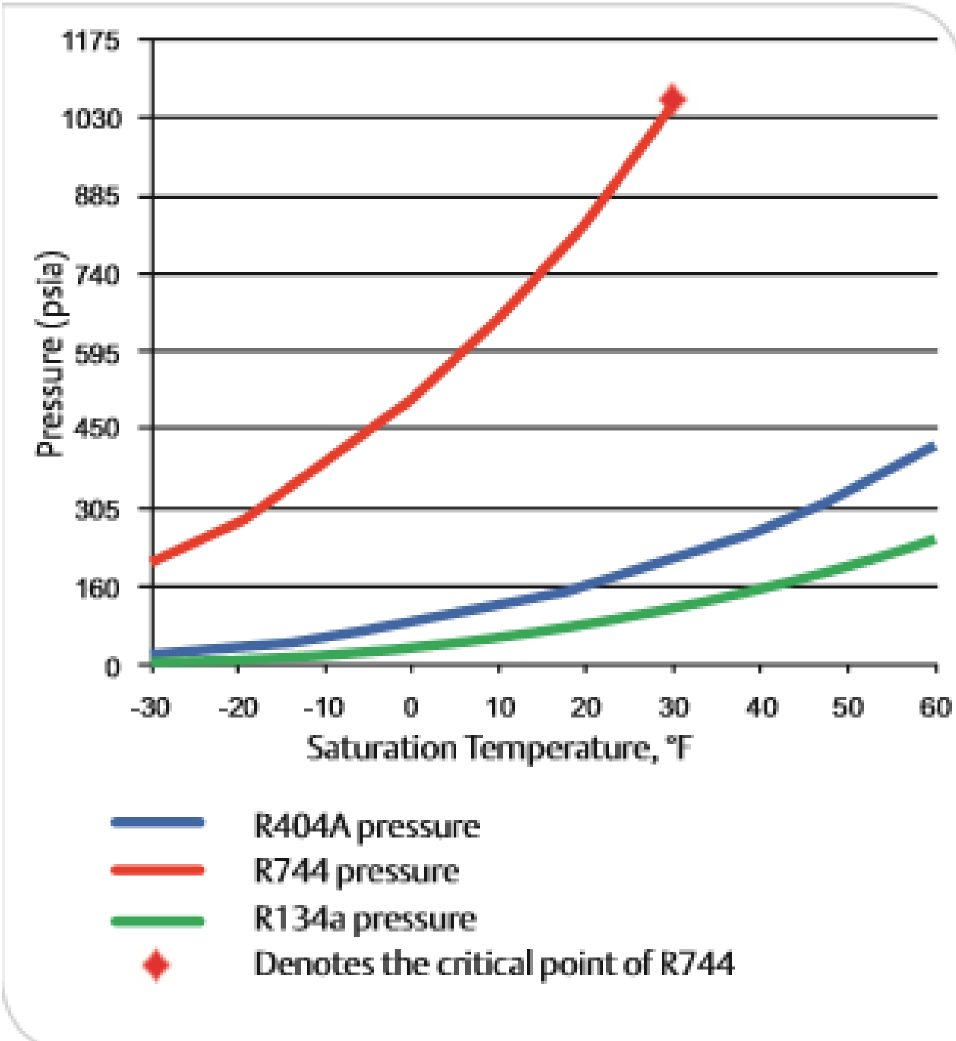


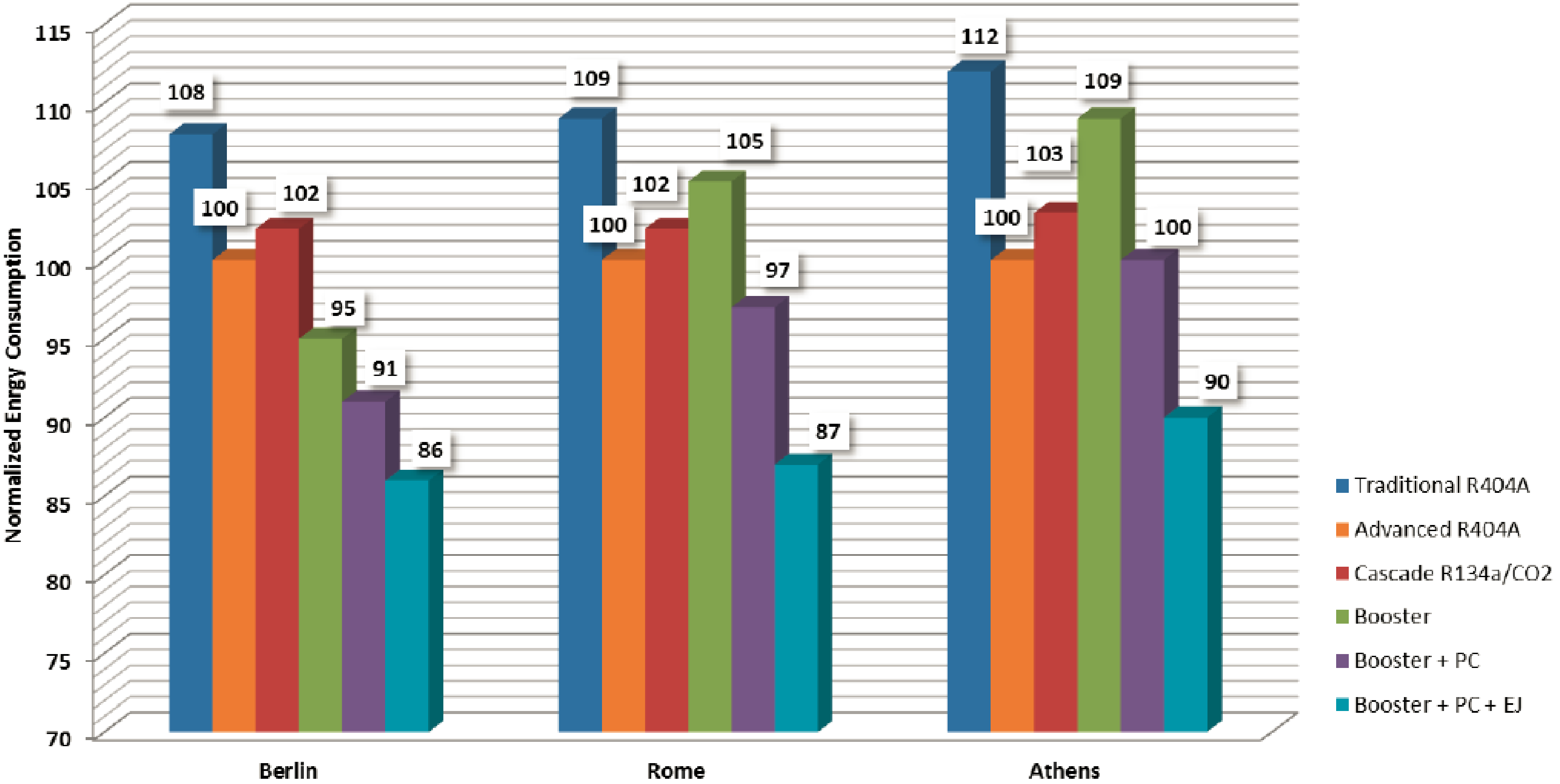
Figure 5. Pressure-temperature relationship comparison

t_{crit} = 31°C

p_{crit} = 73,77 bar

CO_2 refrigerant issues

Performance analysis



General Servicing Issues	NH3 R717	CO_2 R744	HCs R290, R600a …
Weight in relation to air	Lighter	Heavier	Heavier
Refrigerant Purity	99.98 % min Moisture < 200 ppm	99,99 % Moisture < 10 ppm	99.5 % min Moisture < 10 ppm
Gauges & Circuit Equipment	Stainless Steel R717 indication	High Pressure R744 indication	As for HCFC / HFC HC indication
Vacuum Pump	Stainless Steel ATEX, Vent Line	Regular Vent line	Regular ATEX, Vent line
Charging	Scale	Scale Pressure	Sensitive Scale
Tubing	Carbon steel, stainless steel	Copper **HP** Stainless steel	Copper
Leak Finding	Nose, Gas detector, Litmus paper, Sulfur stick, Bubble test, PPE	Gas detector, Bubble test, PPE	Gas detector Bubble test, PPE
Pressure test Leak Test	Nitrogen 4.0	Nitrogen 4.0 Trace Gas (N_2/H_2)	Nitrogen 4.0 Trace Gas (N_2/H_2)
Strength test PS x 1.1	Nitrogen 4.0	Nitrogen 4.0	Nitrogen 4.0

HP copper examples:

Heat treatable copper-iron alloys have a higher strength than copper whilst maintaining a reasonably high electrical and thermal conductivity and excellent welding, soldering and brazing properties. **Pressure (PS) = up to 120bar**

CO_2 > Conclusions

CO_2 is safe if it is used correctly

It is easy to use, and reliable in operation

It offers high efficiency

The two key drivers for increased adoption are:

- Safe design of piping an vessels (pressure)
- Enlightened regulation

Incentive will come from:

- Training and familiarity
- Technical Development
- Economies of Scale

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European Standards and Regulations

Important Rules, Regulations, Laws

- DGUV rule 100-500 > prevention of accidents
- PED European pressure equipment directive
- Machinery directive 95/16/EC
- CEN EN 378/2016 (part 1-4)
- DIN 2405 Pipelines in refrigerating systems and cooling equipment - MarkingEN 378 Part 1 to 4 (new release early 2017)

European Standards and Regulations

Design Considerations: Recommendations

Purchaser:

- Specify EN378 as minimum design
- Detectors and alarms
- Automatic plant room ventilation

Designer/Installer:

- Ensure compliance with EN378 parts 2 and 3
- Pipe an components designed for high pressure
- Design for lifetime operation and efficiency

Operator:

- Ensure that the plant is designed for maintenance

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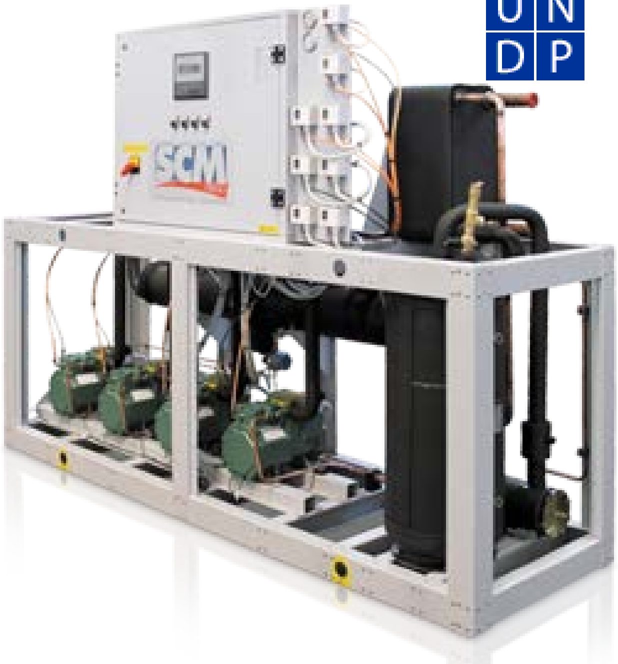
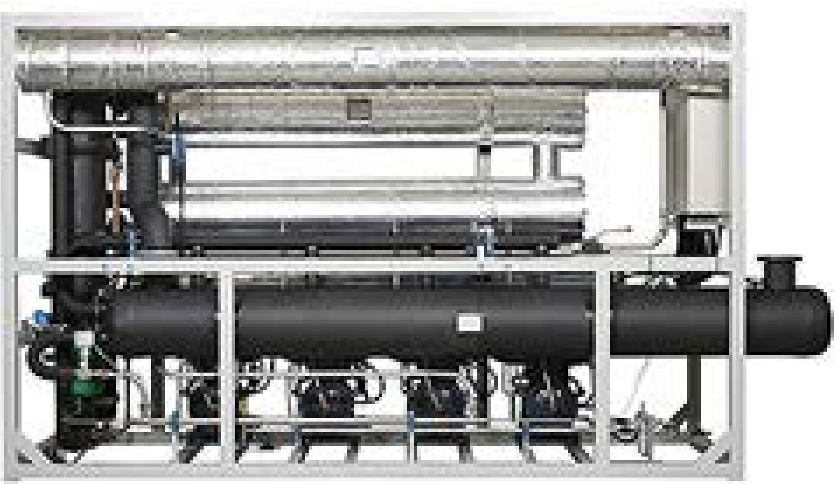
CO2 chillers

- Several companies producing
  - Air-cooled and water-cooled R744 (CO_2) chillers
- Safety aspects
  - Designed to EN 378
- Cost more than HFC/HCFC
- R744 gives higher efficiency than HFC/HCFC in cooler climates



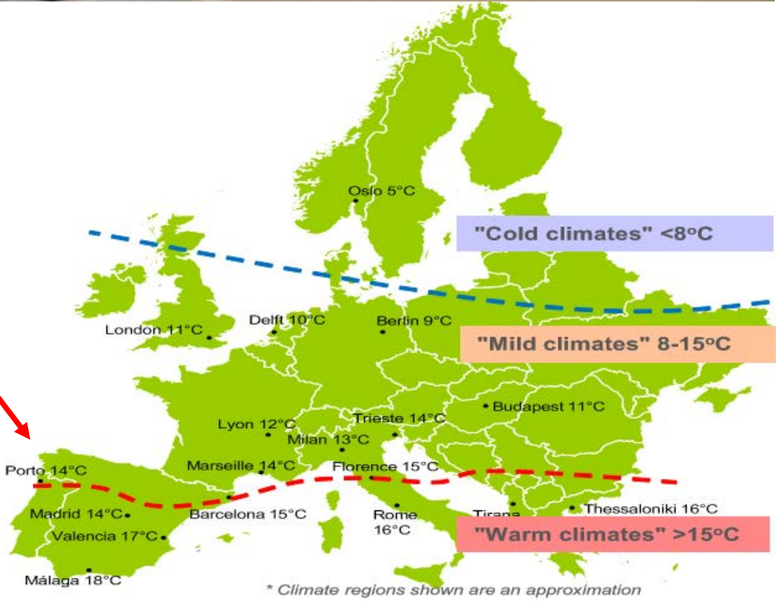


Typical transcritical booster systems

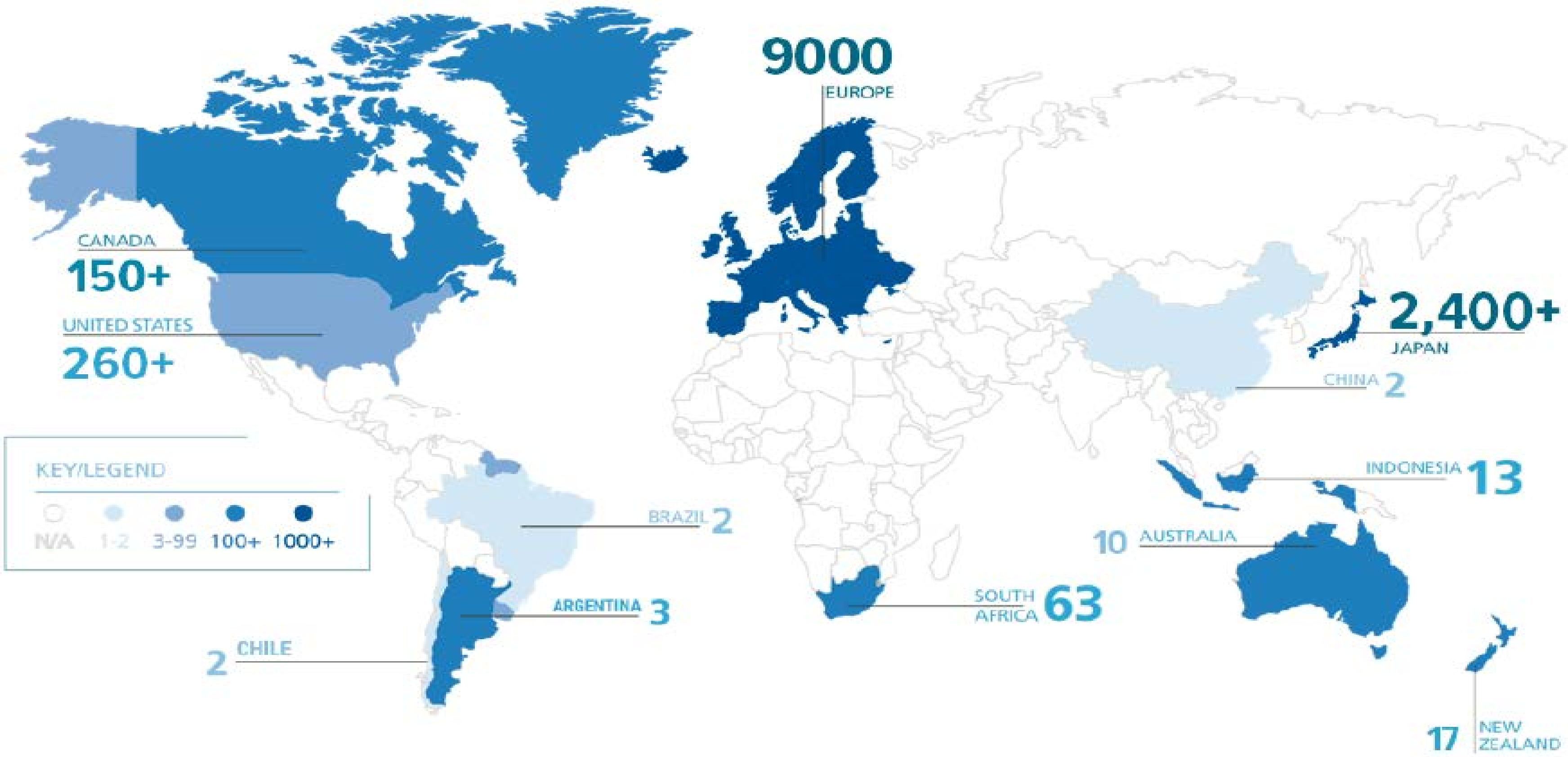
R744 Cascade, Booster systems

Example of products in the commercial sector

	Conventional	Alternative				
Type	Direct expansion, multi-compressor pack	Cascade	Indirect (liquid sec)/ cascade	Indirect (phase-change sec)/ cascade	Trans-critical booster	Distributed water cooled
Medium temp	R404A, R507A, R407F	Lower GWP HFC, (HC-290, HC-1270)	HC-290, HC-1270, R-717, brine	HC-290, HC-1270, R-717, CO2	R744	HC-290, HC-1270, R-717, brine
Low temp	R404A, R507A, R407F	R744	CO2	CO2	R744	HC-290, HC-1270



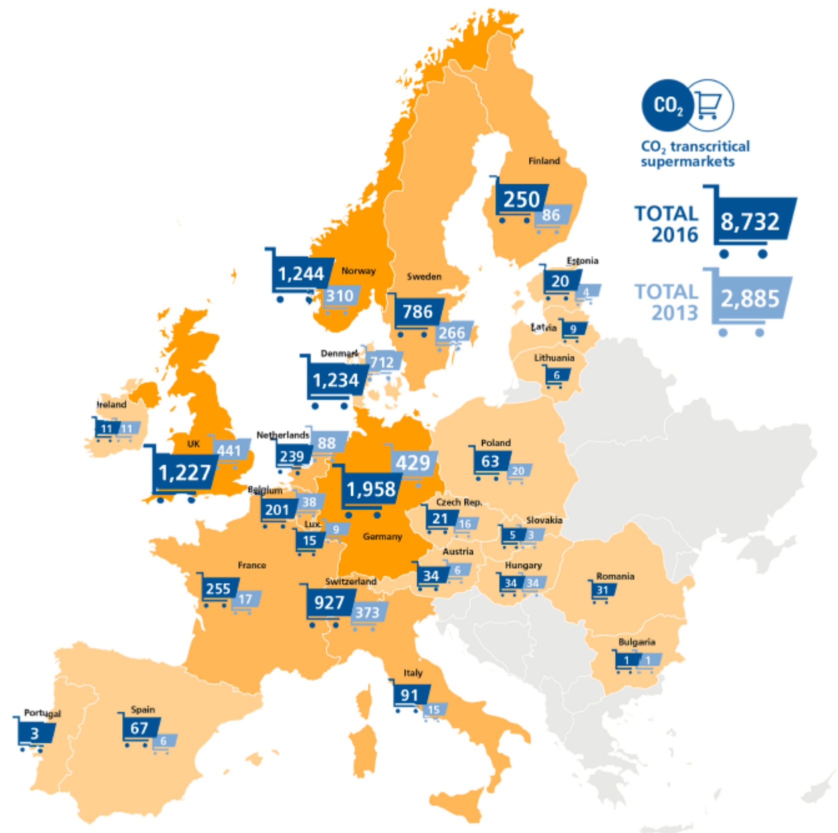
CO2 TC stores growing globally



Source: Shecco, 2017

CO2 TC stores growing globally

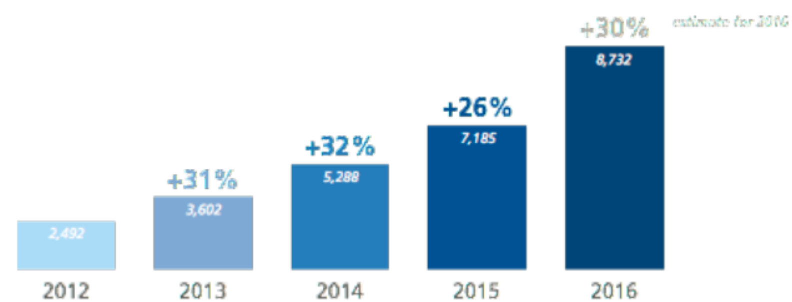
EU Stores using cutting-edge HFCfree technology



Amount of CO2 stores in the EU, Norway, Switzerland has **tripled** in the last 3 years = **8% of the overall market share** in the food retail market

New installations is growing steeply in Southern Europe

Growth of CO_2-based stores



Source: Shecco, 2017

Example of R744 condensing units

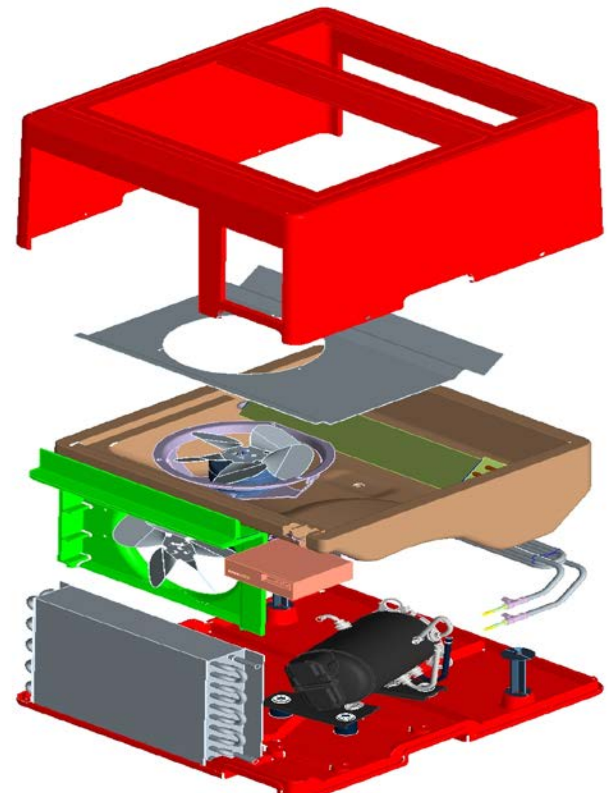
Suited to small stores: compact, CO2 TC units, with high efficiency

- E.g., Advansor
  - —Range of R744 (CO2) condensing units
- Safety aspects
  - —Designed to EN 378
- Cost more than HFC
- R744 gives higher efficiency than HFC
  - —Less likely in hotter climates

Model: compSUPER	XXS 1x0MT4	XXS 1x0MT5	XXS 1x0MT7	XXS 1x0MT9	XXS 0x1 LT4	XXS 0x1 LT16
MT/LT compressors	1/0	1/0	1/0	1/0	0/1	0/1
Frequency range	30/87Hz	30/87Hz	30/87Hz	30/87Hz	35/70 Hz	50/70 Hz
Cooling capacity [kW]*	1,6/4,3	2,1/5,6	2,7/7,2	3,4/9,0	2,2/4,2	12,3/16,1

Application of R744 plug-ins

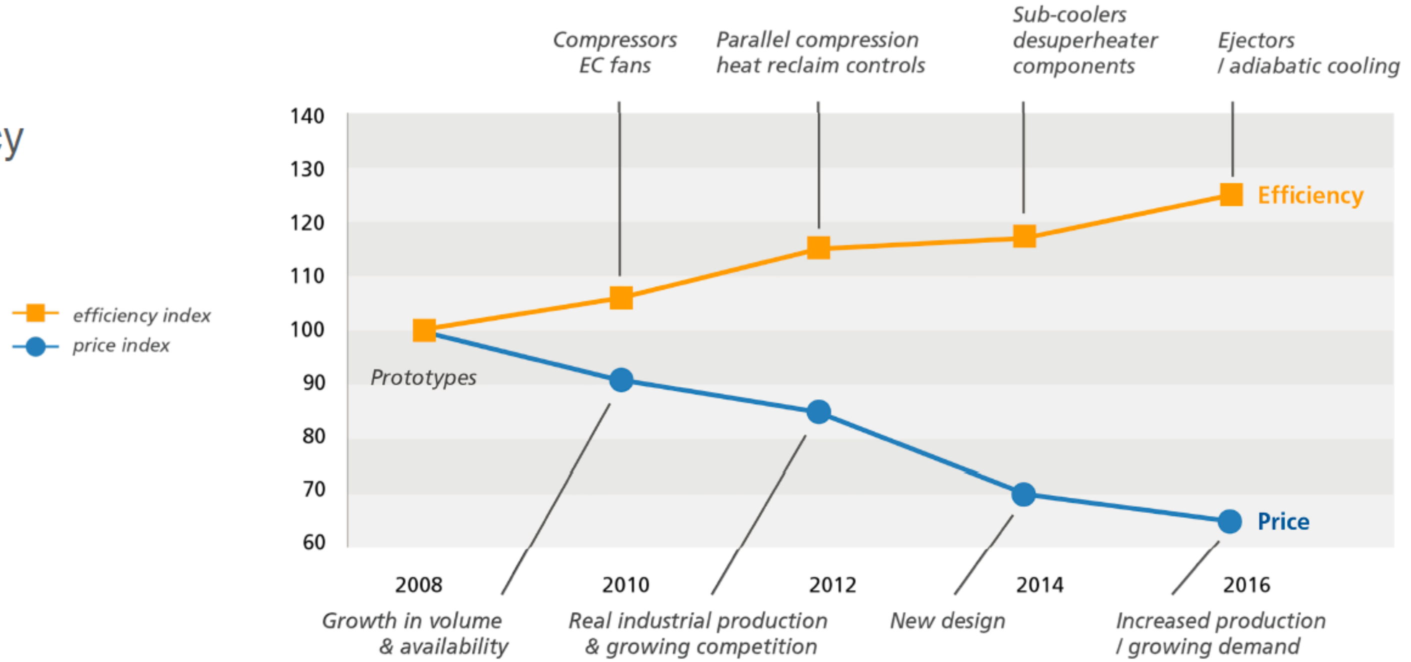
- Coca Cola adopted "cassette" concept for bottle coolers and vending machines
  - The components of a R744 refrigeration system are similar to those used in an R134a system



CO2 cost of equipment decreasing

Higher energy efficiency but lower prices

In Commercial Refrigeration, price is the same as HFC technology or 5-10% higher



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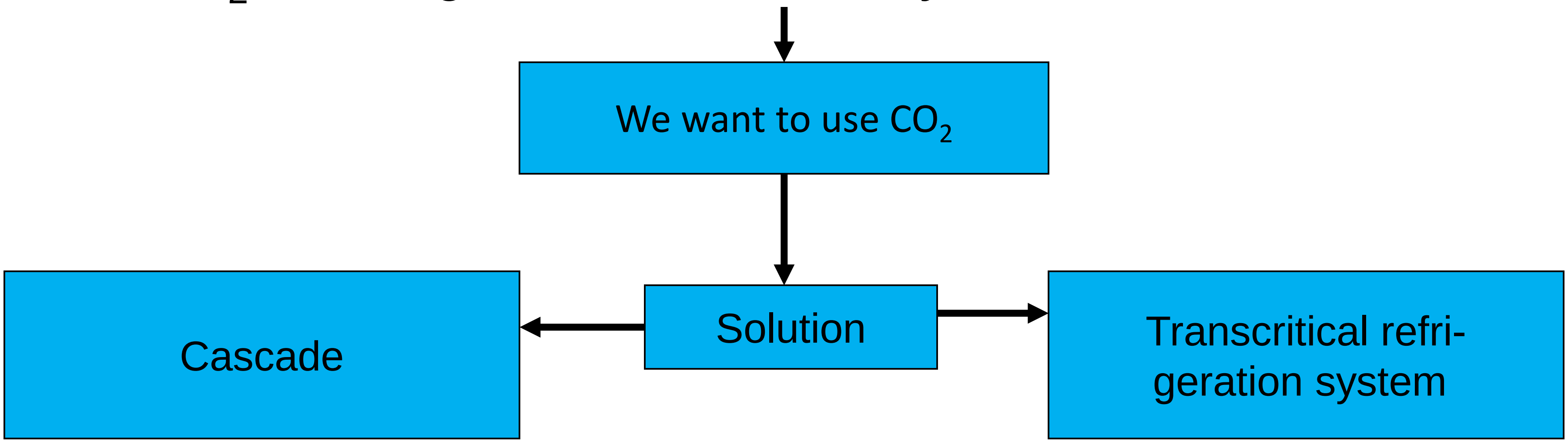
The critical point of CO_2

CO_2 has a critical temperature of t_{crit} = 31° C and a critical pressure of p_{crit} = 73,77 bar.

With an ambient temperature in summer of $t_{ambient}$ = 35 ° C and as a result from ΔT = 10 K the „condensing“ temperature is t_C = 45 ° C.

With CO_2 as refrigerant this is already transcritical.



High Pressure

Comparison of typical pressures in CO_2 systems to those in R404A systems.

	CO_2	R404A
Evaporating pressure	10 to 30 bar g	0.5 to 4 bar g
Condensing (gas cooler) pressure	35 bar g cascade Up to 120 bar g trans critical	Up to 25 bar g
Standstill pressure	Up to 75 bar g	Up to 14 bar g

R744 system sizing

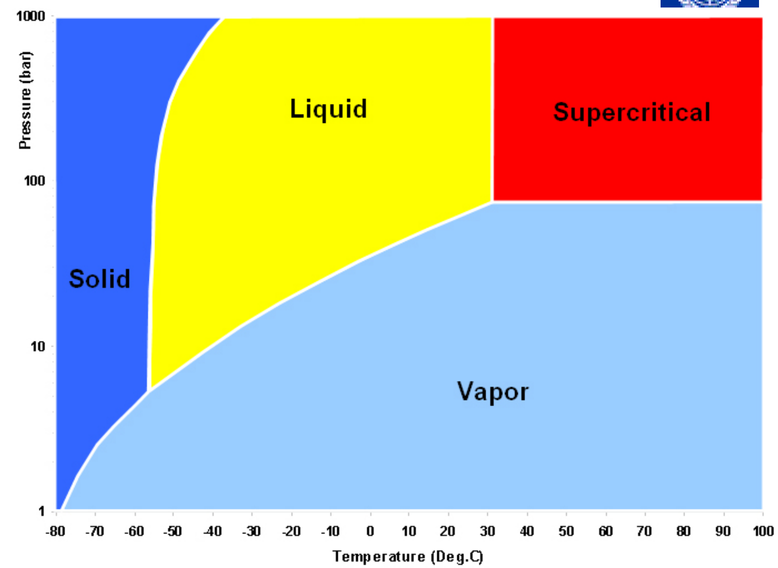
- Higher gas density of R744 results in high volumetric refrigeration effect compared to all other refrigerants. This has an effect on compressor displacement and pipe sizing, evaporators and condensers.

	R404A	R744
Suction line diameter	28 mm	12 mm
Liquid line diameter	8 mm	6 mm

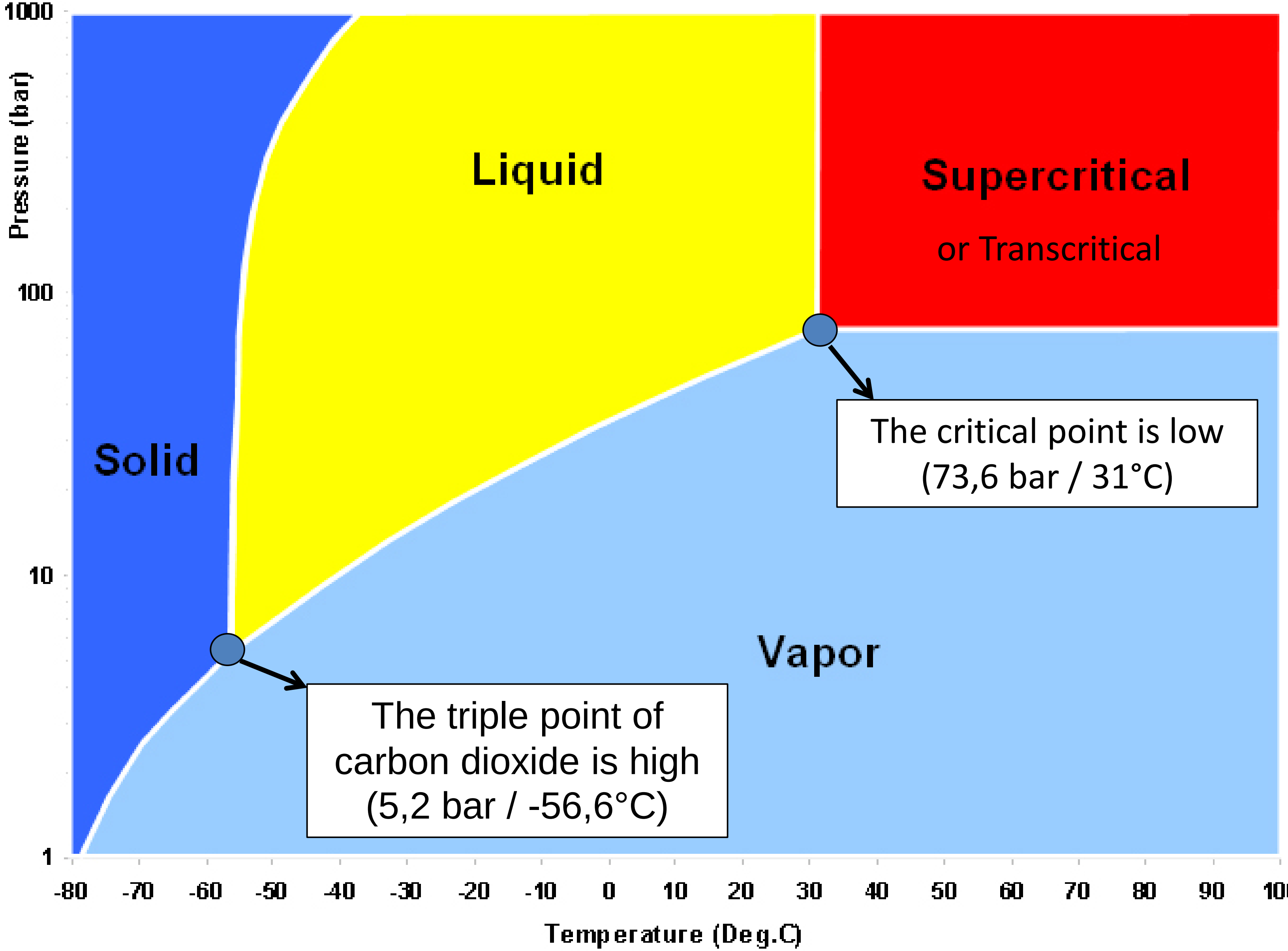
- Power consumption for a given capacity is similar to that of HCFC (HFCs).

Basic Consideration for Service and Design

- The critical point is the condition at which the liquid and gas densities are the same. Above this point distinct liquid and gas phases do not exist.
- The triple point is the condition at which solid, liquid and gas coexist.
- The triple point of carbon dioxide is high (5,2 bar / -56,6°C) and the critical point is low (73,6 bar / 31°C) compared to other refrigerants.



CO2 Phase Diagram



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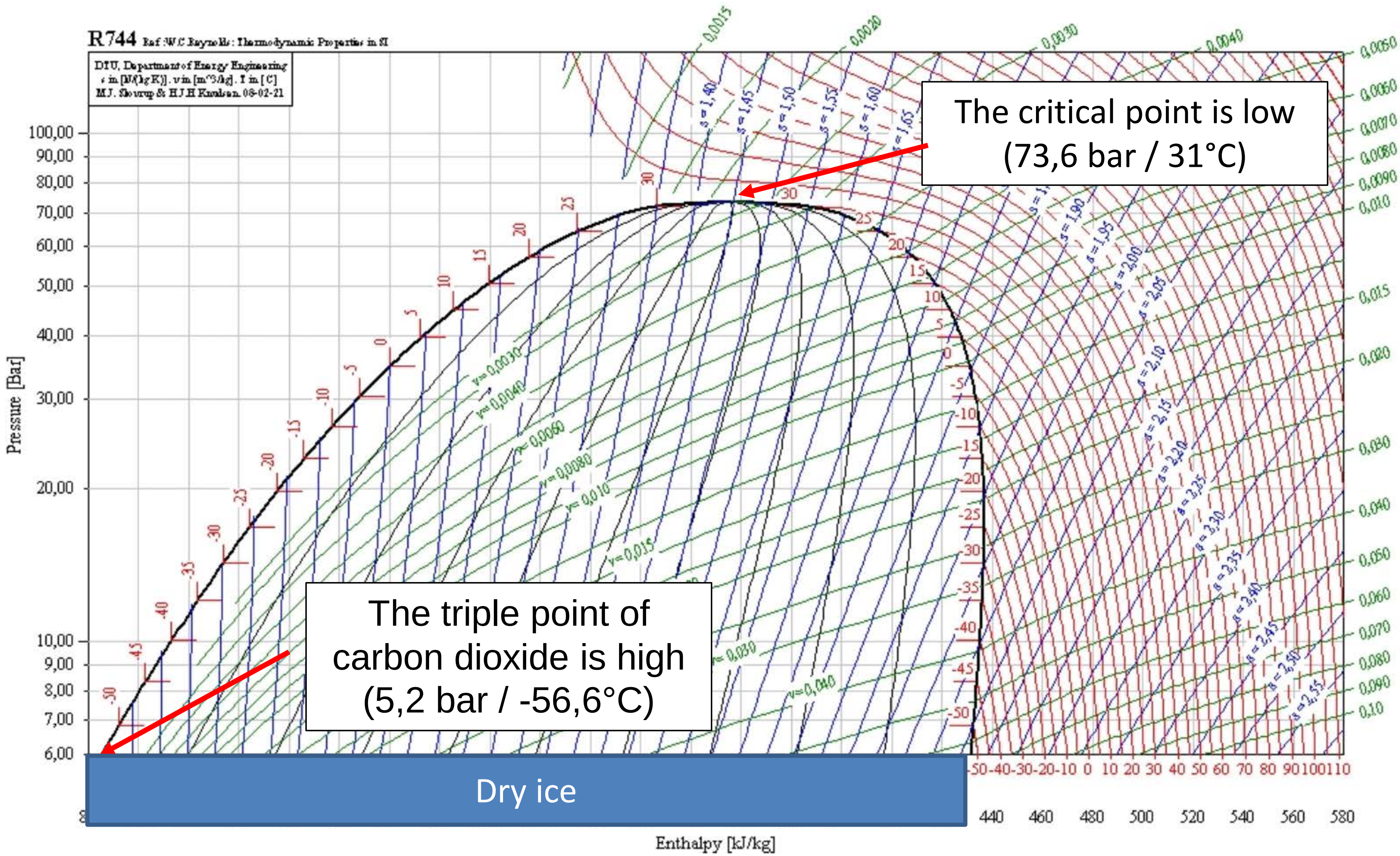
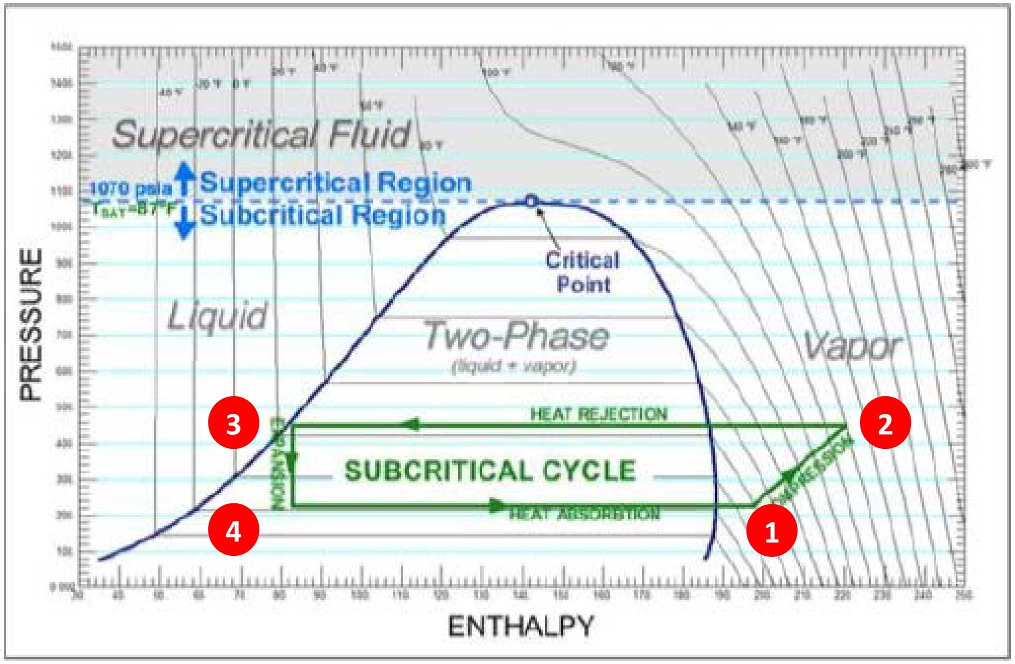
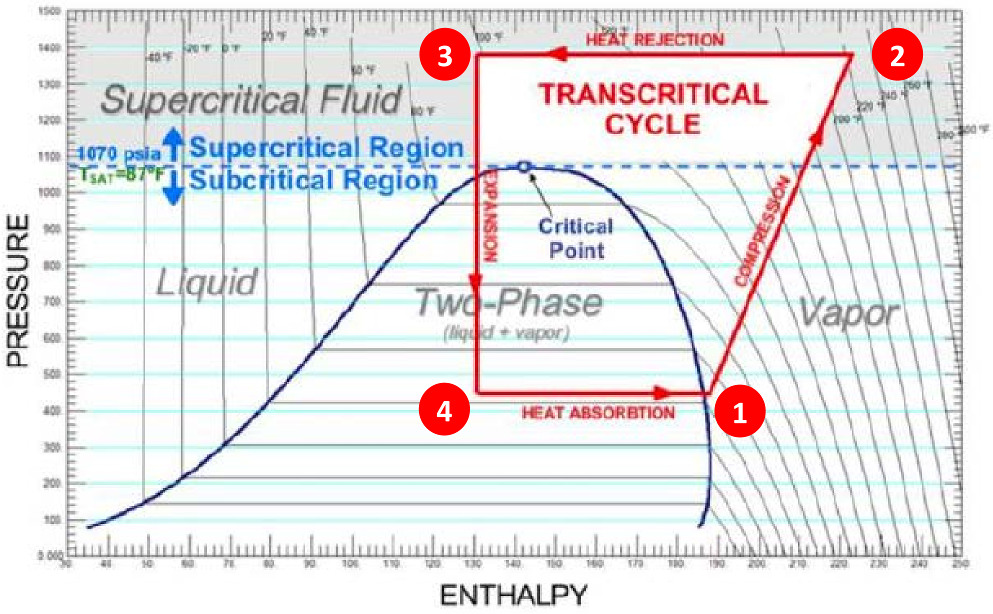


Single-stage subcritical process



1-> 2	Compression
2-> 3	Condensation
3-> 4	Expansion
4-> 1	Evaporation

Single-stage transcritical process



1-> 2	Compression
2-> 3	Heat rejection
3-> 4	Expansion
4-> 1	Evaporation

Two-stage transcritical process

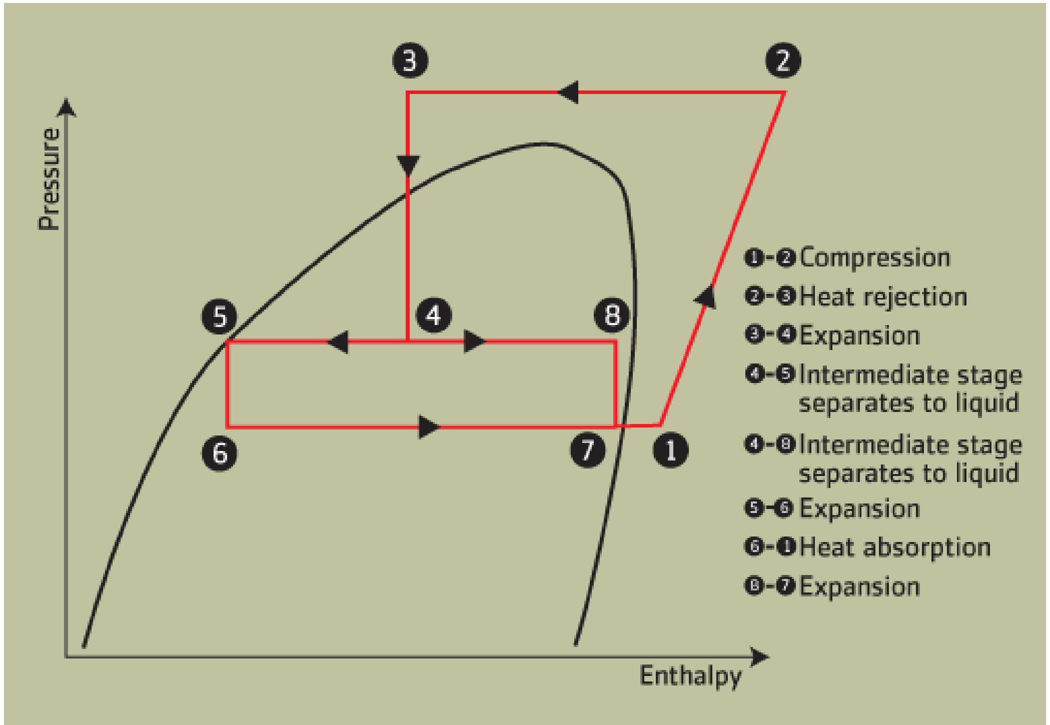
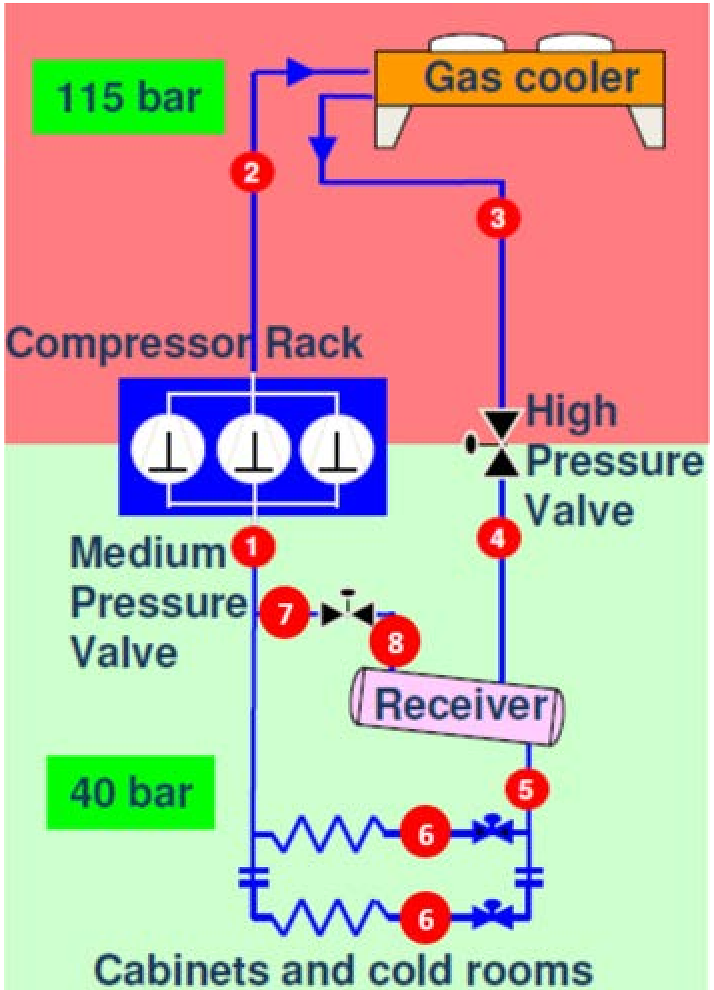


FIGURE 5: Pressure-enthalpy chart of a transcritical CO_2 refrigeration system



Two-stage transcritical process

Compression (1-> 2)

Transcritical approx. 102_bar(g)
Subcritical min.ca. 45bar(g)

Gas cooling (2 -> 3)

Cooling to gas cooler end temperature.
Transcritica approx.2K above ambient temperature.
(with sprayed water: approx.3 to 6K below ambient temperature)
Subcritical 3K subcooling

Expansion (3-> 4)

Transition from high to intermediate pressure level.
Intermediate pressure approx. 35 bar(g) (approx. 0° C)

Separation (4-> 5)

Liquid separates from gas within intermediate vessel.

Expansion (5-> 6)

CO2 expands into evaporator (AKV)

Evaporation and superheating (6-> 7)

Gas throttling (8-> 7)

From intermediate pressure to evaporation pressure.
Intermediate pressure regulation (Flash gas)

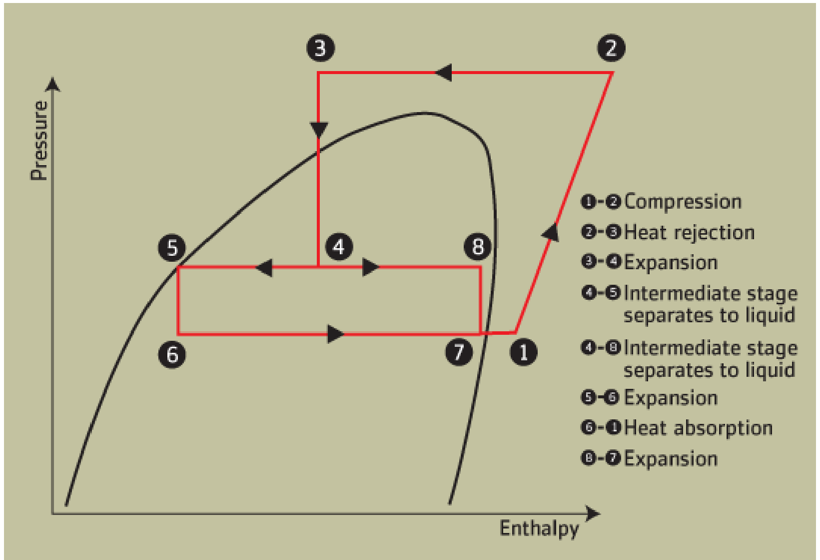
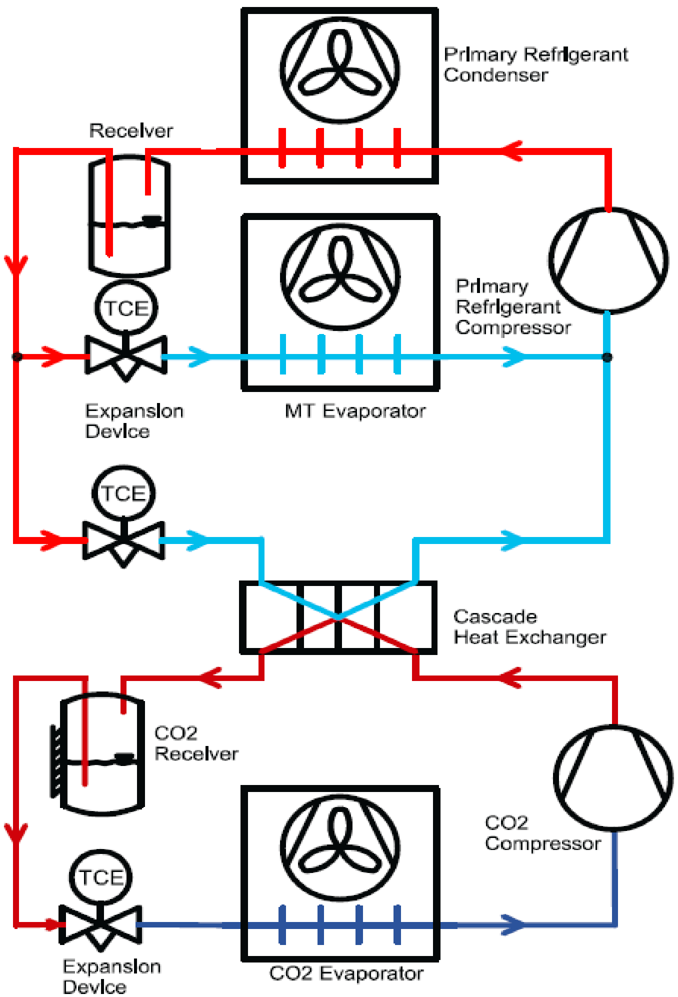


FIGURE 5: Pressure-enthalpy chart of a transcritical CO_2 refrigeration system

CO^2 system configurations

Simple cascade system



The cascade system comprises:

- The low-stage, which provides the cooling for the load. It uses R744 and is always subcritical
- The high-stage, which absorbs the heat from the condensing R744 at the cascade heat exchanger

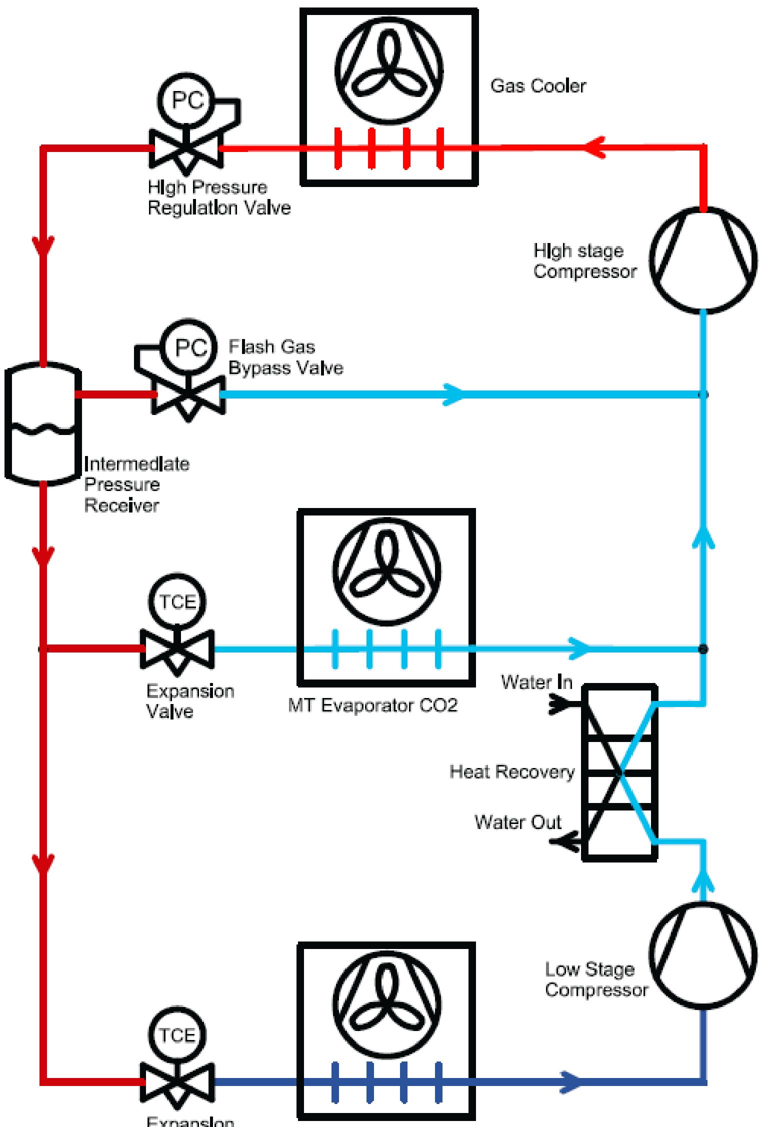
Within the cascade heat exchanger the evaporating high-stage refrigerant absorbs the heat rejected by the condensing R744.

The R744 condensing temperature is maintained below the critical point.

The high-stage refrigerant is usually an HFC or HC, in which case the cascade is a hybrid system. In some systems R744 is used in the high-stage.

CO^2 system configurations

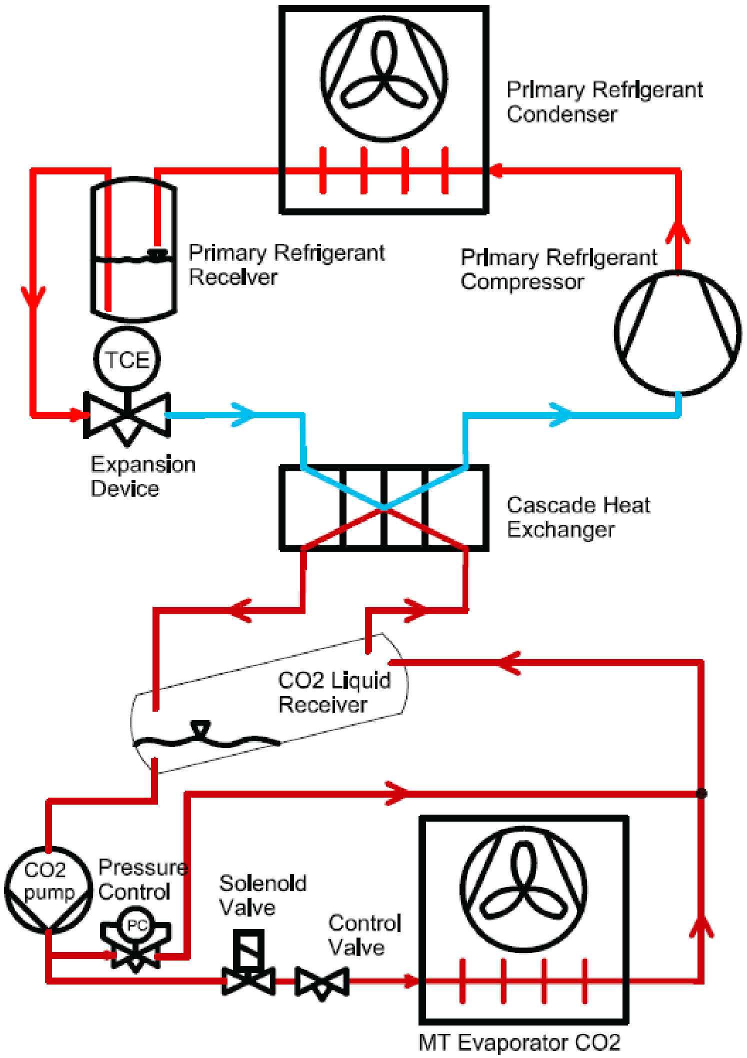
Simple booster system without oil management



- Two-stage compression is used for transcritical low temperature applications because the discharge temperature of R744 is high and will potentially result in lubricant break down.
- The refrigerant from the low temperature loads is drawn into the low-stage compressors. The discharge from these compressors goes into the suction of the high-stage compressors.
- The refrigerant from the medium temperature (MT) loads is drawn into the suction of the high-stage compressors. The refrigerant from the receiver pressure regulating valve is also drawn into the suction of the high-stage compressors.

CO² system configurations

Simple pump system secondary



The high-stage system cools the liquid R744 in the secondary circuit.

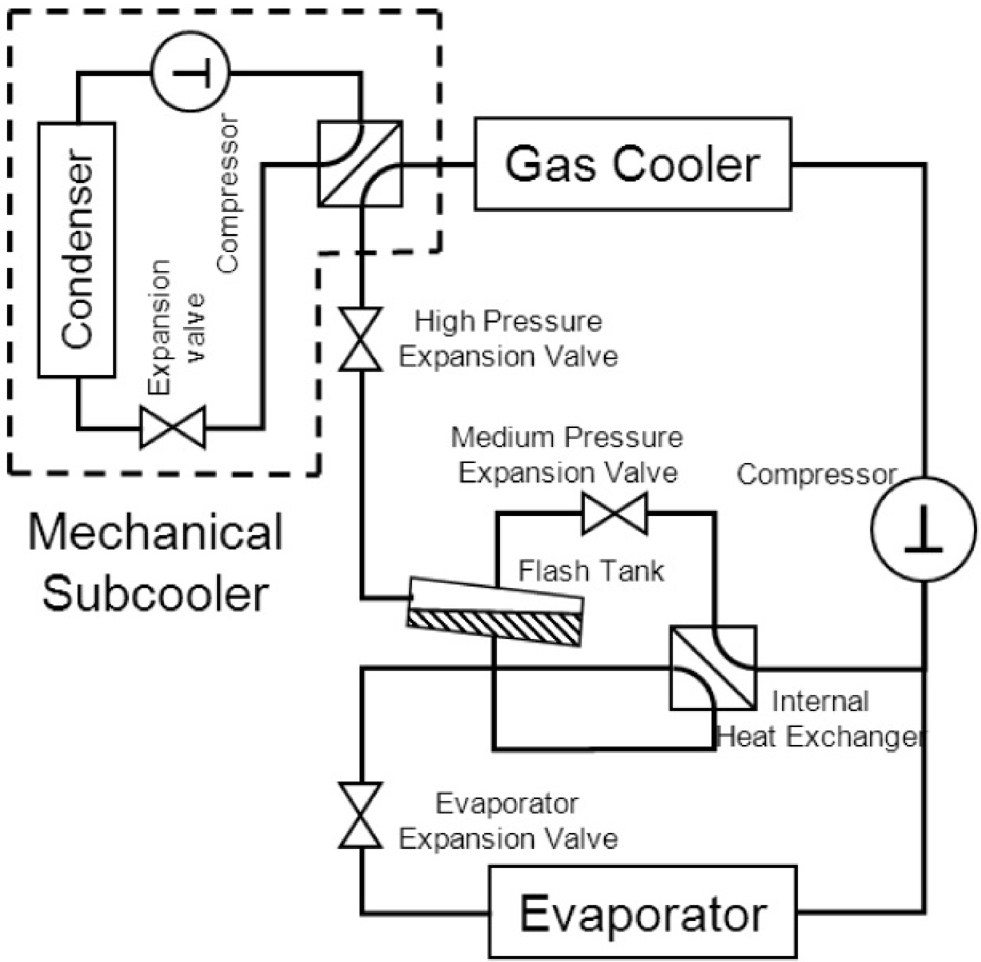
The R744 is pumped around the load. It is volatile, so unlike a conventional secondary fluid such as glycol it does not remain as a liquid, instead it partially evaporates.

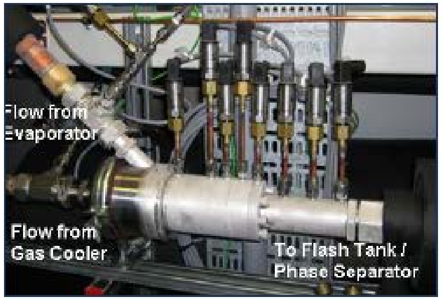
It therefore has a significantly greater cooling capacity than other secondary fluids. This reduces the pump power required and the temperature difference needed at the heat exchanger.

The R744 would typically be cooled to -3°C for the MT load, and to -25°C for the LT load.

The high-stage system is a simple chiller type system, typically running on an HFC or HC refrigerant.

For higher ambient temperatures also a mechanical sub-cooler offers good potentials, based on components available today

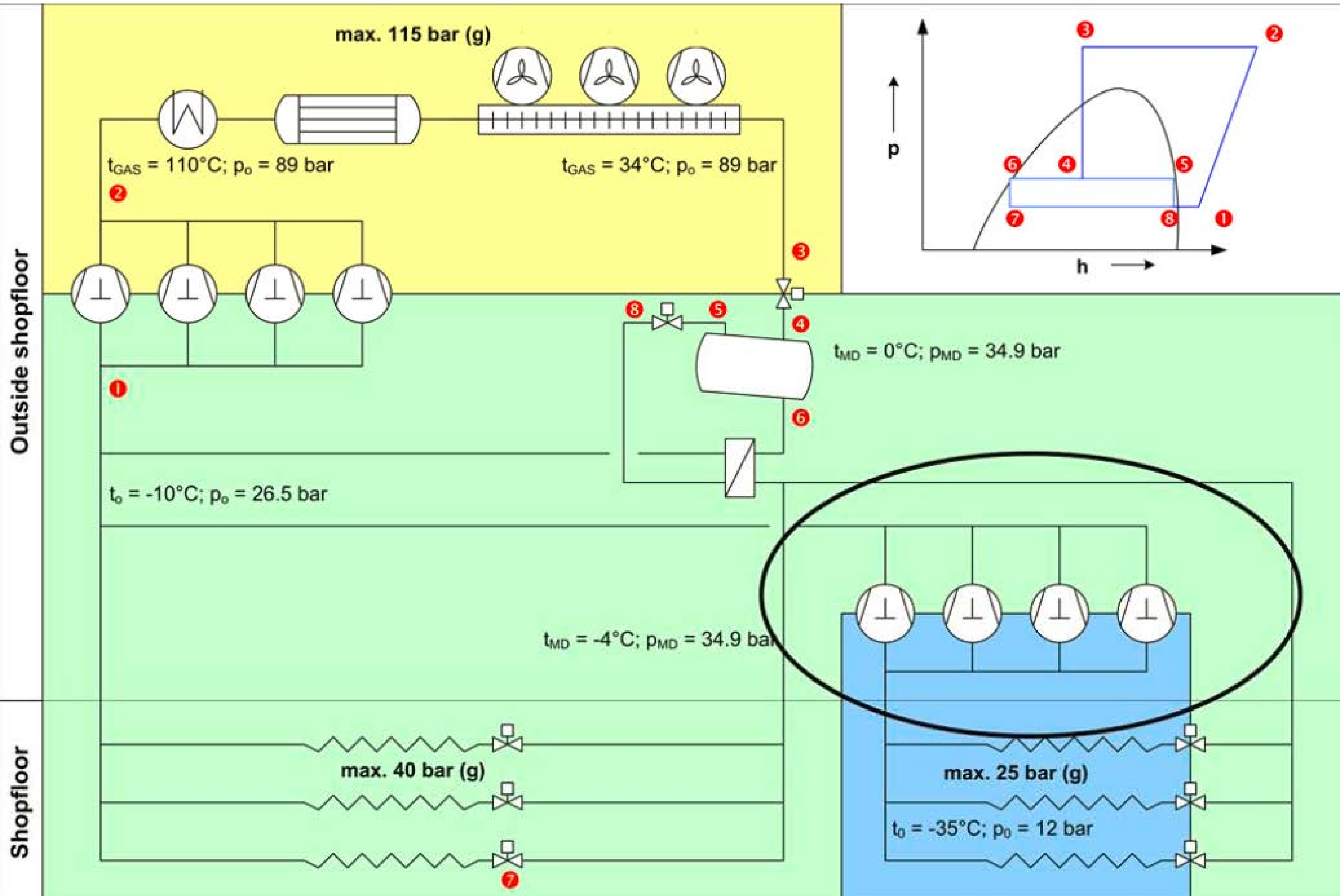




Source: adapted from Carrier, 2012

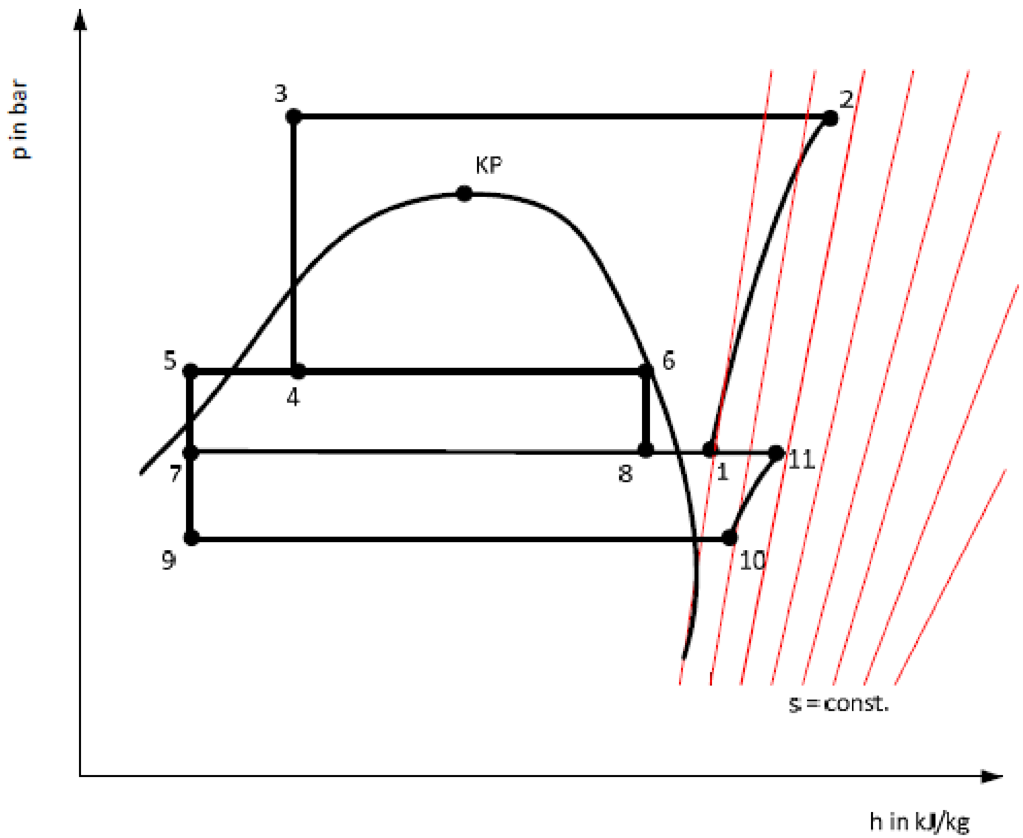
CO^2 system configurations

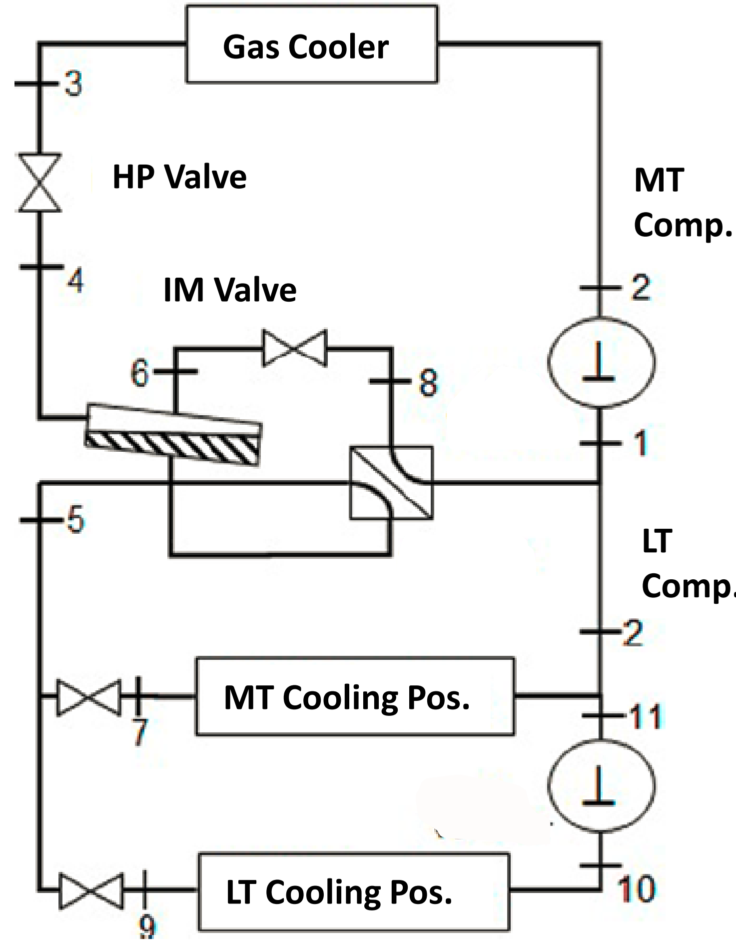
Supermarket booster system



CO² system configurations

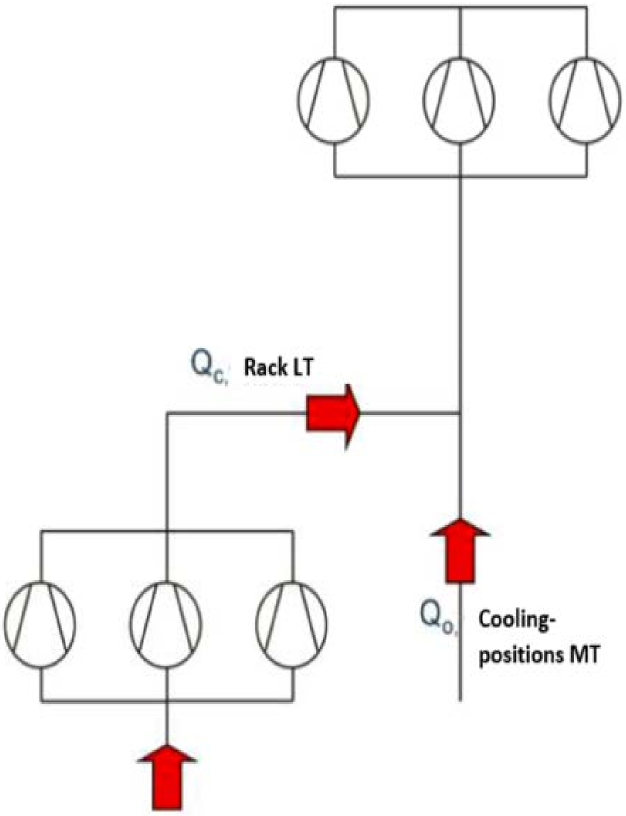
Supermarket booster system





CO^2 system configurations

Supermarket booster system



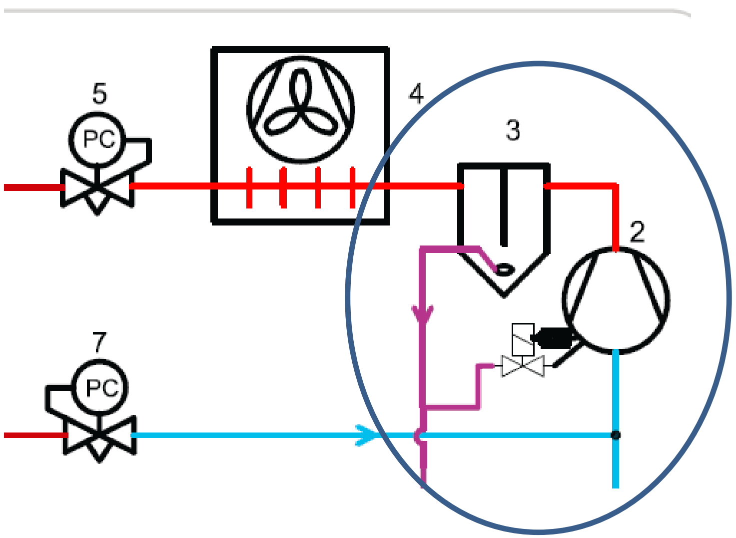
MT rack takes the hole LT condensing capacity:

$Qo_{\text{rack system}}$ (MT) = $Qo_{\text{cooling positions}}$ (MT) + $Qc_{\text{rack system}}$ (LT)

To (MT) = tc (LT)

CO^2 system configurations

Supermarket booster system



Oil management systems:

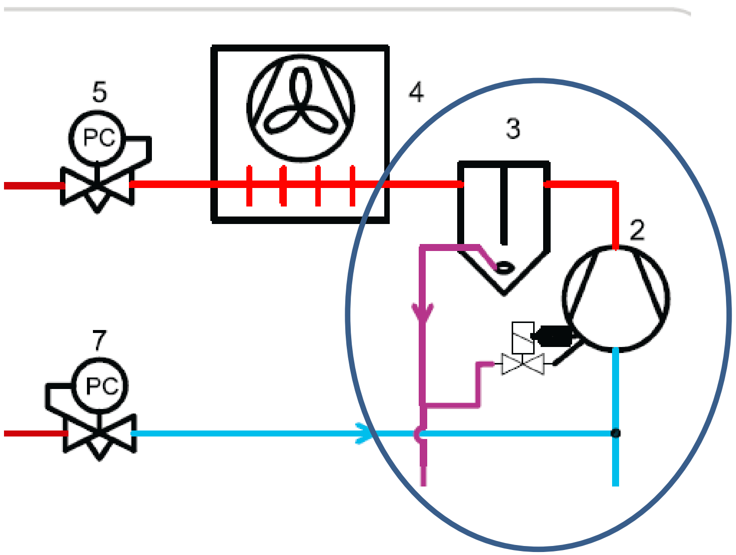
The oil separator and reservoir work on the same principles as a conventional oil management

system (optical level switches), designed for the higher operating pressures (up to 125bar)

Oil charge = 4-6% of refrigerant charge

CO^2 system configurations

Supermarket booster system



Oil:

CO2 Refrigeration oils are based on special synthetic esters, formulated for use in Carbon Dioxide (C02) compressors in all fields of industrial and commercial refrigeration.

Some synthetic oil can be used in sub as well as trans-critical applications.

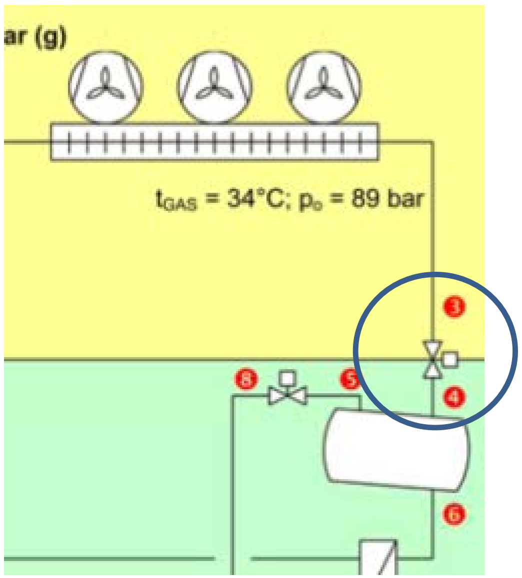
The oil needs to ensure optimum wear protection even under arduous C02 operating conditions.

Propertys as high thermal and chemical stability, excellent deep-temperature flow-ability and good lubrication at high pressure levels.

Product name	ISO Viscosity mm²/s	Pour point °C	Flash point °C	Water Content mg/kg	Colour index DIN ISO 2049	Sizes Available Litre	Refrigerants
RENISO C 55	55	-48	286	< 30	< 30	5	R744
RENISO C 85	85	-42	246	< 30	< 30	10	
RENISO C 170	170	-40	286	< 30	< 30	10	

CO^2 system configurations

Supermarket booster system

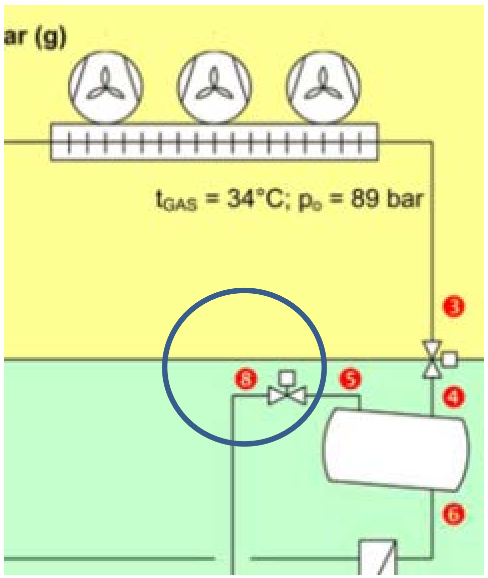


High pressure valve:

- Engine driven valve
- Operates like a expansion valve
- Analogue controlled (such as: 0-10V)

CO^2 system configurations

Supermarket booster system



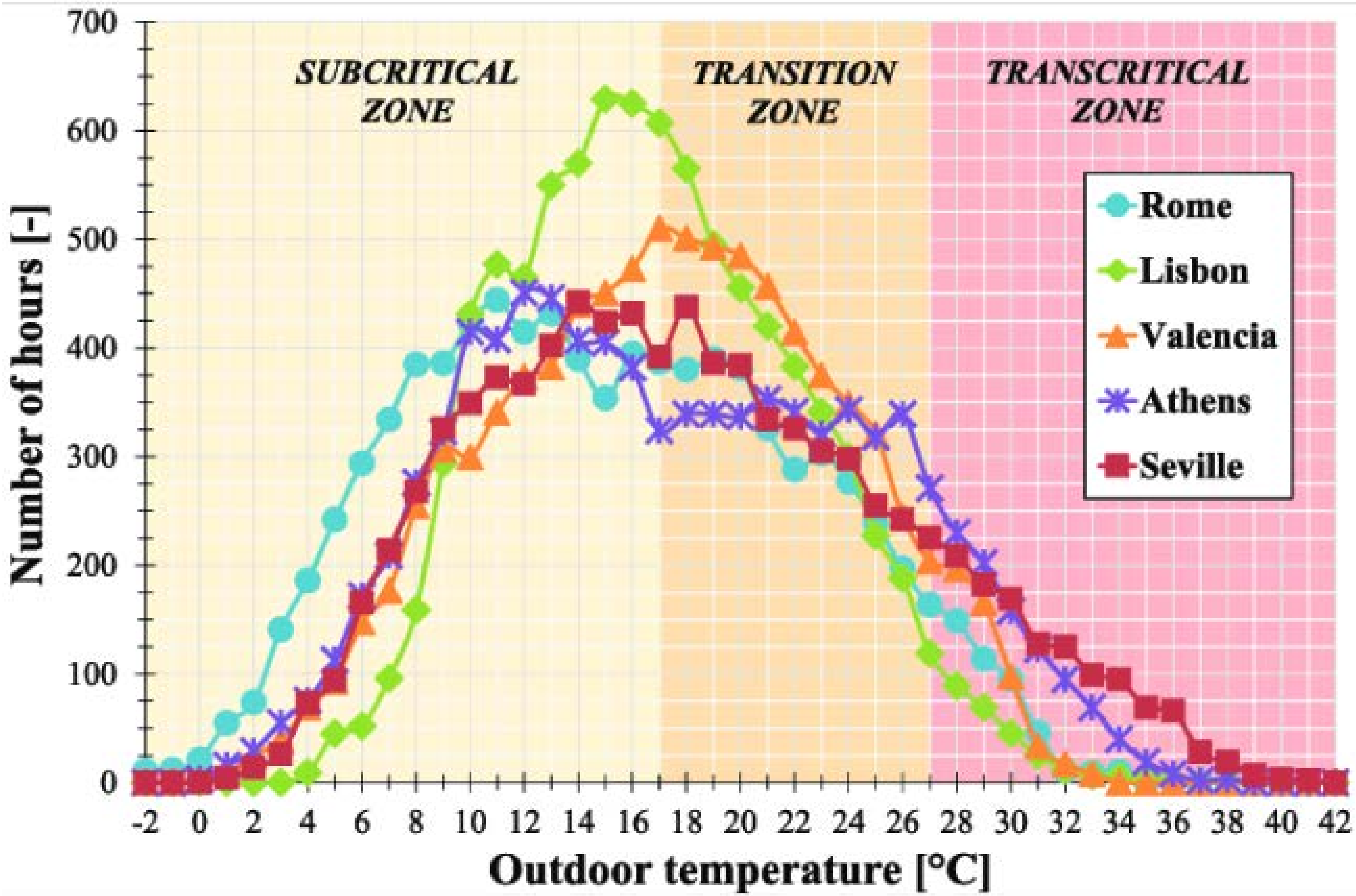
Intermediate pressure valve:

- Engine driven valve
- Operates like a expansion valve
- Analogue controlled (such as: 0-10V)

CO^2 system configurations

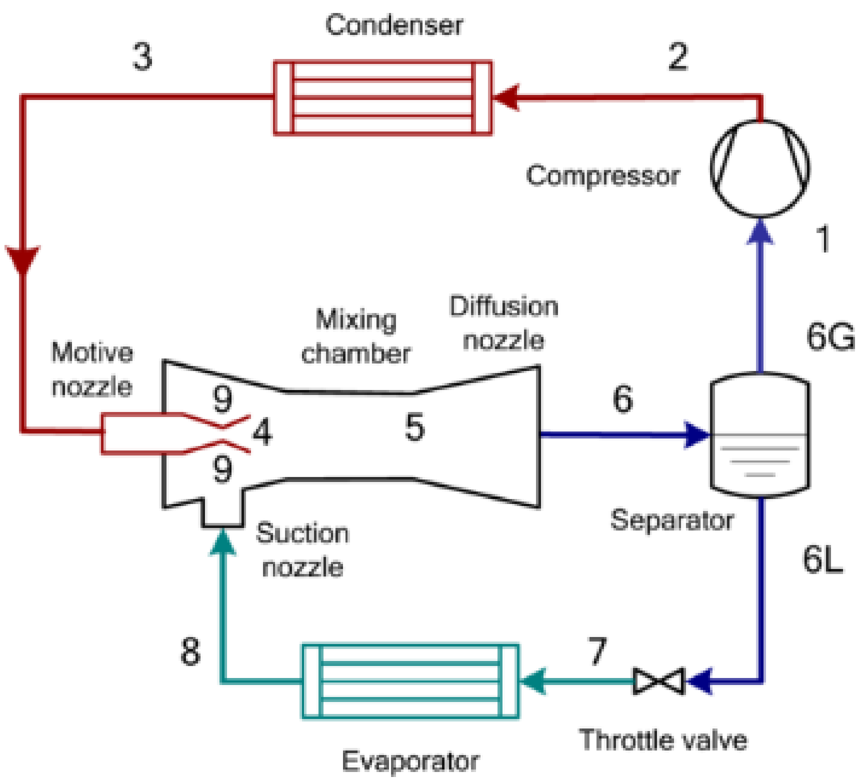
Ejector efficiency

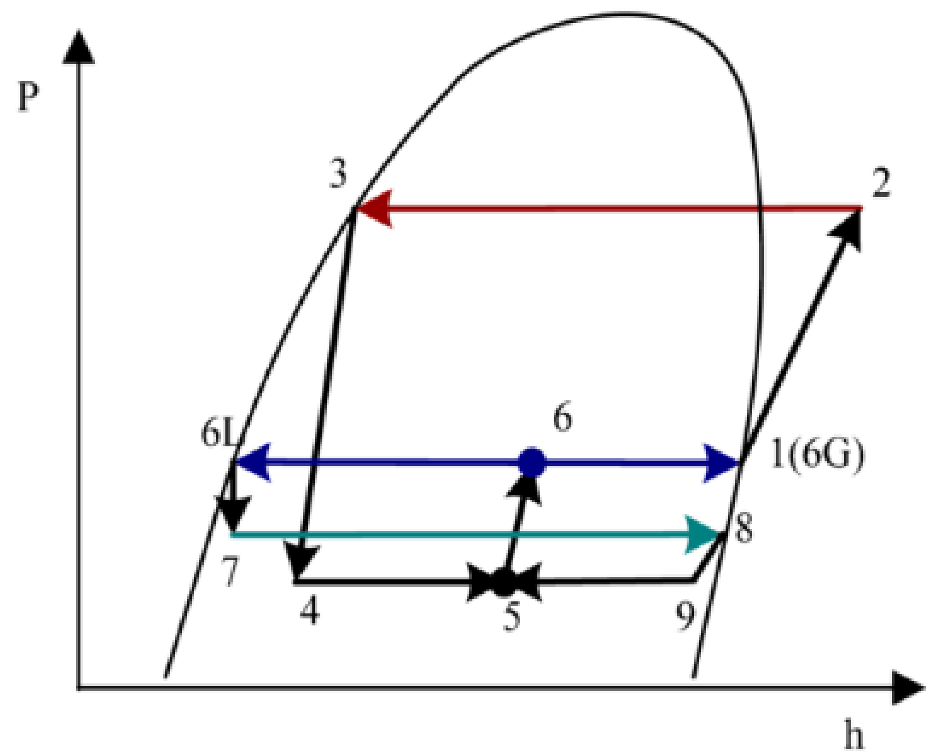
- Number of hours per year at different outdoor temperatures in the selected locations (Remund et al., 2014).



CO^2 system configurations

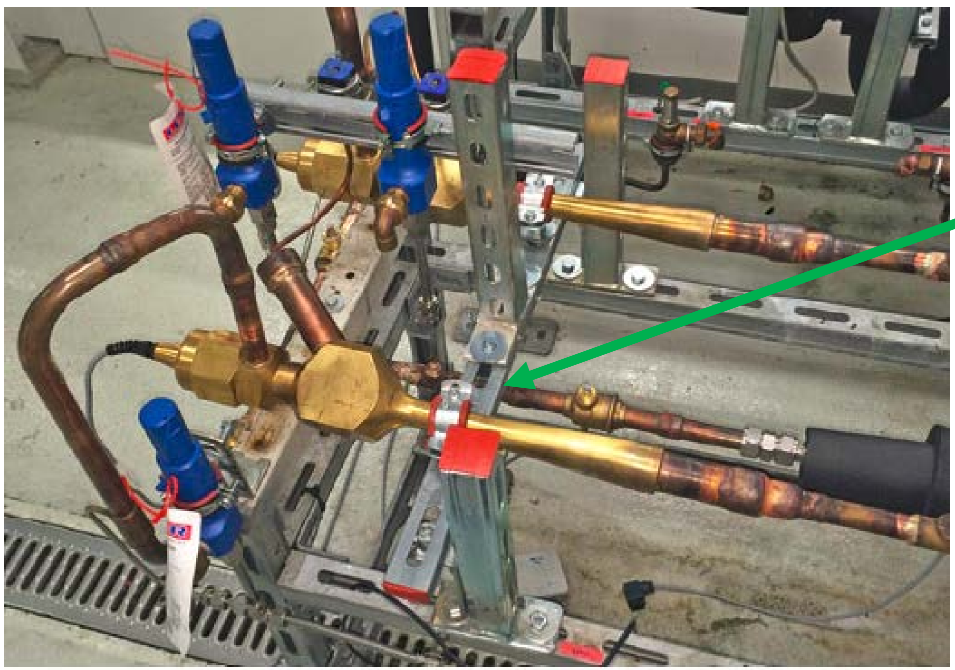
Ejector system

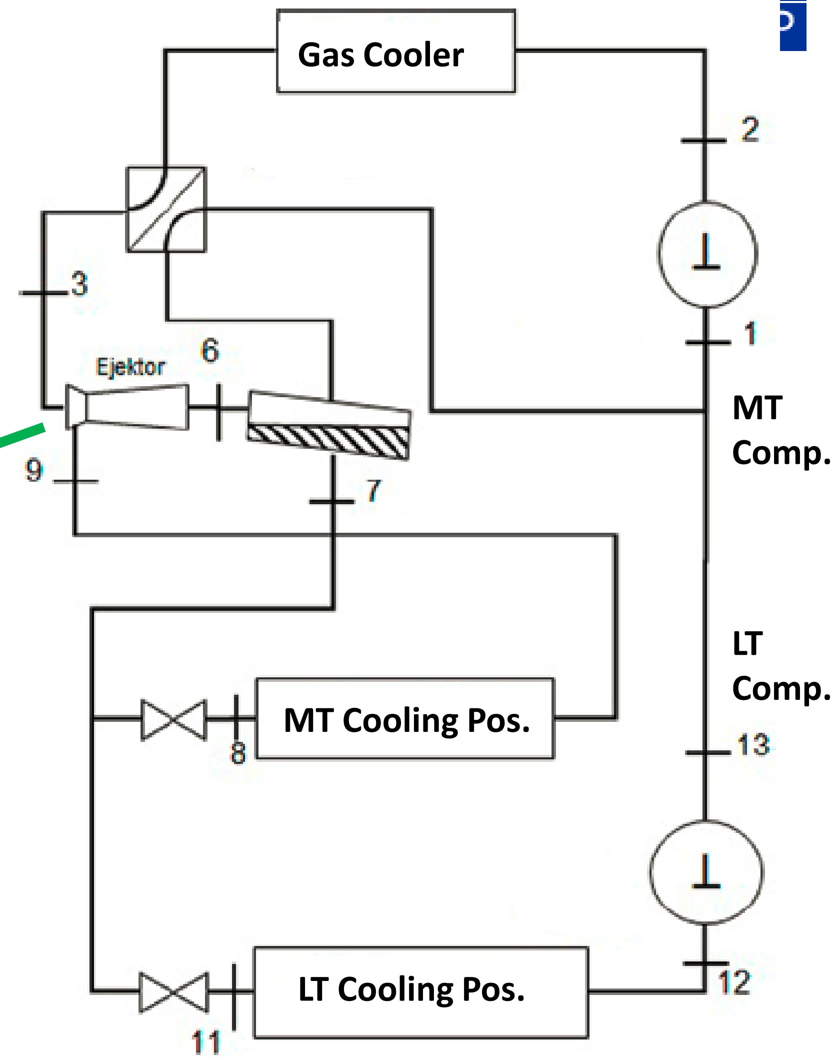




CO^2 system configurations

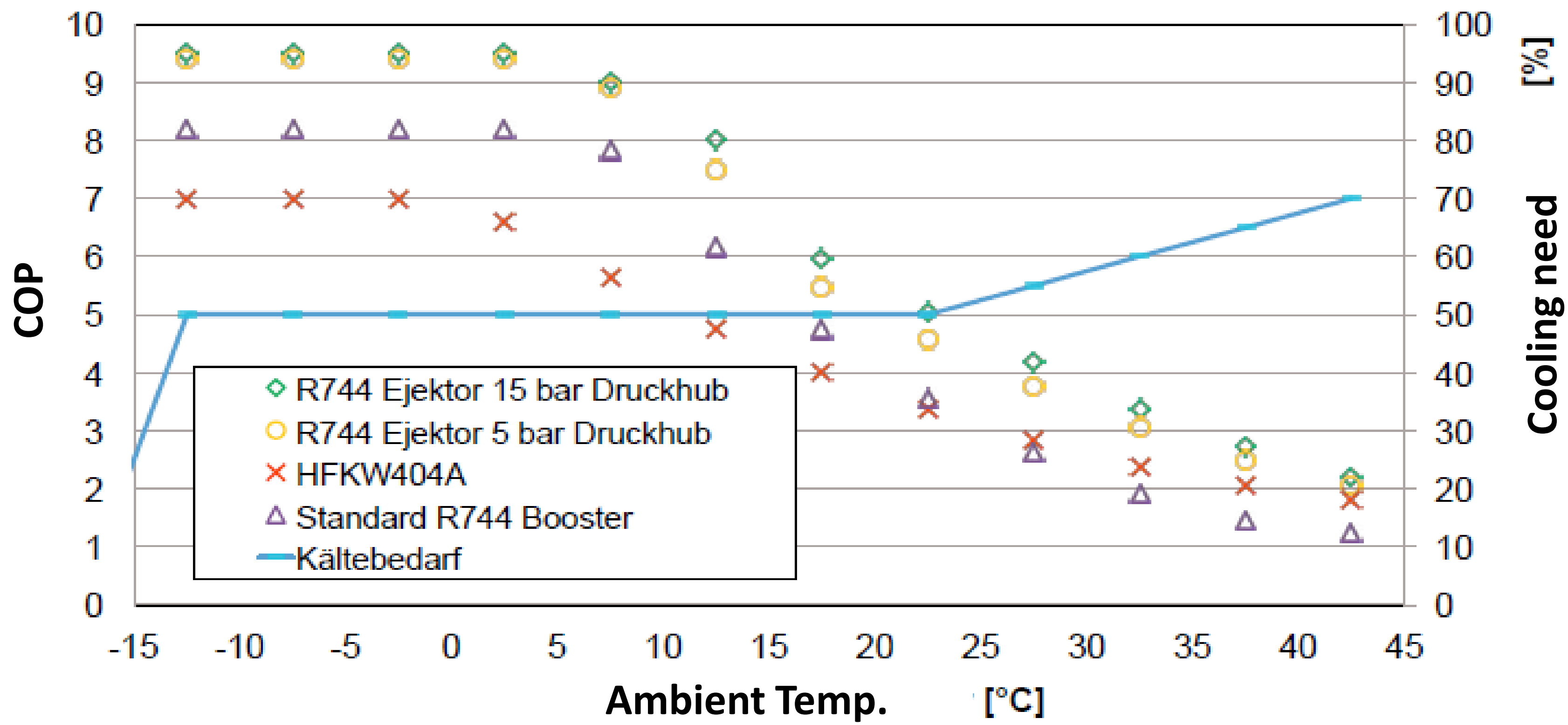
Ejector system





CO^2 system configurations

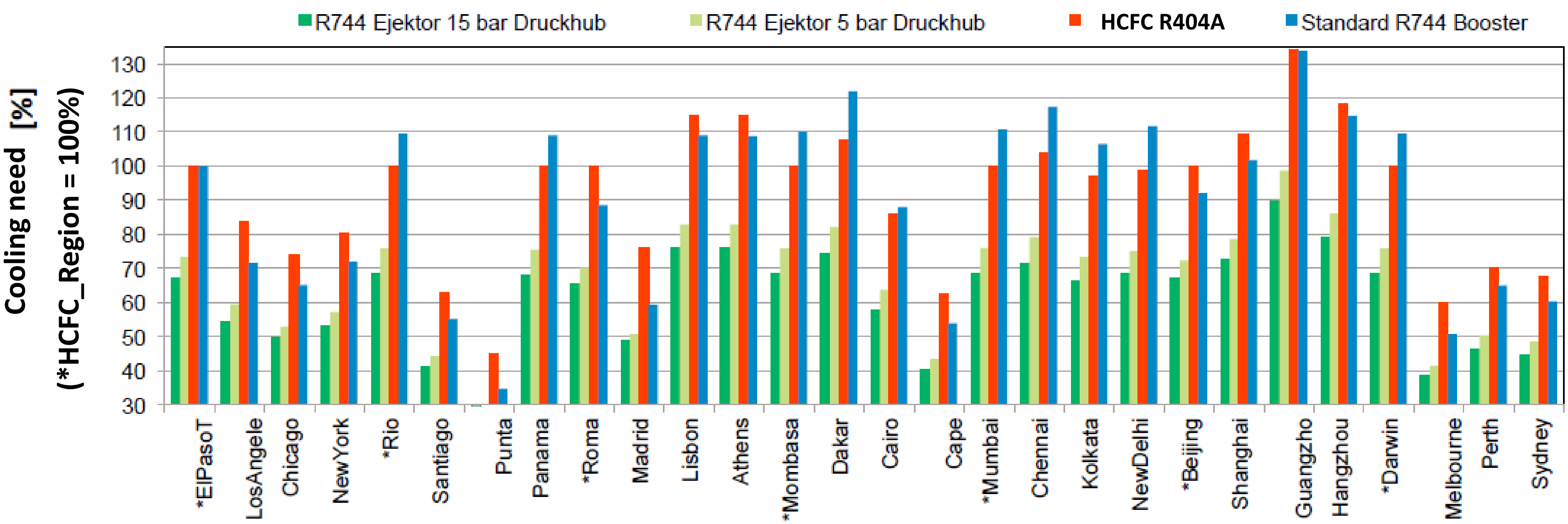
Ejector efficiency



COP and cooling need of diff. system configurations relating to ambient temperature

CO^2 system configurations

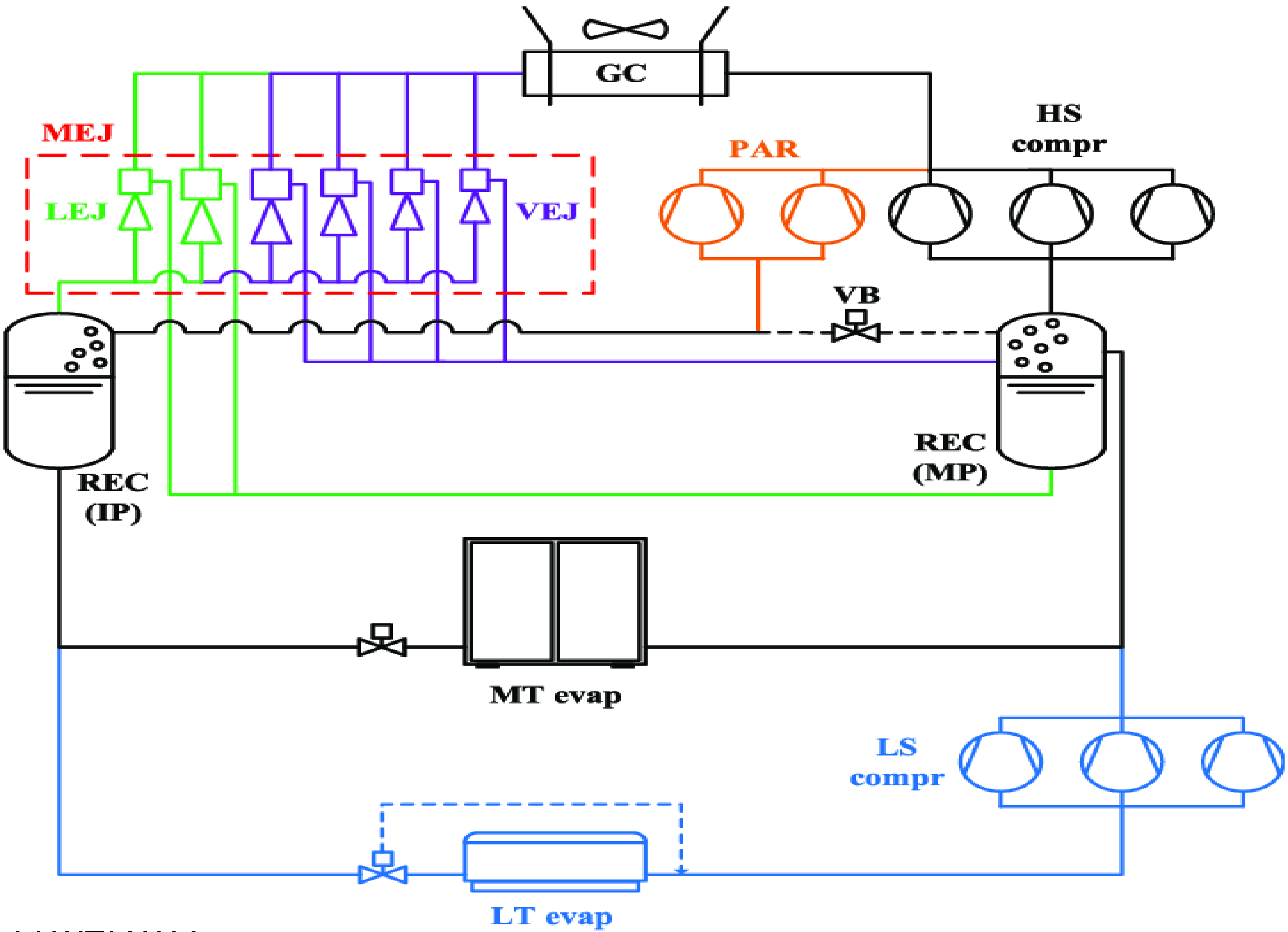
Ejector efficiency



Annual energy requirement (relative) of commercial refrigeration systems in four different locations

CO^2 system configurations

Ejector system & parallel compression



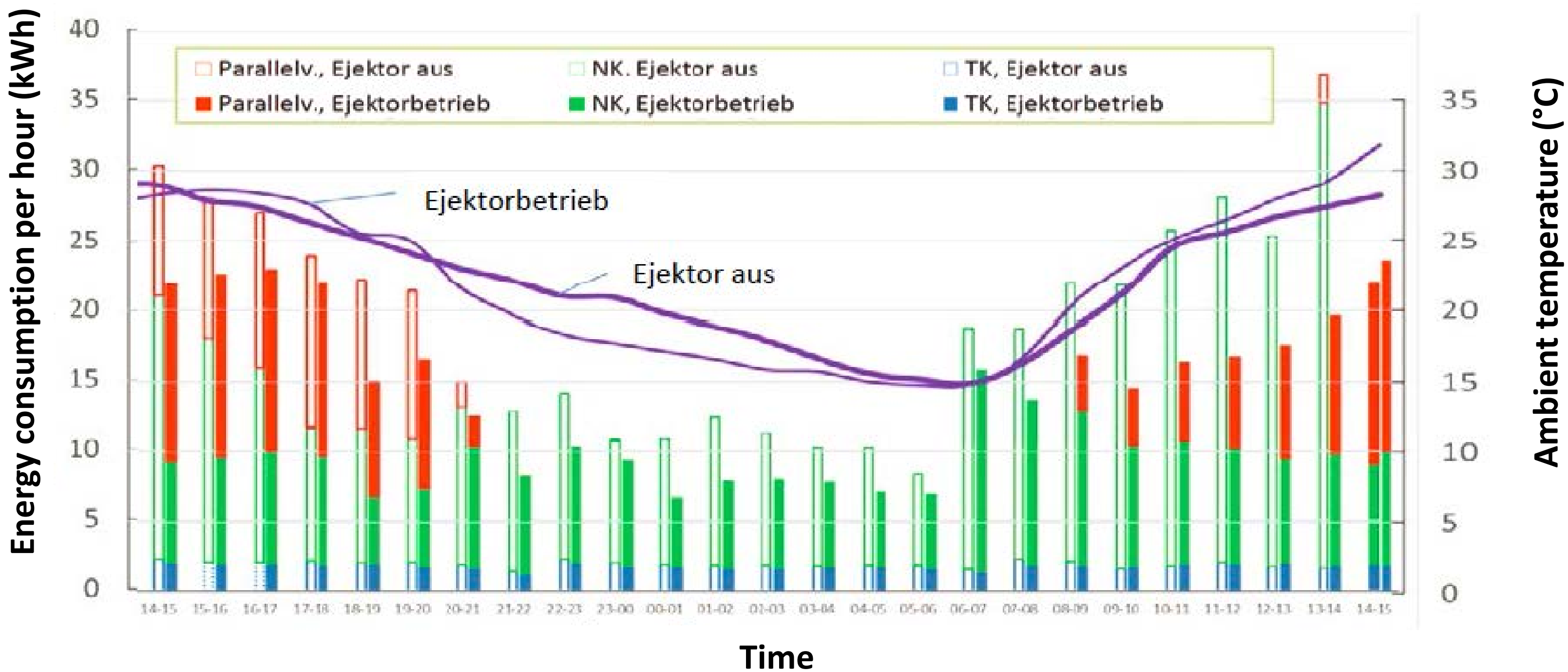
CO^2 system configurations

Ejector system & parallel compression

11/04/2017

CO^2 system configurations

Ejector efficiency



Energy consumption of compressor groups per hour measured on 2 days in June (2015) -> 1 day with ejector / -> 1 day without ejektor

Overview: Modules and Sections

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- Safety issues
- First Aid
- Review of tools and equipment
- Commissioning and maintenance
- Mechanical integrity

Basic personal protective equipment (PPE)

Wear the adequate PPE for each activity!

Gloves and goggles for protection against freeze burns (as with all refrigerants)

Overall / long sleeves and legs

Safety shoes

Check: All necessary personal protective equipment is available and being used correctly.

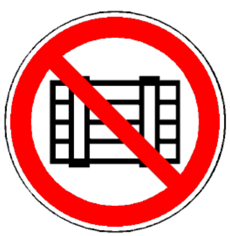
Safety Issues

Prohibitions

No smoking

No open flames / fire

Do not cross / walk through



No storage of materials / goods

Not for non-authorised persons

Safety Issues

Warnings

Risk : presents of high concentration of CO_2

existence of pressurised cylinders with CO_2

Safety Issues

Commandments

Wear safety goggles and canister respirator mask

Wear suitable working clothes and hard hat

Wear suitable working gloves

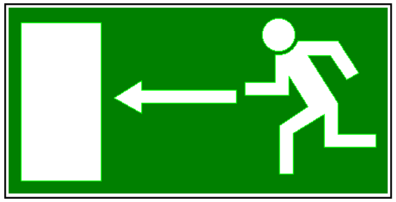
Wear ear protection

Disconnect from electrical mains when servicing

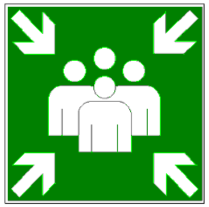
Safety Issues

First Aid

First aid station



escape / rescue way



People assembly point

Place of water shower

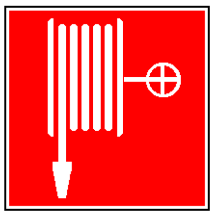
Place of eye shower / equipment

First aid / emergency telephone

Safety Issues

Fire Protection

Place of fire extinguisher – CO_2 or powder



Place of fire hose – if applicable

Location sign

Fire fighting telephone

What are the Hazards of CO_2

The hazards of CO_2 should not be underestimated.

The main safety hazards are:

- Suffocation;
- High pressures;
- Rapid expansion of trapped liquid or gas;
- Low “boiling point”;
- Solidification.

Comparison of some of these hazards to those of HFC R404

	CO_2	R404A
Asphyxiation	PL* = 0.1 kg/m^3 Odourless Heavier than air	PL* = 0.48 kg/m^3 Odourless Heavier than air
Pressure at 15°C	51 bar g	8.5 bar g
Boiling point at atmospheric pressure	-78.5°C	-47°C
Solidification	Possible	Not possible

PL* is the practical limit specified in EN378 (Refrigerating systems and heat pumps - safety and environmental requirements). It is the highest concentration level in an occupied space which will not result in "escape impairing effects".

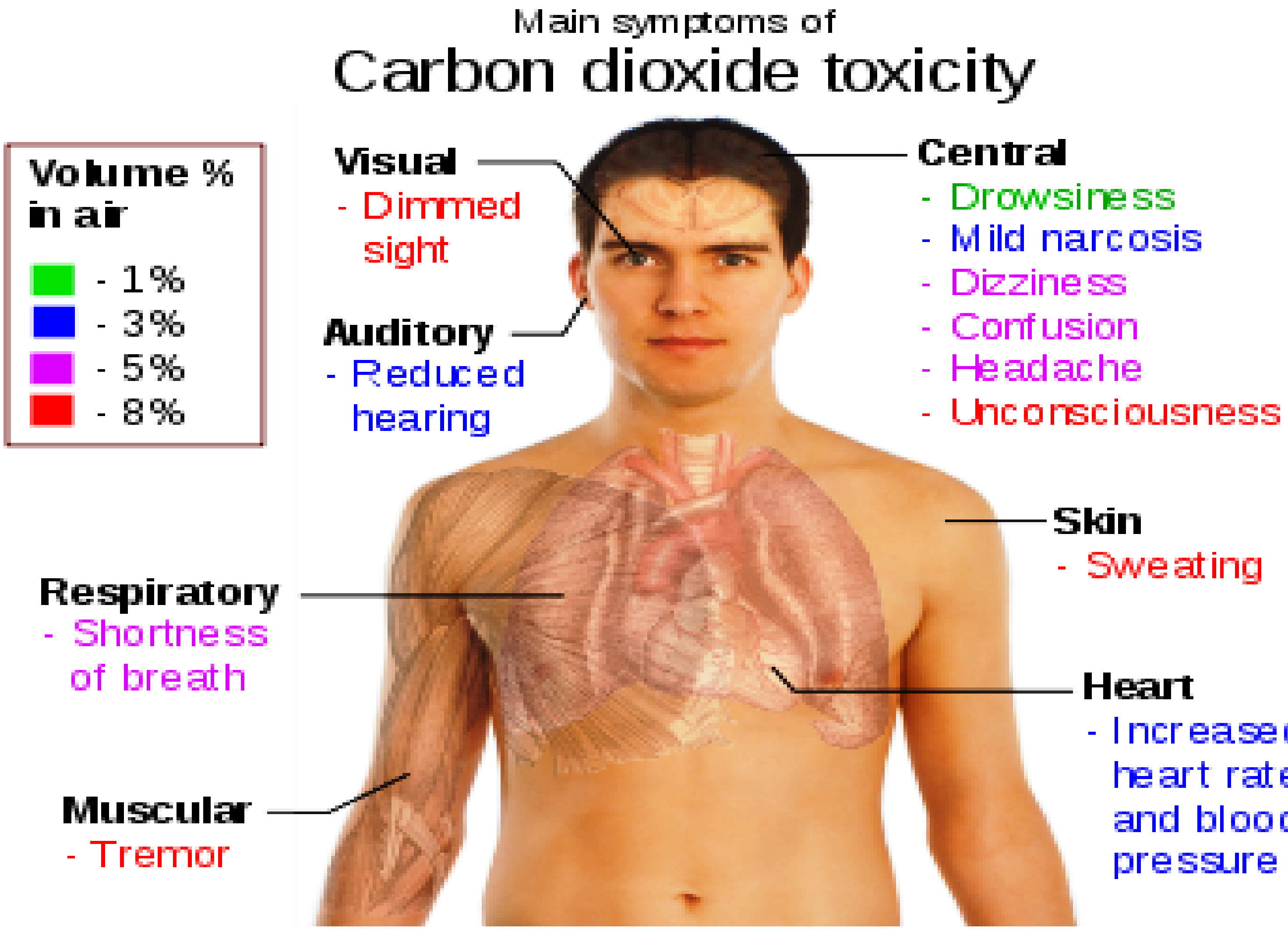
Suffocation

The practical limit of CO_2 is significantly lower than HFCs/HCFC to reflect the different physical effects CO_2 has when inhaled:

CO2 concentration in air		
Vol %	**ppm**	**Info**
0,0368	386	CO2 concentration in the atmoshere
0,5	5.000	maximum allowable concentration (MAC) at workspace
1,5	15.000	Pre - alarm (Gaswarning system)
2	20.000	Main- alarm (Gaswarning system)
3-> 5	30.000-> 50.000	Headache; disruption of respiration; discomfort
5,4	54.000	Practical limit (PL) En 378-1
8-> 10	80.000-> 100.000	Cramps; black out; shortness of breath; high frequent heart beat lead to unconsciousness, can lead to death in 30-60 min.
20	200.000	Lead to death within 5-10min.

CO2 is Invisible, Silent, there is No Smell and than it Kills

Suffocation



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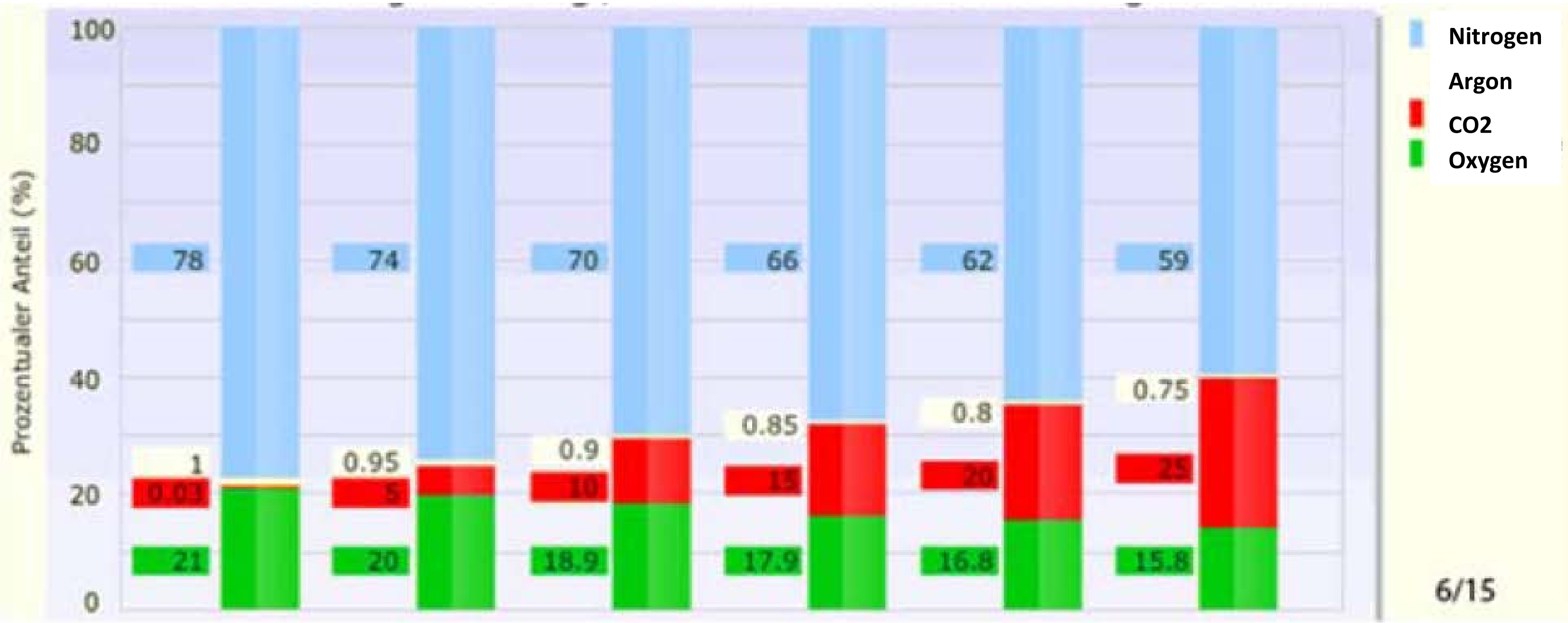
Suffocation



The steady increase of co2 increasingly displaces argon and nitrogen, while the oxygen content remains almost constant.

!! Never use oxygen detector to indicate CO_2

Avoid Suffocation with a number of measures

- Areas around CO_2 systems should be very well ventilated
- If you feel any of the warning signs of suffocation (dizziness, numbness, tingling in fingers) you should move into the fresh air as quickly as possible.
- A personal gas detector should be used in working areas.
- Gas detection should be located in any area where a leak of CO_2 would exceed the practical limit (0.1 kg/m3).
- This should be fitted at low level, 30cm above the floor. These sense CO_2, not oxygen deficiency, and typically alarm at 1%.
- Do not enter a room if the gas detector is alarming.
- CO_2 is vented from systems rather than recovered – ensure it is vented into a very well ventilated area or to outside.
- Wear ear defenders when venting - this is a very noisy process.

Suffocation

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

FINAL DRAFT
FprEN 378-1

June 2016

ICS 01.040.27; 27.080; 27.200

Will supersede EN 378-1:2008+A2:2012

English Version

Refrigerating systems and heat pumps - Safety and environmental requirements - Part 1: Basic requirements, definitions, classification and selection criteria

Systèmes frigorifiques et pompes à chaleur - Exigences de sécurité et d'environnement - Partie 1 : Exigences de base, définitions, classification et critères de choix

Kälteanlagen und Wärmepumpen- Sicherheitstechnische und umweltrelevante Anforderungen - Teil 1: Grundlegende Anforderungen, Begriffe, Klassifikationen und Auswahlkriterien

This draft European Standard is submitted to CEN members for formal vote. It has been drawn up by the Technical Committee CEN/TC 182.

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

This draft European Standard was established by CEN in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

Ref. No. FprEN 378-1:2016 E

CO_2 is suffocating like HCFC and HFC refrigerants

CO_2 = Safety classification A1

<u>EN 378-3 (9.1)</u>
When the concentration of the refrigerant can exceed the practical limit in accordance with EN 378-1:2016, Annex C, detectors shall at least actuate an alarm and in the case of the machinery room the emergency mechanical ventilation.

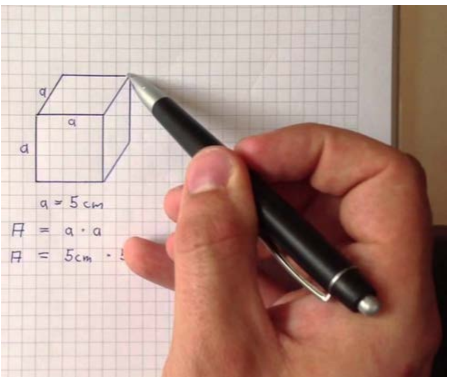
PL of R404A = 0,48 kg/m^3

PL of R134a = 0,25 kg/m^3

PL of R744 = 0,10 kg/m^3

Suffocation

Room calculation for gas detection



Room = L 10m x W 20m x H 3m

Volume = $600 m^3$

Chare size of the system = 120kg CO_2

0,1 x 600 = 60kg

If charge is higher than 60kg a gas detection needs to be install!

Alarm : equal or less than 50% of practical limit (PL)

Suffocation

Gas detection

Position gas sensor close to rack or evaporators where leaks could occur and refrigerant could accumulate (EN378-3:2016 article 9.2)

Gas sensor to be fitted 20 cm to 30 cm above floor level; (CO2 is approx. 1.8 times heavier than air; EN378-3:2016 art. 9.3)

Gas alarm has to be robust, contain self-test function and set points must not be adjustable by unauthorized people (EN378-3:2016 article 9.4)

Safety issues

Before starting service:

- Check working conditions
  ->Do not work in confined spaces
  ->If not preventable: 2. technician as safeguard outside
- As for working permission and inform customer when service job is done.
- Check Gas alarm system before entering controlled areas
- Always ensure proper ventilation while working on CO_2 refrigeration cycle.

Safety issues

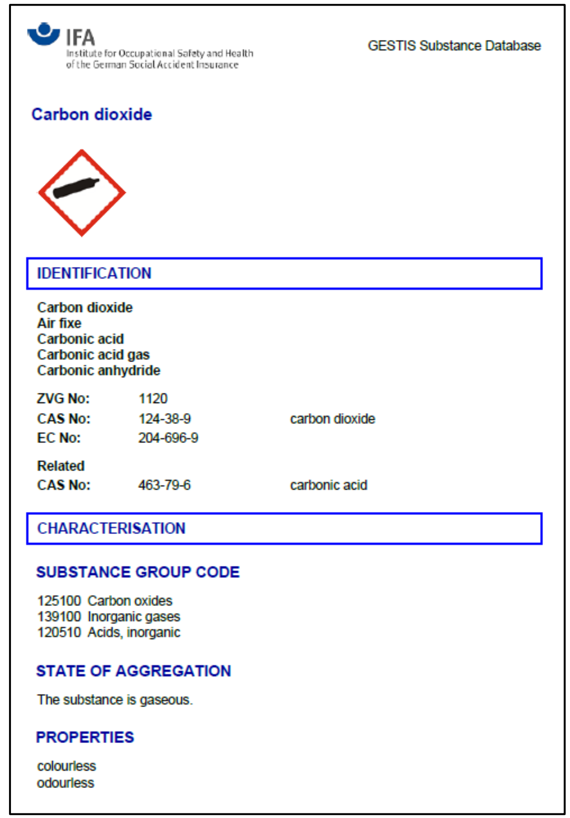
In case of gas alarm:

- Leaf the affected area immediately
- Inform persons around
- Ensure proper ventilation
- Enter the affected area only if gas alarm is off and gas alarm system shows normal operation
- In case persons need to be rescued, only entering the room by using Self Contained Breathing Apparatus

Safety issues

First Aid:

Always follow the first aid rules according safety data sheet!


IFA
Institute for Occupational Safety and Health of the German Social Accident Insurance

GESTIS Substance Database

Carbon dioxide

IDENTIFICATION

Carbon dioxide
Air fixe
Carbonic acid
Carbonic acid gas
Carbonic anhydride

ZVG No:	1120	
CAS No:	124-38-9	carbon dioxide
EC No:	204-696-9	
Related CAS No:	463-79-6	carbonic acid

CHARACTERISATION

SUBSTANCE GROUP CODE

125100 Carbon oxides
139100 Inorganic gases
120510 Acids, inorganic

STATE OF AGGREGATION

The substance is gaseous.

PROPERTIES

colourless
odourless

Overview: Modules and Sections

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Avoid Problems Associated with High Pressure

- The equipment used to pressure test, charge, vent and measure pressures must be suitable for the pressures of CO_2.
- A standard gauge set must not be used.
- The equipment must not allow refrigerant to be trapped between closed valves.
- Take great care when accessing a system, even if it is off.
- Ensure cylinders are secure (ideally in a suitable trolley) and open them slowly - the pressure can de-stabilise the cylinders if they are opened quickly.

Manifold set (4-Way recommended)

<u>Commissioning:</u>

CO_2 manifold 120bar is needed

-> strength test (Psx1,1)

<u>Service:</u>

Some electronic manifolds (incl. R744) are available for pressure up to 60bar.

(Intermediate pressure)

Portable gas sensor: how to use it

While technicians are working on the system, it can be advisable to use a portable gas detector.

- Detector can be clipped to clothing or placed on the floor within the working area.
- It should be switched on for the duration of the work and set to alarm at 50% of the PL, to alert staff members
- For safety reasons, the gas detector should not have a "Zero Background" function.
- Do not use Oxygen detectors as PPE
- Technicians are capable of immediately acting on the relevant emergency procedures.

Vacuum pump

Standard vacuum pump (electrical connections and sealing)

Do not use “home-made” vacuum pumps

Recovery unit

There is no recovery process, due to high pressure!

Refrigerant venting to the environment!

Take care to avoid oil contamination to the environment!

Oxygen free dry nitrogen (OFDN)

Must have for the applications:

- Pressure / strength test
- Equipment flushing
- Inert gas brazing

Cylinder Content (Litre)	Filling Pressure (bar)	Gas Content (m³)	Cylinder gross weight (ca. kg)
5	200	1	9,8
10	200	1.911	15,7
20	200	3.822	37,0
50	200	9,556	77,7
Purity 4.0 OFDN gas is of 99,99 % and a water content of maximum of 30 ppm.			

Charging equipment

For refrigerant charge

Measuring range ≤ 100 kg

Accuracy of about +/- 0.5%

! You are only able to empty the cylinder until intermediate pressure (max. suction pressure)

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High coefficient of expansion

In addition to the hazard caused by the very high standstill and operating pressures, trapped CO2 liquid or gas expands rapidly.

This causes an extremely high pressure increase.

For example, if liquid is trapped in an evaporator at -30 °C, its pressure will rise to over 100 bar/g if its temperature rises to -20 °C.

As a rule of thumb
for every 1°C rise in
temperature, the pressure
of trapped CO_2 liquid rises
by 10 bar.

Safety relive valves

All pressure level of CO_2 systems need to be secured against excessive pressure.

Due to the extremely high pressure increase, CO_2 systems do have safety relive valves at all pressure levels.

Example of pressure levels:

High pressure	= 120bar
Intermediate pressure	= 45bar
MT cooling positions	= 45bar
High pressure LT	= 45bar
LT cooling positions	= 25bar

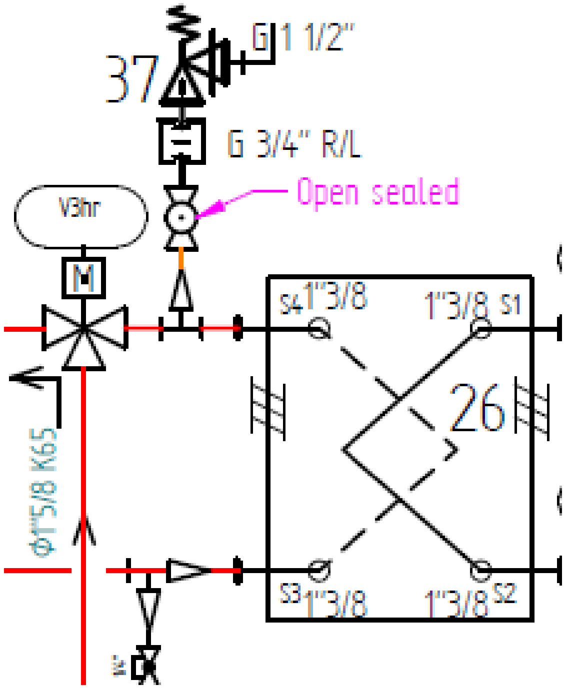
We differentiate into 2 types of safety valves:

- Main safety valves
- Secondary safety valves

Safety relive valves

Main safety valves

- Necessary at each pressure level
- Vent line always connected to the outside
- Always activated not lockable (without tools)



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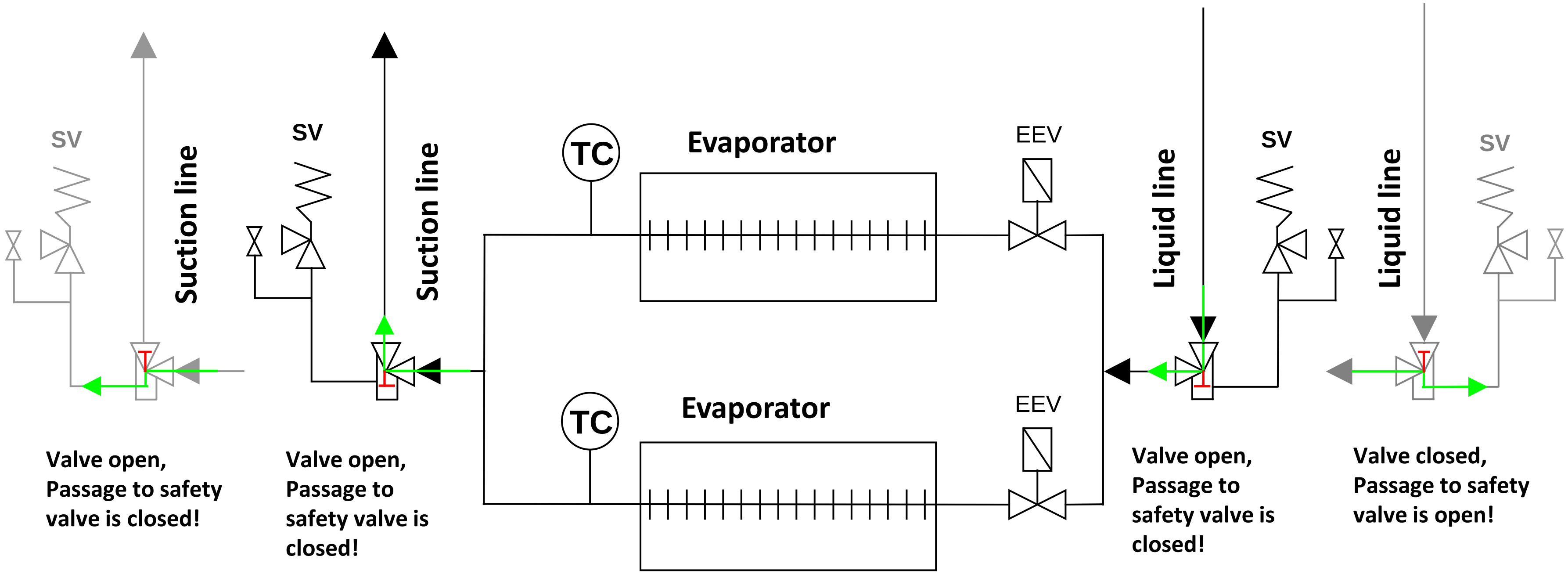
Safety relive valves

Secondary safety valves

- Necessary for service safety
- Vent line to surrounding
- Only activated in case of service

Safety relive valves

Secondary safety valves



Dry Ice Formation

Solid CO_2 (dry ice) is formed at certain conditions when the pressure or temperature of CO_2 is dropped.

This can occur when charging CO_2 into an evacuated system or when CO_2 is vented.

The pressure drops, but when the dry ice turns to gas (sublimes) the pressure rises rapidly.

Dry ice has a very low surface temperature.

Avoid problems associated with rapid expansion of trapped CO_2 in the system:

- Do not allow liquid to be trapped in pipes or components between closed valves.
- Do not weld or braze pipe work or components which contain CO_2.
- Ensure valves are open, for example by using a magnet to open solenoid valves.

Preventing dry ice formation

- To prevent dry ice formation when charging, charge gas until the pressure in the system is at least 4.2 bar g (i.e. above the triple point), then charge liquid to complete the charge.
- To prevent dry ice formation when venting the refrigerant should be vented in the liquid state if possible.
- Be aware that if dry ice does form the pressure drops to atmospheric pressure, and will rise again when the dry ice sublimes.

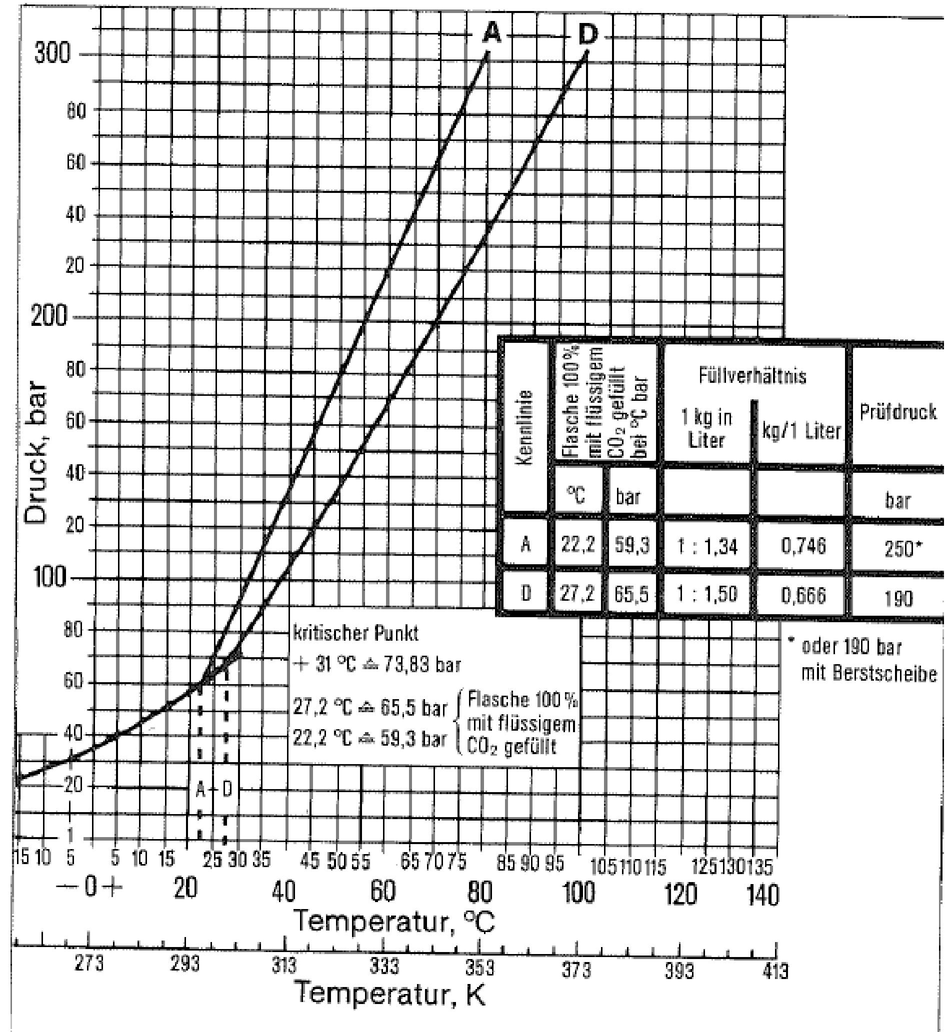
System charging

R744 cylinders are high pressure cylinders!

-> at hot day`s cylinders can easily reach 100bar

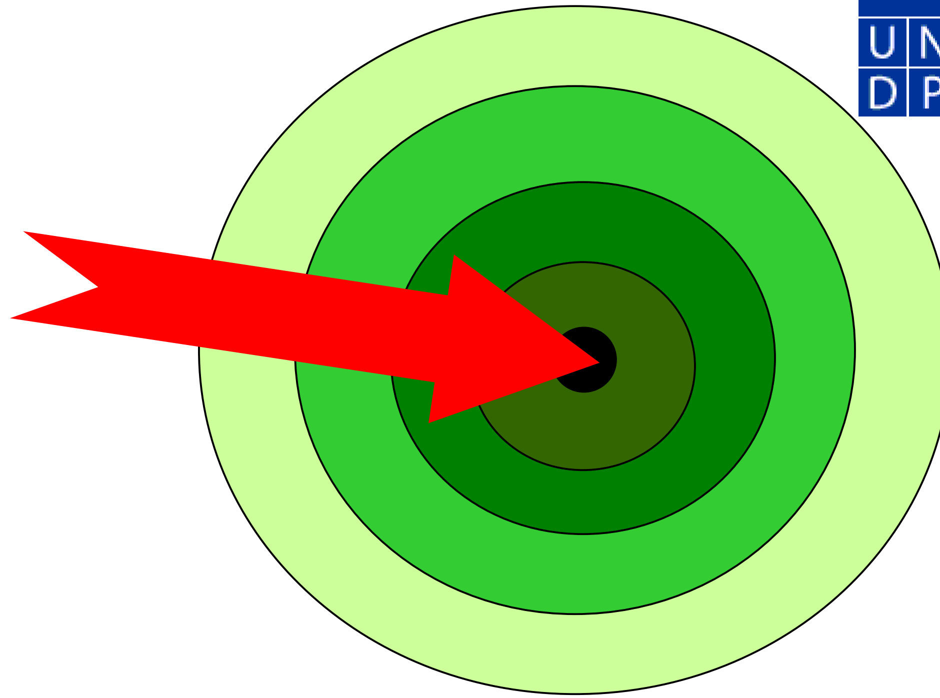
! Only use approved tools!

-> at cold day`s cylinder pressure can be lower than system pressure



Work with CO2

Targets



no Accident

no Environment Pollution

no Health Hazard

Thank You for Your attention!