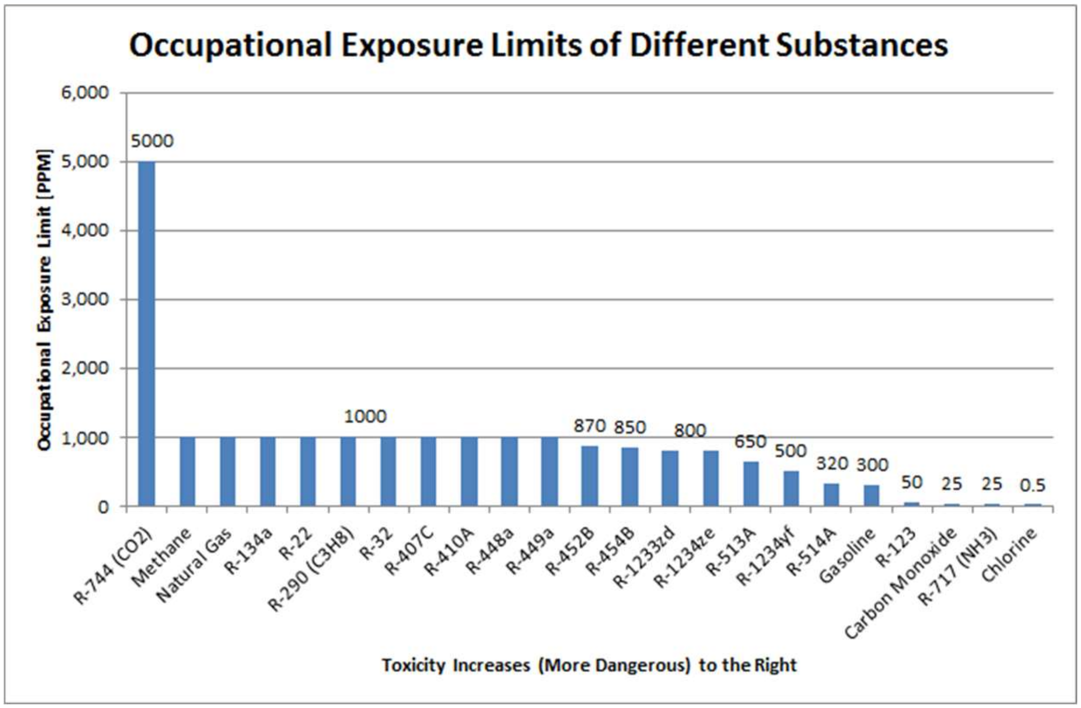
Balance of Plant

Benoit Rodier, Ing.
Cimco Refrigeration

- Safety in CO2 mechanical room
- Leak detection and prevention
- CO2 Quality
- Relief lines and stack
- Oil charging
- Co2 charging
- Water in system
- Where to fit a CO2 heat pump

CO2 as a Refrigerant

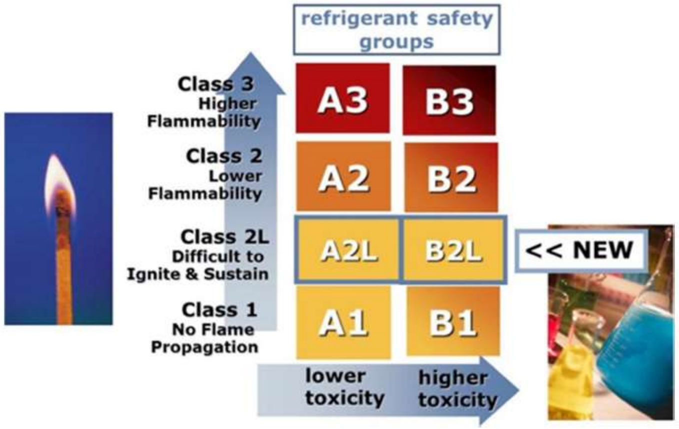


CO_2 :Isn't it the big evil in the climate debate?

The CO_2 we use for refrigeration systems would have been emitted in other processes e.g. ammonia production

Is CO_2 toxic?

CO2 is not toxic in the classical meaning of toxic, but it is an asphyxiant that depletes the O_2 in the room or space



CO2 in Mechanical Room

Exposure concentration in ppm	Effect	Source
350	Normal value in the atmosphere	Bearg, 1993
1.000	Recommended not to be exceeded for human comfort	ASHRAE, 1989
5.000	TLV according to AGGIH	Rieberer, 1998
20.000	Can affect the respiration function and cause excitation followed by depression of the central nervous system. 50% increase in breathing rate.	Berghmans, 1999
30.000	100% increase in breathing rate after short time exposure	Amin, 1999
50.000	IDLH value: Maximum limit from which one could escape within 30 minutes without any escape-impairing symptoms or any irreversible health effects.	Rieberer, 1998
80.000	Short term exposure limit	Amin, 1999
100.000	Lowest lethal concentration	Berghmans, 1999
200.000	Death accidents have been reported	Berghmans, 1999
300.000	Quickly results in an unconsciousness and convulsions	Berghmans, 1999

CO_2 and respiration process

Effect of reduced oxygen

21% - normal atmosphere
16% - breathing becomes labored
14% - moving becomes an effort
12% - muddled thinking
10% - nausea. vomiting. collapse
8% - loss of consciousness
6% - respiratory failure

CO_2 is heavier than air!!

Health and Safety

- All industrial gases are a certain risk
- Gas detectors are not only for flammable or toxic refrigerants
- Oxygen deprivation sensors may be more suitable
- Risk assessment and hazard analysis are required in all cases
- A safe system of working is required which is specific to site conditions
- CO_2 is different to other gases but it is not more or less safe!
- CO_2 effects are felt at lower levels than R134a or N_2 but the warning sign can be as clear as NH_3 to those trained to spot them

- ❑ Detectors that can show the concentration and the Oxygen level
- ❑ Fresh air apparatus with full face coverage is the only safe solution
- ❑ Leak detectors in mechanical room
- ❑ Ventilation system required, return near the floor

Quality of CO2 in Refrigeration System

Is CO_2 expensive?

That really depends on what you specify. Be aware that a quality 2.5 is 99.5% and a quality 3 is 99.9%. We normally recommend a quality 3 or 4. Quality 5 is over specification and very expensive.

AHRI Standard 700 with Addendum 1

2014 Standard for

Specifications for Refrigerants

Table 1C. Carbon Dioxide Refrigerant and its Maximum Allowable Levels of Contaminants

	Reporting Units	R-744
CHARACTERISTICS:		
Sublimation Point[1]	°C at 101.3 kPa	-78.4
Sublimation Point Range[1]	K	± 0.3
VAPOR PHASE[2]:		
Air and other non-condensables	% by volume at 10°C below the critical temperature and measure non-condensable directly	1.5
LIQUID PHASE[3]:		
Water	ppm by weight	≤ 10
High boiling residue	% by weight	≤ 0.0005
Particulates/solids	Pass or Fail	Visually clean
Purity	% by weight	≥ 99.9

Notes:

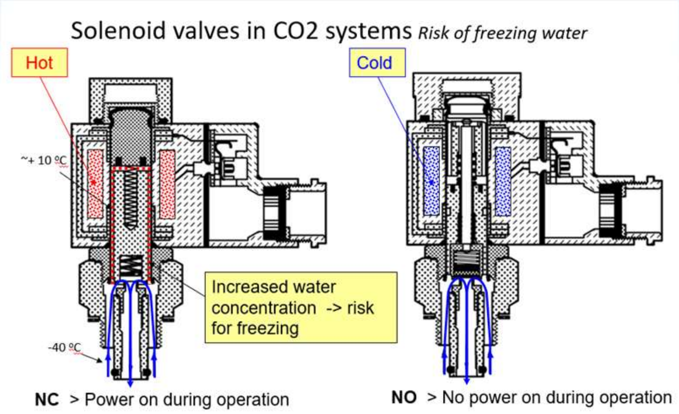
1. Sublimation point, sublimation point range, although not required, are provided for informational purposes. Refrigerant data compiled from Refprop 9.1.

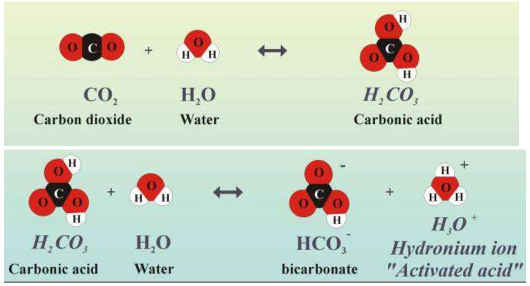
2. Sample taken from vapor phase

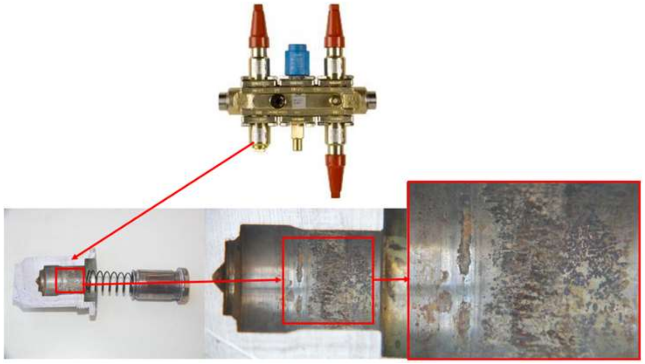
3. Sample vaporized from liquid phase

Worst Enemy of CO2

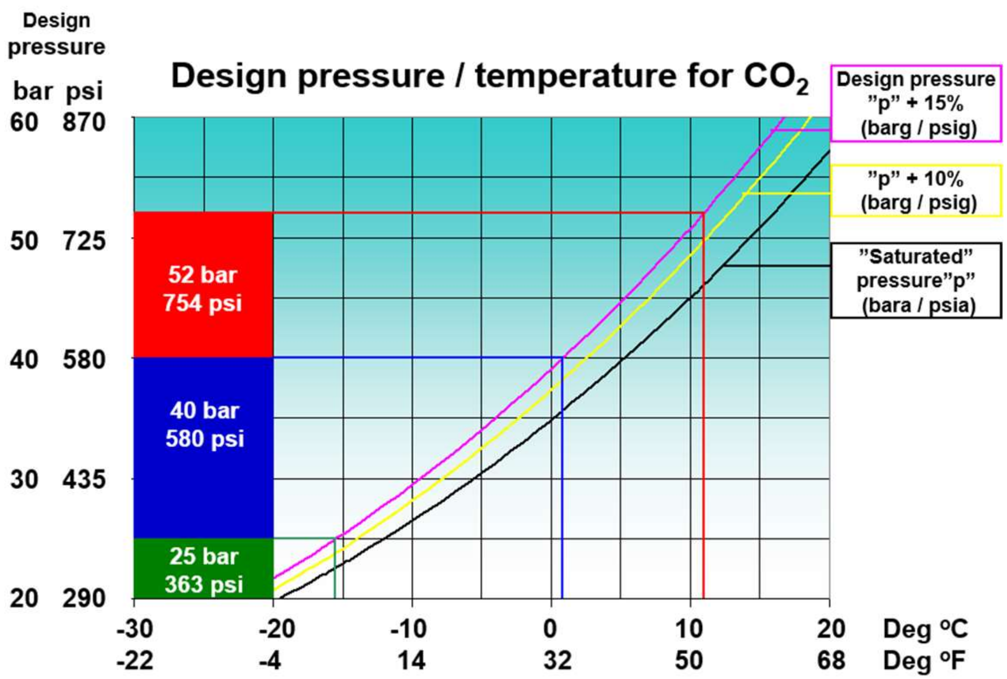
- Water can form ice layer on heat exchangers
- Water can form water ice crystals in valves
- Water can hold a pump
- Water is easy to arrest in filter dryers
- Water can come from the lubricant
- Lower CO_2 quality = more water

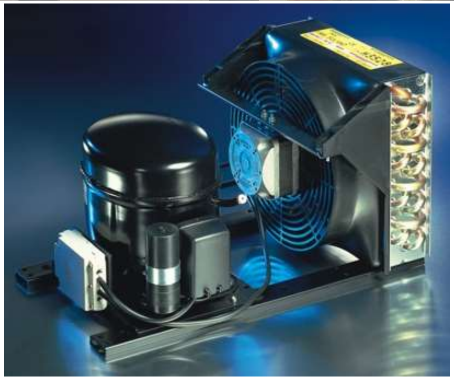






Design Pressure

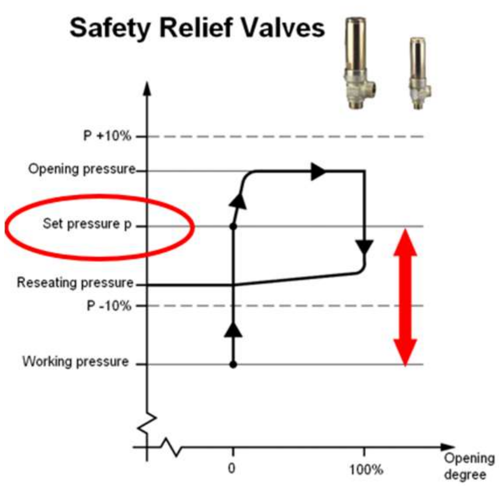




Relief Lines

Venting of CO_2 to atmosphere

- Only into open air
- PR valve at the end of line
- Attention! Dry ice, sublimed CO_2
- Dry ice forms at -56.6°C / -69.9°F
-     at 5.2 bar(a) / 75.4psia
- Vent no liquid CO_2 – vent first to an uninsulated vessel @ a pressure above the triple point
- Vent to atmosphere through another relief device from that vessel



Commissioning / Charging / Start-up

Commissioning

- First: all safety and monitoring devices must be checked!!
- All relevant data must be available
- Operating instructions of compressor must be followed
- System must be observed during commissioning
- After commissioning operating conditions must be checked and should be stored

=>The commissioning of CO_2 compressors requires a very careful approach!!

Charging

- Preparatory work
  - Energise the Crankcase heater
  - Oil must have a temperature of 35-40°C (95-105°F) before charging refrigerant
  - Check oil level in compressor
  - Do not switch on compressor!!
- Connect CO_2 cylinder via pressure reducer and service connection
  Charing hoses must withstand 90bar (1300psia)
- Connect HP and LP site with charging lines
- Check for correct CO_2 quality
  - Charge through filter driers (reduces water content)
- Flush the charging lines with CO_2 vapour
  - Charge only CO_2 vapour
  - Break the vapour up to 10bar (145psia)
  - Close compressor service valves
  - Charge system up to 20bar (290psia)
  - Solenoids on evaporators must be closed!!
- Charge further liquid only into receiver

Start-up

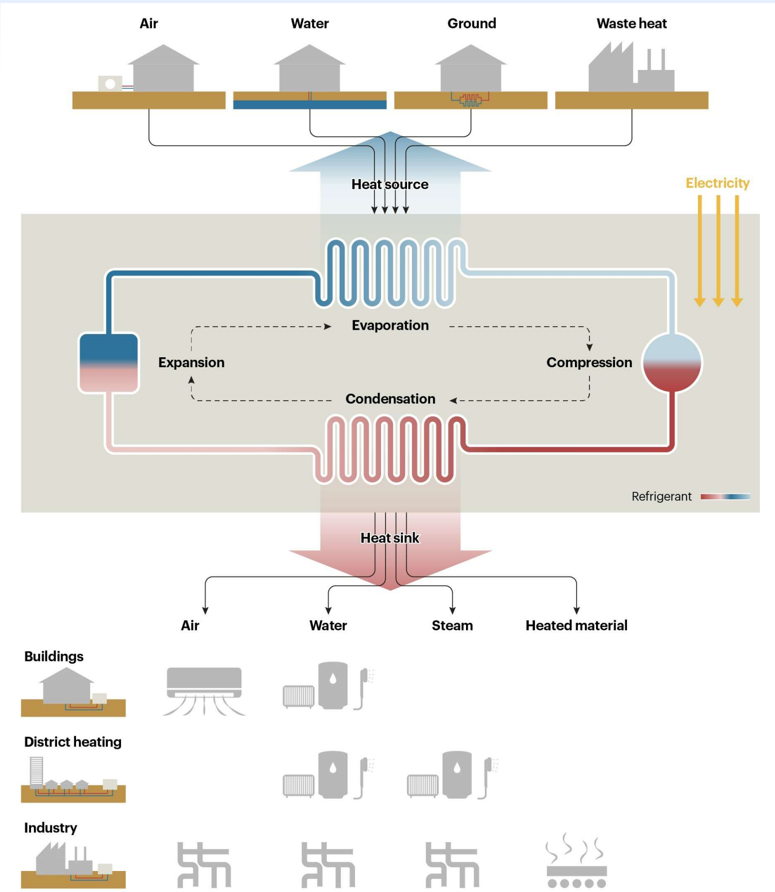
- Open discharge valve of compressor
- Open suction valve by one turn

- Start the compressor
- Open suction valve slowly when suction pressure decreases
- Open solenoid valves in LP stage as demand and capacity of compressor allows.

- Charge vapour CO_2 in suction line if needed
- Start step by step further compressors or evaporators depending on system configuration

- Avoid high pressure fluctuations and high cycling rates
  => oil foaming and lack of lubrication can occur

Heat Reclaim and Heat Pump



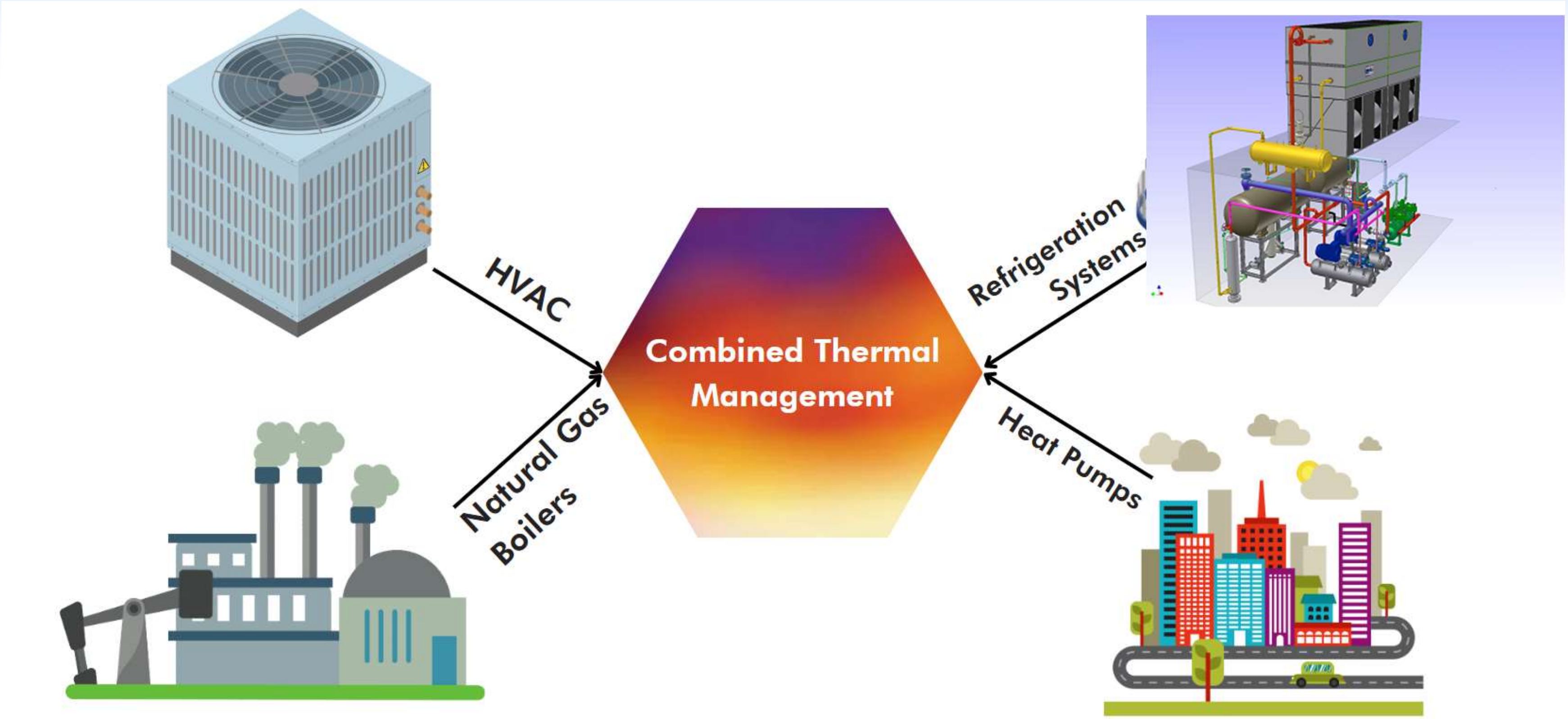
1) Identify Heat Sources and Sinks
The first step is locating suitable thermal energy to "pump" and a destination that needs it.
•**Low-Potential Heat Sources (LPHS):** Common sources include turbine exhaust steam, cooling tower water, or flue gas. Using cooling water is often ideal because its temperature remains relatively constant year-round.
•**Heat Sinks (Consumers):** The recovered heat can be used for preheating natural gas before combustion, warming boiler feedwater, or supporting a **District Heating (DH)** network.

2. Choose the Integration Method
Depending on your goals, several integration architectures are possible:
•**Waste Heat Recovery:** Use the heat pump to upgrade low-temperature waste heat to a level suitable for hot water or steam network
•**Hybrid Systems:** Pair the heat pump with existing boilers. The heat pump handles the base load, while the boiler provides supplemental heat during peak demand or extreme cold.
•**Power-to-Heat Storage (I-PHES):** Integrate heat pumps with thermal storage to act as large-scale electricity storage. Surplus electricity drives the heat pump to "charge" a thermal storage tank, which is later converted back to power or used for heating.

3. Engineering and Technical Setup
•**Selection of Heat Pump Type: Vapor Compression Heat Pumps (VCHP)** are used for more significant temperature boosts, such as heating gas to over 90°C.
•**Pinch Analysis:** Use Pinch Analysis to identify the exact "pinch point" where heat availability overlaps with demand. This ensures the heat pump is right-sized and optimally placed within the complex plant cycle.
•**Connection Layout:** For hydronic systems, connecting the heat pump upstream of the existing boiler allows it to receive the lowest return water temperature, which maximizes its **Coefficient of Performance (COP)**.

4. Optimize and Monitor
•**Working Fluids:** Select refrigerants based on the required temperature lift; for instance **CO2** may be used in high-temperature
•**Efficiency Gains:** Successful integration will increase a plant's overall seasonal efficiency and significantly reduce carbon footprint

How Does It Fit in the Big Picture



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