


**Chillventa Specialist Forums 2022**  
**Chillventa Fachforen 2022**

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Joris Kortstee

Danfoss

## **The natural choices in Industrial Refrigeration system design**

**Talk** green. **Walk** green.

# The natural choices in Industrial Refrigeration system design

- Introduction

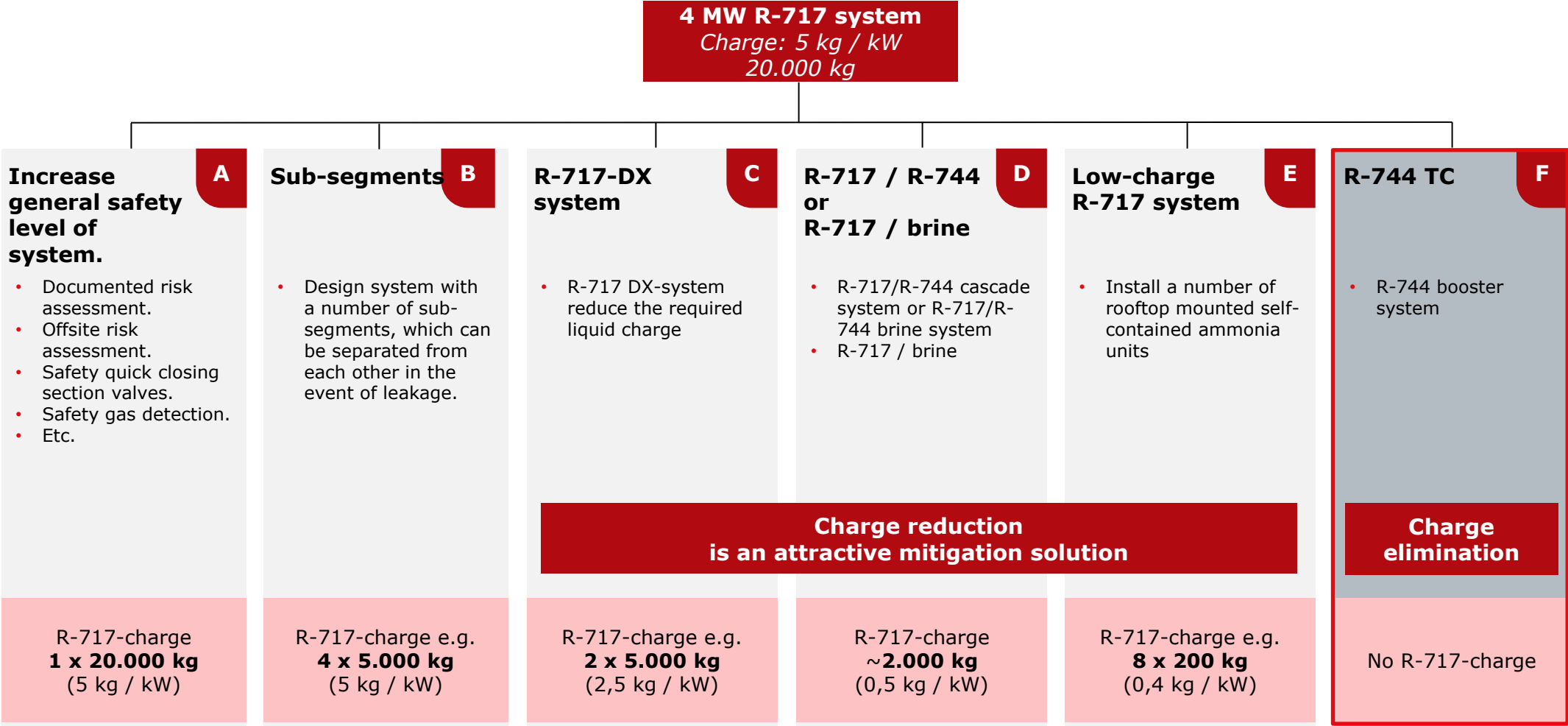
**Talk**green.  
**Walk**green.



- For decades, R-717 has been used in Industrial Refrigeration systems as the primary refrigerant due to its excellent thermodynamic properties. Pump circulated systems are regarded as the "reference R-717 system" with highest system efficiency and a mature and solid reputation.
- R-717 is a natural refrigerant. GWP=0, ODP=0. However it's classified as a toxic and flammable refrigerant. There's a huge focus on charge reduction to mitigate risks. This can be done in many ways and with different system types.
- The purpose of this presentation is to give a snap shot of some of these system types with R-744 as a refrigerant option.
- There is not 1 "best" solution. This depends on the local requirements and legislations, end users requirements and focus, possibilities regarding first costs, TCO considerations, and geographical location.
- We try to give a transparent and neutral overview of possibilities.
- We will focus a bit deeper into a transcritical R-744 pump circulated systems
- We will show you some ongoing developments for supporting such larger systems



# Offset risk mitigation by charge reduction / segmentation



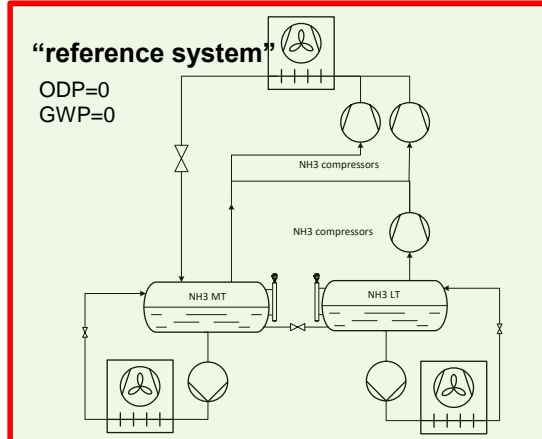


# Industrial Refrigeration system types

## - A few examples

Talk green.  
Walk green.

R-717 booster pump circulation (1)



### Features

- R-717 MT/LT pump circulation (flooded)
- Larger capacities
- Multi stage temperature levels
- Long life time (25+)

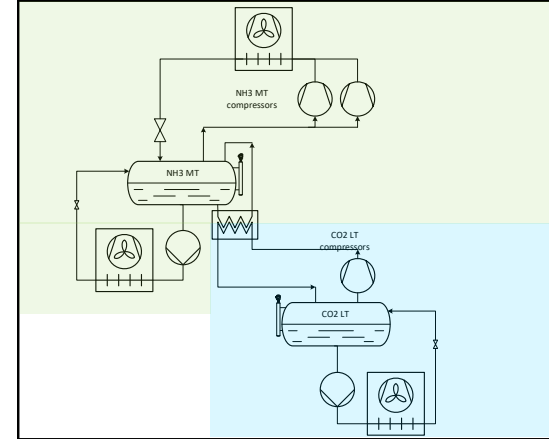
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- Natural refrigerant, ODP=0, GWP=0
- Excellent thermodynamic properties R-717
- Mature, proven and reliable technology
- Generally acknowledged as **most efficient**
- Relatively easy to control
- Flexible in temp levels
- Can handle high peak demands due to the two-phase state and liquid separation

-

- **NH3 classifications and charge**
- Special design requirements needed (R-717)
- Oil management required (R-717)
- First costs (compared to DX)

R-717/R-744 cascade pump circulation (2)



### Features

- R-717 MT pump / **cascade R-744 LT pump**
- Larger capacities
- Multi stage temperature levels
- Long life time (25+)

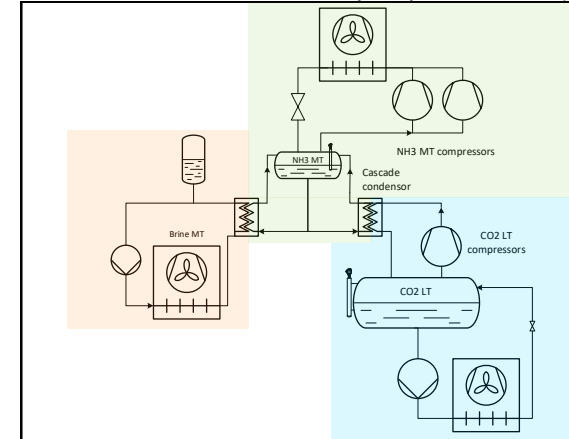
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- Natural refrigerants (R-744: ODP=0, **GWP=1**)
- **R-717 charge red. on LT side**
- Excellent thermodynamic properties R-717
- Mature, proven and reliable technology
- Relatively easy to control
- Flexible in temp levels
- **R-744 LT pumped can** handle high peak demands due to the two-phase state and liquid separation
- **Same/or better efficiency** (LT R-744 compressors)

-

- NH3 classification and charge
- Special design requirements needed (R-717)
- Oil management required (R-717)
- First costs
- **Higher pressure (R-744)**
- **Oil management required (R-744)**

R-717/brine/R-744 cascade pump circulation (3)



### Features

- R-717 MT/cascade R-744 LT pump/**Brine MT pump**
- Medium/Large capacities
- Multi stage temperature levels
- Long life time (25+)

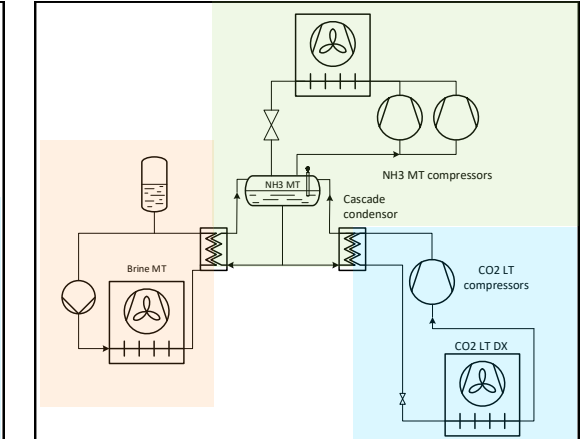
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- **Partly** natural refrigerants
- Huge R-717 **charge reduction on MT** (70/80%)
- Mature, proven and reliable technology
- Relatively easy to control
- Flexible in temp levels
- R-744 LT pumped can handle high peak demands due to the two-phase state and liquid separation

-

- NH3 classification and charge
- Special design requirements needed (R-717)
- Oil management required (R-717)
- (First costs) **and running costs**
- Higher pressure R-744
- Oil management required (R-744)
- **Efficiency loss (mostly due to MT brine)**

R-717/brine/R-744 LT DX cascade (4)



### Features

- R-717/brine MT pump / **R-744 cascade LT DX**
- Medium/(large) capacities
- Multi stage temperature levels
- Long life time (25+)

+

- Partly natural refrigerants
- Huge R-717 charge reduction (70/80%)
- Mature, proven and reliable technology
- Relatively easy to control
- Flexible in temp levels

-

- NH3 classification and charge
- Special design requirements needed (R-717)
- Oil management required (R-717)
- (First costs) **and running costs**
- Higher pressure R-744
- Efficiency loss (mostly due to brine)
- **Efficiency loss due to DX on LT**

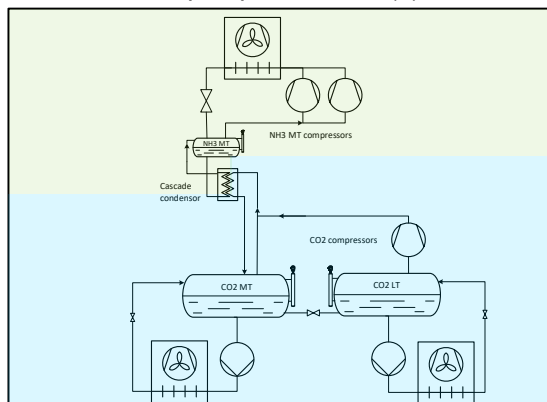
# Industrial Refrigeration system types

## - A few examples

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R-717 / R-744 pump circulation (5)



### Features

- R-717/R-744 cascade system (flooded)
- Medium/Large capacities
- Multi stage temperature levels
- Long life time (25+)

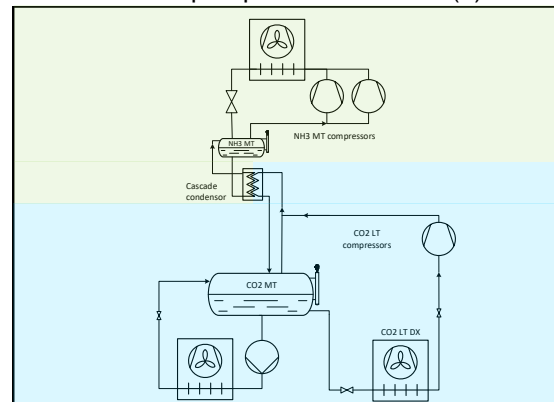


- **Natural refrigerants**
- **Huge R-717 charge reduction (70/80%)**
- Excellent thermodynamic properties R-717
- Mature, proven and reliable technology
- Relatively easy to control
- Flexible in temp levels
- Can handle high peak demands due to the two-phase state and liquid separation



- NH3 classification and charge
- Special design requirements needed (R-717)
- Oil management required (R-717)
- Oil management required (R-744)
- First costs (compared to DX)
- Higher pressure R-744
- **Efficiency loss (cascade)**

R-717 / R-747 pump circulation / DX (6)



### Features

- R-717/R-744 cascade system (flooded and DX)
- Medium/Large capacities
- Multi stage temperature levels
- CO2 MT pump circulation (Large) and LT DX (small)
- Long life time (25+)

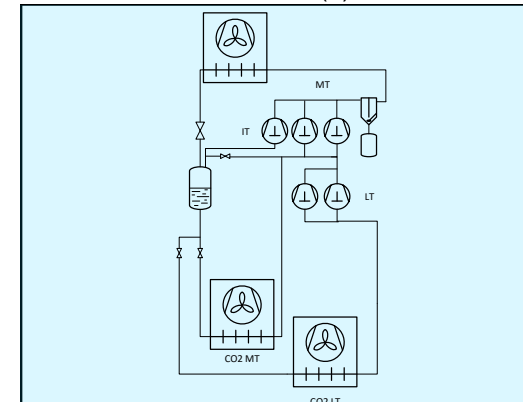


- Natural refrigerants
- Huge R-717 charge reduction (70/80%)
- Excellent thermodynamic properties R-717
- Mature, proven and reliable technology
- Relatively easy to control
- Flexible in temp levels
- Can handle high peak demands due to the two-phase state and liquid separation



- **NH3 classification and charge**
- Special design requirements needed (R-717)
- Oil management required (R-717)
- Oil management required (R-744)
- First costs
- Higher pressure (R-744)
- Efficiency loss (cascade)
- **Efficiency loss due to DX on LT**

Transcritical R-744 / DX (7)



### Features

- R-744 booster system (transcritical)
- **DX**
- **Commercial system type**
- Small/medium/large capacities
- Multi stage temperature levels
- < 25 year life time

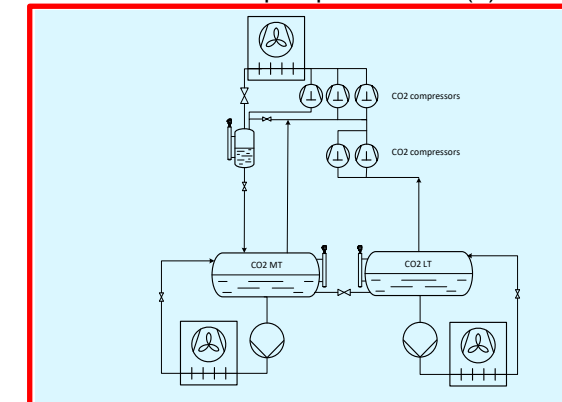


- **No R-717**
- Relatively simple design
- Mature systems
- First costs



- **System efficiency is depending on geographical location**
- Transcritical pressures
- **Useful superheat in evaporators reduces efficiency**
- **Less efficient** compared to flooded when SH not 0K

Transcritical R-744 pump circulation (8)



### Features

- R-744 booster system (transcritical)
- **Pump circulation**
- **Industrial system type**
- **Medium/large** capacities
- Multi stage temperature levels
- < 25 years life time



- **No R-717**
- **Relatively easy to control (No expansion valves)**
- **Flexible in temp levels**
- **Can handle high peak demands due to the two-phase state and liquid separation**
- **No useful superheat in evaporators. Smaller dT, higher evaporating temperature, better heat transfer, increased efficiency**
- **Controlled oil management**
- Safe and reliable hotgas defrost

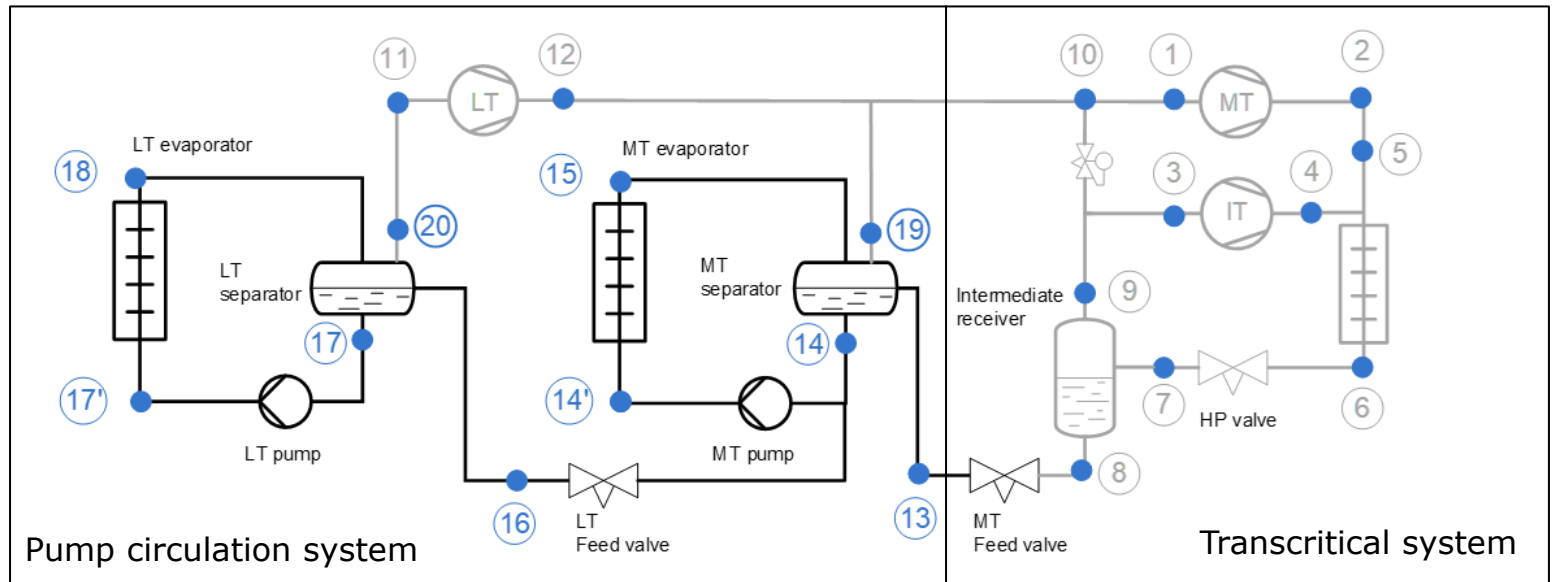
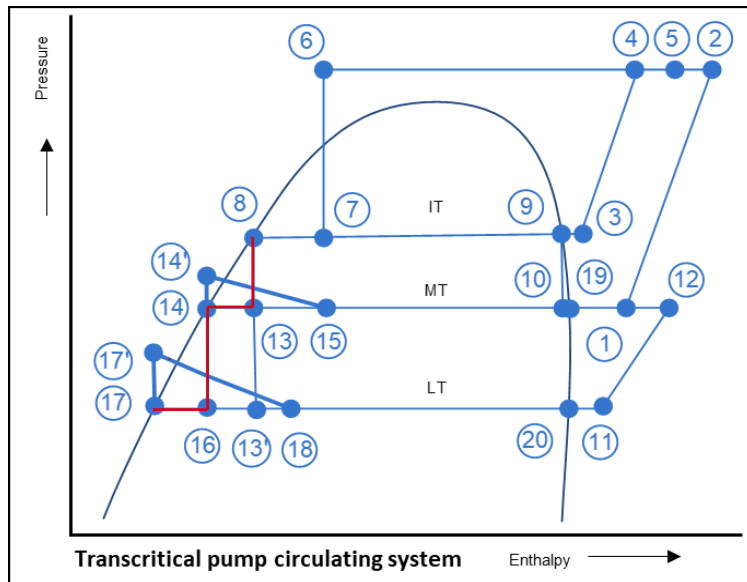


- System efficiency is depending on geographical location
- Transcritical pressures
- **Oil management required**
- **Level/pump control required**
- **First costs**

# CO2 booster system pump circulation

## - Principle explanation

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### Characteristics of pump circulation systems

- No DX but flooded systems
- No expansion valves
- Liquid separation always ensures dry gas to compressors
- No useful superheat. Better utilization of evaporator surface area.
- Better heat transfer, so increased efficiency
- Can operate on higher evaporating temperatures compared to DX operation (smaller dT)
- Relatively easy to control (on/off)
- Can handle high peak demands safely and reliably due to the two-phase state and liquid separation
- Easy and safe hotgas defrost, controlled drain into liquid separators

### Control of TC CO2 pump circulation systems

- Larger high pressure line components
- Larger high pressure motor expansion valves
- Large gas bypass valves
- Larger ejectors
- Hot gas defrost
- Pump separator control
- Evaporator control incl. defrost
- Oil management
- System coordination

# Industrial CO2 transcritical pump circulation systems

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## Industrial transcritical valves 140 bar CO2

### Stop valves / Strainers

- Industrial design
- Serviceable
- DN 50/65/80/100
- Straight / Angle



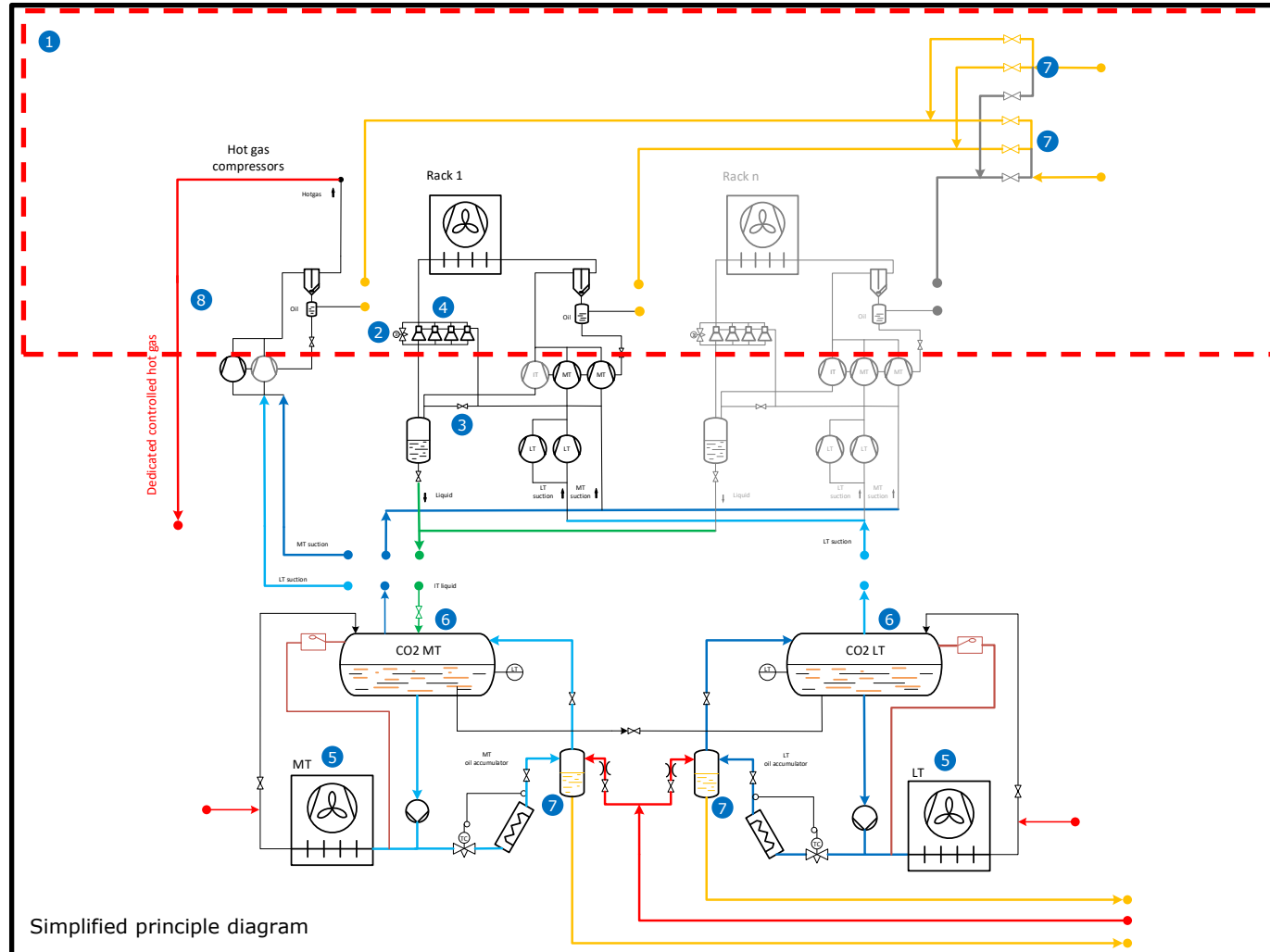
### Large motor valves

- HP EEV (+/- 3 MW)
- Gas bypass valve
- Industrial design
- Serviceable
- DN 65/80
- Straight / Angle
- Standard ICADTS



### Large ejectors

- HP type (+/- 650 kW)
- Replaceable cartridge
- Incorporated solenoid
- Incorporated strainer
- Incorporated check valve



## Controls

### 5 Cold room controller (EKE 400)

- Pump circulation / DX
- Room / medium, temp. ctrl
- Several defrosts methods
- Save defrost cycles
- Fan control
- Suction control

### 6 Pump vessel controller

- Liquid level control
- Several high/low level alarms
- Liquid injection control
- Pump protection
- Pump control
- Timers/delays
- Oil rectifying

### 7 Oil management

- Oil accumulation
- Oil return
- Oil distribution

### 8 Hot gas supply

- Defrost
- Oil return



# Conclusion

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1

R-717 is still the dominant refrigerant for industrial refrigeration systems. R-744 is finding its place as well.

2

R-717 charge reduction remains an obvious goal and offer a significant lower regulatory burden.

3

R-744 as refrigerant has the potential to play a role in the R-717 charge reduction.

4

However: transparent comparison of energy efficiency of different system types is extremely important!

5

Commercial and Industrial R-744 TC systems are different-both due to different performance, lifetime, reliability and safety expectations.

6

R-744 transcritical pump circulating systems close the gap for mid size capacity plants capacities when R-717 is not considered in the first place.

7

Larger transcritical R-744 compressor capacities are paving the way for larger refrigeration systems.

8

Danfoss Industrial Refrigeration is developing larger industrial transcritical valves and controls for such systems.

9

The viability of R-744 TC Systems in Industrial Refrigeration applications should become more clear in the next few years.



**Thank you for  
your attention**

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