

ENGINEERING  
TOMORROW

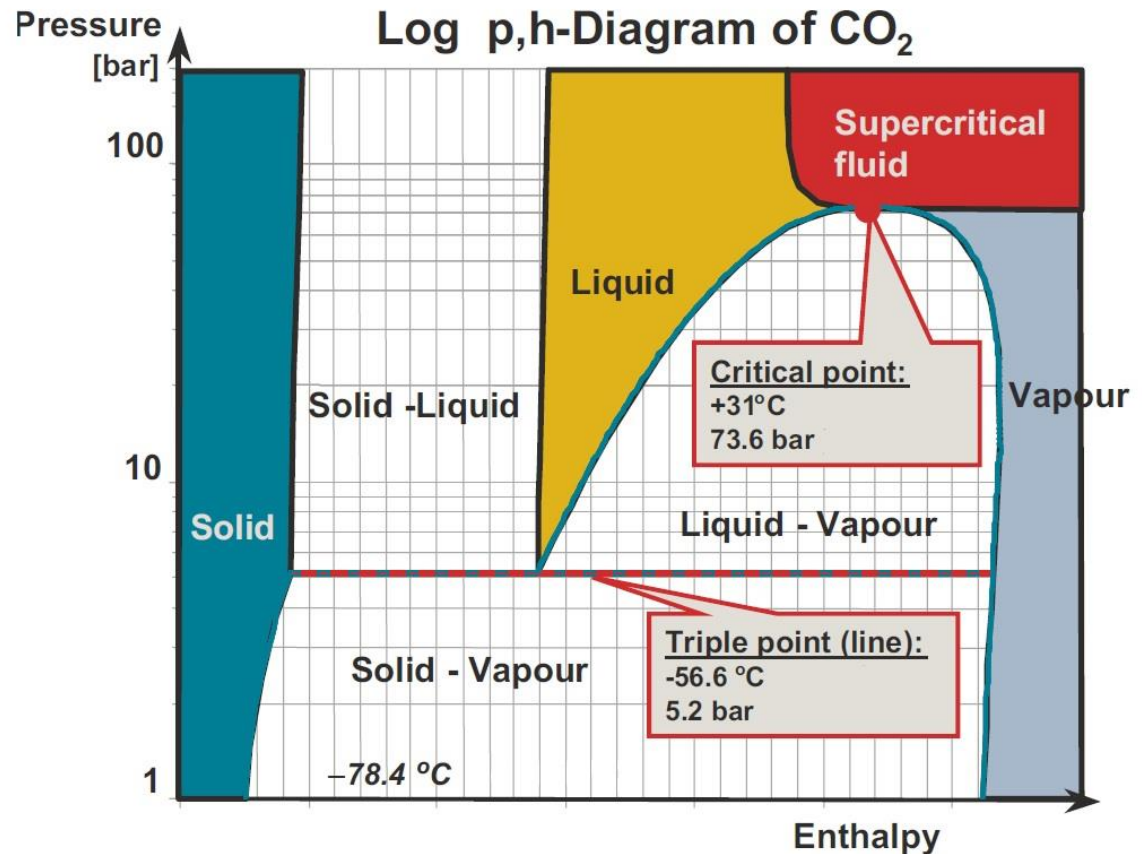
*Danfoss*

CO<sub>2</sub>

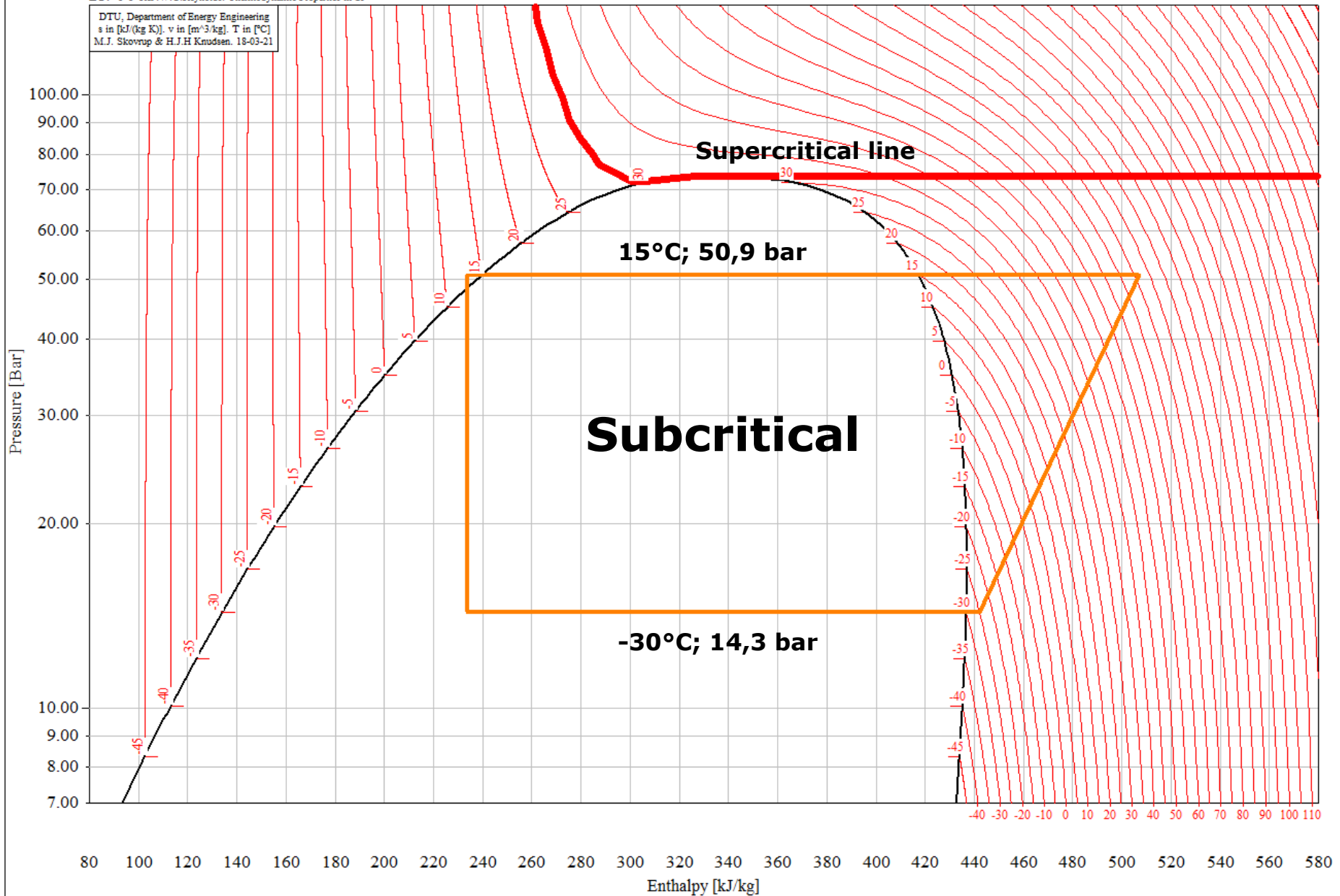
*Danfoss*

# CO<sub>2</sub> as refrigerant

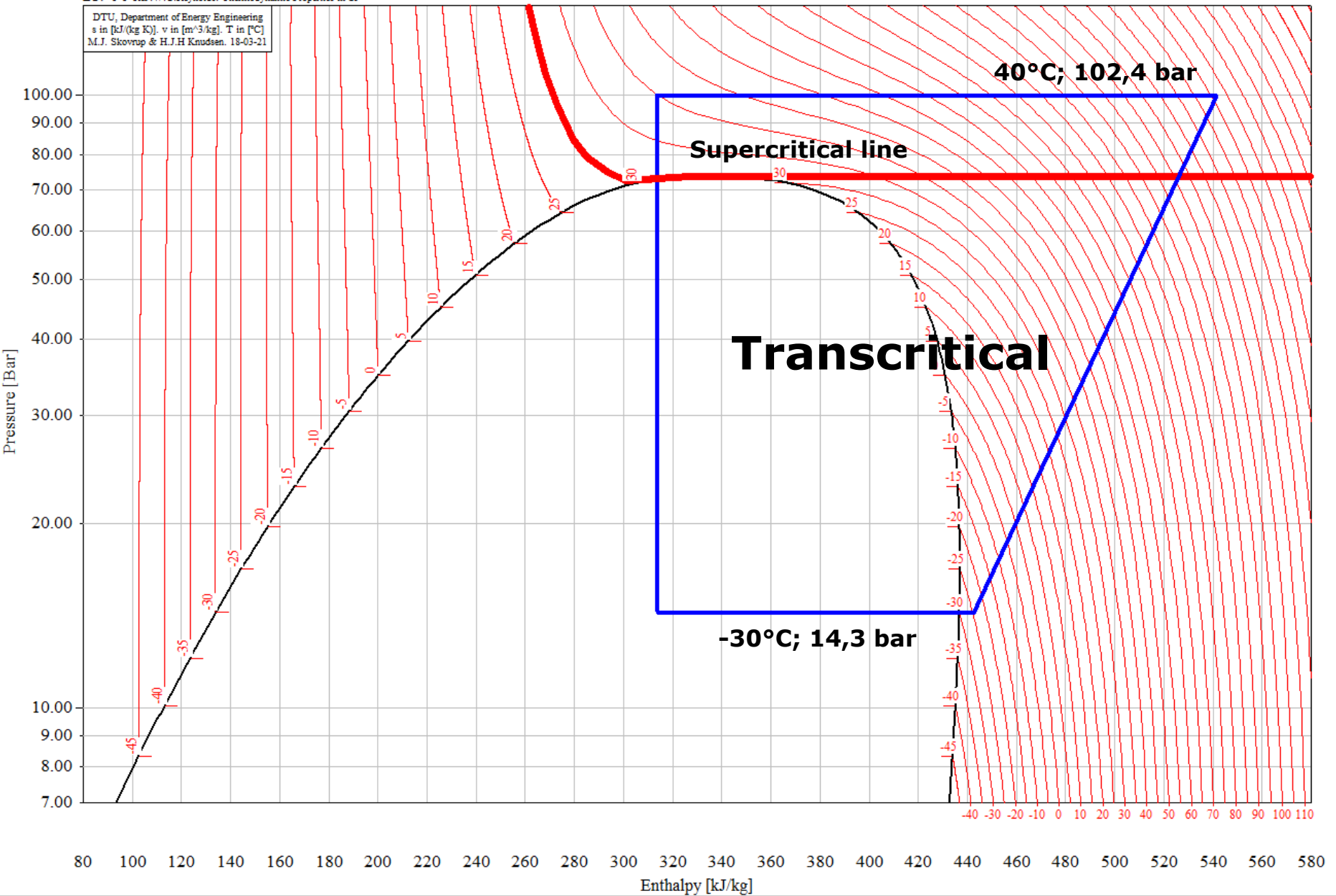
- R744
- GWP = 1; ODP = 0
- Not flammable
- Not toxic
- Natural refrigerant
- High working pressures
- Low critical point
- Heavier than air

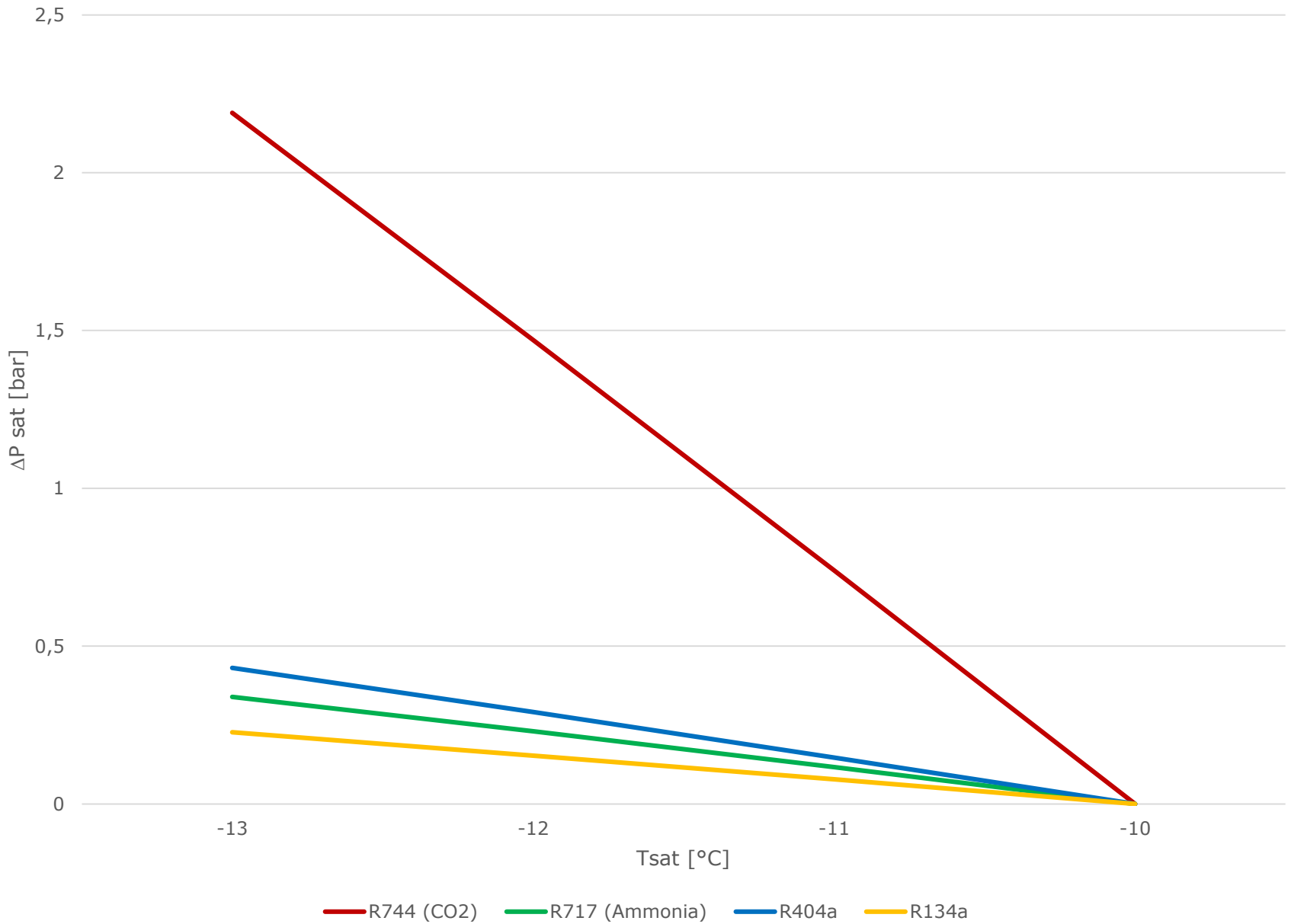


DTU, Department of Energy Engineering  
s in [kJ/(kg K)], v in [m<sup>3</sup>/kg], T in [°C]  
M.J. Skovrup & H.J.H Knudsen, 18-03-21



DTU, Department of Energy Engineering  
s in [kJ/(kg K)], v in [m<sup>3</sup>/kg], T in [°C]  
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Operating conditions:

Capacity:

Cooling capacity:  kW

Evaporation:

Temperature:  °C

Useful superheat:  K

Additional superheat:  K

Condensation:

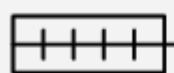

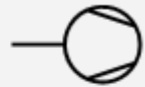


Temperature:  °C

Subcooling:  K

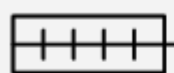

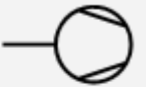


Additional subcooling:  K

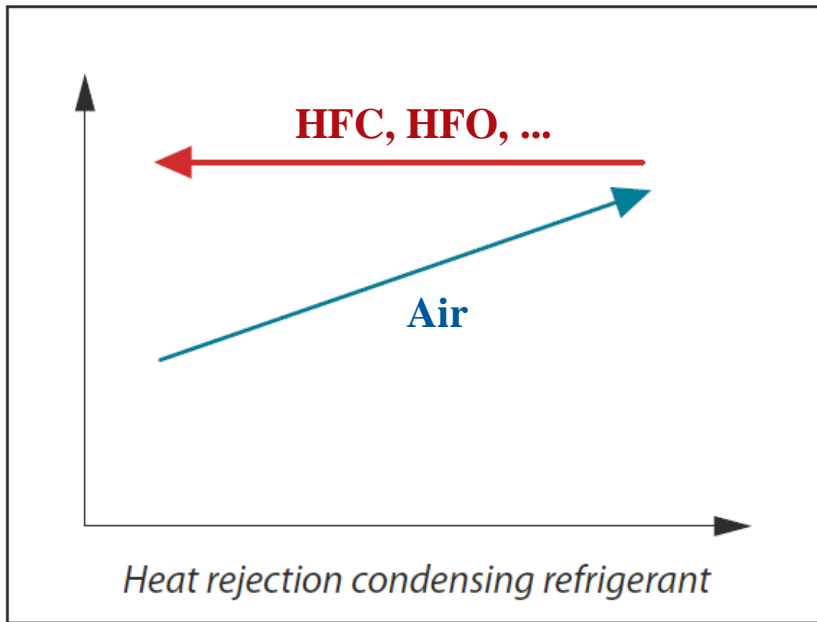
Additional:

# R404a

| Evaporator   | Compressor   |
|--|--|
|   <p>Copper pipe<br/>DIN-EN 54</p> |  <p><b>73,7 m<sup>3</sup>/h</b></p> |
| DP distribution: 100%  | <b>Total</b>   |
| Length [m]: 10.00  |  |
| Angle [deg]: 0   |  |
| DP [bar]: 0.024  | <b>0.024</b>   |
| DT_sat [K]: 0.2  | <b>0.2</b>   |
| Velocity, in [m/s]: 9.49   |  |
| Valve state: -   |  |
| Connection: OK   |  |
| Result:   |                                   |

# CO<sub>2</sub>

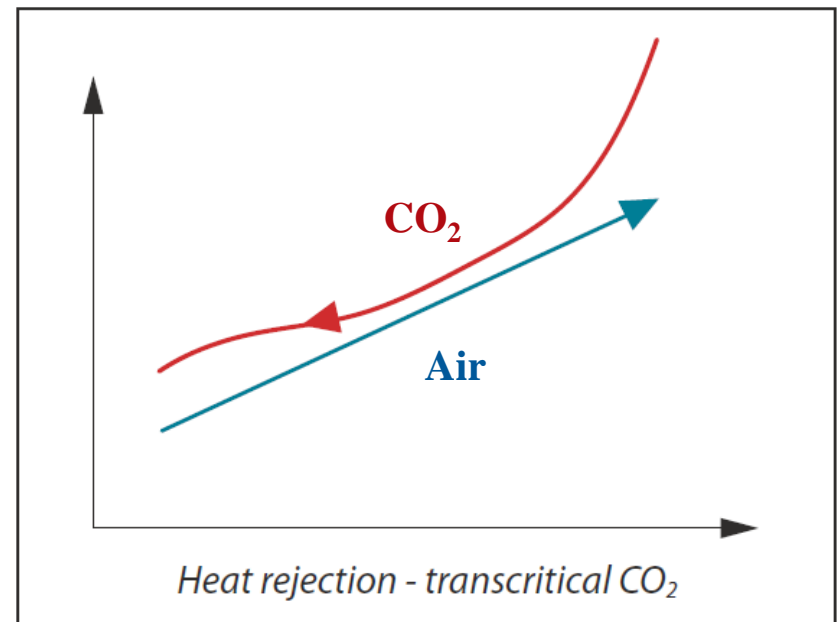
| Evaporator   | Compressor   |
|--|--|
|   <p>Copper pipe<br/>DIN-EN 28</p> |  <p><b>21,2 m<sup>3</sup>/h</b></p> |
| DP distribution: 100%  | <b>Total</b>   |
| Length [m]: 10.00  |  |
| Angle [deg]: 0   |  |
| DP [bar]: 0.163  | <b>0.163</b>   |
| DT_sat [K]: 0.2  | <b>0.2</b>   |
| Velocity, in [m/s]: 9.86   |  |
| Valve state: -   |  |
| Connection: OK   |  |
| Result:   |                                   |

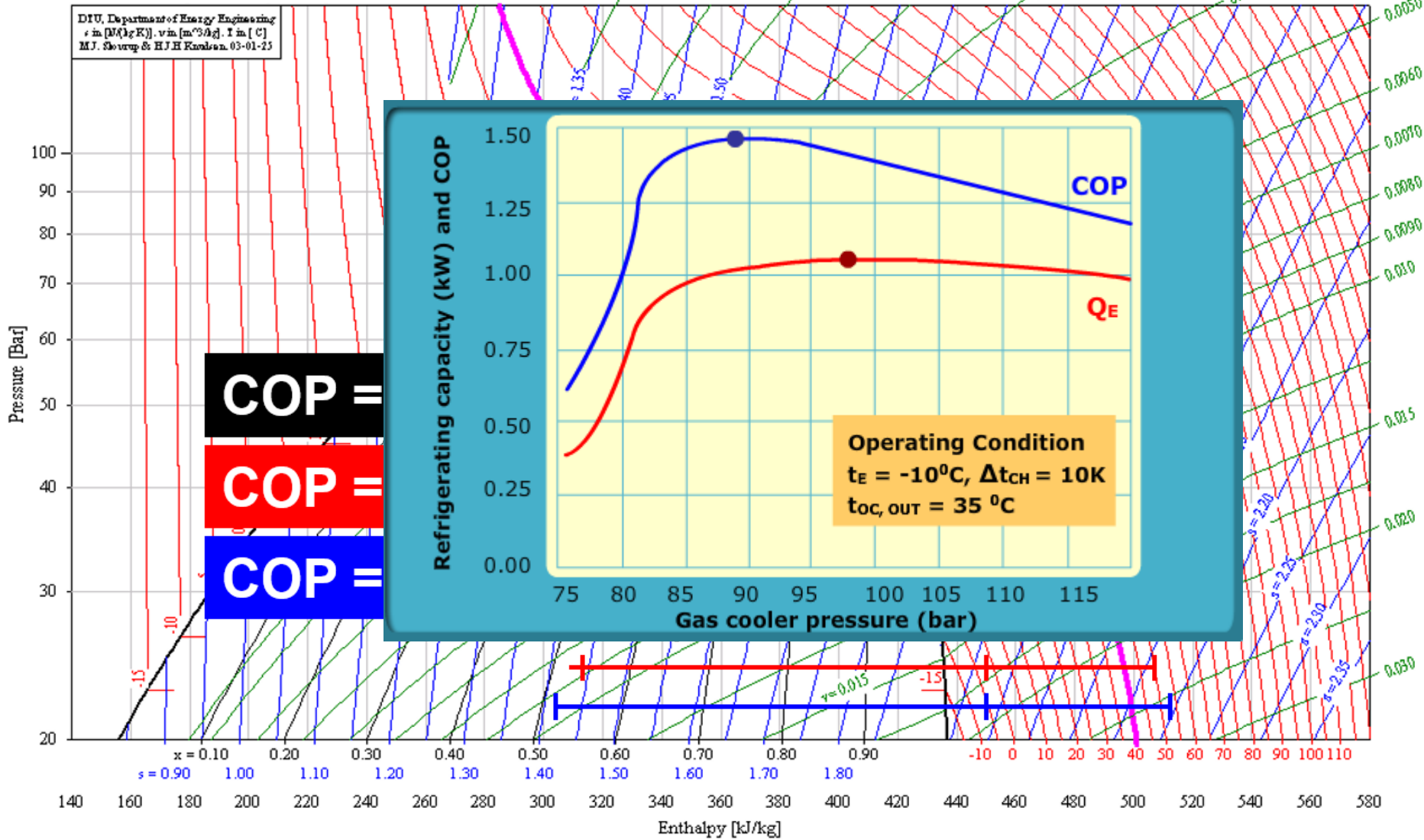


$$\Delta t = 8^{\circ}\text{C} - 12^{\circ}\text{C}$$

- Gas cooler dimensioning for subcritical condition, for air temperature around  $27^{\circ}\text{C}$

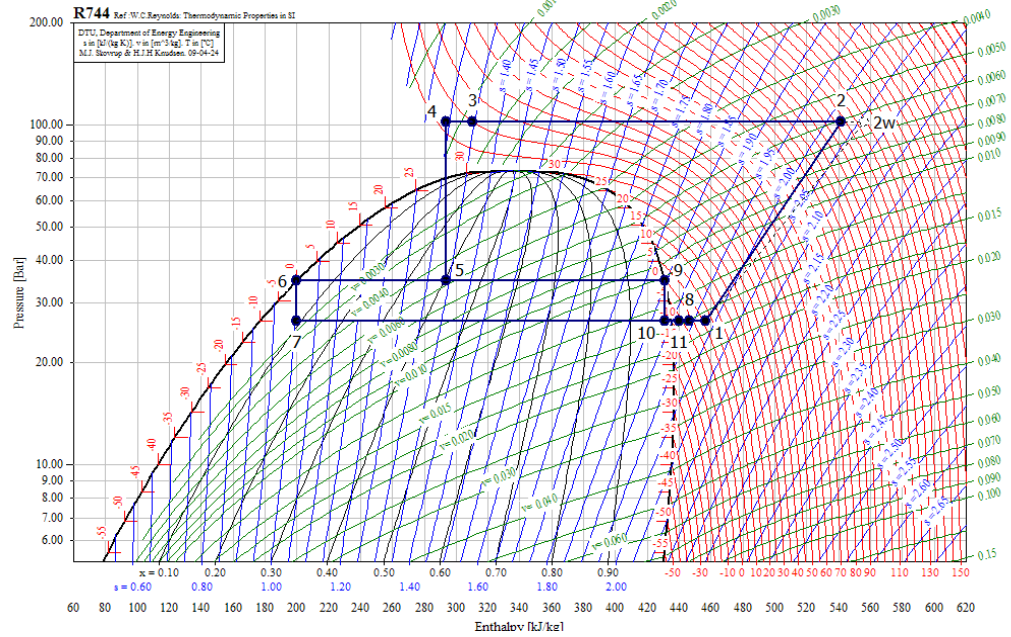
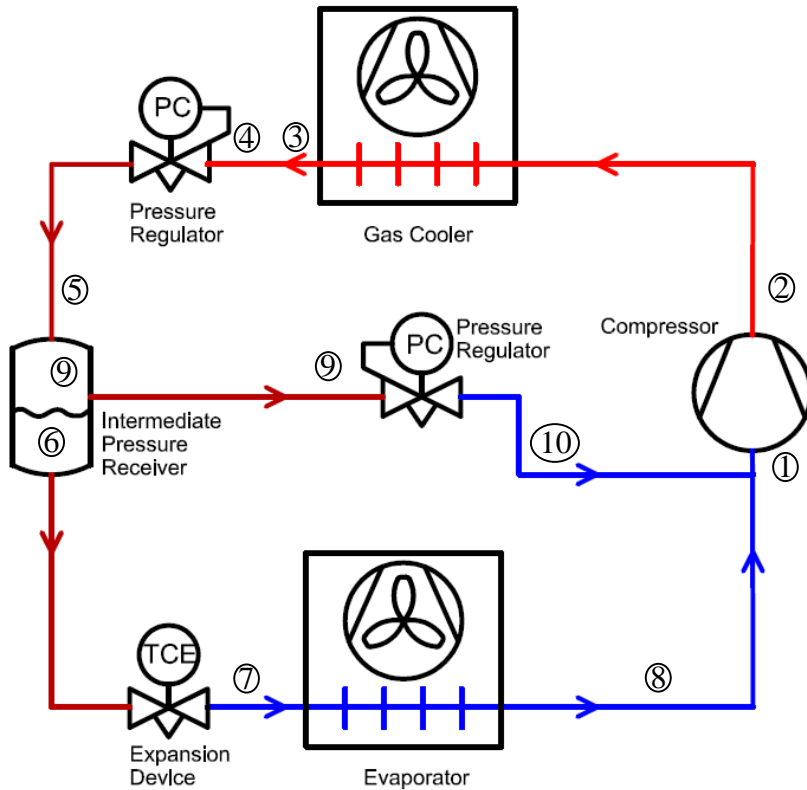
$$\Delta t = 2^{\circ}\text{C} - 6^{\circ}\text{C}$$



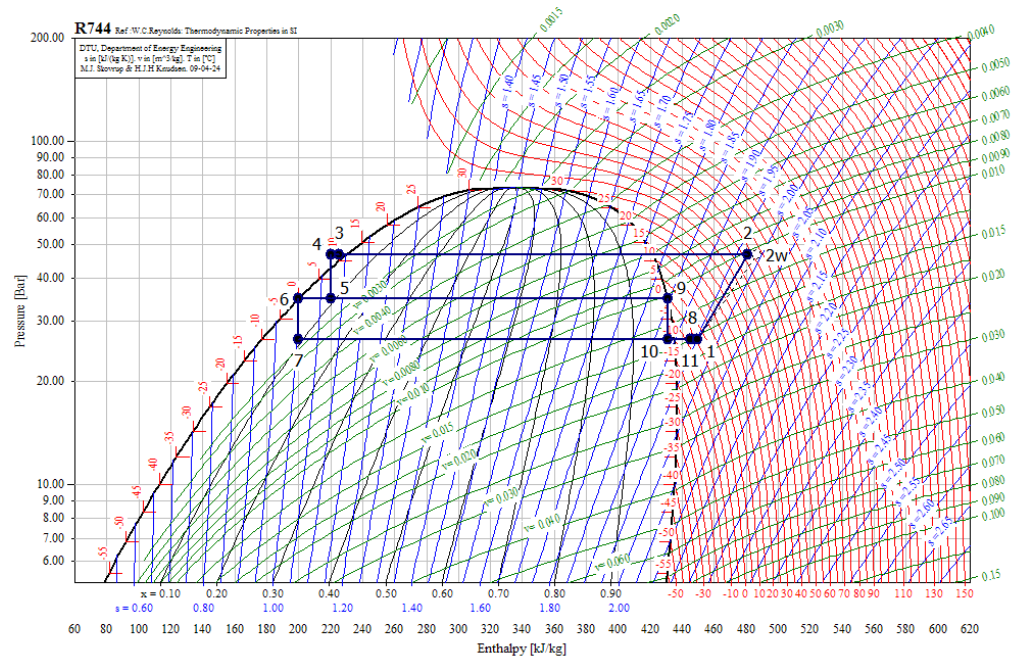
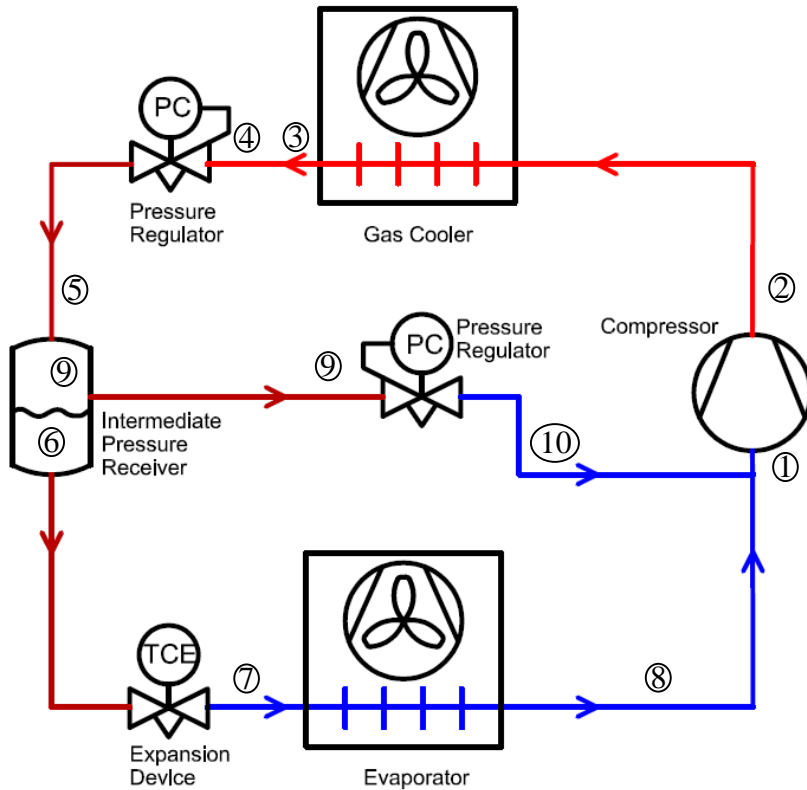




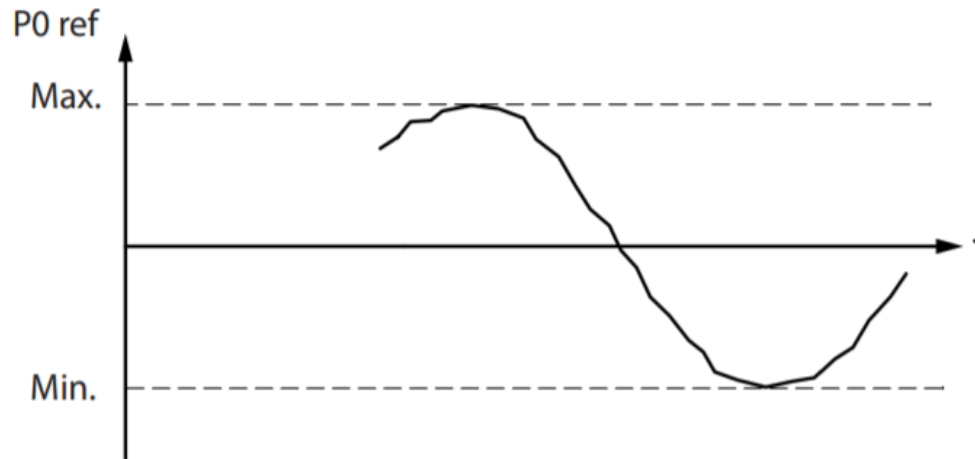
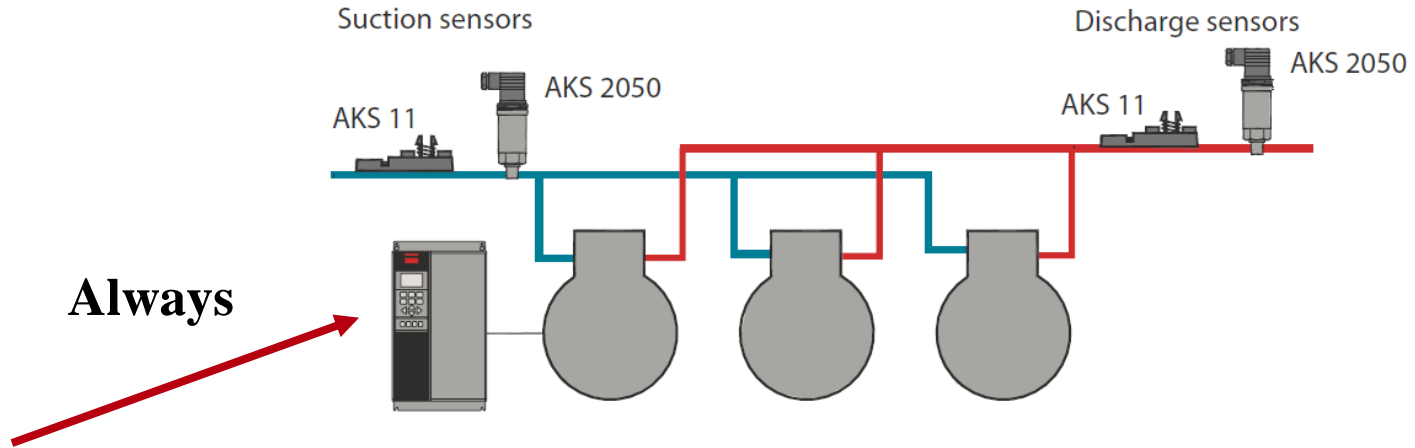
# CO2 one stage with gas bypass



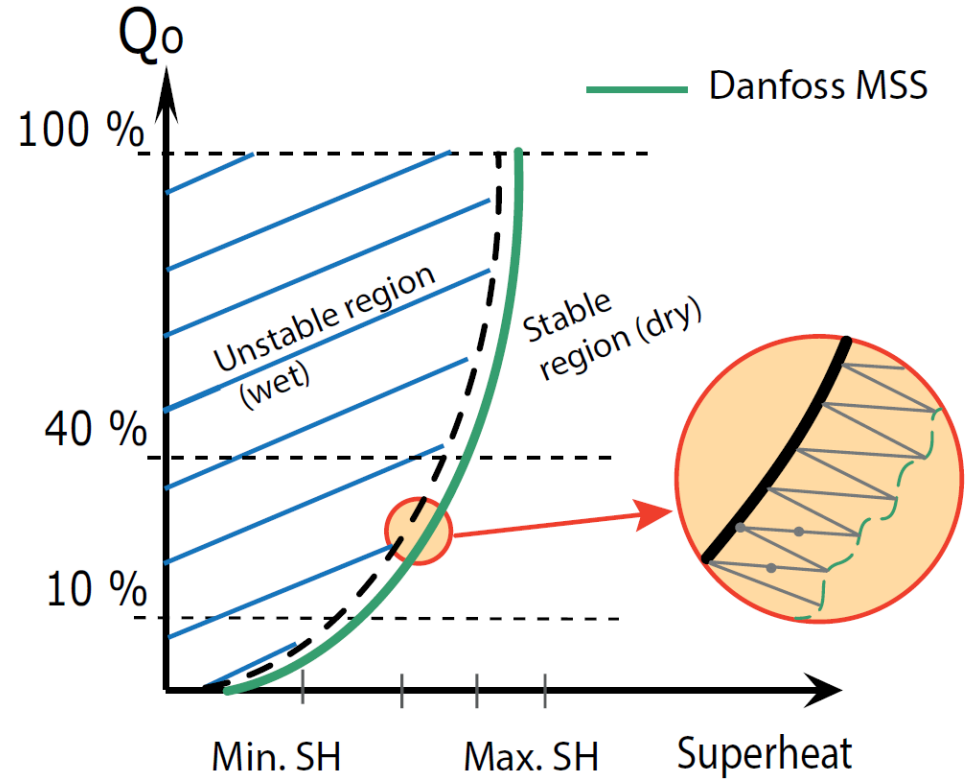
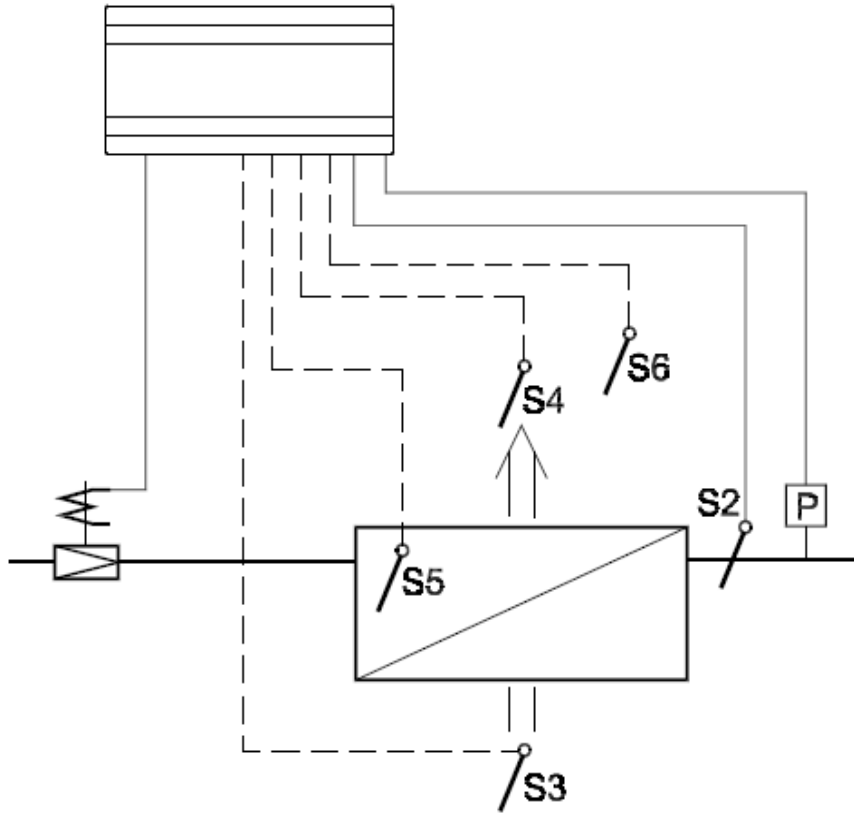
# CO2 one stage with gas bypass



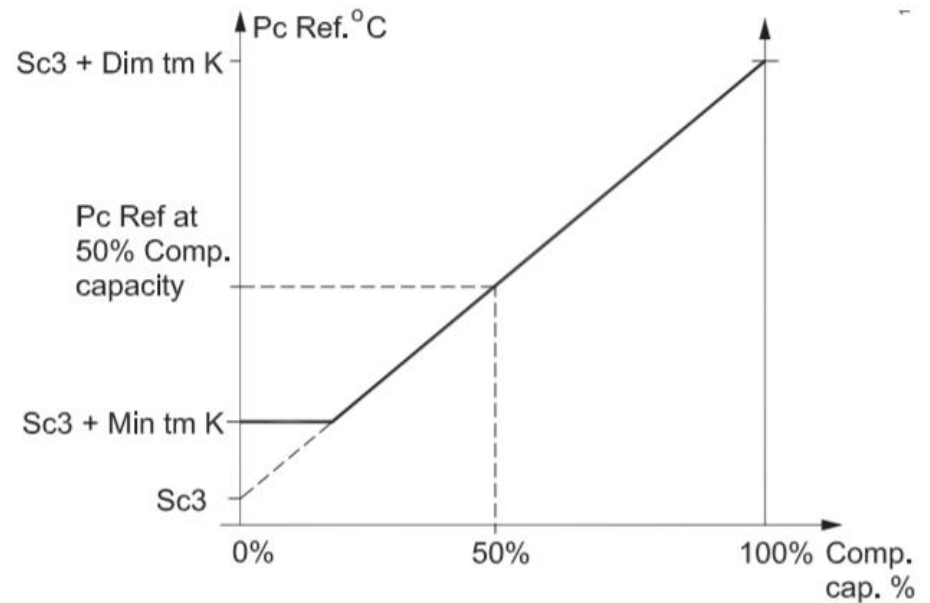
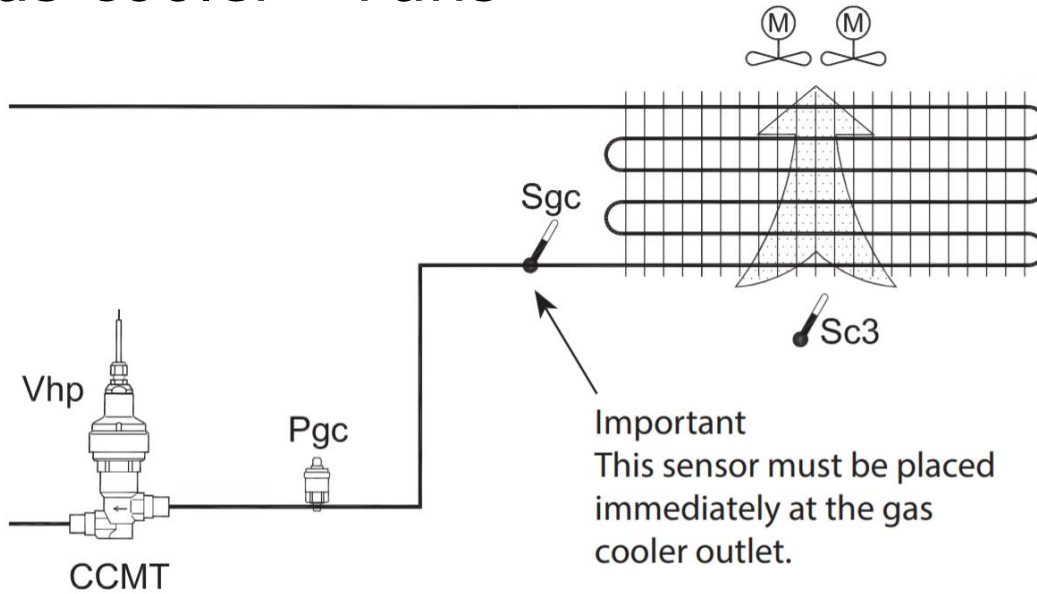
# Compressors



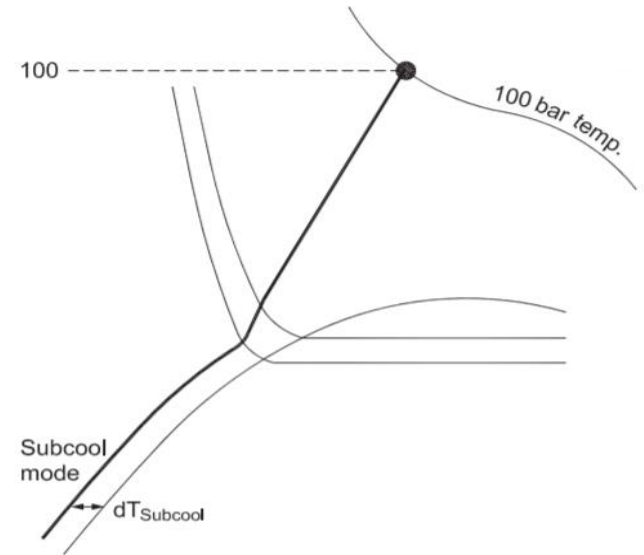
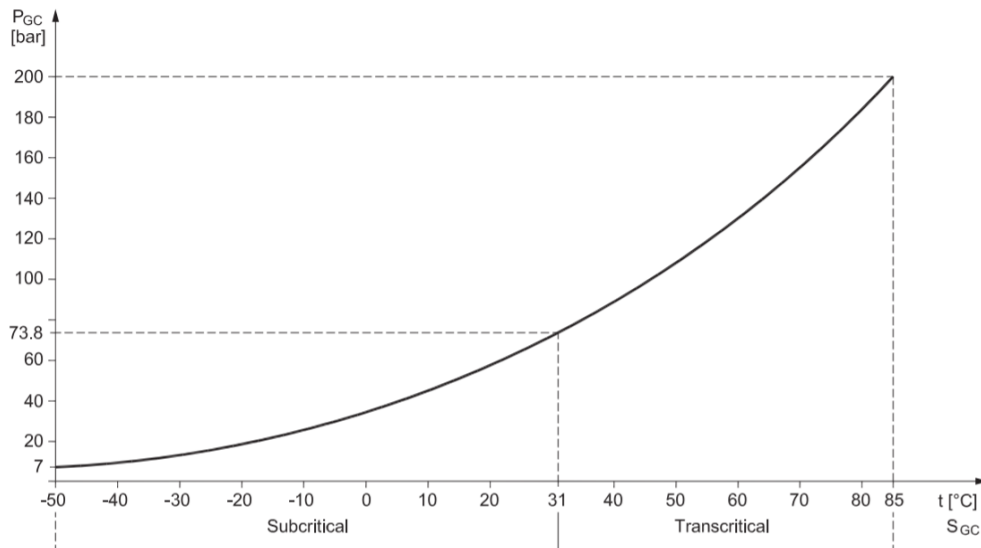
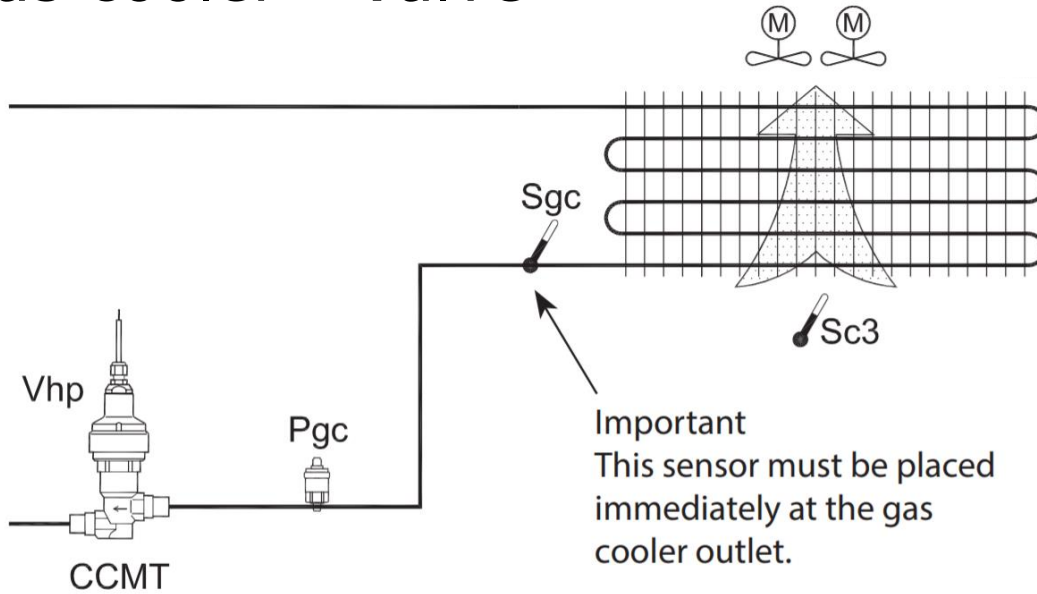
# Evaporators



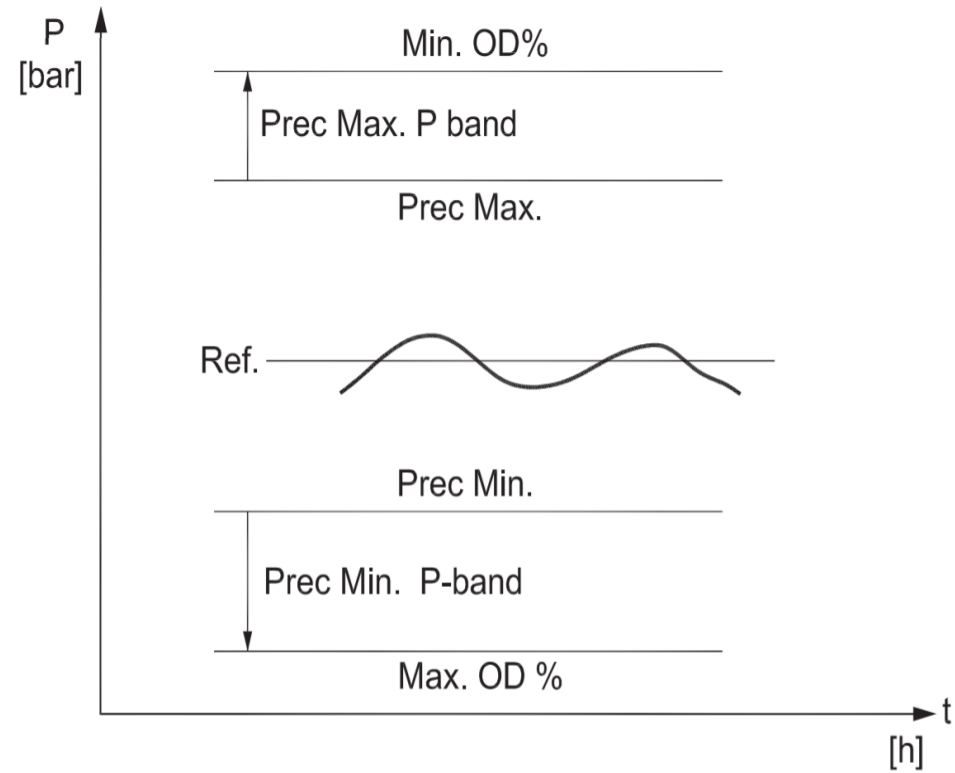
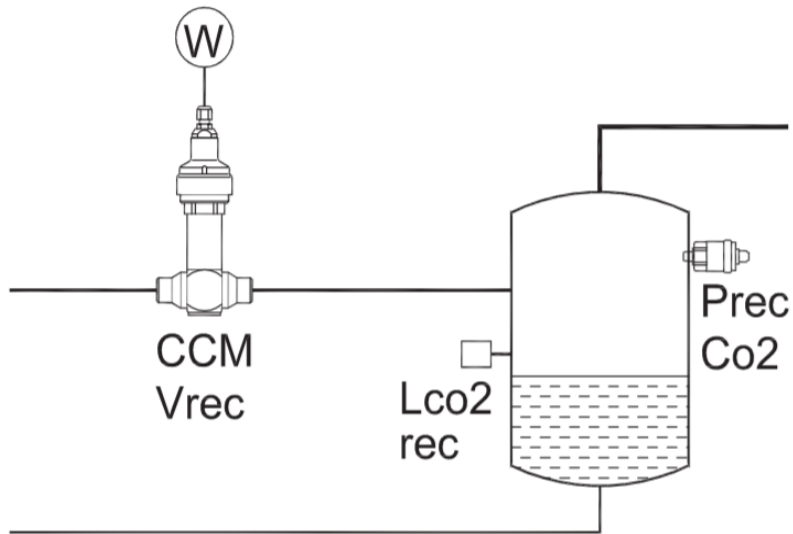
# Gas cooler - Fans



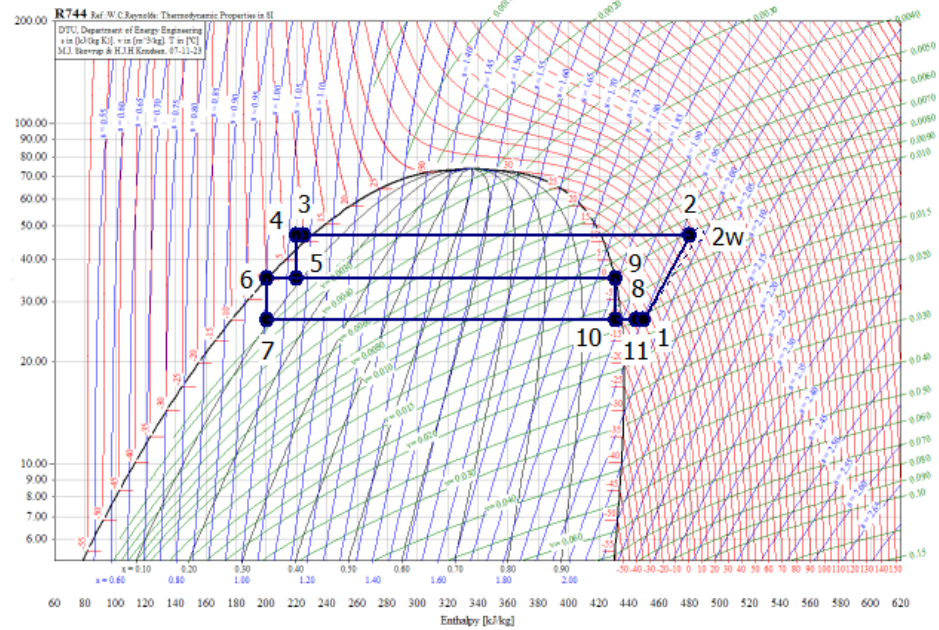
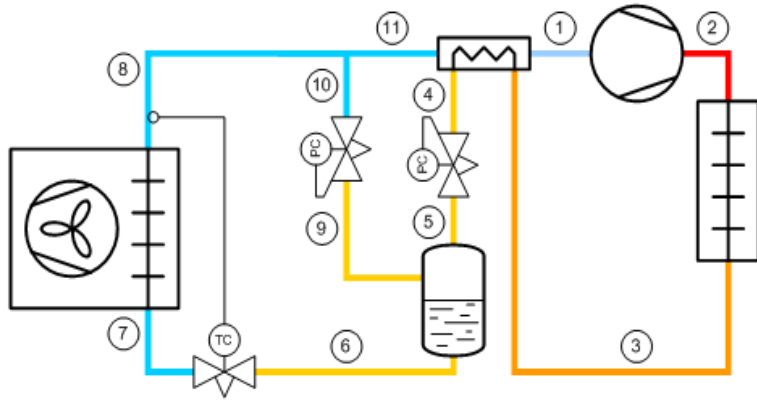
# Gas cooler - Valve



# Receiver - Valve



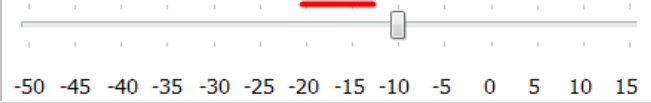
# CO2 one stage with gas bypass



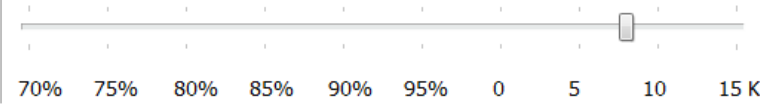
**COP<sub>c</sub> = 6.09**

**COP<sub>h</sub> = 6.94**

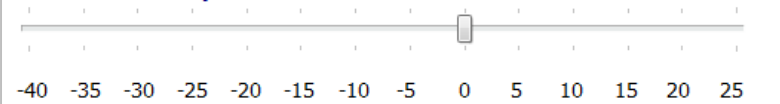
Evaporation temperature: -10 °C



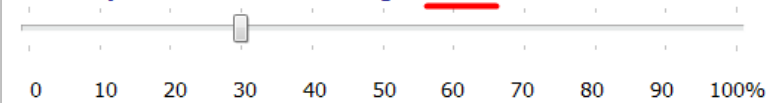
Outlet from evaporator. Superheat: 8 K



Intermediate temperature: 0 °C



Efficiency of internal heat exchanger: 30 %



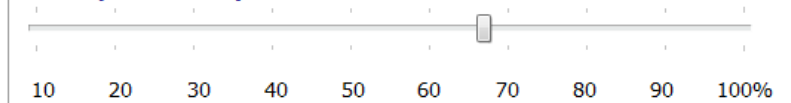
High pressure: 47 bar



Outlet temperature from gas cooler: 10 °C

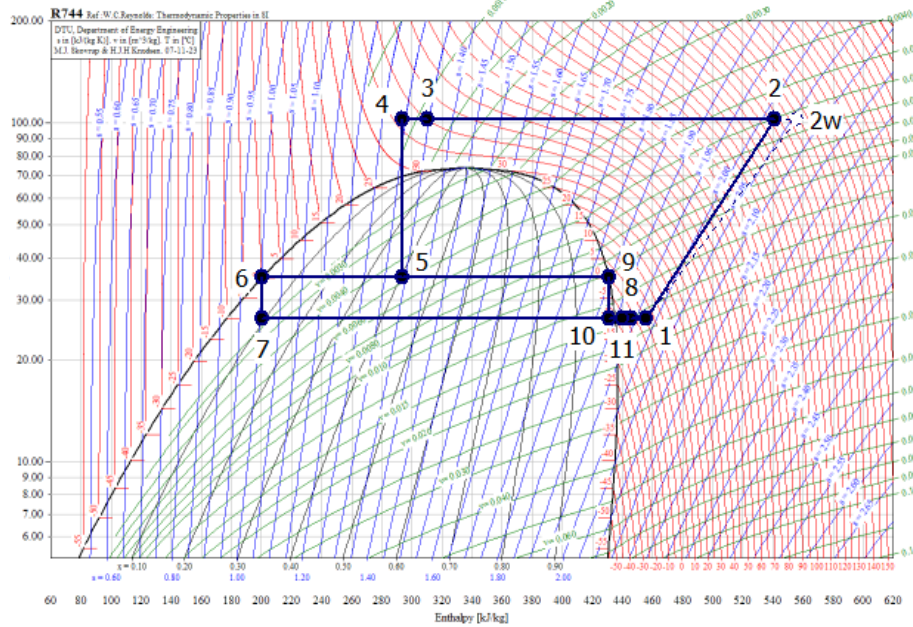
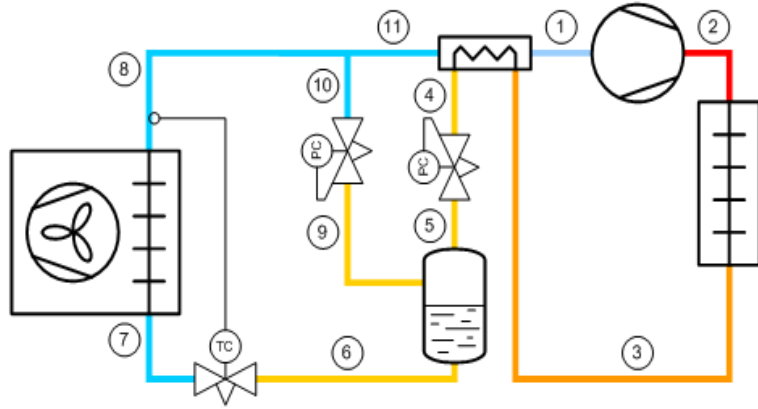


Isentropic efficiency: 67 %



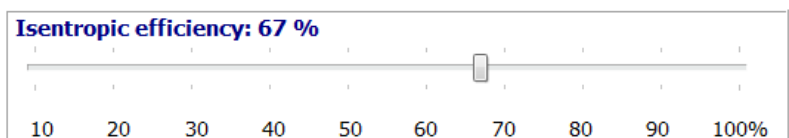
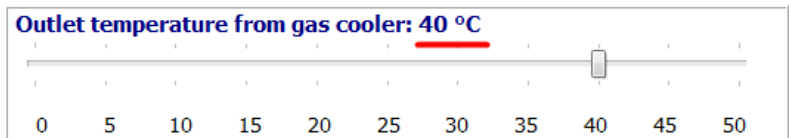
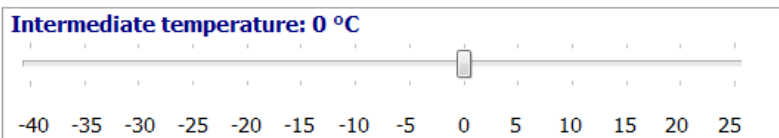
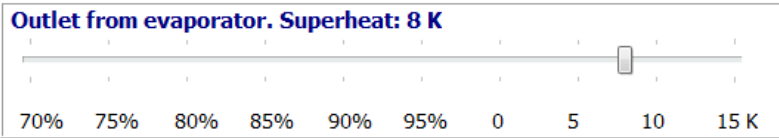
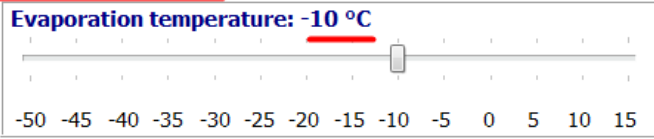


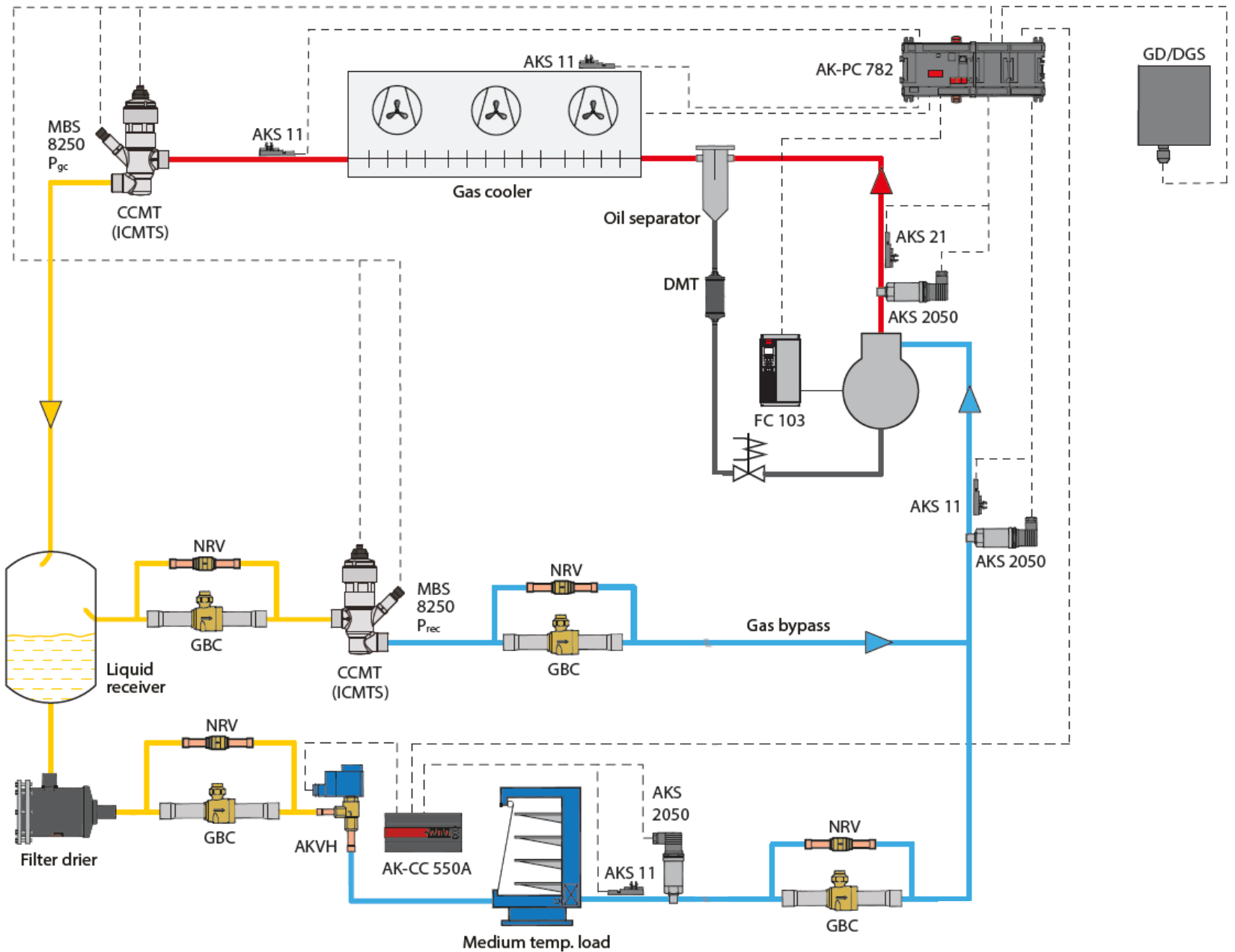
# CO2 one stage with gas bypass



**COP<sub>c</sub> = 1.46**

**COP<sub>h</sub> = 2.31**





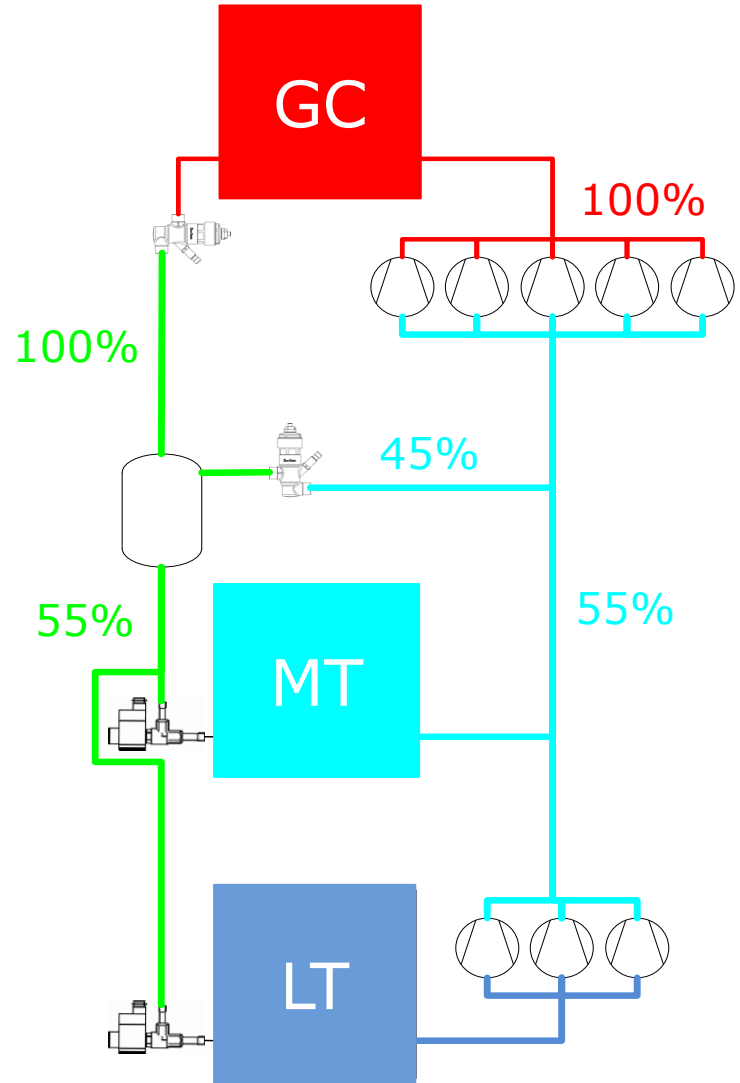
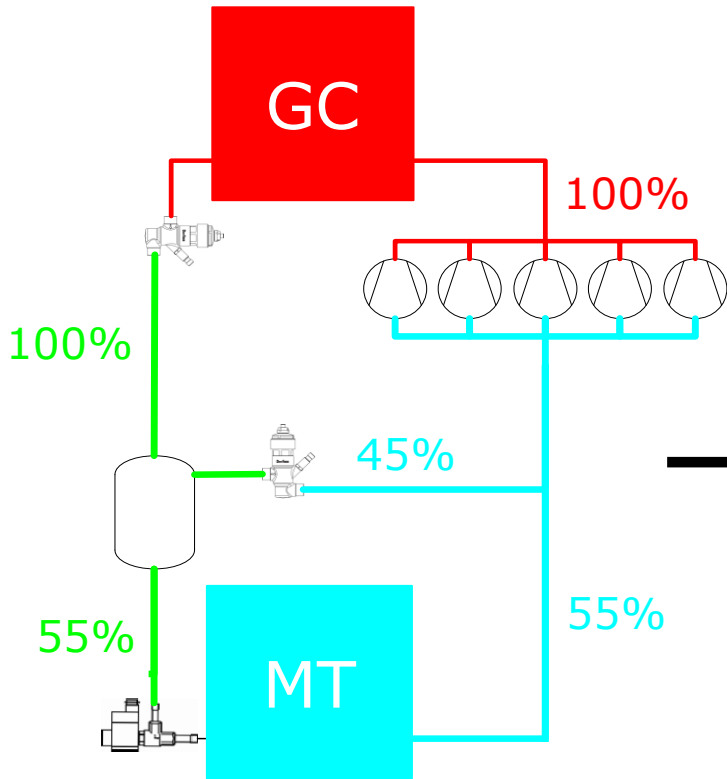
# 1<sup>st</sup> generation: Booster system

110 bar

37 bar

30 bar

16 bar



# 1<sup>st</sup> generation: Booster system

