Various evaporator configurations for CO_2 based refrigeration systems to enhance the performance

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Introduction

Heat transfer rate during evaporation:

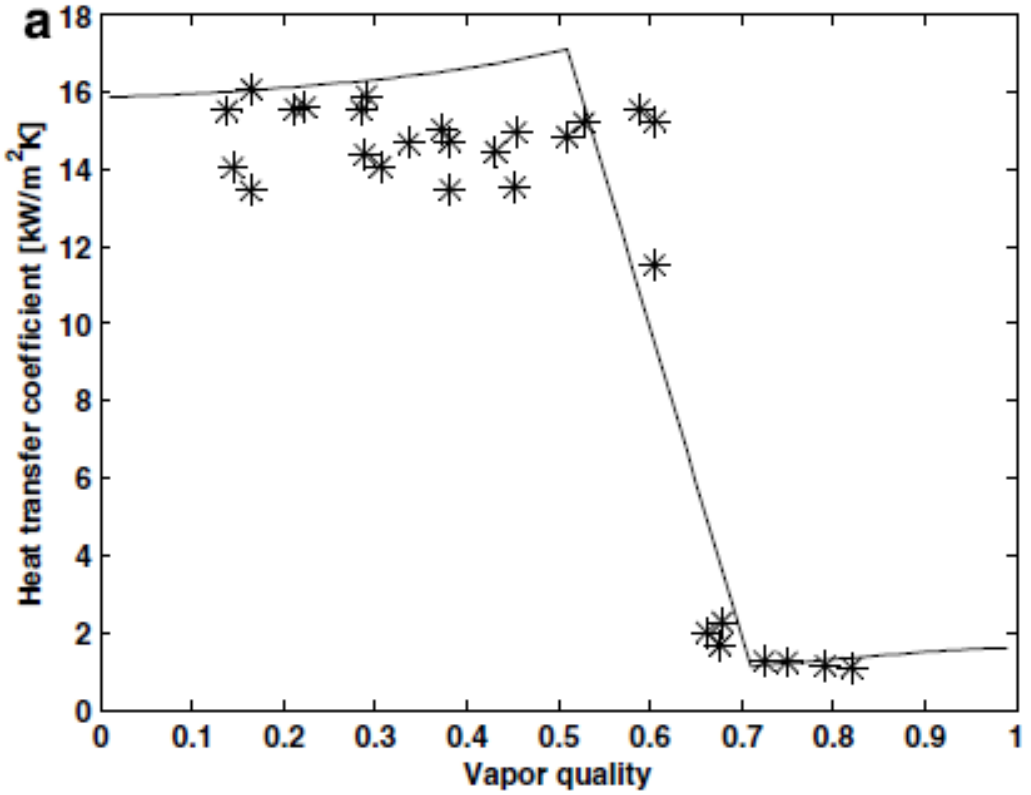
- Increases for higher heat transfer coefficient
  - ❖ Lower vapor fraction (increased liquid contact with evaporator surface)

This leads to:

- Better overall performance
- Compact heat exchanger design

Objective:

- Investigate various evaporator configurations
- Design specifications for compact heat exchangers



Heat transfer coefficient of CO_2 during evaporation, d = 1 mm, G = 720 kg. m^{-2}. s^{-1} [1]

Evaporator configurations and controls

Can be divided into two broad categories:

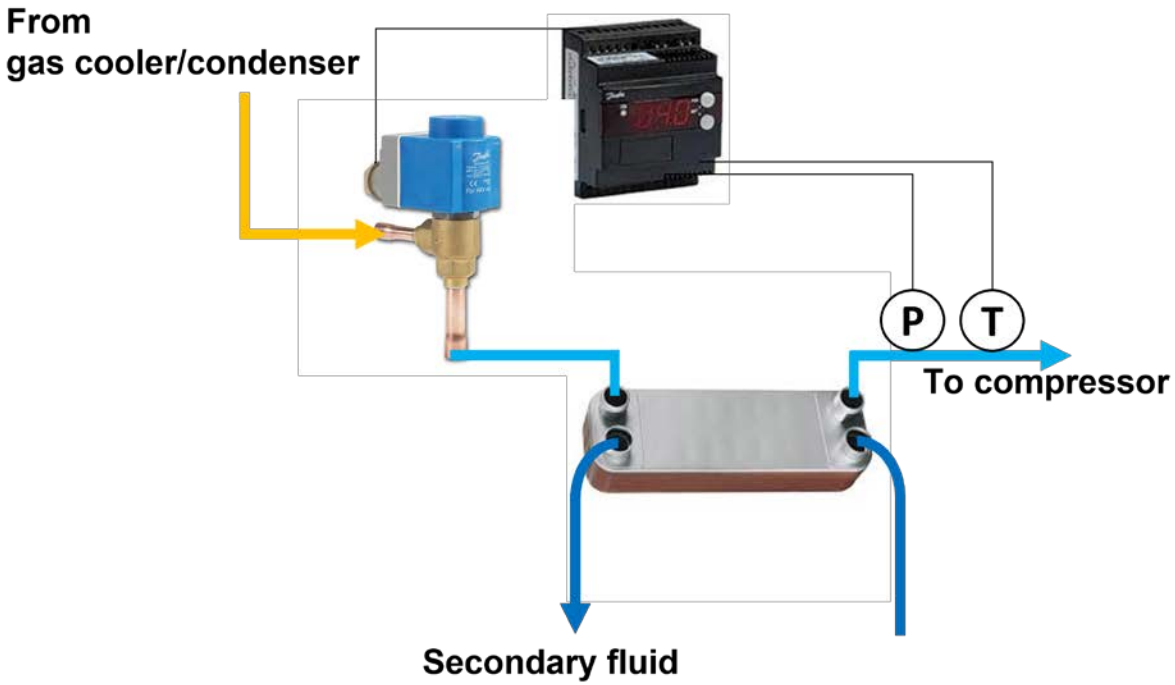
- Dry-expansion (DX) evaporators with superheat control
- Flooded evaporators (including liquid level control)

Dry expansion evaporators with superheat control

- Common solution for small/medium scale units
- Electronic expansion valve is commonly used
- Not recommended for large scale units

Major drawbacks:

- ❖ Poor liquid contact (95% – 99% vapor contact [2])
- ❖ Pressure drop and request for lower evaporation temperature to achieve superheat
- ❖ Maldistribution within evaporators in parallel runs
- ❖ Pulsations in the system

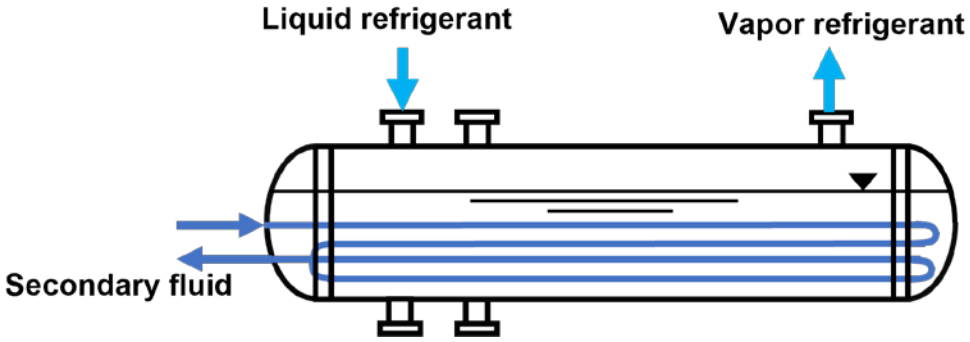


Flooded evaporators with liquid level control

Can be classified into two broad categories:

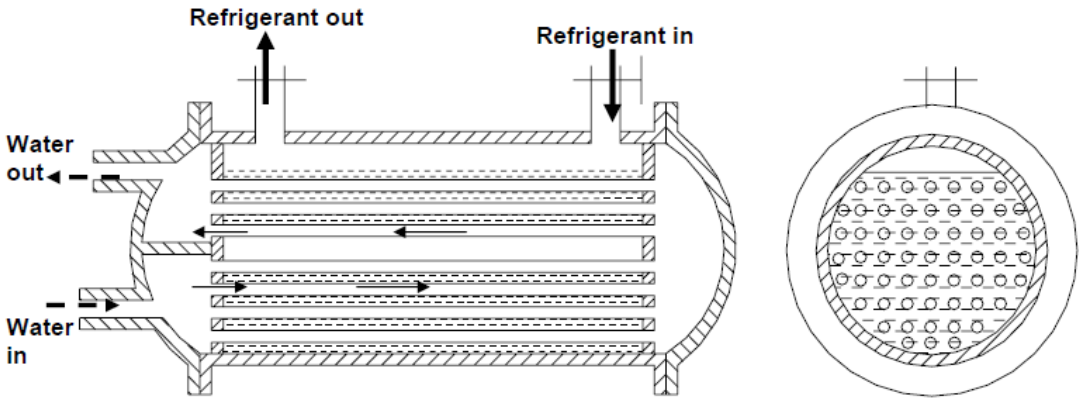
➡ **Without liquid circulation**

- ❖ Shell and tube heat exchanger is used.
- ❖ Tubes are entirely submerged.



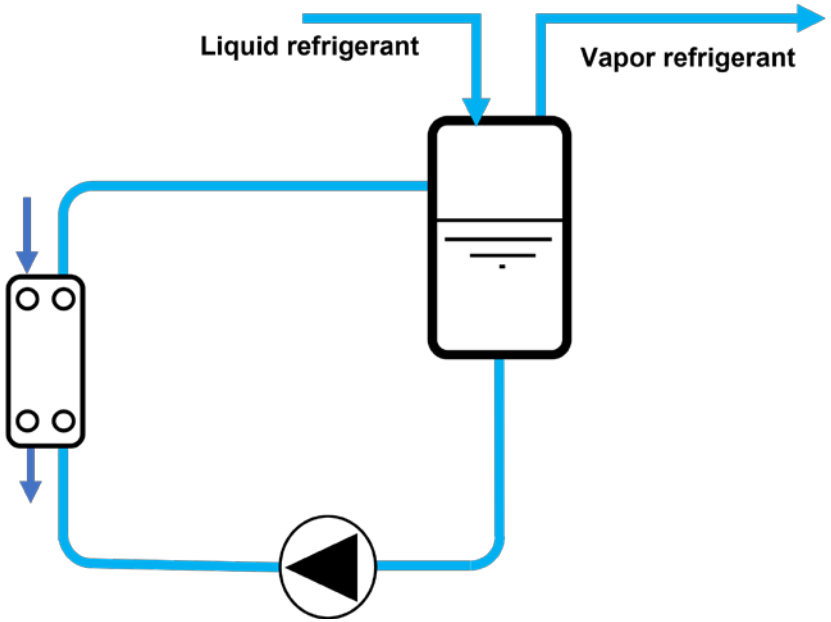
➡ **With liquid circulation**

- ❖ Fouling issues on water side

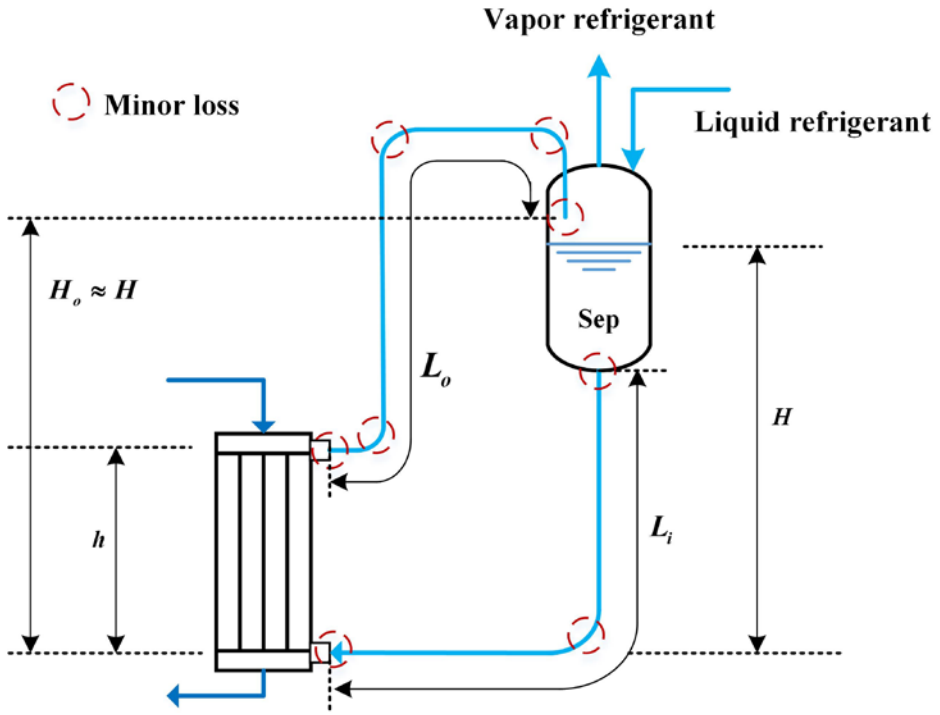


Flooded evaporators with liquid level control

With liquid circulation



Forced circulation with pump



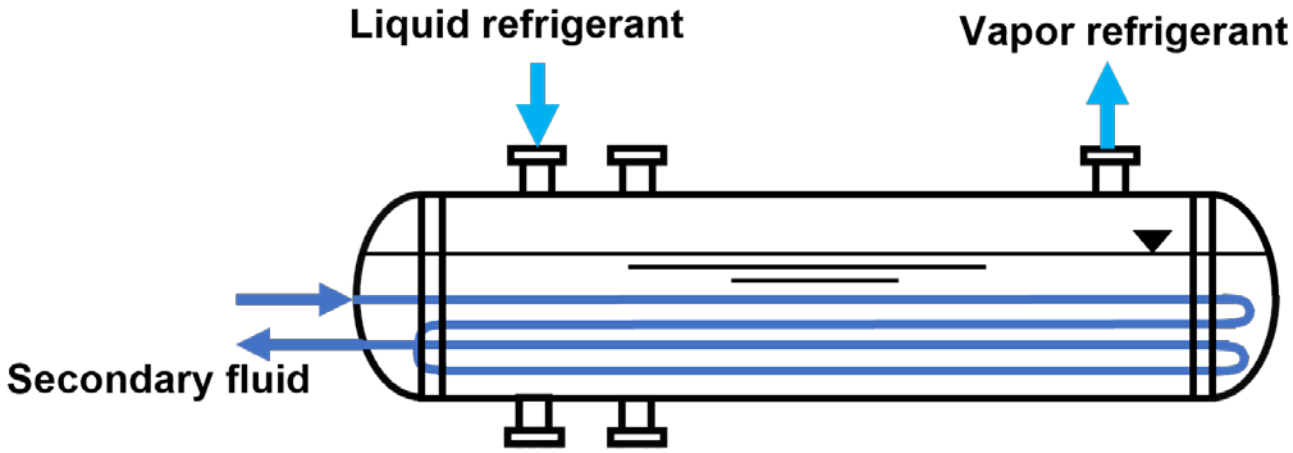
Gravity-fed evaporator loop

Various evaporator configurations to be investigated at test-facility available at NTNU/SINTEF

- Shell and tube heat exchanger
- Gravity-fed evaporator loop
- Novel two-stage evaporator configuration

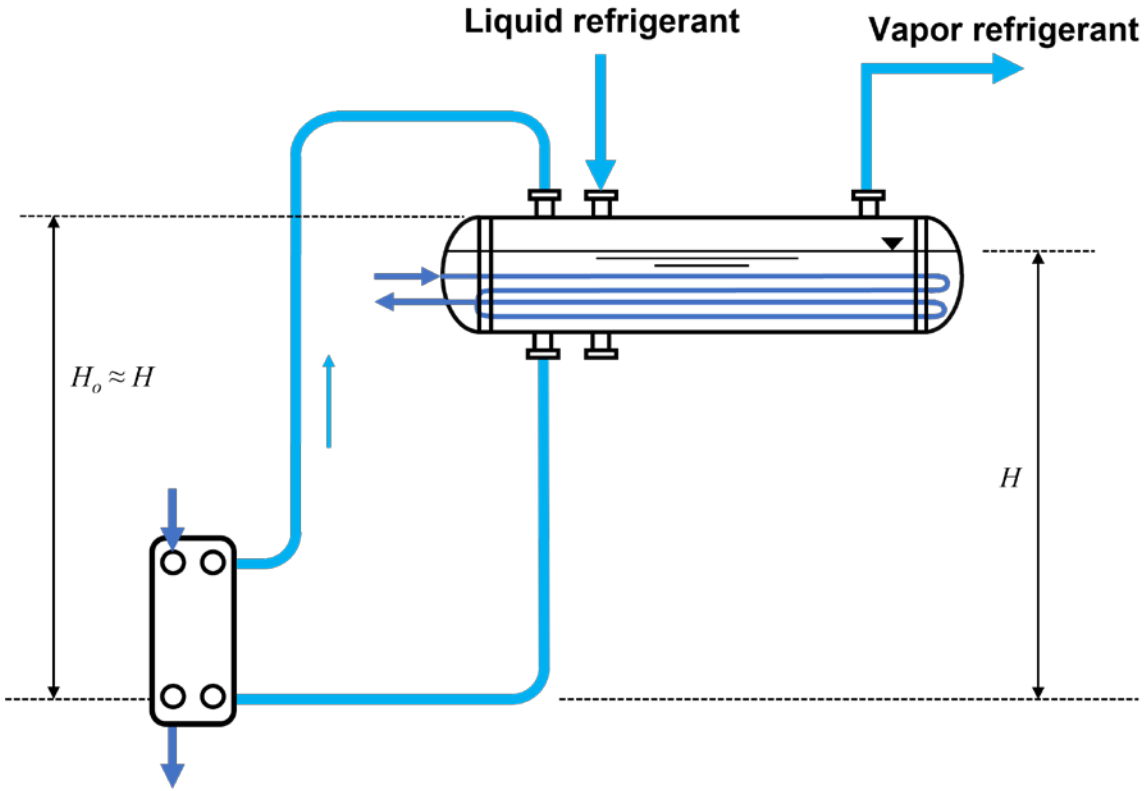
Shell and tube heat exchanger

- Utilization of waste heat
- Non clean fluids (grey water)
  - Singe circuit on water side



Gravity-fed evaporator loop / self-circulation loop

- Natural circulation due to density difference
- Selection of static head, *H*
  - ❖ To overcome total pressure drop in loop

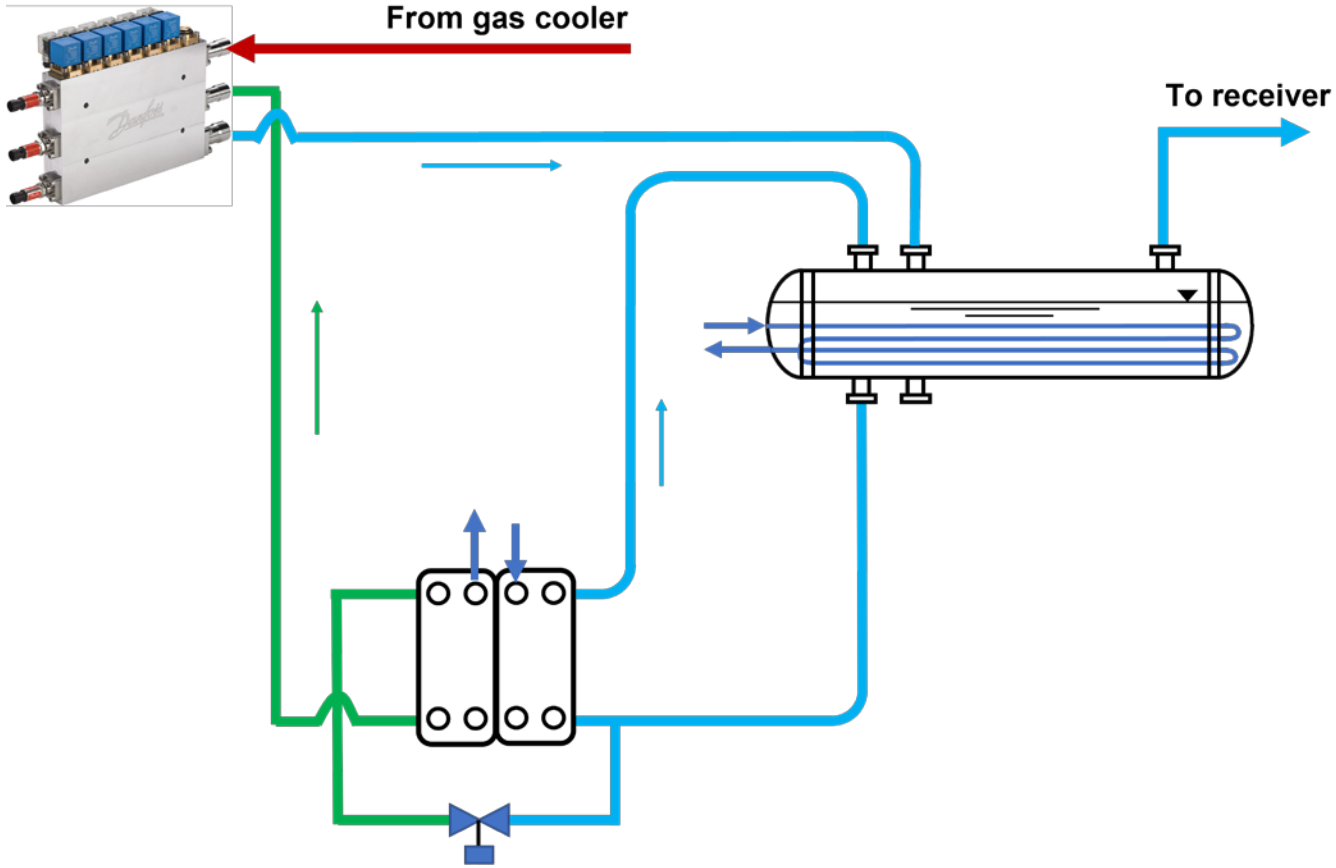


Novel two-stage evaporator configuration

- Very compact arrangement
  - ❖ *Significant less pipework on water side*

To be verified in early 2022

→ paper at GL2022



Test-facility available at NTNU/SINTEF

Summary

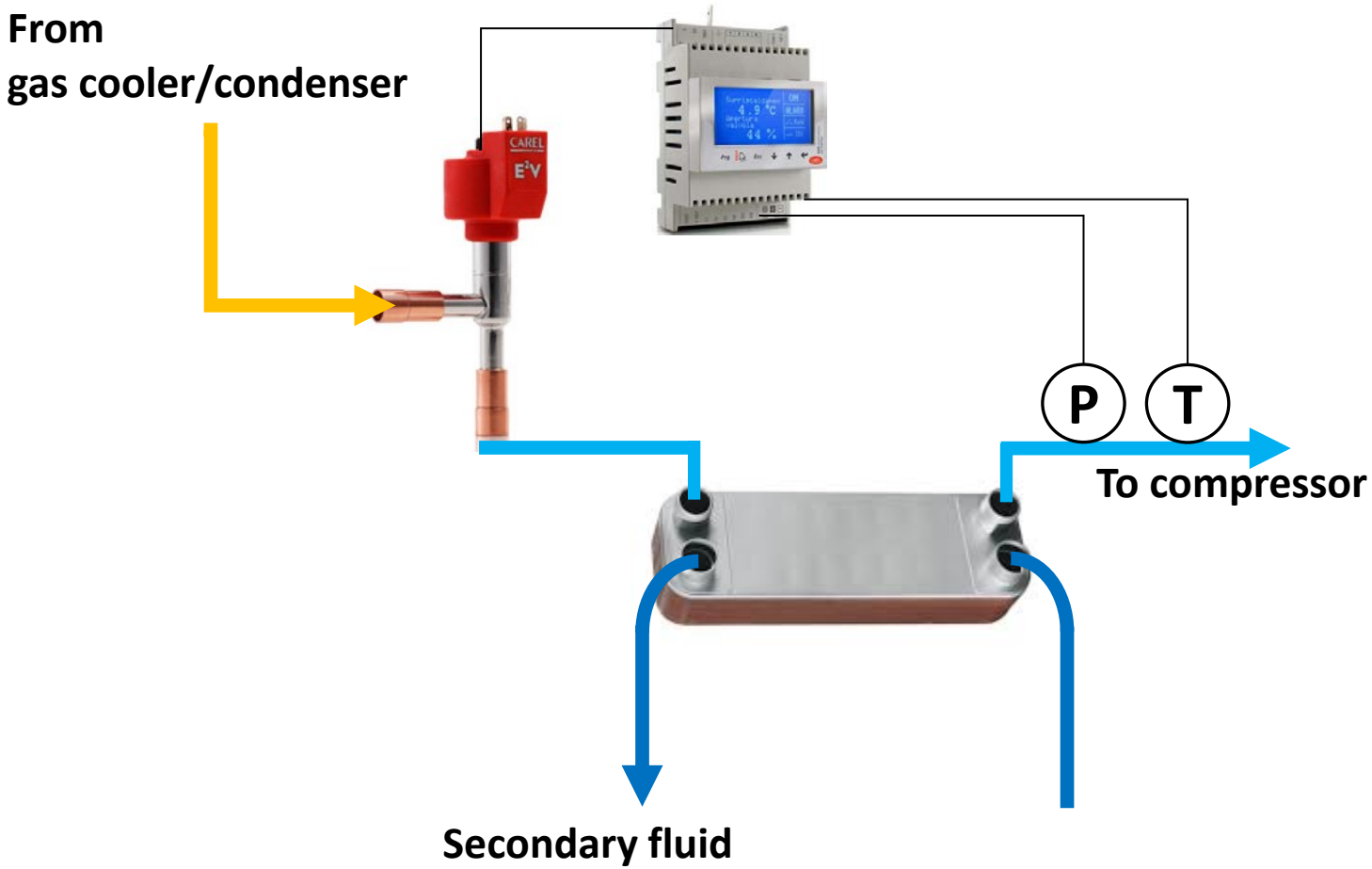
Flooded heat exchangers have advantages:

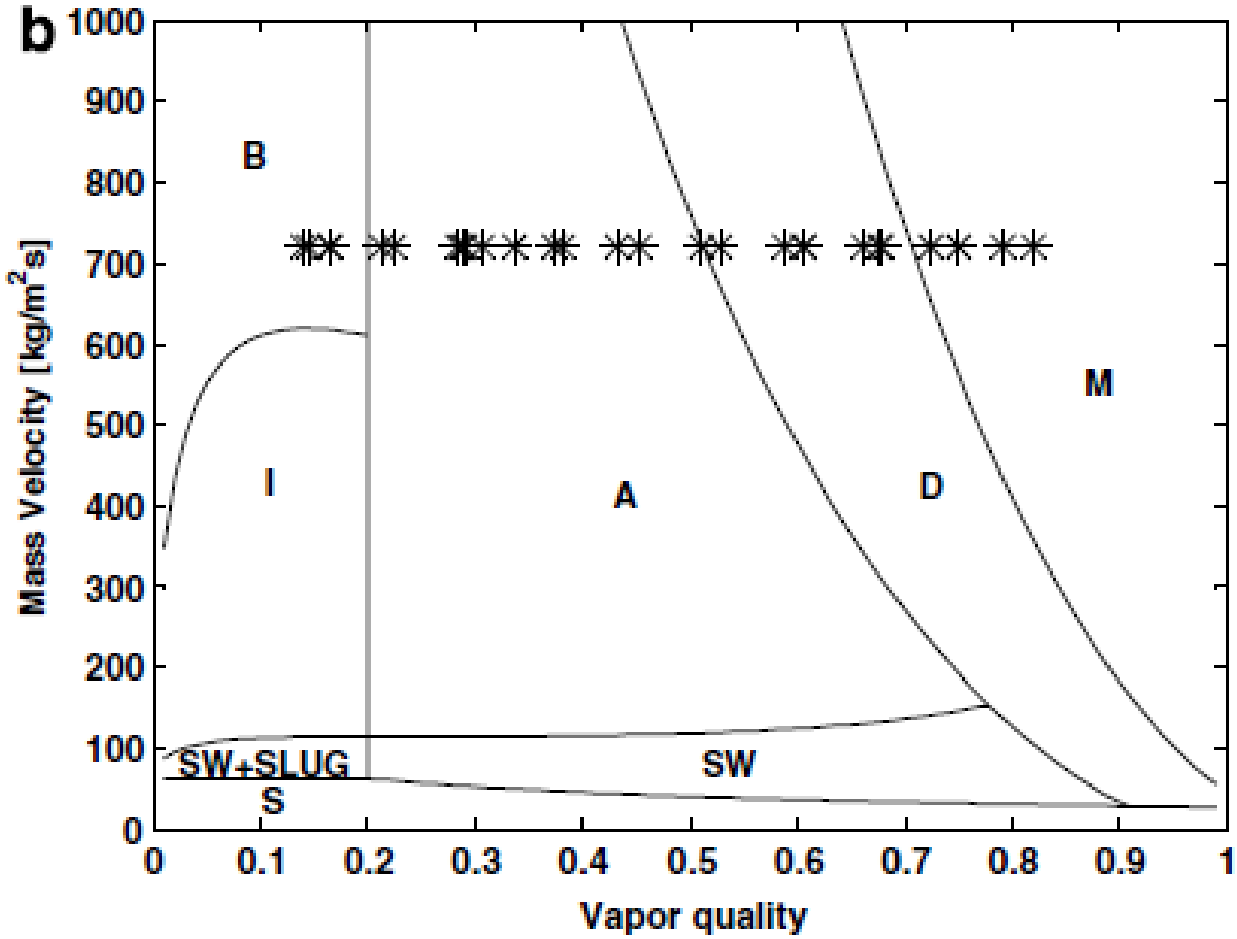
- Higher heat transfer rates
- More compact design
- Increased overall performance

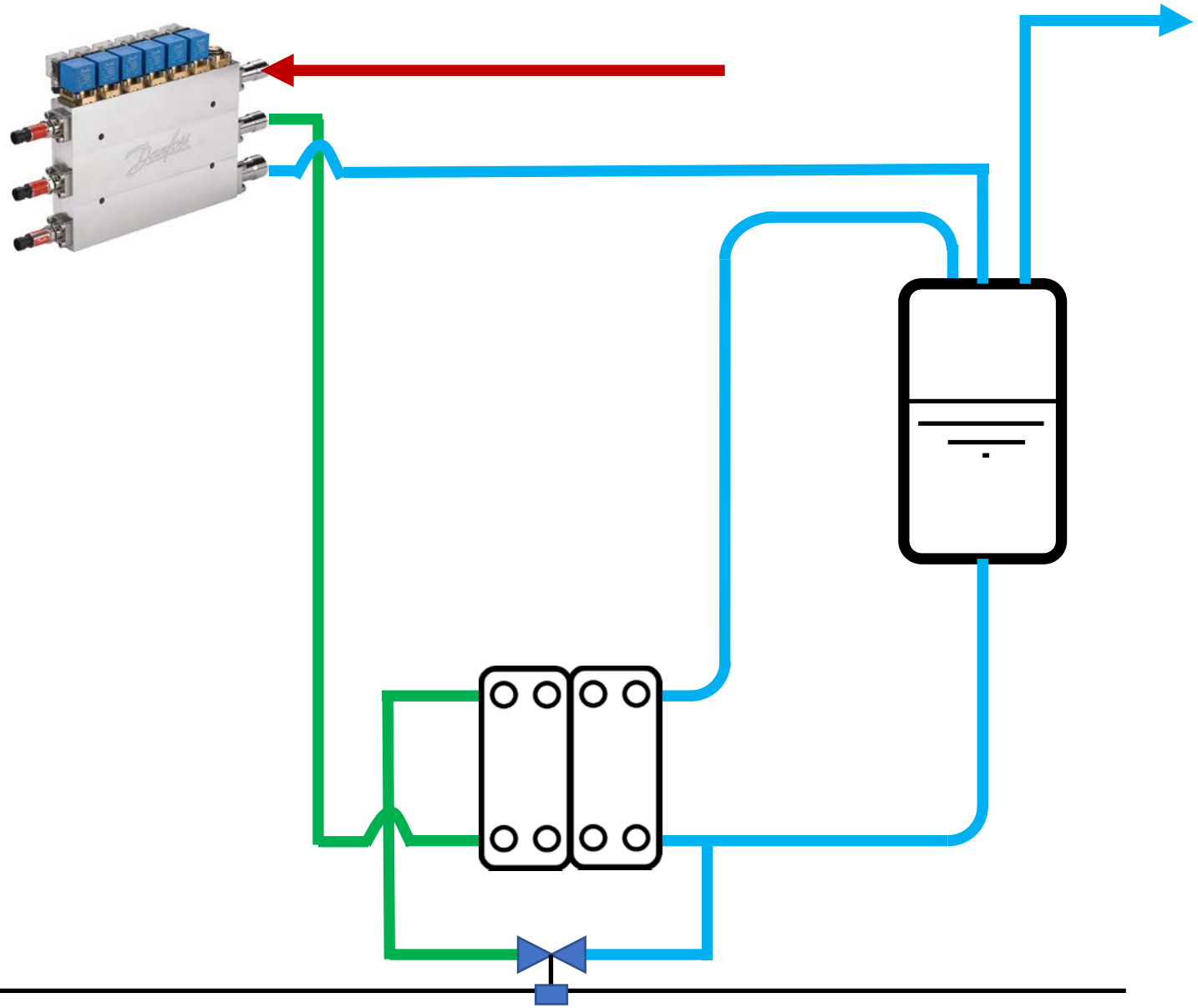
References

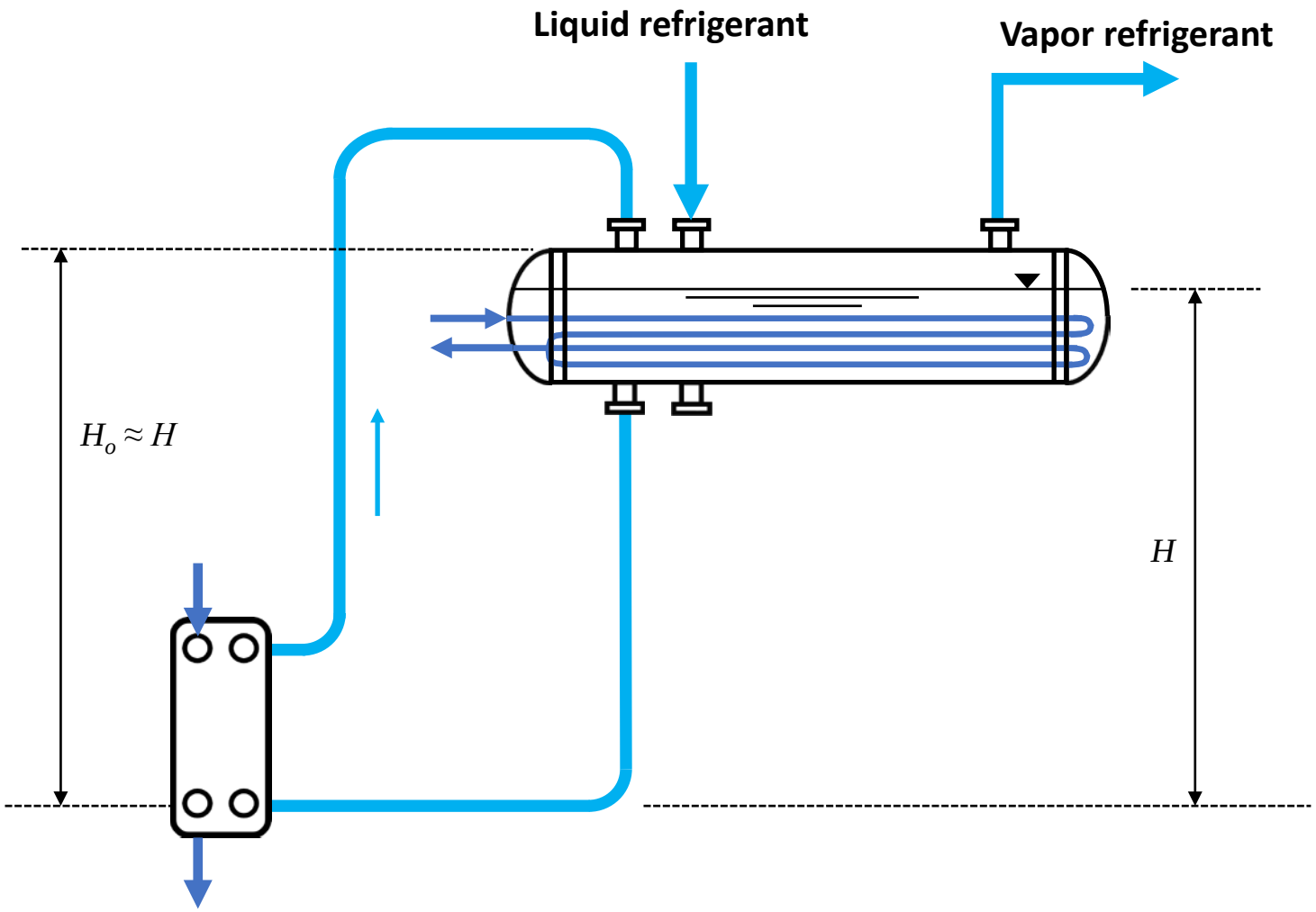
1. Cheng, L., Ribatski, G., Thome, J.R., New prediction methods for CO2 evaporation inside tubes: Part II – An updated general flow boiling heat transfer model based on flow patterns, *Int J Heat Mass Transf.* (2008) 51, 125 – 135.
2. Lorentzen, G., Evaporator design and liquid feed regulation, *Bull HR, Annexe 1958-2 Moscow* (1958) 235-256

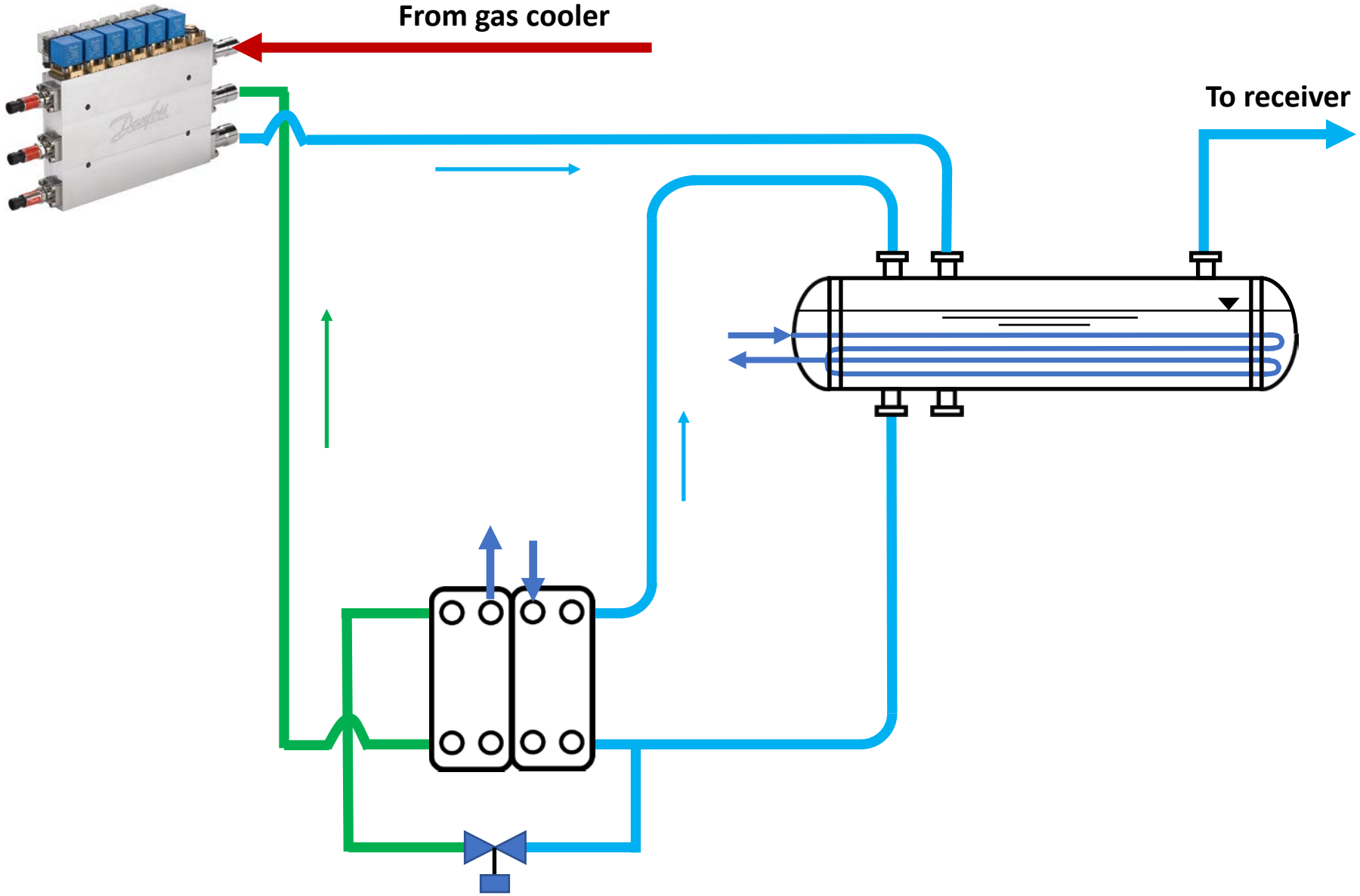
Thank You /
Tusen takk

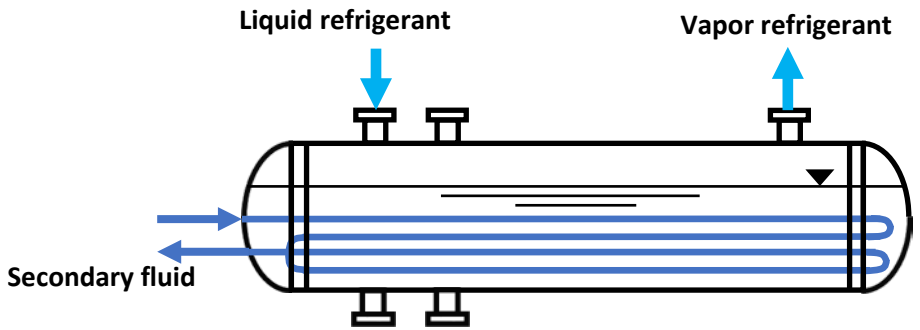

From
gas cooler/condenser
CAREL
E²V
P
T
To compressor
Secondary fluid

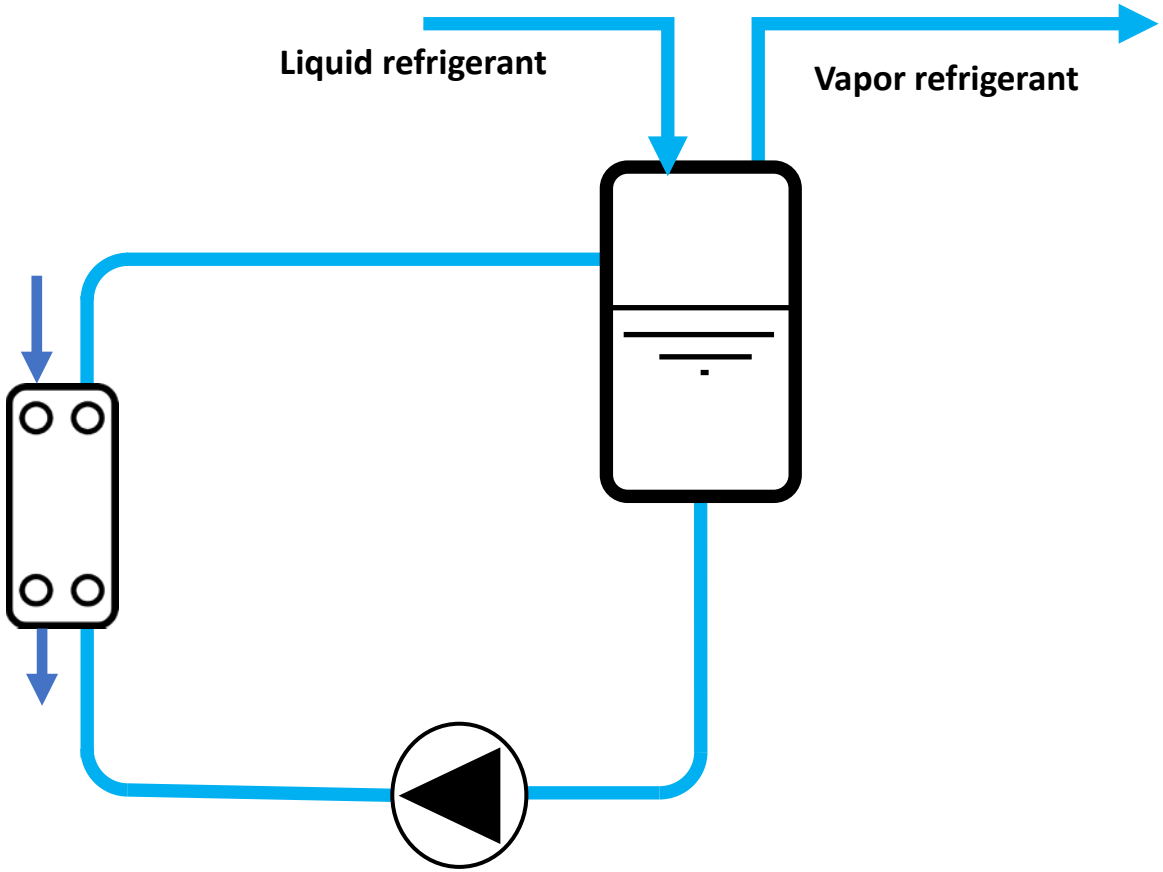

b
Mass Velocity [kg/m²s]
Vapor quality
B
I
A
D
M
SW+SLUG
S
SW
0
100
200
300
400
500
600
700
800
900
1000
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1




Liquid refrigerant
Vapor refrigerant
$H_o \approx H$
H


From gas cooler
To receiver


Liquid refrigerant
Vapor refrigerant
Secondary fluid


Liquid refrigerant
Vapor refrigerant