Bring ideas to life
VIA University College

DES M1
Refrigeration circuit, components

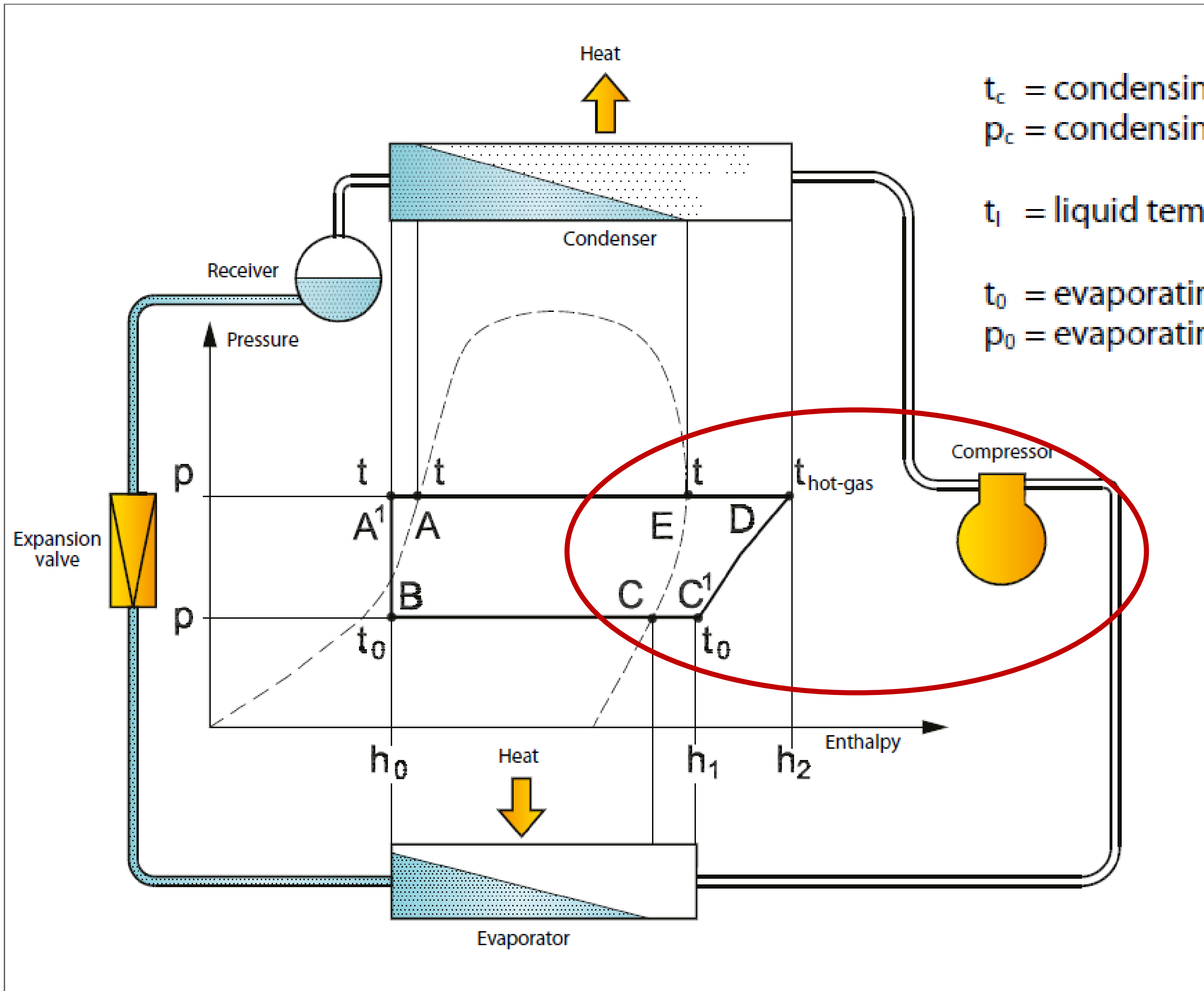
Lesson 4

- Feed back on hand in exercise Refrigeration Circuit 1
- Intro to compressors
- Basic calculations for compressor dimensioning
- Evaporator and condenser dimensioning

Refrigeration circuit components

- **Intro to compressors**
- Basic calculations for compressor dimensioning
- Evaporator and condenser dimensioning

Refrigeration circuit
Compression



t_c = condensing temperature
p_c = condensing pressure

t_l = liquid temperature

t_0 = evaporating temperature
p_0 = evaporating pressure

Hermetic compressor video

Commercial refrigeration systems with semi hermetic or hermetic compressor

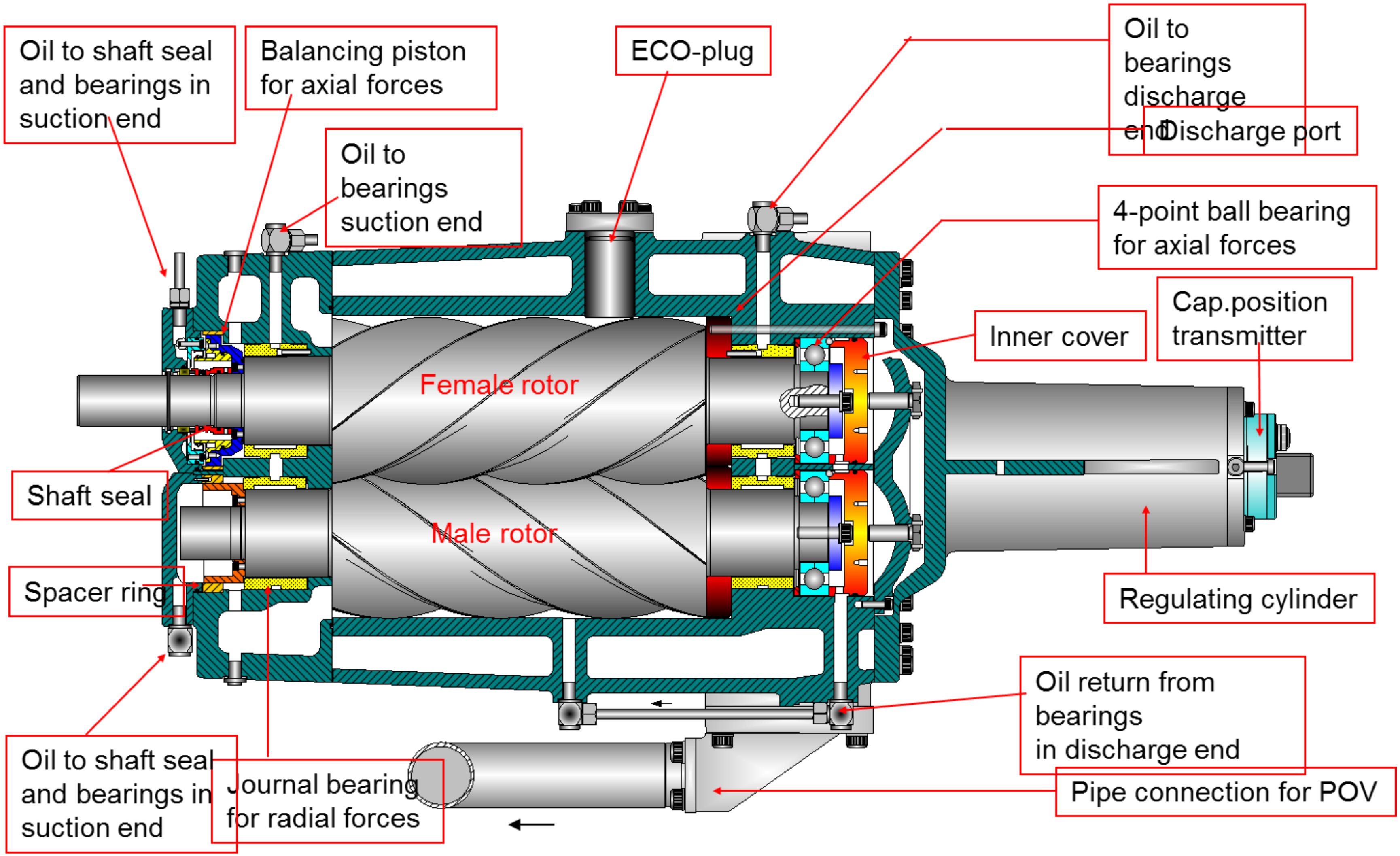
Open compressor example

SMC 108 single-stage reciprocating compressor unit with Unisab III systems controller

From Sabroe catalogue

Screw compressor Internal view

https://youtu.be/stjvbAO_6JQ



SAB 202 - principle

Industrial system with open compressors

Refrigeration circuit components

- Intro to compressors
- **Basic calculations for compressor dimensioning**
- Evaporator and condenser dimensioning

Chosing the right compressor
"The engineer's challenge"

The criteria you have to balance normally include:

- Required capacity
- Operating conditions
- Available space
- Part-load requirements
- Temperature levels
- Energy consumption
- Choice of refrigerant
- Environmental concerns
- Maintenance issues
- Peak vs average ratio.

From Sabroe catalogue

Compressor data Sabroe compressors

Calculated from mass flow rate, volumetric efficiency and specific volume in suction pipe

Should match Cooling Capacity

HPC 108 single-stage reciprocating compressor block (40 bar) with Unisab III systems controller

Model	Number of cylinders	Swept volume at 1500 rpm m³/h	Swept volume at 1800 rpm m³/h	Nominal capacities in kW at 1500 rpm: Heating R717 +35/+72°C	Cooling R717 0/+55°C	Cooling R410A 0/+35°C	Cooling R744 -50/-10°C	Cooling R744 -40/-5°C
HPO 24	4	97	116	267	71	117	92	138
HPO 26	6	146	175	397	106	176	138	207
HPO 28	8	194	233	529	141	235	184	276
HPC 104 S	4	226	N/A	629	168	284	228	338
HPC 106 S	6	339	N/A	942	252	426	343	507
HPC 108 S	8	452	N/A	1256	335	568	457	676

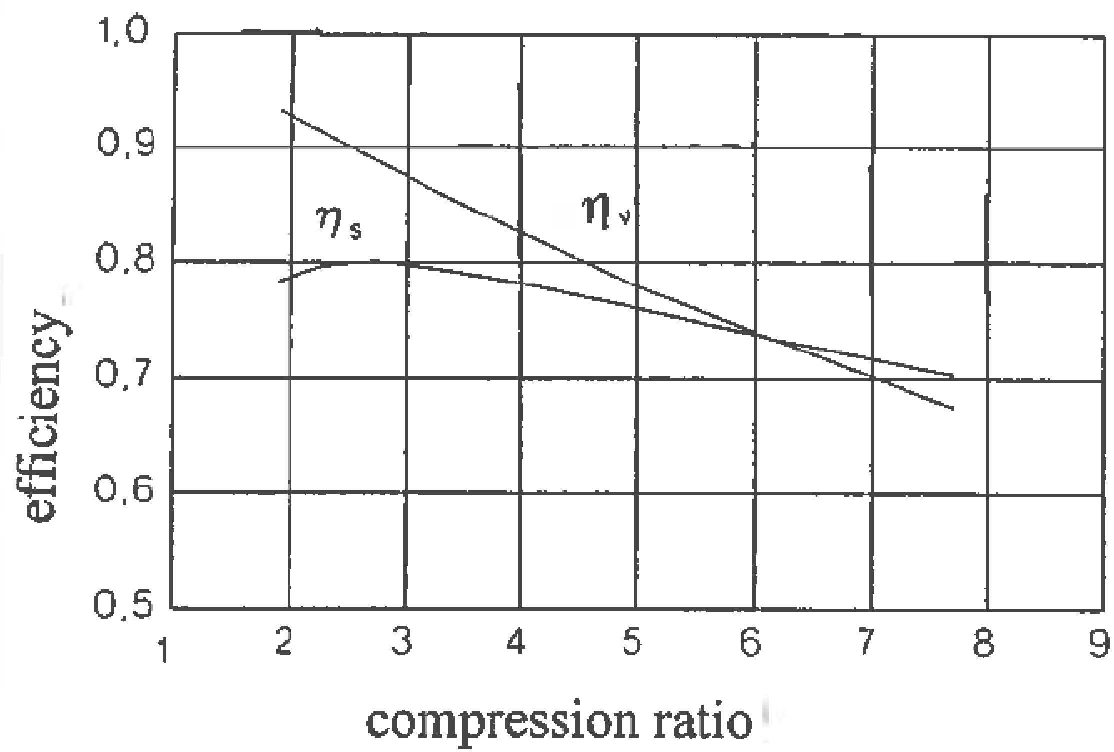
Compressor dimensioning overview

To find	Calculate	Using
Mass flow, q_m	Cooling capacity, ϕ_0	Cooling load
Pressure ratio	Evaporator and condenser temperatures	Room and outdoor temperatures
Compressor/motor size	Compressor shaft power, P_{shaft}	Isentropic efficiency, η_i
Compressor discharge temperature, h_2	Cooled/uncooled compression	Compressor cooling flow rate
Compressor capacity	Swept volume, $V_{s,v}$	Volumetric efficiency, η_s
COP_{El}	Compressor motor power, P_m	Motor efficiency

Compressor Isentropic efficiency

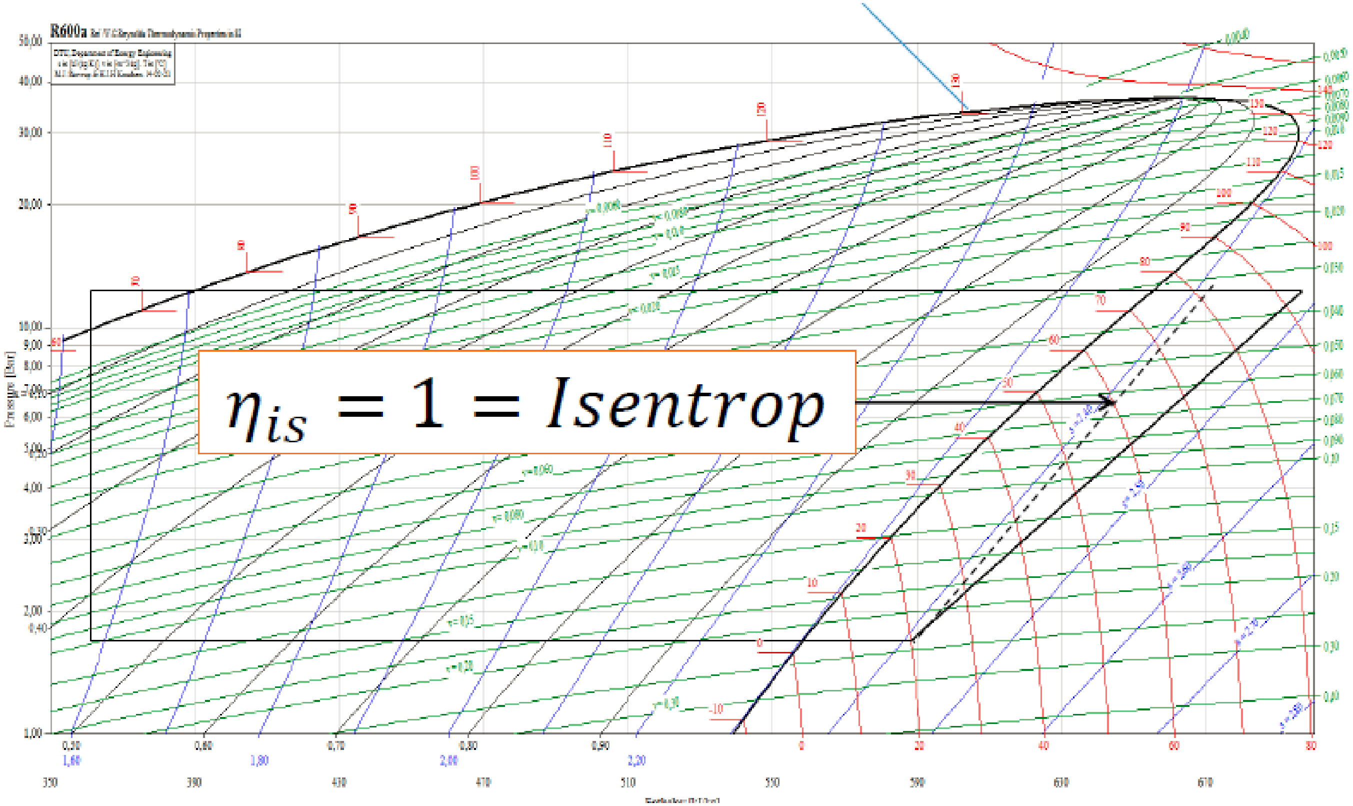
The isentropic efficiency is dependent on the pressure ratio PR, ratio between suction pressure (P_L) and discharge pressure (P_H).

Typical values for isentropic efficiency, η_s (reciprocal compressor).

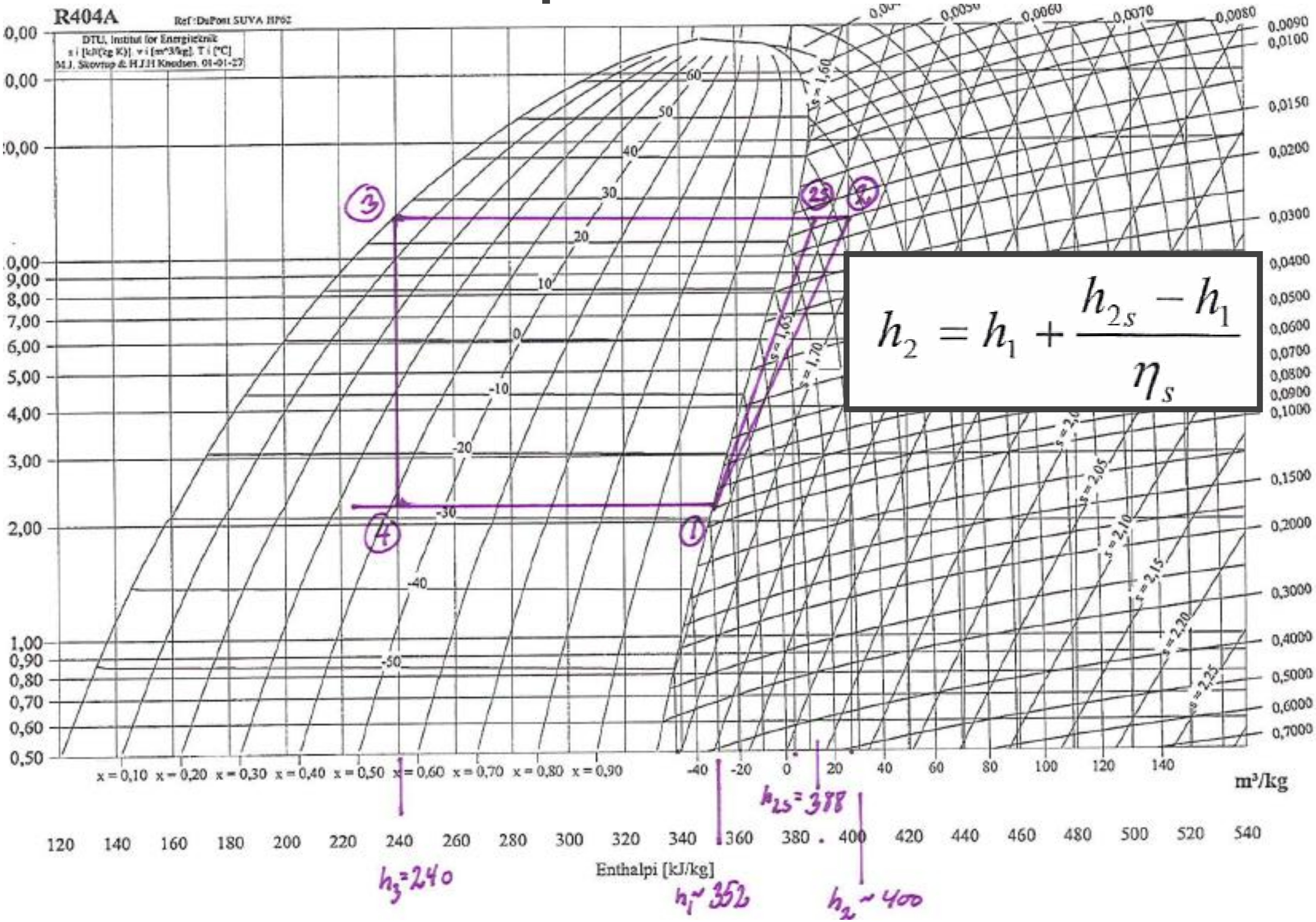


Isentropic efficiency
Ideal and real compression

The model for an ideal compression follows an isentropic process – there is no friction and no heat exchange with surroundings (adiabatic process). The compressor's specific work w_{is} is parallel to the constant entropy line (s= constant).



Uncooled compression



$$h_2 = h_1 + \frac{h_{2s} - h_1}{\eta_s}$$

Isentropic efficiency
Influence on shaft power

In a real refrigeration system the compressor's power consumption is higher than the ideal power needed.

Influence on shaft power:

$$P_{shaft} = \frac{q_{m(h_2 - h_1)}}{\eta_{is}}$$

Exercise
Isentropic efficiency

150 kW

An ammonia refrigeration plant has a cooling capacity of 150 kW at an evaporation temperature of −10°C. There is a superheating in the evaporator of 5°C.
The condensing temperature is 30°C and the refrigerant is sub-cooled 5°C in the condenser.

Efficiencies: $\eta_s = 0{,}75$ (Presuppose adiabatic compressor process) and $\eta_{mot} = 0{,}89$

Volumetric efficiency $\eta_v = 0{,}7$

1. Calculate h2, find discharge temperature
2. Plot process i log P h diagram
3. Calculate mass flow rate

Isentropic efficiency
Real compression

In a real refrigeration system the compressor's power consumption is higher than the ideal power needed.

The specific internal work w_i (real internal work) is influenced by mechanical friction and "flow friction" in the compressor.

The compressors isentropic efficiency η_s is defined by:

$$\eta_s = \frac{w_{i12s}}{w_{i12}} = \frac{h_{2s} - h_1}{h_2 - h_1}$$

h_{2s} enthalpy at discharge valve if the process is isentropic.

h_2 entalphy at discharge valve for the real compression process.

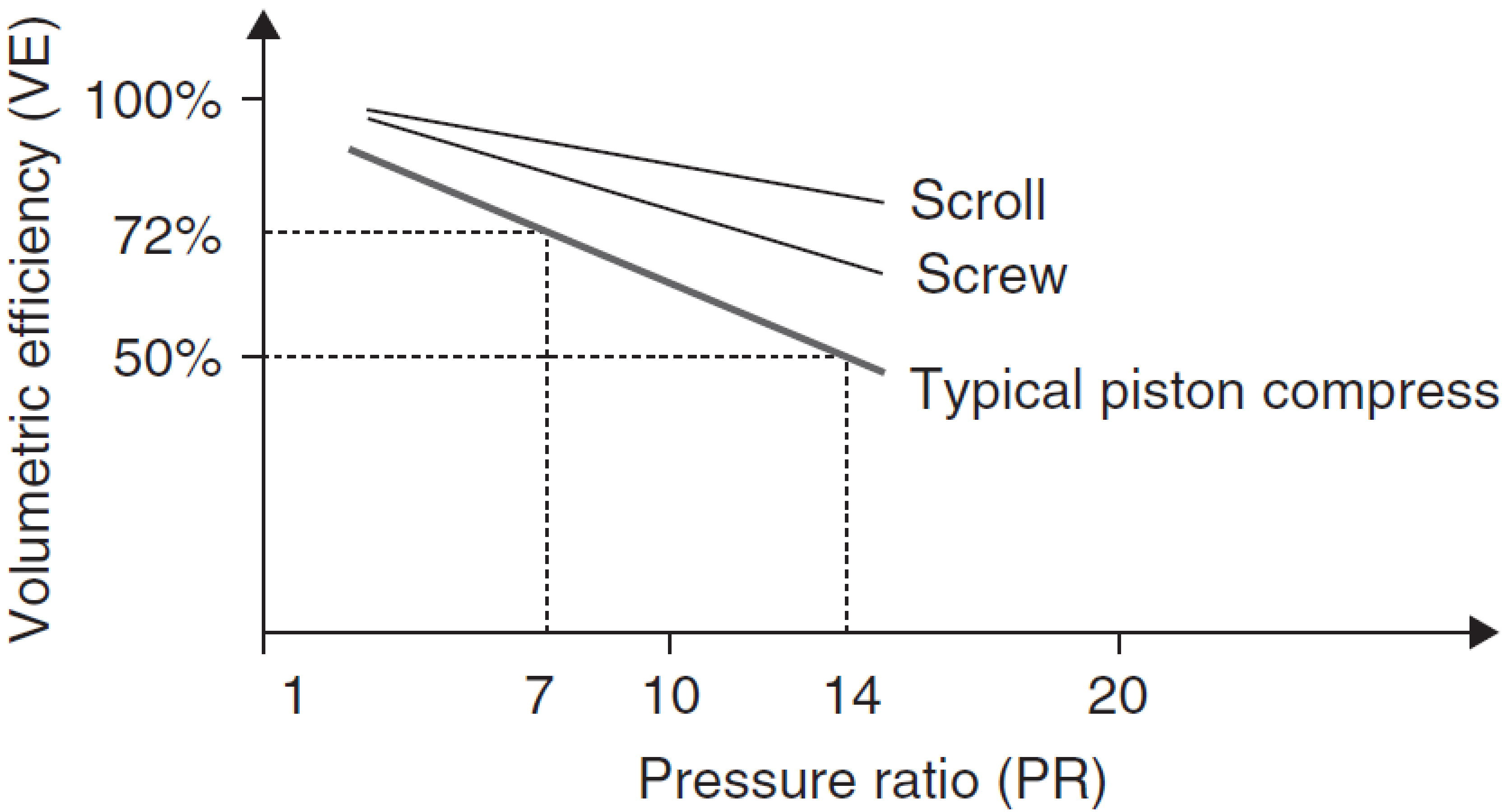
Compressor Swept volume

The volumetric efficiency for a **reciprocating compressor** is highly influenced by the compression ratio and depends on several factors as:

- Recompression of refrigerant vapour from cylinder “top space”.
- Pressure drop in valves.
- Leak from high pressure side to low pressure side.
- Heating of refrigerant in suction inlet.

The volumetric efficiency for a **screw compresssor** is less influenced by the compression ration because there is no top dead center.

Compressor
Volumetric efficiency



Compressor Volumetric efficiency

Animation

The compressors capacity is characterized by the volume flow rate q_{v1} in the suction inlet valve.

The volume flow rate in the suction pipe depends on the compressors swept volume $q_{v,s}$ and the volumetric efficiency η_v.

$$\eta_v = \frac{Actual\,Volume}{Theoretical\,Swept\,Volume} = \frac{q_{v1}}{q_{v_s}}$$

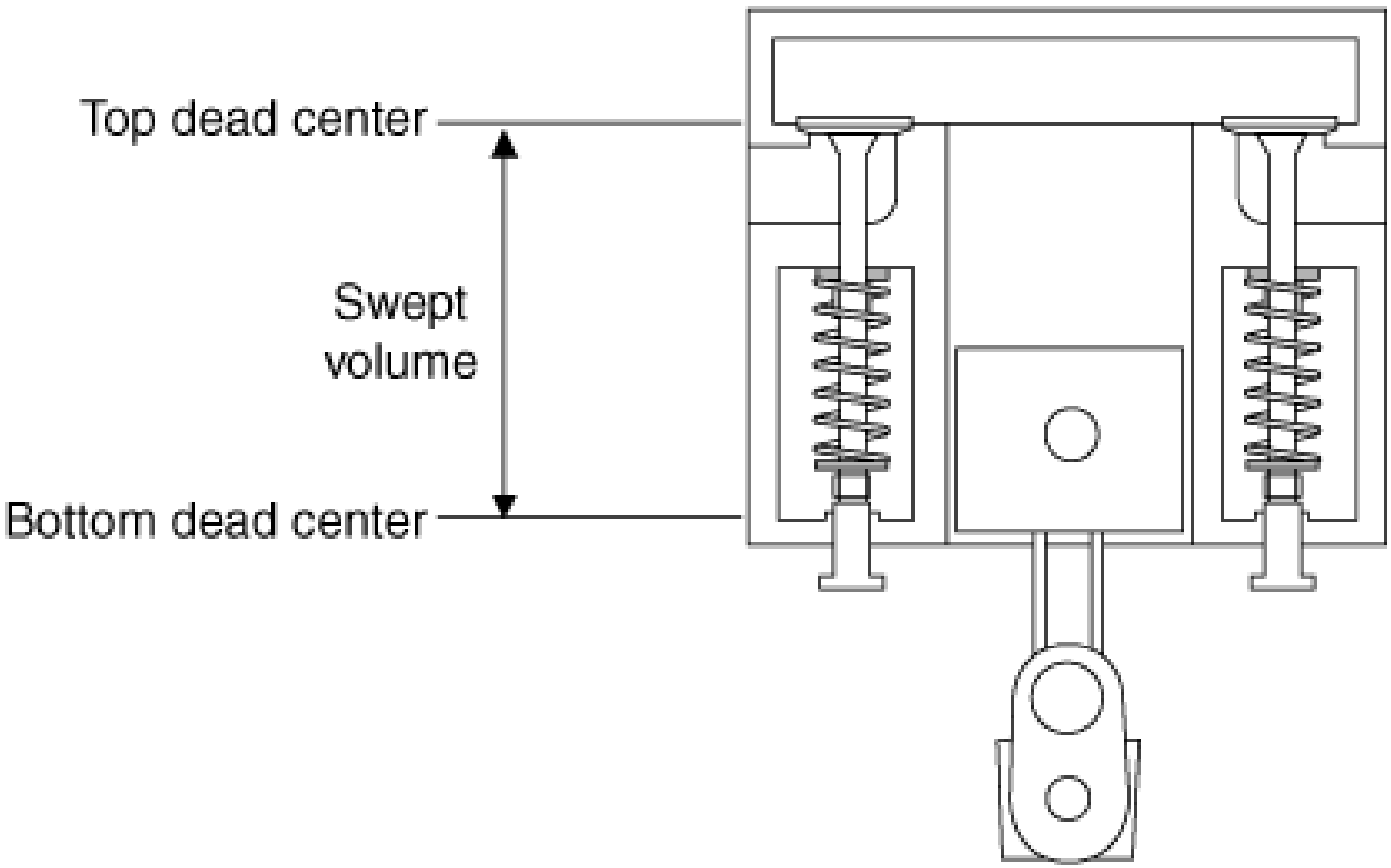
Compressor
Capacity and mass flow

Relation mass flow rate $q_{m,R}$ can be calculated by:

$$q_{m,R} = \frac{q_{v1}}{v_1} = \frac{q_{v,s} \cdot \eta_v}{v_1}$$

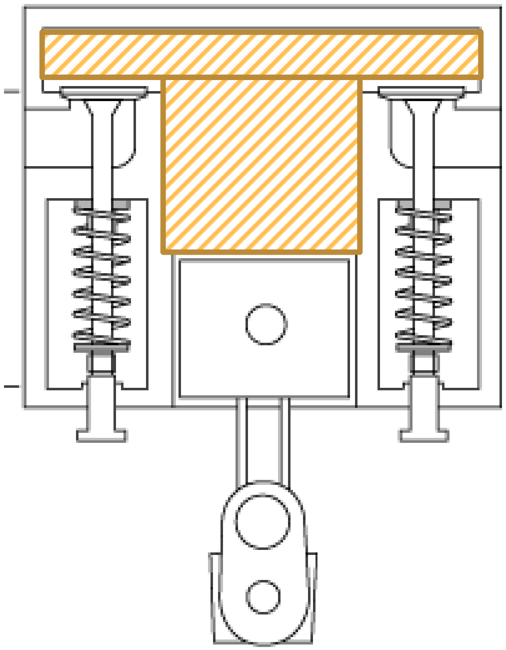
Compressor Swept volume

Animation



Compressor
Swept volume

The compressors swept volume $q_{v,s}$ for a reciprocating compressor is defined by:



$$q_{v.s} = \frac{\pi}{4} \cdot D \cdot S \cdot n \cdot z = V_s \cdot n$$

D diameter of cylinder [m]
S length of stroke [m]
n number of revolutions [s^{-1}]
z number of cylinders
V_s compressor displacement [m^3]

A similar formula cannot be given for a screw compressor.

Exercise
Volumetric efficiency

An ammonia refrigeration plant has a cooling capacity of 150 kW at an evaporation temperature of −10°C. There is a superheating in the evaporator of 5°C.
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Efficiencies: $\eta_s = 0{,}75$ (Presuppose adiabatic compressor process) and $\eta_{mot} = 0{,}89$

Volumetric efficiency $\eta_v = 0{,}7$

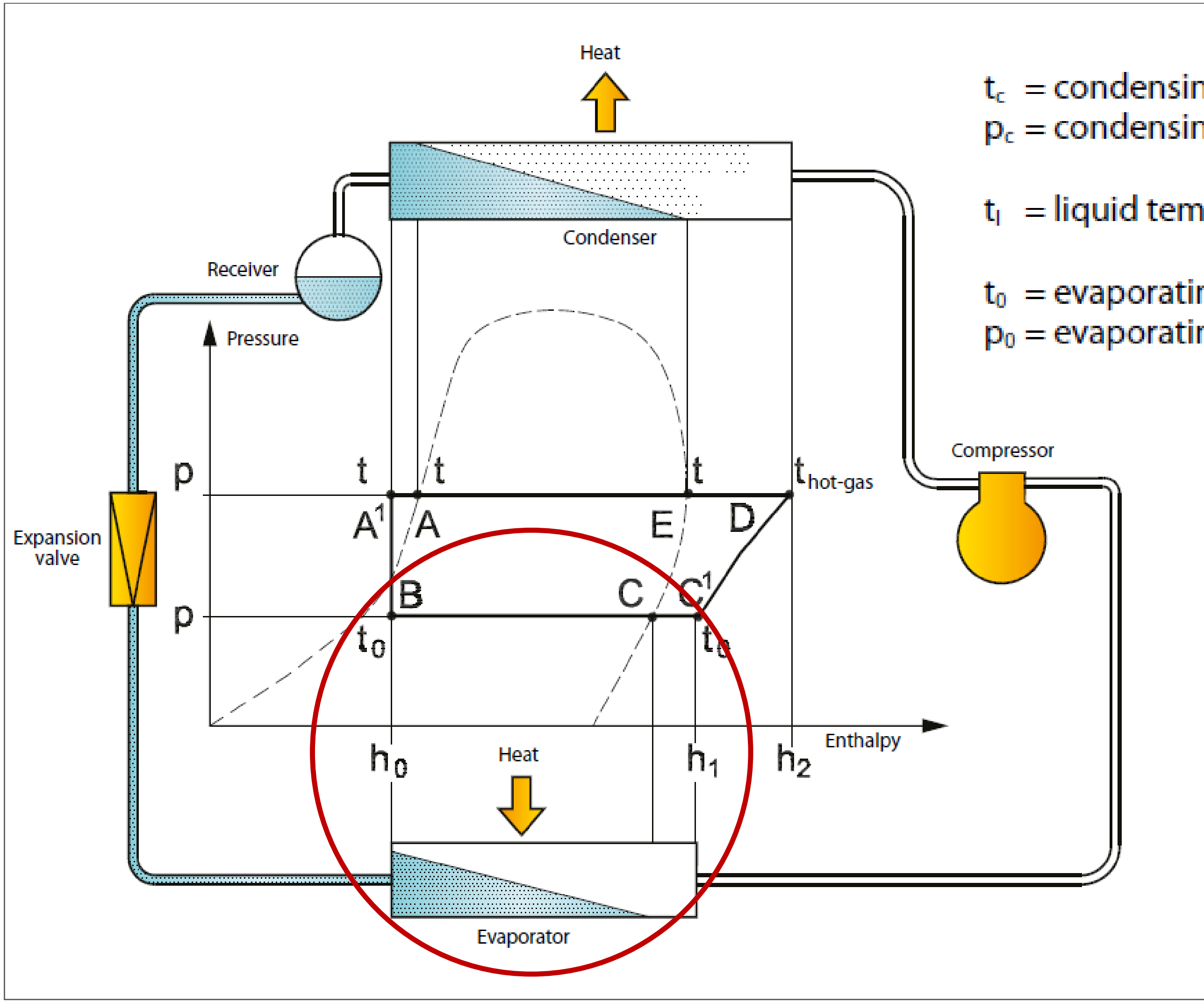
1. Calculate h2, find discharge temperature
2. Plot process i log P h diagram
3. Calculate mass flow rate
4. **Calculate swept volume**
5. **Find a compressor in Sabroe catalog (Studynet)**

Refrigeration circuit components

- Intro to compressors
- Basic calculations for compressor dimensioning
- **Evaporator and condenser dimensioning**

Cold side
Evaporator

Refrigeration circuit
Evaporation



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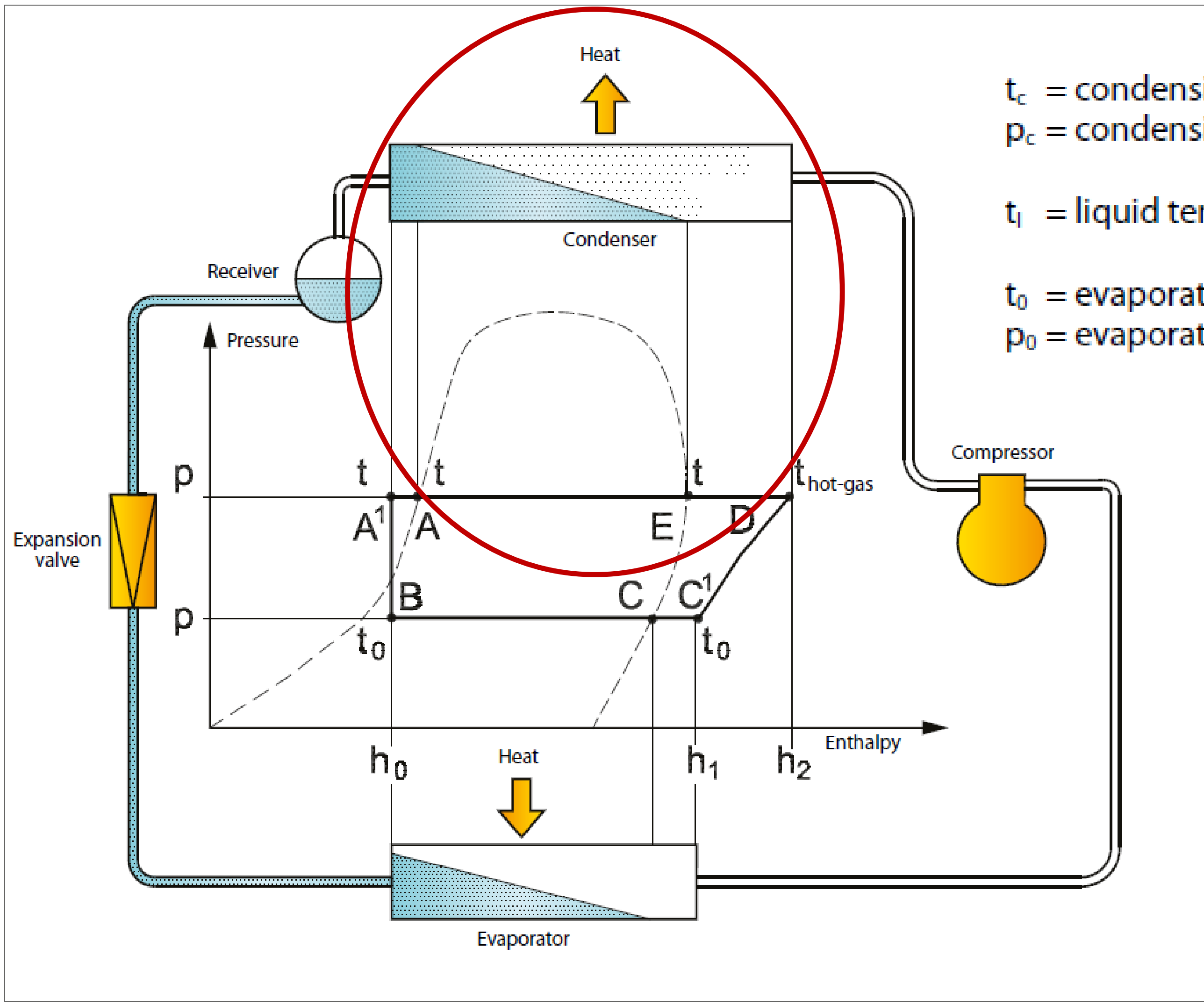
t_0 = evaporating temperature
p_0 = evaporating pressure

Evaporator and ΔT
Rating temperatures

Most fruits and vegetables	ΔT ~ 4 K
Products sensitive to dehydration	ΔT ~ 6-8 K
Products not sensitive to dehydration	ΔT ~ 10K or higher

Hot side
Condenser

Refrigeration circuit Condensation



t_c = condensing temperature
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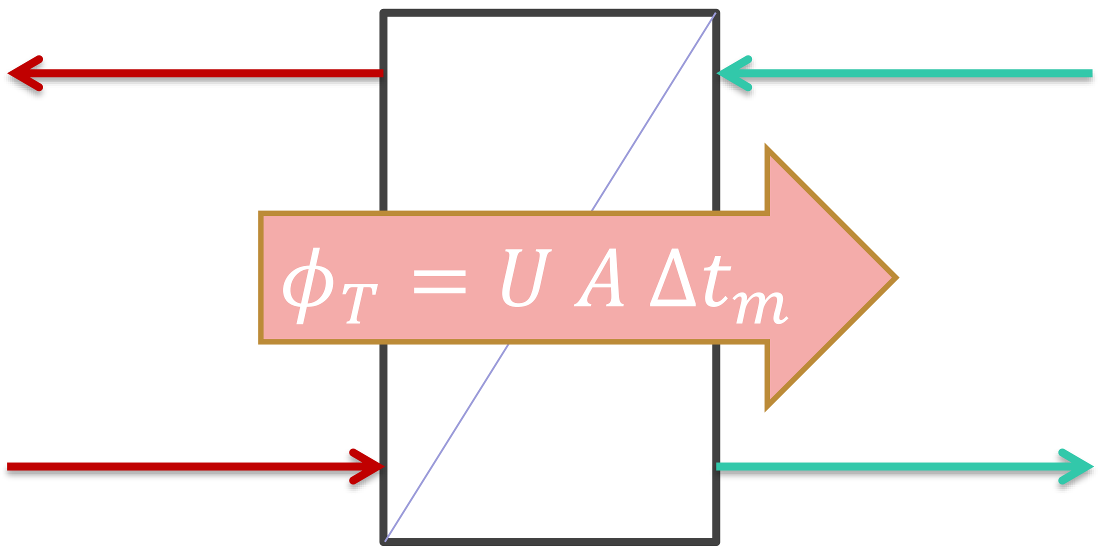
Condenser and ΔT Rating temperatures

Dry aircooler	ΔT ~ 10-15 K
Evaporating condenser	ΔT ~ 8-12 K

Heat transfer

Heat flow rate calculations, air cooled

$$\phi_{air} = q_m \, c_p \, (t_i - t_o)$$



$$\phi_0 = q_{m,r} \, (h_1 - h_4)$$

$$\phi_T = \phi_a = \phi_0$$

Design parameters, temperature Question

- Cooling room for vegetables
- Temperature of cooling room: -10 °C
- Average max. outdoor temperature: 30 °C
- Air cooler, dry

Find evaporator and condenser temperatures.