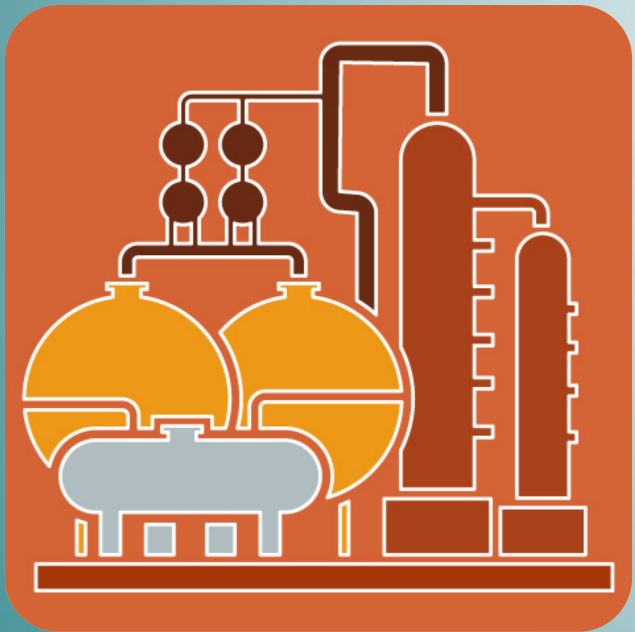
Chemical Process Design / Diseño de Procesos Químicos

Topic 5.7. Refrigeration



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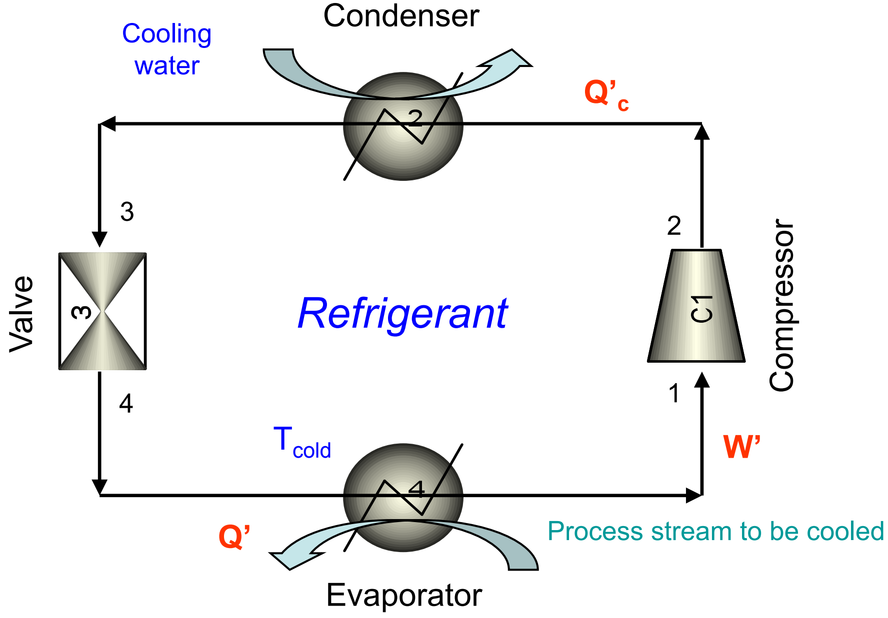
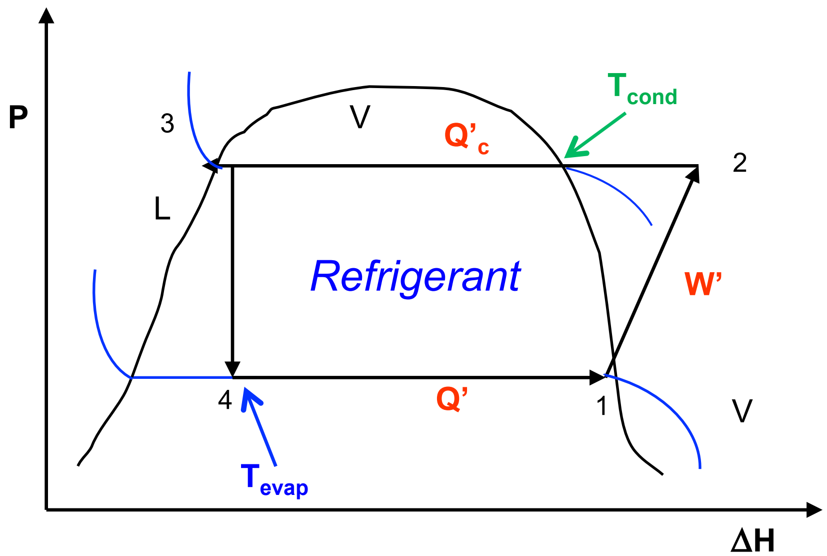
Shortcut for Refrigeration Sizing

Given Q or Q´ cooling duty at T < 300 K:

- We have the **Refrigeration system** where the compressor is the most expensive device in the cycle.
- The **equilibrium P – ΔH** for one Refrigerant.
- Q’, Q_c’ and W’ is for mass unit.

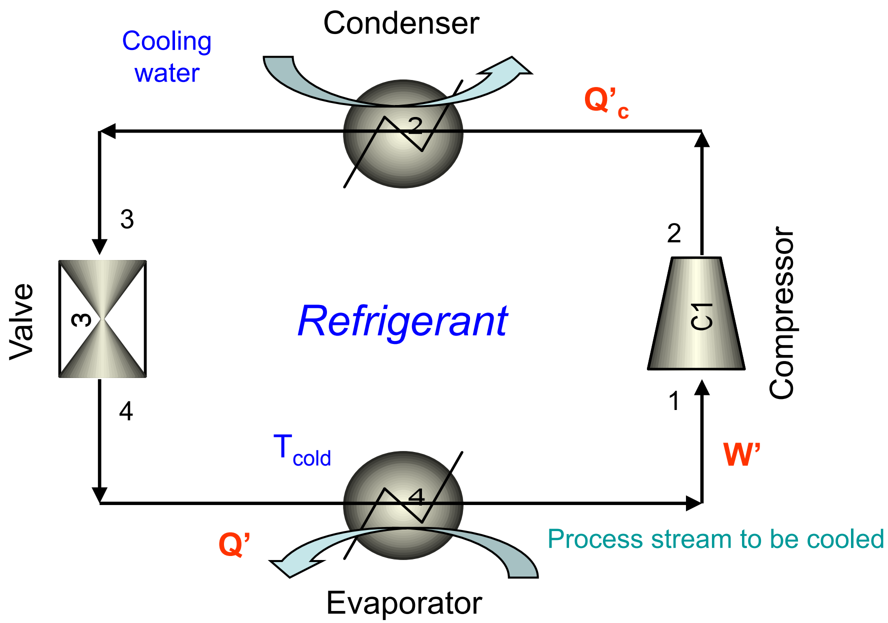


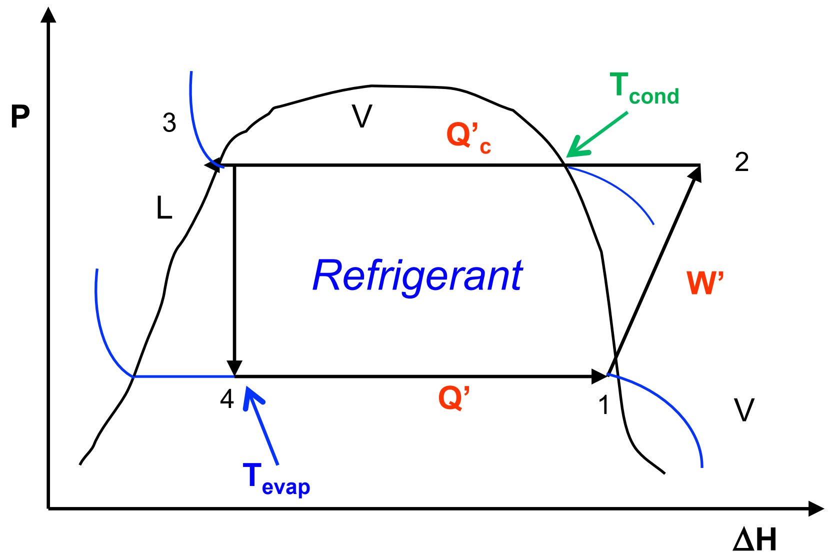


Shortcut for Refrigeration Sizing

Shortcut model (one cycle/one stage):

- 1 cycle for process stream T not too low.
- Coefficient of performance (CP) o *Coeficiente de Rendimiento (COP).*





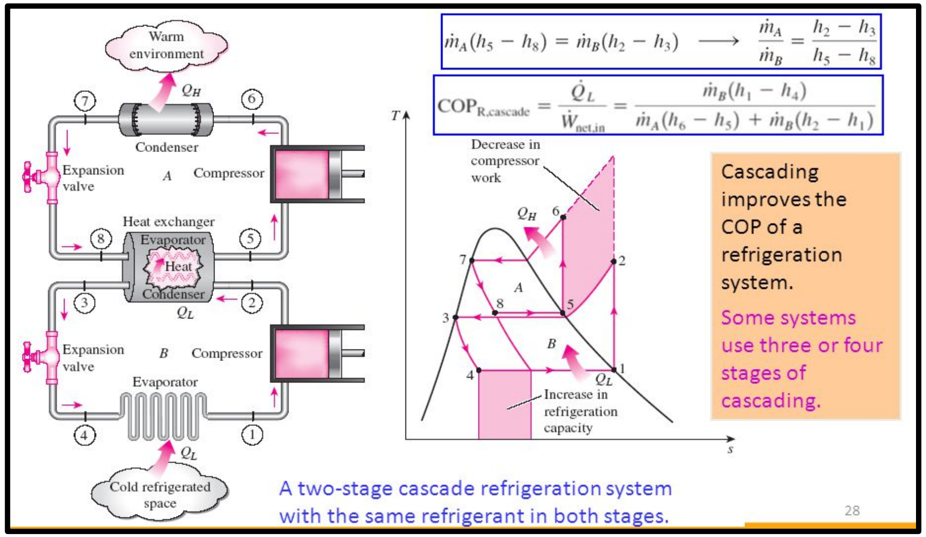
CP = Q / W, typically CP ≈ 4 → Compressor W = Q / 4

For η = 0.9 ; η_{comp} = 0.8 → W_b = W / 0.72 ; Cooling duty Q_c= W + Q = 5 / 4 Q

Shortcut for Refrigeration Sizing

Shortcut model (multiple stages):

- Multiple stages for low **T** process stream.



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- Refrigerant **R (A, B)** must satisfy:

  a) $T_{cond} < T_c^R$ max $T_{cond} = 0.9$ Tc (critical temperature).

  b) $T_{evap} > T_{boil,\,R}$ → $P_{evap} = P_R^0 > 1$ atm. (To prevent decreasing η due to air entering the system).

  c) T_{evap} and T_{cond} must be feasible for heat exchange; $\Delta T \approx 5K$.

More steps → Less energy vs. More capital investment (compressors) → Trade-off.

Rule of Thumb: one cycle for 30 K below ambient → **N° cycles = N = (300 – T_{cold}) / 30**

$$W = Q\left[\left(1+\frac{1}{CP}\right)^N - 1\right]; \qquad Q_c = \left[1+\frac{1}{CP}\right]^N Q$$

Guthrie Material and Pressure Factors for Mechanical Refrigeration

REFRIGERATION

Guthrie MPF for Mechanical Refrigeration

MPF = Ft

Evaporator Temperature,	Ft
278 K / 5 C	1.00
266 K / –7 C	1.95
255 K / –18 C	2.25
244 K / –29 C	3.95
233 K / –40 C	4.54

Refrigeration

Equipment Type	C_0 (\$$10^3$)	S_0	Range (S)	α	MF2 / MF4 / MF6 / MF8 / MF10
Refrigeration	60	200	**50 - 3000**	0.70	1.42

S = ton refrigeration (12,000 Btu/h removed)

S ≡ Q in evaporator

MF (Module Factor) = 1.42

$$C = BC = C_0 (S / S_0)^{\alpha}$$

Materials and Pressure correction Factor (Vessels): MPF = F_t

Update Factor UF = Present Cost Index (CI_{actual}) / Base Cost Index (CI_{base})

Updated bare (simple) module cost: BMC = UF(BC) (MPF + MF – 1)