Refrigeration Cycle

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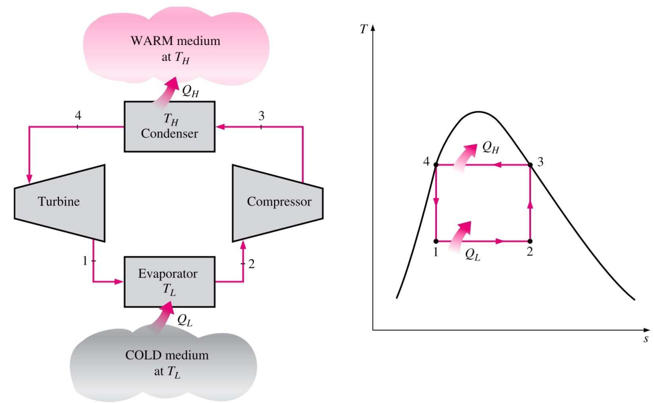
ME 415: Refrigeration & Building Mechanical Systems

Reversed Carnot Cycle



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$$\text{Coefficient of Performance, } COP = \frac{Q_L}{W_{net}} = \frac{T_L}{T_H - T_L}$$

Wet Compression in Carnot Cycle vs. Dry Compression

- During compression, droplets present in liquid are vaporised by the internal heat transfer process which requires finite time. High-speed compressors are susceptible to damage by liquid because of the short time available.
- In wet compression, the droplets of the liquids may wash the lubricating oil from the walls of the cylinder, accelerating wear. Dry compression takes place with no droplets and is preferable.
- Liquid refrigerants may be trapped in the head of reciprocating compressor by the rising piston, possibly damaging the valves or the cylinder head.

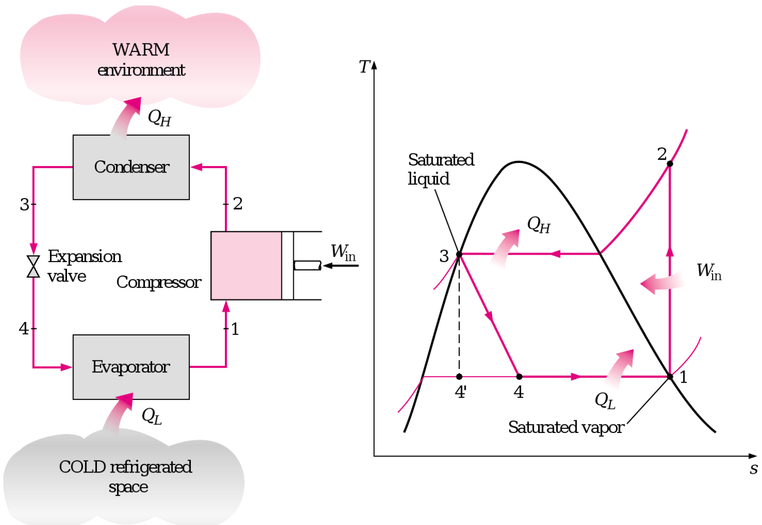
Expansion Process in Carnot Cycle

Carnot cycle demands that the expansion take place isentropically and that the resulting work be used to help drive the compressor. Practical difficulties, however, militate against the expansion engine:

- the possible work that can be derived from the engine is small fraction that must be supplied to the compressor.
- practical problems such as lubrication intrude when a fluid of two phases drives the engine.
- the economics of the power recovery have in past not justified the cost of the expansion engine.

A throttling device, such as a valve or other restriction, is almost universally used for this purpose.

Ideal Vapour Compression Refrigeration Cycle



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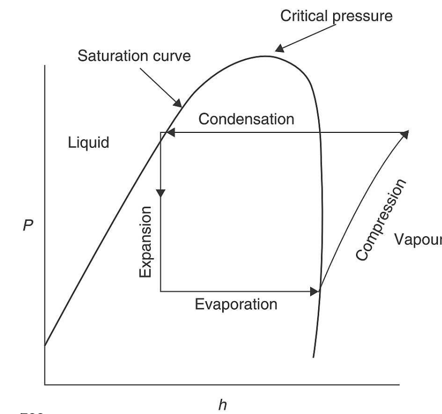

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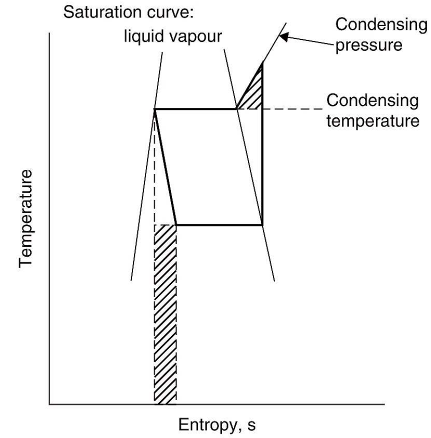

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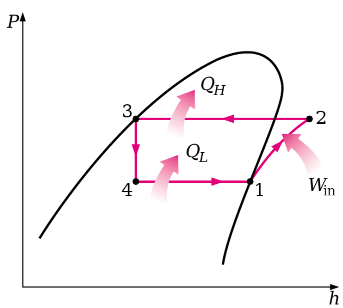
Processes of VC System



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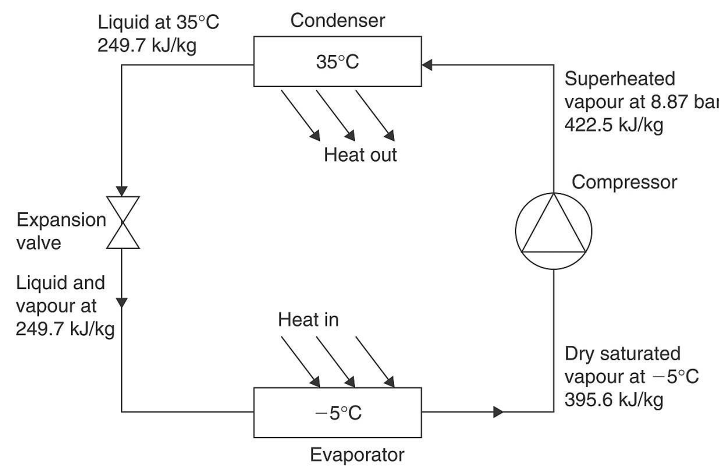
$$\begin{aligned} Q_L &= Q_{41} = m(h_1 - h_4) \\ Q_H &= Q_{23} = m(h_2 - h_3) \\ W_{in} &= W_{12} = m(h_2 - h_1) \\ COP &= Q_L / W_{in} \end{aligned}$$

1 → 2: Isentropic compression, $P_{evap} \rightarrow P_{cond}$

2 → 3: Isobaric heat rejection, Q_H

3 → 4: Isenthalpic expansion, $P_{cond} \rightarrow P_{evap}$

4 → 1: Isobaric heat extraction, Q_L



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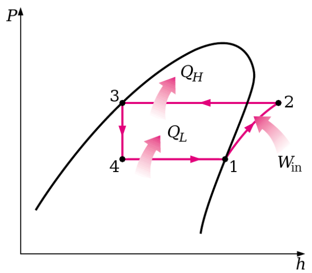
Simple vapour compression cycle with pressure & enthalpy values for R134a

Example

A theoretical single stage cycle using R134a as refrigerant operates with a condensing temperature of 30^{o}C and an evaporator temperature of -20^{o}C. The system produces 50 kW of refrigeration effect. Estimate:

1. Coefficient of performance, COP
2. Refrigerant mass flow rate, m



$$
\begin{aligned}
Q_L &= Q_{41} = m(h_1 - h_4) = 50 \text{ kW} \\
&\rightsquigarrow m = 0.345 \text{ Kg/s} \\
W_{in} &= W_{12} = m(h_2 - h_1) = 12.5 \text{ kW} \\
COP &= Q_L/W_{in} = 50.0/12.5 = 4.0
\end{aligned}
$$

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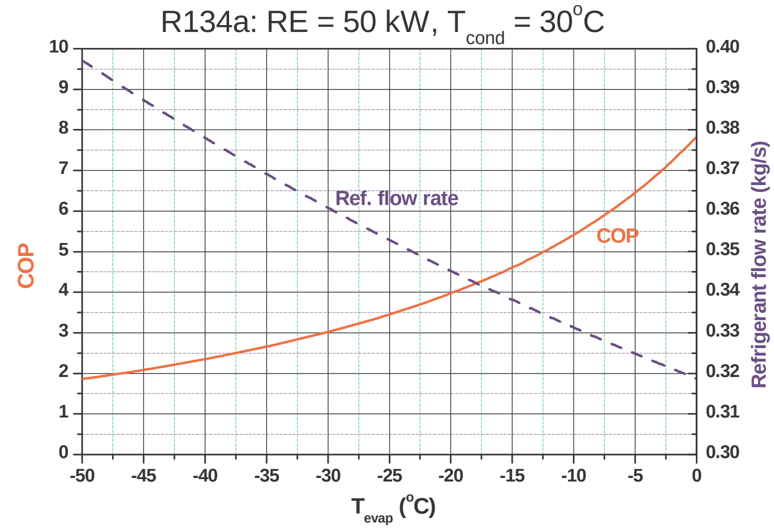
Effect of Evaporator Temperature



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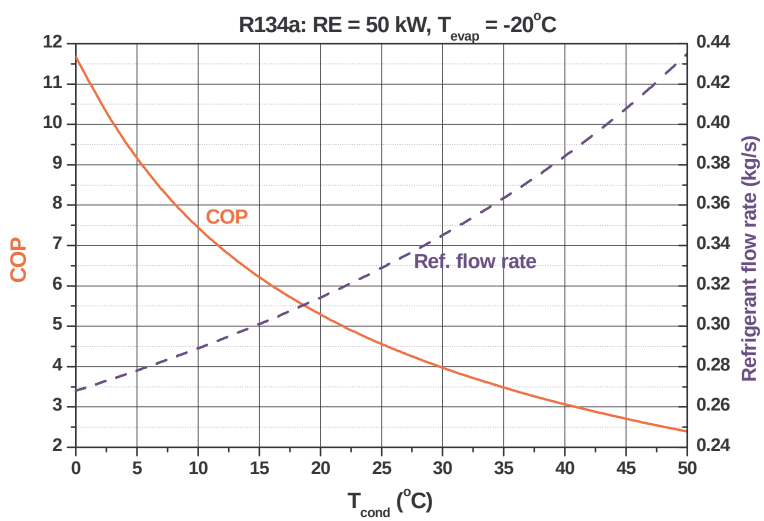
Effect of Condenser Temperature



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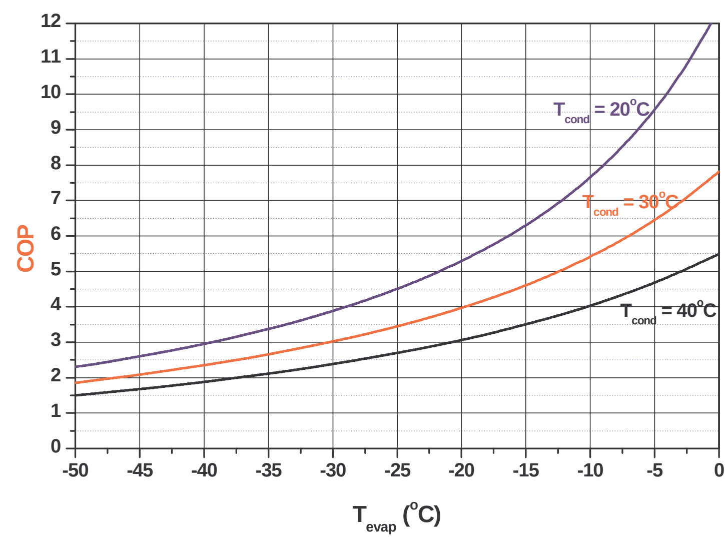
Effect of Evaporator & Condenser Temperatures



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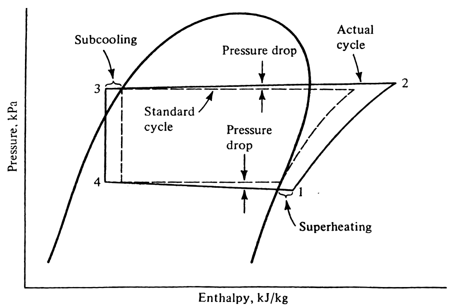
Deviations from Ideal Cycle

1. Refrigerant pressure drop in piping, evaporator, condenser, receiver tank, and through the valves and passages.
2. Sub-cooling of liquid leaving the condenser.
3. Super-heating of vapour leaving the evaporator.
4. Compression process is not isentropic.



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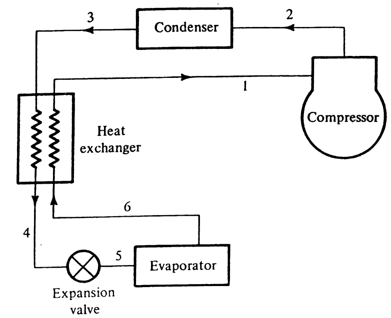
Deviation from Simple Cycle

Super-heating & Sub-cooling



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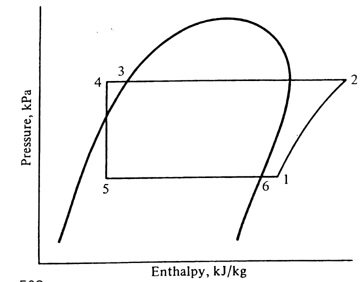

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- Sub-cooling of liquid serves a desirable function of ensuring that 100% liquid will enter the expansion device.
- Super-heating of vapour ensures no droplets of liquid being carried over into the compressor.
- Even through refrigeration effect is increased, compression work is greater & probably has negligible thermodynamic advantages.