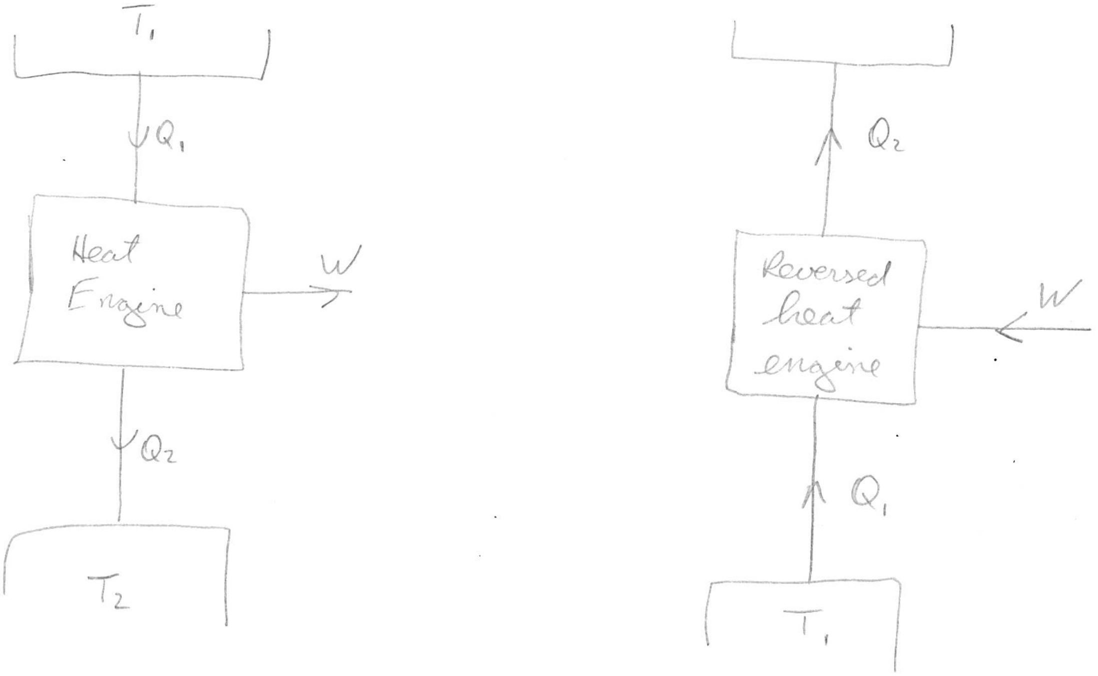
REFRIGERATION & HEAT PUMPS

The purpose of refrigerators and heat pumps is to force heat to flow against its natural tendency. That is a heat pump or refreigerator is able to make heat flow from a low temperature reservoir to a higher temperature reservoir. This flow of heat against the natural tendency is achieved at the expense of a mechanical work input.

Refrigerators and heat pumps have exactly the same setup. However when the required effect is the cooling at the low temperature reservoir we commonly refer to this as a <u>refrigerator</u> (or air conditioner). When the same system is used to heat the higher temperature it is referred to as a <u>heat pump</u>.



By the First Law of Thermodynamics for the Reversed heat engine

$$Q_1 + W = Q_2 \quad \Rightarrow \quad W = Q_2 - Q_1$$

The Coefficient of Performance COP is a term which is used to measure the performances of refrigerators and heat pumps

For a refrigerator the important quantity is Q_1

$$\text{C.O.P. refrigerator} = \frac{Q_1}{W}$$

For a heat pump the important quantity is Q_2

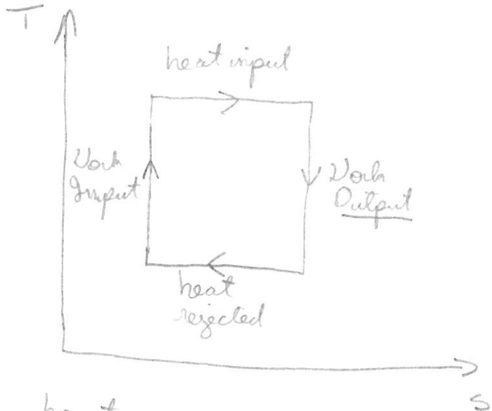
$$\text{C.O.P. heat pump} = \frac{Q_2}{W}$$

From $Q_1 + W = Q_2$

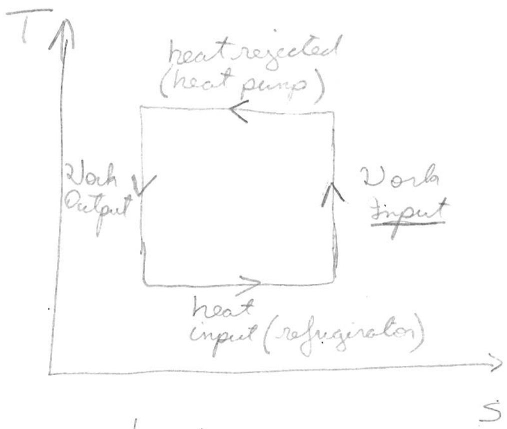
$$\frac{Q_1}{W} + \frac{W}{W} = \frac{Q_2}{W}$$

$$COP_{ref} + 1 = COP_{h.p.} \quad \text{ALWAYS}$$

The best C.O.P's are given by a cycle which is a reversed Carnot cycle as used for a heat engine. That is

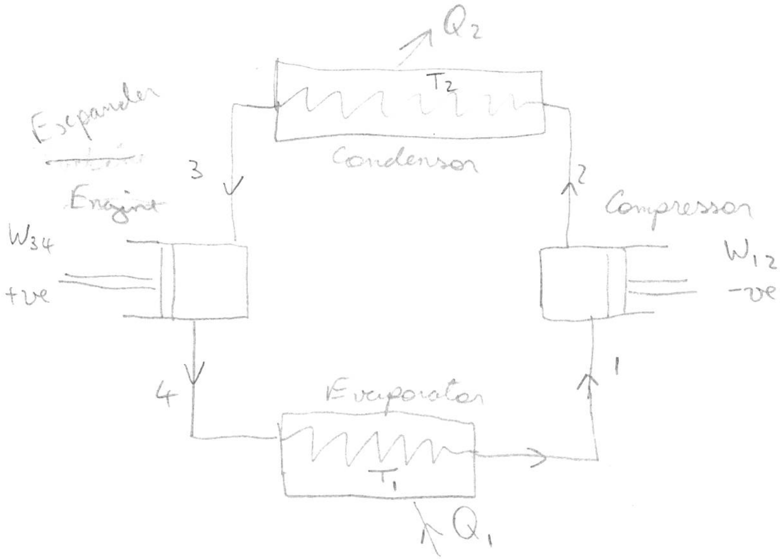


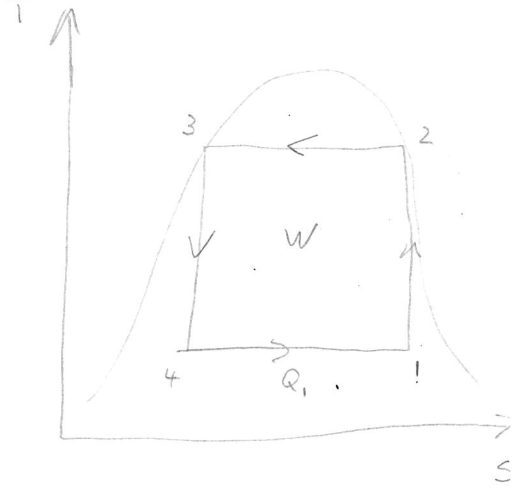
heat engine



heat pump

For such a heat pump the set up would be





The net work input to the system is $W = W_{12} - W_{34}$

and as written above by 1st Law $W = Q_2 - Q_1$

$$C.O.P._{ref} = \frac{Q_1}{W} = \frac{Q_1}{Q_2 - Q_1}$$

but as shown in T-S diagram for carnot cycle,

$Q_1 = T_1(S_1 - S_4)$ Area under 4 to 1

& $Q_2 = T_2(S_2 - S_3)$ Area under 2 to 3

but $S_1 = S_2$ & $S_3 = S_4$

$\therefore Q_2 = T_2(S_1 - S_4)$

$$\therefore COP_{ref} = \frac{T_1(S_1 - S_4)}{(T_2 - T_1)(S_1 - S_4)} = \frac{T_1}{T_2 - T_1}$$

Also for heat pump

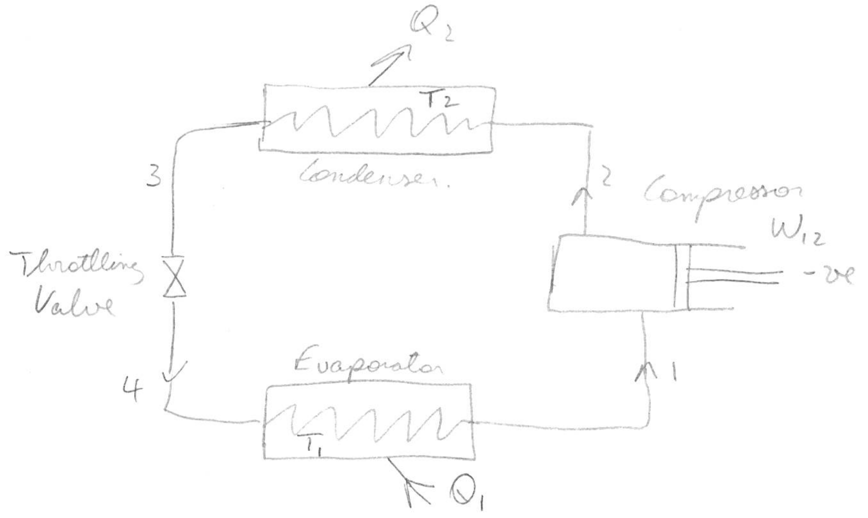
$$C.O.P._{hp} = \frac{Q_2}{W} = \frac{Q_2}{Q_2 - Q_1} = \frac{T_2(S_1 - S_4)}{(T_2 - T_1)(S_1 - S_4)} = \frac{T_2}{T_2 - T_1}$$

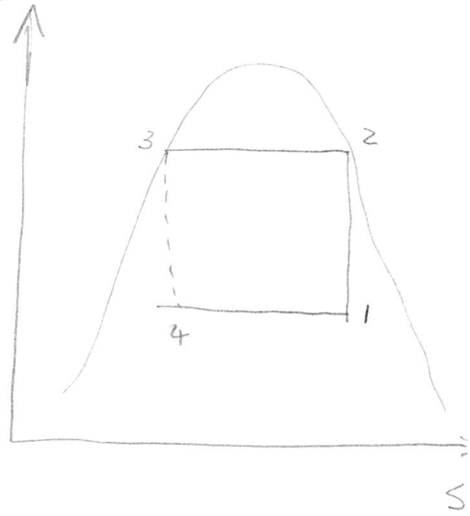
These eqns for the COP's of a reversed Carnot cycle give the maximum possible values of COP's between T_1 & T_2. Remember that when the Carnot cycle was used for the heat engine the maximum possible efficiency was determined for the available temperatures.

The Carnot cycle gives very high COP's which are not obtainable in real systems. The Carnot cycle is difficult to implement and a number of modifications are done to have a more practicable system.

a) Use of Expansion Valve

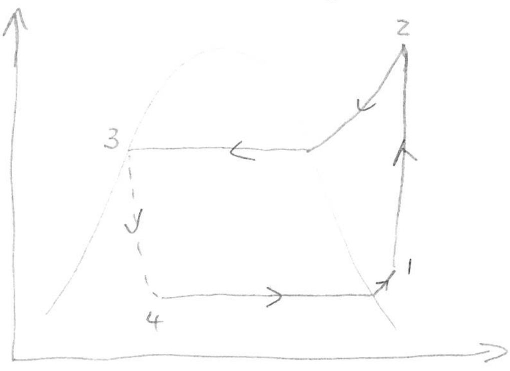
Since the inclusion of an engine to take the +ve work from the fluid is too much of a complication in small systems, it is replaced by a throttling valve. Then we have





b) Dry or superheated inlet to compressor

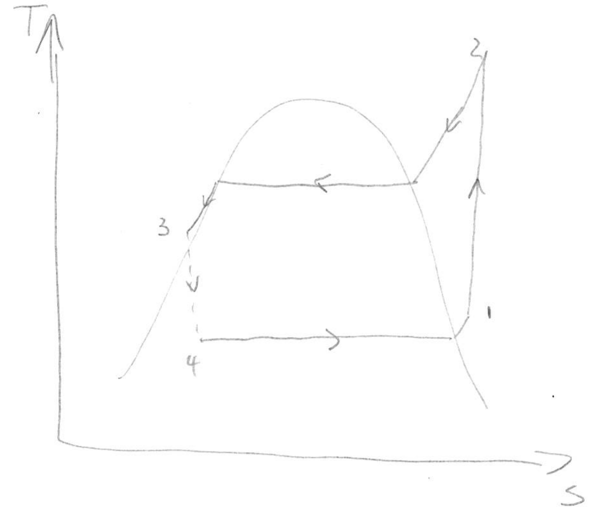
Since the compressor is designed to pump gases, droplets in the flow may cause damage. Hence the refrigirant is left to evaporate completely before it is admitted to the compressor. In fact it is also better if the refrigirant is slightly superheated before the compressor to be perfectly sure that only gases are pumped by the compressor



This is achieved by the physical connections to the evaporator, i.e. take the refrigirant gas from the high levels so that droplets are left behind and have an evapora a little larger ~~greater than if Carnot~~.

c) Undercooling in the condenser.

Since the use of an expansion valve results in a shorter 4 to 1 line, the refrigiration effect is reduced. Hence undercooling of the condensate in the condenser is preferred so that point 4 is moved to the left.



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