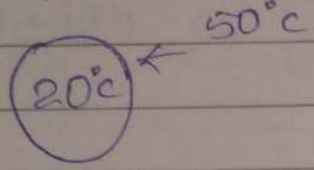
BASIC CONCEPTS

Hand written notes by Deepak Sharma

Refrigeration Effect :-

It is the amount of heat which is required to extract from the System. in Order to provide and maintain lower temperature than that of Surrounding.



$$Q = mc\Delta T$$
$$= mc(T_f - T_i)$$
$$= mc(20-50)$$
$$\boxed{Q = -30\,mc.}$$

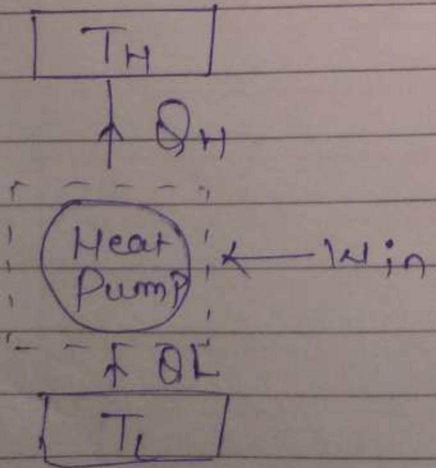
Refrigerant :-

It is the working fluid or working Substance which is used to extract the heat from storage space.

Coefficient of Performance :-

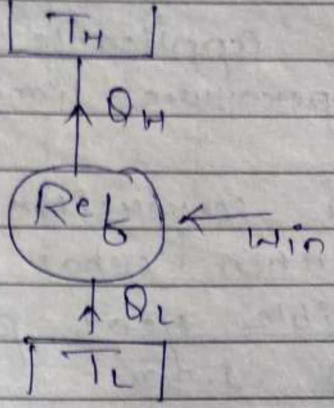
or Energy Performance Ratio :-

It is defined as the ratio of desired Effect to the work input.



$$COP = \frac{\text{Desired Effect}}{\text{Work Input}}$$
$$= \frac{Q_H}{W_{in}}$$
$$\because Q_H = Q_L + W_{in}$$
$$\therefore W_{in} = Q_H - Q_L$$

$\therefore$ $\boxed{COP = \frac{Q_H}{Q_H - Q_L}}$ Also, $\boxed{COP = \frac{T_H}{T_H - T_L}}$



$$(COP)_{Ref} = \frac{\text{Desired Effect}}{\text{Work input}}$$

$$= \frac{Q_L}{W_{in}}$$

$$\boxed{(COP)_{Ref} = \frac{Q_L}{Q_H - Q_L}}$$

$$\boxed{(COP)_{Ref} = \frac{T_L}{T_H - T_L}}$$

Relationship between $(COP)_{H.P}$ and $(COP)_{Ref}$:-

$$(COP)_{Ref} = \frac{T_L}{T_H - T_L}$$

$$1 + (COP)_{Ref} = \frac{T_L}{T_H - T_L} + 1$$

$$1 + (COP)_{Ref} = \frac{\cancel{T_L} + T_H - \cancel{T_L}}{T_H - T_L}$$

$$1 + (COP)_{Ref} = \frac{T_H}{T_H - T_L}$$

$$\boxed{1 + (COP)_{Ref} = (COP)_{H.P}}$$

$$(COP)_{H.P} = (COP)_{Ref} + 1.$$

$$T_H = T_L + 1$$

$$\boxed{(COP)_{H.P} = (COP)_{Ref} + 1}$$

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By above expression is applicable between the same temperature limits.

Q. If the efficiency of a reversible heat engine is 30%, then what will be the COP of Reversible Heat pump.

~~Soln~~ i) 0.33 (ii) 1.33

iii) 2.33 [✓ (iv) 3.33]

Sol

$$\eta = 1 - \frac{T_L}{T_H}$$

$$0.3 = 1 - \frac{T_L}{T_H}$$

$$\frac{T_L}{T_H} = 0.7.$$

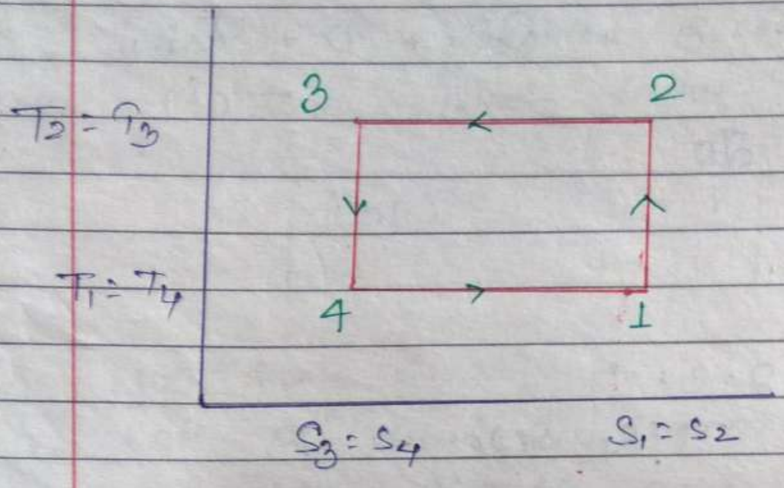
$$(COP)_{H.P} = \frac{T_H}{T_H - T_L} = \frac{1}{1 - \frac{T_L}{T_H}} = \frac{1}{1 - 0.7} = \frac{1}{0.3}$$

$$= \frac{10}{3} = 3.33.$$

$$\boxed{(COP)_{H.P} = 1 + (COP)_{Ref} = \frac{1}{\eta_{HE}}}$$

The above expression is applicable between the same temperature limits.

Ideal Refrigeration Cycle:→ (Reversed Carnot cycle):→



$$dS = (dS)_{IR} + (dS)_{ER}$$

$$dS = S_{gen} + \frac{dQ}{T}$$

$$S_{gen} = 0$$

$$dS = \frac{dQ}{T}$$

$$dQ = T\,dS$$

$$(dQ)_{1-2} = T(S_f - S_i) = T(S_1 - S_1) = 0$$

$$(dQ)_{2-3} = T(S_f - S_i) = T_H(S_2 - S_3)$$

Process 1-2:→ Isentropic Compression
2-3:→ Isothermal heat Rejection
3-4:→ Isentropic Expansion
(Reversible Adiabatic expansion)
4-1:→ Isothermal heat Addition

- for power producing devices process are in clockwise direction. for power absorbing Anticlockwise direc

$$(COP) = \frac{\text{Desired Effect}}{W_{net}}$$

$$W_{net} = Q_{net} = Q_{1-2} + Q_{2-3} + Q_{3-4} + Q_{4-1}$$
$$= 0 + Q_{2-3} + 0 + Q_{4-1} \quad -(i)$$

$$\because dS = S_{gen} + \frac{\bar{d}Q}{T}$$

$$dQ = TdS.$$

for process 2-3 :→

$$(dQ)_{2-3} = T(S_f - S_i)$$
$$= T_H(S_3 - S_2)$$
$$= -T_H(S_2 - S_3)$$
$$= -T_H(S_1 - S_4) \quad -(ii)$$

for process 4-1 :→

$$(dQ)_{4-1} = T(S_f - S_i)$$
$$= T_L(S_1 - S_4) \quad -(iii)$$

from Equi (i) and (ii)

$$W_{net} = Q_{net} = -T_H(S_1 - S_4) + T_L(S_1 - S_4)$$
$$= \underbrace{(S_1 - S_4)}_{+ve}\underbrace{(T_L - T_H)}_{-ve} \quad -(iv)$$
$$=$$

$$\therefore \boxed{W_{net} = Q_{net} = -ve} \rightarrow \text{Work Absorbing device}$$

From the equation no. (4) we can say that our System under Consideration is a work absorbing device.

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COP of Ideal Refrigeration cycle / Reversed Carnot cycle :-

$$(COP) = \frac{\text{Desired Effect}}{\text{Work input}} = \frac{T_L(S_1-S_4)}{(T_H-T_L)(S_1-S_4)}$$

$$\therefore \boxed{(COP) = \frac{T_L}{T_H-T_L}}$$

NOTE :-

a) COP of reversed Carnot cycle is a function of temp. limits only.

b) If there are 'n' number of reversible refrigerators are operating between same temp limits with diff. working fluids, then the value of max. possible COP or reverse Carnot COP or ideal COP will have same value.

c) Reverse Carnot COP is independent of working fluid.

- UNIT of Refrigeration :-

Ton of Refrigeration :-

1 TR = 3.5 KW
= 210 KJ/min
= 50 Kcal/min.