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Steam Engine : Carnot Cycle with Steam

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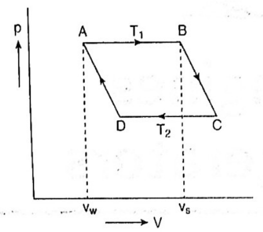
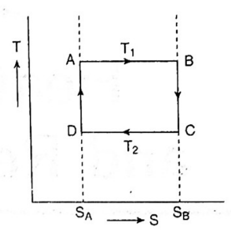
Abstract:

This article is about the reversible carnot cycle.

The carnot reversible cycle is bounded by two isotherms and two adiabats, one alternating the other. The special feature of the isotherms of



p-V diagram of Carnot cycle with steam



T-S diagram of Carnot cycle with steam

saturated or wet steam is that the isotherms are also lines of constant pressure.

The p-V and T-S diagram for a carnot cycle working between the temperatures T_1 and T_2 with 'water substance' as the working medium as shown in the figures.

1. **Operation A —> B :** Let a unit mass of water(specific volume v_w) at T_1 represented by A, be vaporized isothermally along AB to saturated steam, represented by B, when its specific volume becomes v_s.

2. **Operation B —> C :** The steam is then expanded adiabatically along BC and work is done on the piston so that the temperature falls to T_2, the temperature of the condenser.

3. **Operation C —> D :** The steam is partially condensed isothermally at temperature T_2 along the path CD.

4. **Operation D —> A :** The condensation of steam is completed by an adiabatic compression; the point D where the adiabatic compression starts is such that the full condensation is accomplished at A, the starting point of the cycle.

Efficiency:

The efficiency η of a carnot cycle is given by

$$\eta = 1 - \frac{T_2}{T_1}$$

where T_1 and T_2 are respectively the temperatures of the source and the sink.

From the T-S diagram we have

$Q_1 = T_1(S_B — S_A)$ ···(1)

$Q_2 = T_2(S_C — S_D)$ ···(2)

But $S_B = S_C$ and $S_A = S_D$. So we may write eqn(2) as
$Q_2 = T_2(S_B — S_A)$

$$\eta = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2(S_B - S_A)}{T_1(S_B - S_A)} = 1 - \frac{T_2}{T_1}$$

Show the efficiency η of the engine is given by. It is to be noted that a simple device on the above model is simply just not workable. The four operations, as described, within the cylinder of an engine cannot be carried out in practice, the cylinder, having a considerable thermal capacity, is to be heated to T_1 and again cooled to T_2 which has to be much lower than T_1 in each cycle. This involves a large drop in temperature of the material of the cylinder and also a corresponding large absorption of heat at the beginning of evavaporation. Further more the condensation of the whole steam within the cylinder will require an unusually long cylinder. So the carnot cycle is not a practical steam engine cycle.

Reference:

Thermal physics —A.B. Gupta , H.P. Roy.