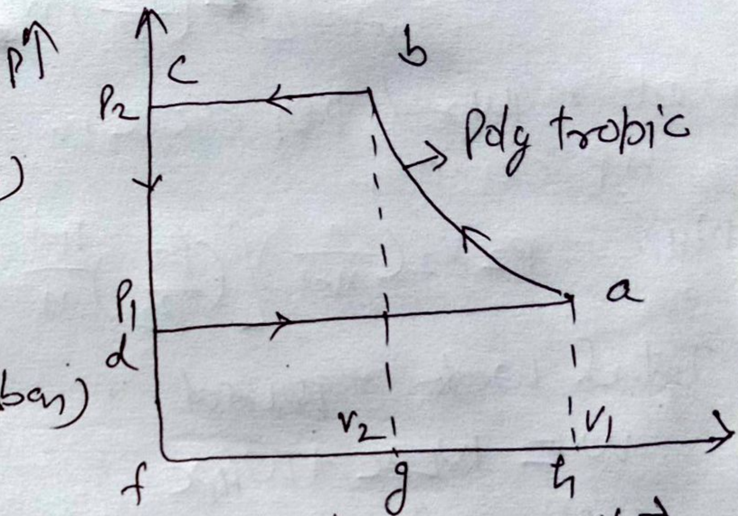
B Tech. M.E. 4th Sem - Applied thermodynamics - by Yogesh Kumar -

Topic - Compressor →

work Required in single-stage Compressor without clearance volume →

The initial conditions of air are, Pressure = P_1 (bar)
volume = V_1 (m^3)
and is Compressed to final Condition of pressure - P_2 (bar)
and volume = V_2 (m^3)



Single stage Compressor

work required per cycle,

W = Area abcd = Area cbgf + Area gbah - Area adfh

$$W = P_2V_2 + \frac{P_2V_2 - P_1V_1}{n-1} - P_1V_1$$

$$= \frac{P_2V_2(n-1) - P_1V_1(n-1) + P_2V_2 - P_1V_1}{n-1}$$

$$W = \frac{nP_2V_2 - P_2V_2 - nP_1V_1 + P_1V_1 + P_2V_2 - P_1V_1}{n-1}$$

$$W = \frac{n}{n-1}(P_2V_2 - P_1V_1) = P_1V_1\left(\frac{n}{n-1}\right)\left(\frac{P_2V_2}{P_1V_1} - 1\right)$$

for Polytropic Compression

$$P_1V_1^n = P_2V_2^n \Rightarrow \frac{V_2}{V_1} = \left(\frac{P_1}{P_2}\right)^{\frac{1}{n}}$$

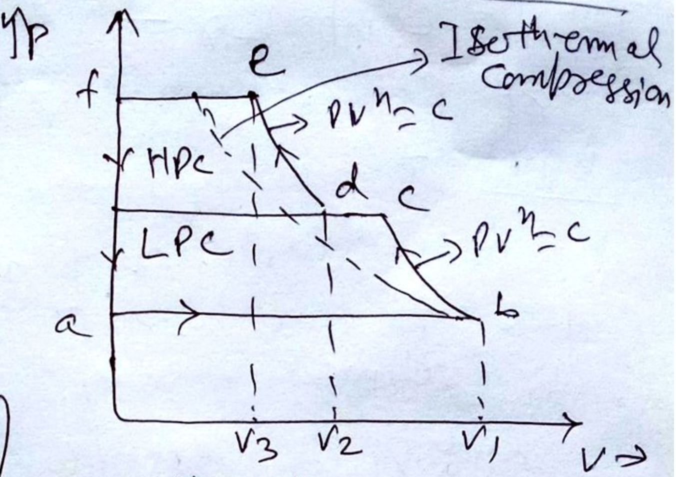
$$\therefore W = P_1V_1\left(\frac{n}{n-1}\right)\left[\frac{P_2}{P_1}\left(\frac{P_2}{P_1}\right)^{\frac{1}{n}} - 1\right]$$

$$W = P_1V_1\left(\frac{n}{n-1}\right)\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$$

$$\boxed{W = \frac{n}{n-1}mRT\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]}$$ [$\because P_1V_1 = mRT_1$]

Discharge Temp^r of air, $\boxed{T_2 = T_1\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}}$

Work Required in two stage compressor without clearance →



Two stage compressor

Work required per cycle in L.P. cylinder –

$$W_{LPC} = P_1V_1\left(\frac{n}{n-1}\right)\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$$

Work required per cycle in HP clinder.

$$W_{HPC} = P_2V_2\left(\frac{n}{n-1}\right)\left[\left(\frac{P_3}{P_2}\right)^{\frac{n-1}{n}} - 1\right]$$

Total work required

$$W = W_{LPC} + W_{HPC}$$

$$= \left(\frac{n}{n-1}\right)\left[\left\{P_1V_1\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right\} + P_2V_2\left\{\left(\frac{P_3}{P_2}\right)^{\frac{n-1}{n}} - 1\right\}\right]$$

if Intercooling is Perfect

$$P_1V_1 = P_2V_2$$

$$W = P_1V_1\left(\frac{n}{n-1}\right)\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} + \left(\frac{P_3}{P_2}\right)^{\frac{n-1}{n}} - 2\right]$$

$$P_1V_1 = mRT_1 = mRT_a$$

$$m = \frac{P_1V_1}{RT_a}$$

$$P_1V_1^n = P_2V_c^n$$

$$P_2V_c = ~~mRT_a~~ \; mRT_c$$

$$T_c \; \frac{P_2V_c}{mR}$$

substituting the value of m and V_c to Calculate T_c

$$\frac{P_2V_c}{T_c} = \frac{P_2V_2}{T_d}$$

$$T_d = \frac{P_2V_2}{P_2V_c} \times T_c$$

$$= \frac{V_2}{V_c} \times T_c$$

Calculate the value of T_d

Heat Rejected in the Intercooler –

$$Q_{ic} = mC_p(T_c - T_d)$$