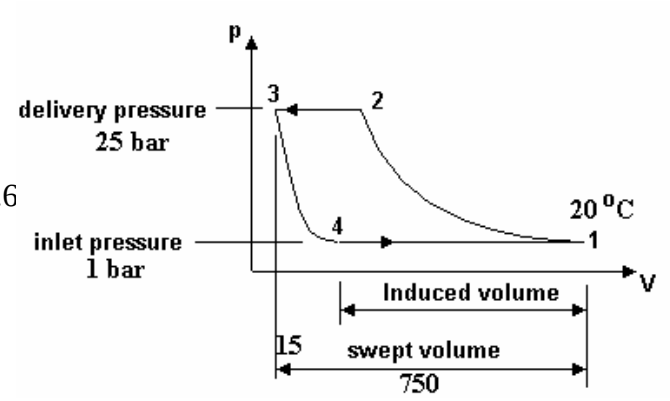
5. A single-stage air compressor has a clearance volume of 15 x 10^{-6} m^3 and a swept volume of 750 x 10^{-6} m^3. Air enters the compressor at a temperature of 20°C and a pressure of 1 bar. The delivery pressure is 25 bar and the compressor speed is 600 rev/min. Assume for the compression and expansion strokes that the polytropic indices are identical and equal to 1.45 respectively, and the gas constant for air is 0.287 kJ/kgK.
   (a) Sketch the ideal indicator diagram.
   (b) Determine
      (i) The delivery temperature.
      (ii) The mass flow rate.
      (iii) The indicated power.

   (c) Show how an actual indicator diagram would differ from the ideal diagram and explain why.

The ideal cycle is as shown.



DELIVERY TEMPERATURE

$$T_2 = T_1 r_p^{\frac{n-1}{n}} = 293 \text{ x } 25^{\frac{1.45-1}{1.45}} = 293 \text{ x } 25^{0.310} = 795.6$$

VOLUMETRIC EFFICIENCY

Clearance ratio c = 15/750

$$\eta_{vol} = 1 - c\left(r_p^{\frac{1}{n}} - 1\right) = 1 - \frac{15}{750}\left(25^{0.6896} - 1\right) = 1 - \frac{15}{750}(8.2065) = 0.8359$$

Induced volume = 0.8359 x 750 = 626.9 cm^3

Induced flow rate = 626.9 x 10^{-6} x 600 rev/min = 0.376 m^3/min

Mass flow rate

$$m = \frac{pV}{RT} = \frac{1x10^5 \text{ x } 0.376}{287 \text{ x } 293} = 0.447 \text{ kg/min} = 0.007455 \text{ kg/s}$$

INDICATED POWER

There are various ways to find this. A derived formula for the standard cycle is as follows.

$$P = mRT_1\left(\frac{n}{n-1}\right)\left\{r_p^{\frac{n-1}{n}} - 1\right\} = 0.007455 \text{ x } 287 \text{ x } 293\left(\frac{1.45}{0.45}\right)\left\{25^{0.310} - 1\right\} = 3465 \text{ W}$$

or

$$P = \frac{nmR}{n-1}(T_2 - T_1) = \frac{1.45 \text{ x } 0.007455 \text{ x } 287}{0.45}(795.6 - 293) = 3465 \text{ W}$$

In practice there is restriction when the air is being sucked in and pushed out and the valves move on their springs so actual cycle is more like this.