The "Ideal" cycle

The calculation described above yields the MEP, steam consumption (and hence Efficiency) of the steam cycle when port pressure drops are taken into account. The main parameters, apart from those determined by the dimensions of the engine, are cut-off and speed. If there were no pressure drops, (the "Ideal" cycle), speed would not affect the MEP and efficiency, but cut-off would. A clearer view of the effect of pressure drop can therefore be presented if MEP, Steam consumption and Efficiency are "normalised" by dividing by the corresponding quantities from an "Ideal" cycle having the same value of cut-off as the real cycle. These quantities are derived below, and Fig 2 defines the parameters required to calculate the MEP and the steam consumption for the "ideal" cycle.

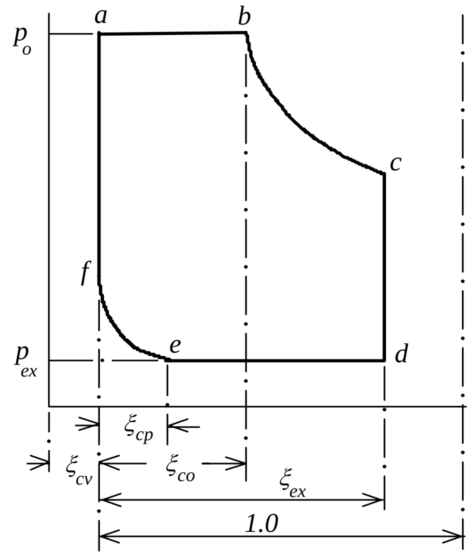


Fig.2 "Ideal" cycle parameters

Work done = $p_o(V_b - V_a) + (p_cV_c - p_oV_b)/(1-n) - p_e(V_d - V_e) - (p_eV_e - p_fV_f)/(1-n)$

where the subscripts refer to the points marked on the cycle diagram. This can be expressed in dimensionless form by means of the following transformations:

$\phi_{ex} = p_{ex}/p_o$
ξ_{cv}= clearance vol./s = $V_a/(A_ps)$
$\xi_{co} = (V_b - V_a)/(A_ps)$
$\xi_{ex} = (V_d - V_a)/(A_ps)$
$\xi_{cp} = (V_e - V_f)/(A_ps)$
where A_p = piston area; s = stroke of piston

With the above definitions the Mean Effective Pressure, which is equal to the work done per cycle divided by the swept volume, can be expressed in dimensionless form as follows:

$$MEP/p_o = \xi_o + \frac{(\xi_{cv}+\xi_{co})}{n-1}\left\{1-\left[\frac{\xi_{cv}+\xi_{co}}{\xi_{cv}+\xi_{ex}}\right]^{n-1}\right\} - \phi_{ex}(\xi_{ex}-\xi_{cp}) - \phi_e\frac{(\xi_{cv}+\xi_{cp})}{n-1}\left\{\left[\frac{\xi_{cv}+\xi_{cp}{}^{n-1}}{\xi_{cv}}\right]^{n-1}-1\right\}$$

. . . . [14]

It will be seen from Eqn.14 that the dimensionless MEP can be expressed in terms of the fractional clearance volume x_{cv}, the fractional cut-off x_{co}, the fractional release point x_{ex}, and the fractional compression point x_{cp}, together with the dimensionless exhaust pressure f_{ex}. The values of x can be determined from the equations given in the section entitled "Motion of Piston and Valve".

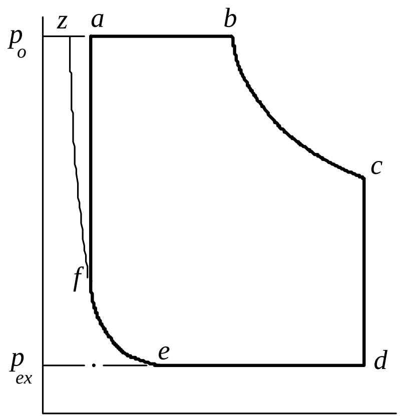
The steam supplied during the cycle is the sum of ;

a) the steam required to raise the pressure in the clearance volume from p_f to p_o

b) the steam supplied from 'a' to 'b'.

a) Assume that the steam at 'e' is compressed adiabatically to pressure $\mathbf{p_o}$ ***and find the volume at 'z' . (i.e we assume that the incoming steam acts like a piston to compress the steam already in the clearance volume). Then determine how much steam is required to achieve this.***

$$V_z = A_p s\,(\xi_{cv} + \xi_{cp})\,(p_{ex}/p_o)^{1/n}$$



As an approximation, assume that the volume of steam to be added at p_o is:

$$V_a - V_z = A_p s\,(\xi_{cv} - \xi_z)$$

Mass added $= A_p s\,(\xi_{cv} - \xi_z)/\,v_o = m_1$

$$m_1 v_o/\,A_p s = \xi_{cv} - (\xi_{cv} + \xi_{cp})\,(\phi_e)^{1/n}$$

b) ***The steam supplied from 'a' to 'b' is*** $\mathbf{m_2 = A_p s.\xi_{co}/v_o}$

Thus the total steam supplied per cycle ***,*** $\boldsymbol{m = m_1 + m_2}$

and $\quad mv_o\,/\,A_p s = \xi_{cv} - (\xi cv + \xi_{cp})\,(\phi_e)^{1/n} + \xi_{co}$ . . . . [15]

[Note: the quantity $mv_o\,/\,A_p s$ is a dimensionless mass flow, and may be interpreted as the ratio of the mass of steam supplied to the mass of steam (with a specific volume v_o) required to fill the swept volume of the cylinder]

The Efficiency of the cycle can be defined as the ratio of the work done per cycle to the enthalpy of the steam supplied. (Note that this differs from the Rankine cycle efficiency because the steam is released before it has expanded to the exhaust pressure.) One should strictly reckon the enthalpy of the steam from a datum of water at the feed temperature). Thus :

Efficiency $= MEP.A_p s/\,m.(h_o + h_f)$ . . . . [16]

where h_o is the enthalpy of the steam supplied, and h_f is the enthalpy of the feed water.