Note 21
Optimum Bore / Stroke ratio

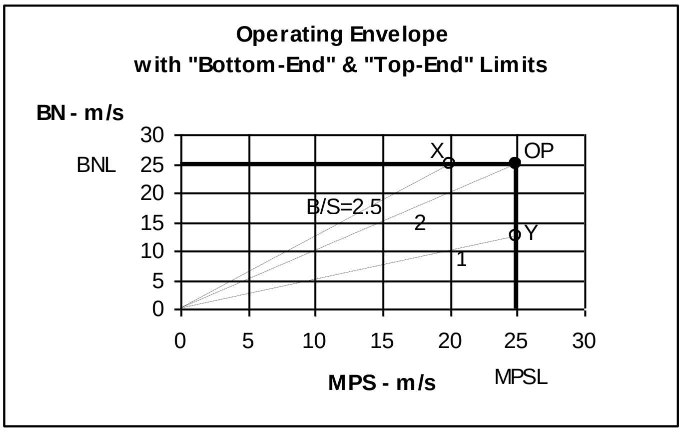
When the "Bottom-End" and "Top-End" limits of a poppet-valve piston engine are set by **MPS** and **BN,** respectively, according to the design conventions and available materials at a particular date and when **BMEP** is at the best attainable level with the knowledge at that date and in accordance with regulations, then for that case:-

$$\frac{\mathbf{P}}{\mathbf{V}} \propto \mathbf{N.}$$

There will be an optimum **B/S** ratio which maximises **N** and therefore **P/V**.

This is shown in the following analysis, which is for engines of fixed **V** and fixed Number of Cylinders (**CN**).

Let (**Limiting MPS**) be **MPSL** and (**Limiting BN**) be **BNL**. A diagram of the Operating Envelope will show (with limits typical of the later review period):-



The slope of the line from the origin to any point is equal to ½.(**B/S**) for that point.

For an Engine operating at point X

Since BN = BNL and MPS at X is < MPSL, therefore B/S at point X is *higher* than that at the limits intersection point OP.

Suppose it is required to alter the engine to raise MPS by a factor "f". As BNL = ½.(B/S).MPS, therefore (B/S) must be *reduced* by a factor 1/f. Because V and CN are fixed, (B^2.S) is fixed and so (B/S) $\propto B^3$ and the reduction ratio required of B = $1/(f)^{1/3}$. Since BNL is fixed, this reduction of B allows an $(f)^{1/3}$ rise in N. For e.g., a 10% increase in MPS is obtained with a 3.2% rise in N.

Thus *moving point X towards point OP creates a rise of N.*

For an Engine operating at point Y

Since MPS = MPSL and BN at Y is < BNL, therefore B/S at point Y is *lower* than at point OP.

Suppose it is required to alter the engine to raise BN by a factor "f". As MPSL = 2.BN/(B/S), therefore (B/S) must be *raised* by a factor f. As before, (B^2.S) is fixed and so (B/S) $\propto (1/S)^{3/2}$ and the reduction ratio required of S = $(1/f)^{2/3}$. Since MPSL is fixed, this reduction of S allows an $(f)^{2/3}$ rise in N. For e.g., a 10% rise in BN is obtained with a 6.6% rise in N.

Thus *moving point Y towards point OP creates a rise of N.*

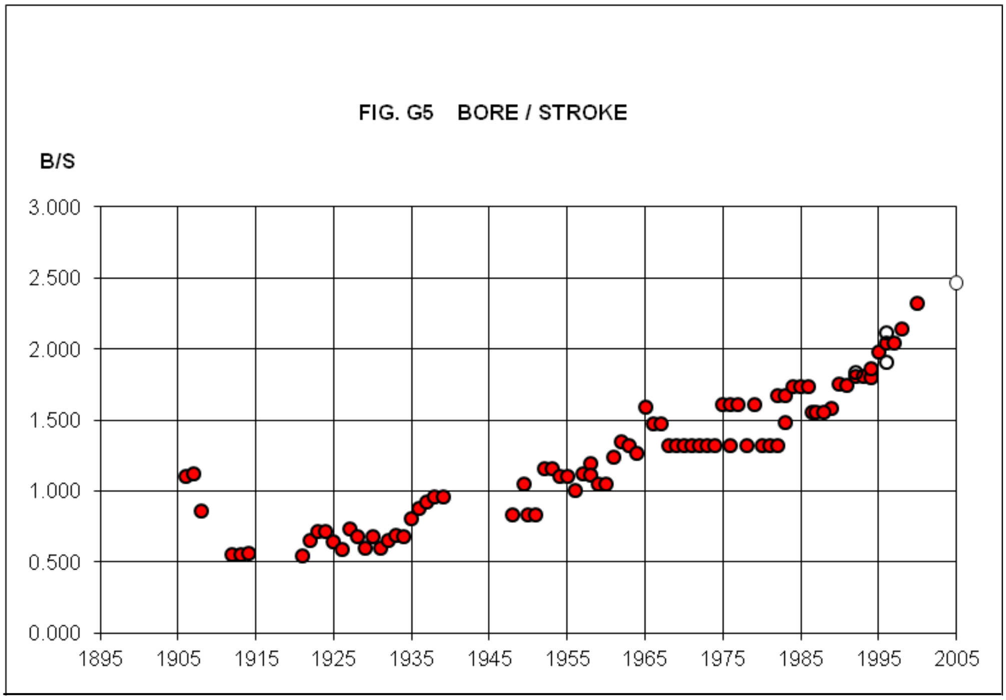
Conclusion

It follows from the above that the intersection of the "Bottom-End" and "Top-End" limits, point OP, represents maximised N and therefore maximised P/V for the chosen value of CN. The value of B/S at OP is optimum **for the design conventions and materials of the particular date**, at:-

(B/S)OP = 2.(BNL)/(MPSL)

Historical Bore/Stroke ratio

The historical B/S ratio for CoY engines from 1906 to 2000 is given on Fig. G2 on P.2.



This chart has been extended to 2005 to include the BMW P85 V10 3L engine, which was the highest B/S ratio reached up to the time of writing (98mm/39.75 = 2.465). The unit was not raced because of a late change to the rules by FIA demanding longer life for which BMW had not designed. The engine was also the last in which the designer had a free choice of maximum B/S ratio, although constrained by a 2001 rule to 10 cylinders. After 2005, for the 2006 – 2013 V8 2.4L formula a maximum Bore of 98 mm was imposed, meaning a generally adopted B/S ratio like the P85.

For the new 3rd PC Era formula beginning in 2014 a maximum Bore of 80 mm has been regulated in V6 engines of 1.6L so that the highest permitted B/S is about 80/53 = 1.51.

It is now unlikely that the B/S ratio will ever be permitted to exceed the P85 figure.

Two comments on the historical series:-

- The initial drop of B/S to around 0.5 is explained in Note 35 "The influence of Maurice Sizaire on piston engine design";
- The long series of B/S around 1.3 from 1968 to 1982 is due to the continuing success of the Cosworth DFV (see "The Unique Cosworth Story").

The valve-gear developments which enabled the B/S ratio to increase so as to raise the volume-specific power are described in Note 15 "Valve-spring problems and their solutions".