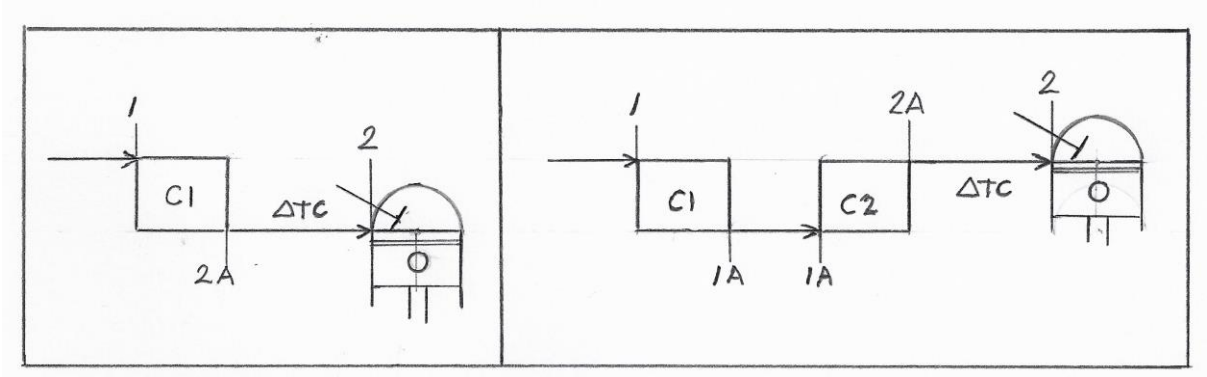
Note 10B

Estimation of Manifold Density Ratio (MDR) for Pressure-Charged (PC) engines

In this Note the flow stations through the Pressure-Charging system are identified as shown on the following diagrams:-



1-Stage Compression 2-Stage Compression

It is assumed that entry conditions are Standard ambient, i.e.

P1 = 1.0133 Bar (14.7 psi); T1 = 288^0K.

MDR, as a multiple of ambient air density, which is required in the basic Power equation (Eqn. 3 of Note 10) and which is taken to be 1 for Naturally- Aspirated (NA) engines, depends upon the absolute charge temperature at the inlet valve, T2, where:-

MDR = IVP/(T2/T1)

(T2/T1) depends upon:-

- The Efficiency of Compression (CE) to the pressure at the inlet valve (IVP = P2/P1);
- The post-Compression cooling (ΔTC) by fuel evaporation* or by intercooler. For the 1st method ΔTC depends on
  the Latent Heat of the fuel constituents;
  and the richness of the Air/Fuel Ratio (AFR).

- It is assumed in the calculations for simplicity that ΔTC occurs after the Compressor has added heat, although all Grand Prix CoY in the 1st PC Era 1924 – 1951 except the 1924 Alfa Romeo P2 and the 1935 Mercedes-Benz M25C had their fuel sprayed into the airstream by a carburetter upstream of the supercharger. In the 2nd PC Era 1983 – 1988 fuel was injected post-Compression.

The Temperature rise is given fundamentally by:-

$$\Delta T12A = T1 \times \left[(IVP)^{0.286} - 1 \right] / CE$$

1st PC Era: 1924 – 1951

For the Roots-type mechanical superchargers used exclusively for Grand Prix CoY between 1924 and 1951, an empirical expression by Maleev (641) was used in this review which gives:-

$$\Delta T12A = T1 \times \left[(IVP)^{0.5} - 1 \right]$$

This has implicit values of CE:- at IVP = 1.3, CE = 55%; at IVP = 2.1, CE = 53%.
An IVP of 2.1 is the highest figure for a Roots supercharger before the efficiency falls off drastically. Data derived from (468) shows that, at IVP 2.43 used in the 1938 Mercedes M154, CE = 35%. No other GP CoY operated in the region between 2.1 and 2.4 and it was realised by Mercedes in 1938 that higher than 2.1 the compression should be shared between 2 superchargers in series, each within the "normal" Roots efficiency range around 50%.

In this review for the calculation of MDR with 2-stage supercharging it was assumed that the 1st and 2nd stage pressure ratios were equal, i.e. at √(IVP).

Fuels

The fuels used for each CoY engine are given in Appendix 1, referenced to details in Appendix 2 Table.

Air/Fuel Ratio (AFR)

No data are available on the mixture strengths used in the engines considered in this review so a figure has been assumed according to their circumstances.

For 50% Petrol + 50% Benzole and for the widely-used "Elcosine" (53% Benzole + 44% Ethanol, etc,) over 1924 – 1934, a 20% richness for maximum power seemed reasonable. In 1934 Mercedes introduced 'WW' 86% Methanol fuel and they were concerned about its high consumption so the chemically-correct AFR ratio would have been appropriate, as it would be for the lower-alcohol mixture used in 1935 – 1937. The inefficient M154 of 1938 would have needed 'WW' at full power 44% richness to cool its supercharger outflow. The 2-stage more-efficiently-supercharged M163 would have needed a substantially less-rich 'WW' mixture to avoid cooling below ambient temperatures which would have caused icing-up in wet weather. This M163 had a full-throttle super-rich feature on its carburetter which sometimes jammed, including during the German GP which was run in cold and wet conditions that did upset the carburetion set up in practice.

The 2-stage supercharged post-WW2 Alfa Romeo of 1948 to 1951 was assumed to require steadily-enhanced richness with its 98% Methanol fuel as boost pressure was increased until reaching full 44% richness in 1951 when IVP = 3.9. This mixture would have been unable to deduct all the compression heating.

2nd PC Era: 1983 – 1988

In this 2nd PC Era, which was exclusively Turbo-Charged (TC) in Grand Prix CoY, fuel to 102 RON was the regulation, which the authorities intended to mean Petrol. The CoY PC engines actually ran on an artificial fuel which met the Octane limitation in the low-speed control engine but gave superior performance in the racing engine (see Note 90). The ΔTC available from evaporation was only 22^0C at the max.-power richness of 20%. Consequently most of the post-Compression cooling needed to restore charge density and avoid knocking was provided by intercoolers between Compressor and inlet valve. All GP CoY engines used air-to-air intercoolers. These were made large enough, even at IVP = 4 Bar, to restore T2 to 40^0C above T1 for maximum power with 84% Toluene + 16% Heptane fuel, egs the 1987 – 1988 Hondas (20). Therefore this ratio of (T1/T2) = 0.92 was used in the estimates of MDR for all TC GP CoY engines since all ran on high-Toluene fuel.