## Tumble Swirl: side ports and vertical ports

The inflow on suction through a poppet valve is biased by its momentum to the further side of the valve as it passes round the unavoidable curve to the valve head. With a 'side-draught' port (ie in relation to the cylinder axis) and with an inclined valve, part of the flow then impinges on the far wall of the cylinder and is caused thereby to loop or 'tumble' downwards. As the piston rises again on the compression stroke, the conservation of angular momentum while the rotary motion in the crankshaft plane is reduced in radius gives much increased circulation velocity to the mixture. This raises the rate of burning after ignition and so improves Combustion Efficiency (EC).

Swirl imparted around the cylinder axis by inlet ports curved in that plane, which was patented by Harry Weslake in 1948 when applied first to the Jaguar XK120 (214) (See sub-Note A), is less magnified by the rising piston compressing the charge into the combustion chamber.

'Tumble Swirl' (TS) in the crank plane is likely to have occurred naturally in many engines with inclined valves and side ports, but not by design intention. In the Cosworth FVA, designed by Keith Duckworth in 1965, TS was encouraged deliberately by having the outer part of the inlet passage non-orthogonal to the valve head by 20° and by increasing Inlet Valve Maximum Lift/Head Diameter to 0.3 from the then-usual 0.25. Volumetric Efficiency (EV) was sacrificed to some extent so as to gain EC and maximise (EV x EC). By having 4 valves-per-cylinder to provide the necessary areas the valve stems could be at only 20° to the cylinder axis, so that the inclination of the outer inlet passage wall at approach to the valve head was 20° + 20° = 40°. Therefore, the biased flow did not go straight across into the exhaust during the timing overlap period used to create extra suction. The central sparking plug made possible by four valves was placed perfectly to ignite the change whirling beneath it.

Sketches illustrating Axial Swirl and Tumble Swirl are given on P.2.

In the '30s, the two valves-per-cylinder 'flat port' motor-cycle head design also had non- orthogonal inlet passages near the valve head but, with a valve stem at 45° so that the outer wall angle was around 65°, they suffered from the charge loss to exhaust mentioned above, as pointed out by Phil Irving (76). The 1949 works 500cc Norton (which is believed to have been the same as the 1938 engine) had 27° non-orthogonality from a valve head with a stem at 37° to the cylinder axis, so that the outer flow angle was 64° to that axis (68). The later works Nortons (post 1950) had a 20° non-orthogonal wall but a valve stem at 32°, ie 52° wall inclination (480).

In the Cosworth DFV, designed one year after the FVA, the stem angle was reduced to 16° so that the flow struck the cylinder wall at a nominal 36°.

With an 'axial' (or 'vertical' or 'fully downdraught') inlet port, ie one at 0° to the cylinder axis, the inflow is biased by the inclined valve to pass directly into the cylinder, which raises EV but does not create TS and so (EV x EC) is lower than the 'side draught' engine. Walter Hassan, as a result of his experiments (going back to a pre-XKl20 design (214», was convinced that the axial port was not as good as the side port for producing maximum power, although it could be better at lower speeds (515). Harry Weslake also disliked the vertical port and the late Brian Lovell stated that this was because of its reduced contribution to rotational swirl in the cylinder (587). It is possible, however, that Weslake was considering that such a port could not be arranged tangentially to provide circumferential swirl.

**Sub-Note A: Early use of axial swirl**

Axial swirl was used before 1914 by Dr K Hesselman of the Swedish Atlas Co in Diesel engines for submarines in order to help fuel injection without air blast, which was the previous method.
This swirl was created by partial masking of the inlet valve circumference, however, not by the shaped inlet port later introduced by Weslake (852, 947).

After discussion with Ricardo in 1914, when the latter described his theory that petrol engine knocking arose in the end gas, Hesselman built engines with axial swirl in which the petrol (or even kerosene) was injected just upstream of the sparking plug so that the end charge had no fuel and could not detonate. These engines were successful and were also built in the USA (852).

## Harry Weslake's Axial Flow

1948 Jaguar XK120

IL6 83/106 = 0.783 3.441 cc

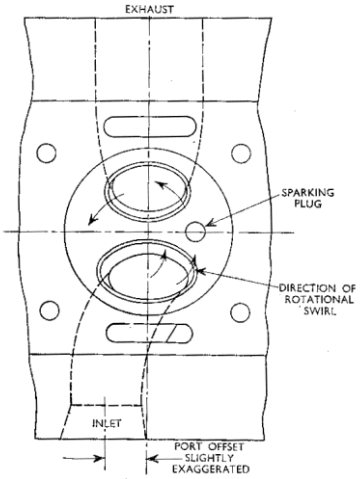
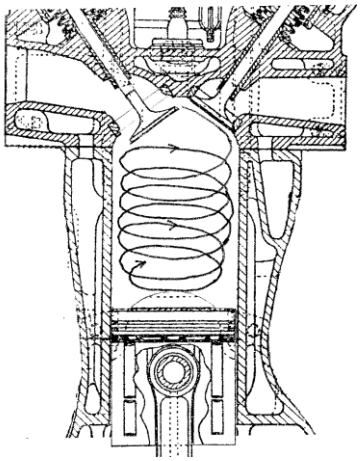



Fig. 9. Plan of Valve Ports



DASO 214

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## Keith Duckworth's Barrel Turbulence (aka Tumble Swirl)

1965 Cosworth FVA

IL4 3.375''/2.722'' (85.725mm/69.139) = 1.24 1,596 cc