Chapter 2.

Designing for Effective Combustion.

Combustion Chamber Layout.

What we call the combustion chamber has to serve a multiplicity of functions. It has to have a means of admitting fresh charge, burning it, and discharging it to exhaust, which means it must be able to ignite the charge at the right moment and ensure that it burns properly, yet also accommodate inlet and outlet valves with room to perform their functions. The volume must not be too large or the compression ratio achieved by the rising piston will be insufficient. This all involves quite a lot of compromise.

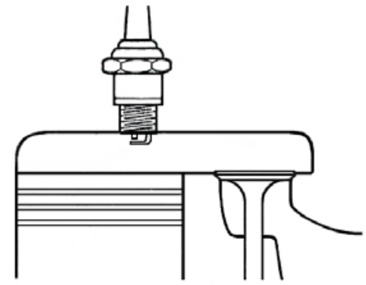

Fig. 2.1 Simple side valve combustion chamber.

In the early days not much was known about the burning process so combustion chambers tended to be rather simple, almost a matter of convenience, with no real thought given to finer details like charge movement and spark plug location (Fig. 2.1).

In time combustion chamber design became almost a science in itself, closely allied to fuel composition and this process of improvement has not ended yet.

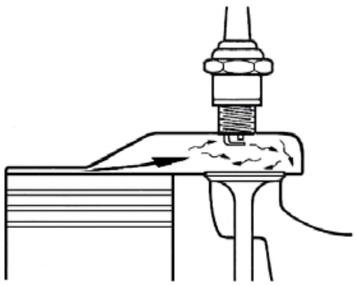

Fig. 2.2 Squish side valve combustion chamber.

By the 1930s it was becoming well known that the charge must be made to move about in the manner described in Chapter 1. Ricardo had shown that bringing part of the cylinder head of a side valve engine down close to the piston crown would not only help to increase the compression ratio, it would also propel the charge across towards the spark plug, itself moved to a better position, and promote turbulence – a method known as 'squish' (Fig. 2.2).

It is easy to be dismissive about the side valve layout but it has compactness and simplicity very much in its favour. The valve train itself is as minimalist as any modern overhead cam arrangement and the low camshaft can be easily driven by simple gears or chain drive with hardly any chance of the flexure and torsional problems that can bedevil overhead valve engines. It is also by far the most compact layout for a four stroke spark ignition engine. It is for such reasons that Ford UK's side valve 100E engine survived as a production car power unit until as late as 1962. It is also why large numbers of side valve engines are still being produced for utilitarian applications such as lawn mowers, cement mixers, cultivators and so on.

Eventually the conflicting requirements for breathing space around the valves and high compression ratio meant the side valve engine was left behind by the motor industry, driven by the demands for increased performance and fuel efficiency.

For similar reasons by the time of WW1 there were no side valve engines of any significance to be found powering aeroplanes even though Bleriot had flown across the English Channel behind an Anzani engine with side exhaust valves just a few years before. The only subsequent side valve aero engine of any note was the little Continental A-40 flat four which found a market because of its simplicity and modest price, powering light aircraft in the USA during the depression years of the 1930s.

There were a number of engines which might be considered to be of intermediate design having overhead inlet valves and side exhaust valves. An attraction was that the inlet valve could be placed directly over the cylinder bore for unrestricted breathing and away from any heat transfer from the exhaust valve. In 1948 Rover introduced an unorthodox variant for their P3 saloon which met the theoretical ideal of a hemispherical combustion chamber around a central spark plug location (Fig. 2.3). This design performed well enough to survive in the Land Rover until 1980.

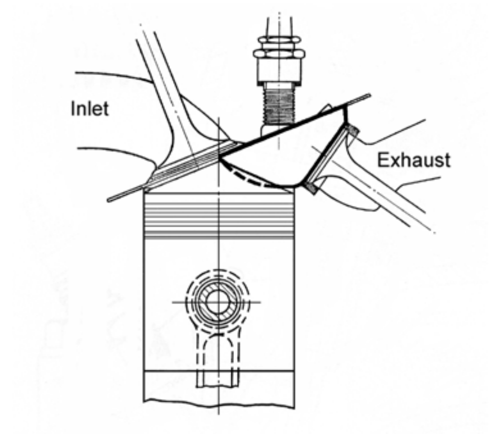

Fig. 2.3 Rover P3 combustion chamber.

The demand for more performance made inevitable the transition to overhead valve engines that could properly exploit the availability of higher octane fuel. The geometry of early overhead two valve engine designs with relatively long strokes and small diameter cylinders nearly always produced a vertical swirl pattern around the cylinder axis (Fig. 2.4).

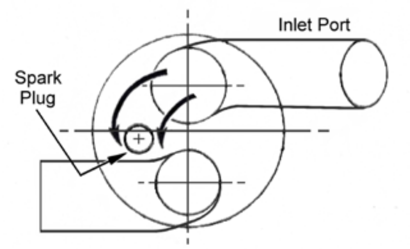

Fig. 2.4 Natural swirl of in-line two valve head.

The ideal spark plug location presents something of a quandary. If it is near the centre then the charge will be rotating around it and not really helping to spread the flame about. On the other hand if the plug is placed at the side where it is swept by the swirling charge then the flame travel becomes far too extended. The spark plug therefore generally ends up placed somewhere in between, but this is not where any swirling fuel particles would easily gravitate, as instead they tend to centrifuge out to the cooler cylinder walls. Consequently the burn process would take a little longer and some fuel could be quenched by the cylinder walls, then burning less thoroughly (Fig. 2.5). Apart from any performance deficit this might have introduced it also caused what we would now regard as an undesirable level of exhaust hydrocarbon emissions.

Fig. 2.5 Swirl around cylinder axis.

In order to reduce the risk of detonation or pre-ignition (see Chapter 5) it was conventional practice to locate the spark plug relative to the swirl pattern so that as the flame was carried along it passed over the hot exhaust valve first thereby reducing any tendency to provoke such problems.

Many two valve engines feature Ricardo's 'squish' principle so that the extremities of the combustion chamber are closely approached by the piston crown at the TDC point, forcing mixture in these areas out of the declining space as the piston rises, thereby stirring up the main charge (Fig. 2.6).

A disadvantage of being too dependent on squish induced turbulence is that because it is generated by the piston closely approaching a matching area of the cylinder head at TDC, it occurs rather late to benefit the formative stages of combustion. There is also a reverse effect as the piston starts to descend, some of the charge then being drawn back out again to the extremities (Fig. 2.7).

Because this part of the charge is now exposed to relatively cool surfaces of the piston and head, there can again be a quenching effect, discouraging combustion and increasing HC emissions, aggravated further by the inevitably greater surface area of the arrangement.

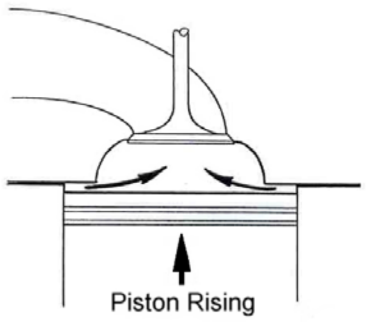

Fig. 2.6 Squish induced turbulence.

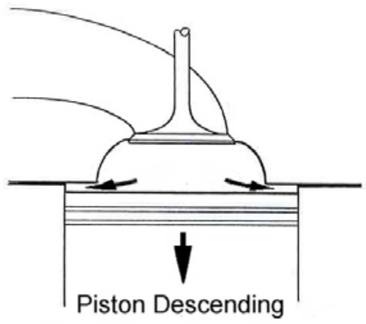

Fig. 2.7 Reverse squish on the down stroke.

Many engines of this type employed a combustion chamber of simple oblong shape encompassing both valves with the spark plug located along one of the sides. Because of some vague resemblance this became known as a bathtub chamber and was widely used in overhead valve engines for many years.

Alternatively the valves could be canted over at about 10 or 15 degrees to form a shape not unlike a wedge of cheese, the spark plug in this case being in the centre of the thick end. The so-called wedge head (Fig. 2.8) was one of the better options for an engine with two in-line valves, combining good breathing with a reasonably compact chamber augmented by squish action. It was particularly attractive for use in V engines because slanting the valves inwards made the engine more compact and gave easy access to the spark plugs. The vast numbers of V8s churned out by Ford and GM mostly used the wedge combustion chamber and more exalted lower volume examples were Rolls-Royce’s V8 and Coventry Climax’s legendary FW series.

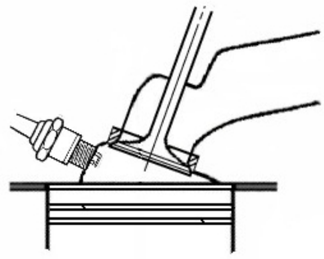

Fig. 2.8 Wedge combustion chamber.

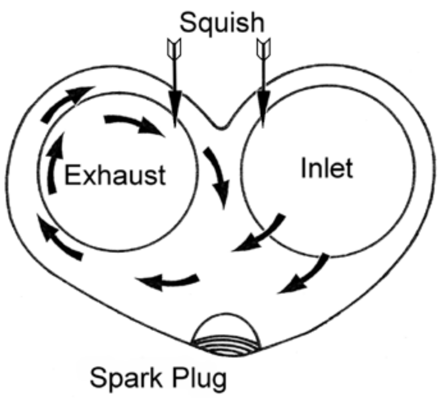

Fig. 2.9 Weslake designed chamber for BMC A Series.

Another successful two valve in-line design was also one of the most humble - the heart shaped chamber (Fig. 2.9) designed by Harry Weslake for Austin (later absorbed into BMC) just after WW2. The hidden subtleties made it an outstanding performer for many years, particularly in terms of part throttle fuel efficiency, despite its obsolescence in many other ways. Introduced in 1952, it finally ceased production in the year 2000. It was used across an entire range of BMC engines (A, B, & C series) ranging from 0.8 to 3.0 litres displacement.

10 pages follow.