FANNING THE FLAMES

Better combustion is the key to more power and one way to achieve it is with twin spark plugs per cylinder. The idea is almost as old as the car and one that only Alfa Romeo is taking seriously. Jeff Daniels explains

Alfa Romeo's latest 2-litre 75 has a twin-spark engine. Why would any engine designer wish to use two plugs per cylinder? Because he cannot get the results he needs with one. If he could get the mixture in the cylinders to light up reliably and burn completely with only one sparking plug, he would use only one. With a couple of exceptions, this has always been the case with genuine production car engines. A few years ago Nissan had a twin-spark version of the Silvia, not sold in this country, and one might also make an exception for the postwar Maseratis, though their production volume was tiny.

Many racing engines, especially those with bigger cylinders, have used two plugs per cylinder. Wankel rotary engines have mostly used two plugs in tandem to fire the mixture in their long, flat combustion chambers but they are a special case. It is worth noting, too, that piston aero engines have twin plugs, but that is for a different reason. Aero engines have completely independent twin ignition systems for belt-and-braces safety.

So why has Alfa Romeo gone twin-spark, with a new cylinder head for the classic twin-cam engine? To understand why twin plugs might be an advantage, we need first to consider the problems facing an engine designer in trying to light and burn his fuel/air mixture. The process happens fast. In an engine turning at 6000rpm the piston descends from top dead centre (at the beginning of the power stroke) to bottom dead centre (at the end of the stroke) in one two-hundreth of a second. In that time the spark plug must fire, the mixture catch light and burn as steadily and completely as possible. At the end of the power stroke, the cylinder should ideally be full of exhaust gas ready for expulsion, with as little unburned hydrocarbon or part-burned carbon monoxide as possible remaining.

Combustion specialists talk about the 'flame front' moving outwards from the sparking plug after it has fired. The manner in which the flame front moves depends on the way in which the mixture may have been stirred up by the engine design. It may have been swirled, by making the inlet valve port into a gentle corkscrew shape. Or it may have been squished, by designing the piston so that an outer ring of the crown comes nearly into contact with a matching part of the combustion chamber; approaching top dead centre, the mixture is 'squished' towards the centre of the chamber. Swirling and squishing help to ensure the mixture is uniformly mixed and, by violently agitating the mixture, speed up the burning process at the expense of making it less smooth and predictable.

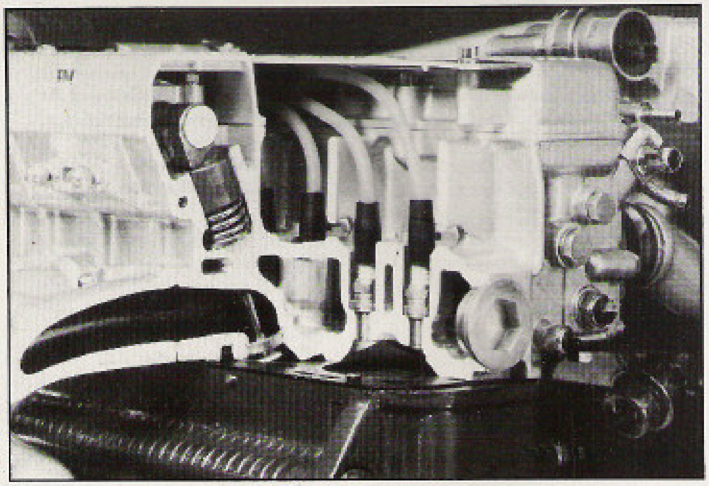
To purist engine designers swirl and squish are undesirable. An inlet port designed to impart swirl allows less air to enter the cylinder than would a 'straight' port of similar dimensions. A combustion chamber with lots of squish exerts a counter-pressure on the rising piston. Both effects represent some loss of potential performance.

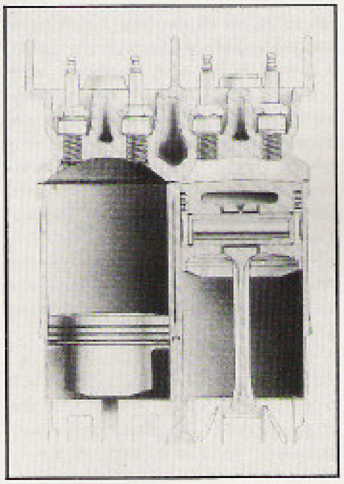
The problem starts with that two-hundreth of a second. It may be enough time if your engine is small, but the larger the engine, the greater the problem. For a mixture of given strength — and in the absence of turbulence created by swirl or squish — the flame front will always move at much the same speed. Thus the bigger the engine, the longer the flame front will take to reach the farthest corners of the combustion chamber. In a very big engine (the Maserati 3500GT had 86mm bore and 100mm stroke) the flame front from a single sparking plug may not have enough time to lick into every corner of the chamber. The engine is not static, remember: a flame front fired off at top dead centre finds itself chasing after a rapidly descending piston.

In practice the picture is more complicated still. The tidy, idealised four-stroke engine of theory is compromised by variations in valve and ignition timing. The valves 'overlap' top and bottom dead centre in order to help scavenge away burnt gas, and encourage fresh mixture to start flowing into the cylinder early and strongly. The ignition timing will be adjusted to achieve the best results at each engine speed. The higher the speed, the earlier the ignition — so the fire is lit while the mixture is still being compressed, to give it more time to burn fully. Every such adjustment tends to move the engine away from the theoretical ideal and sacrifice a little power.

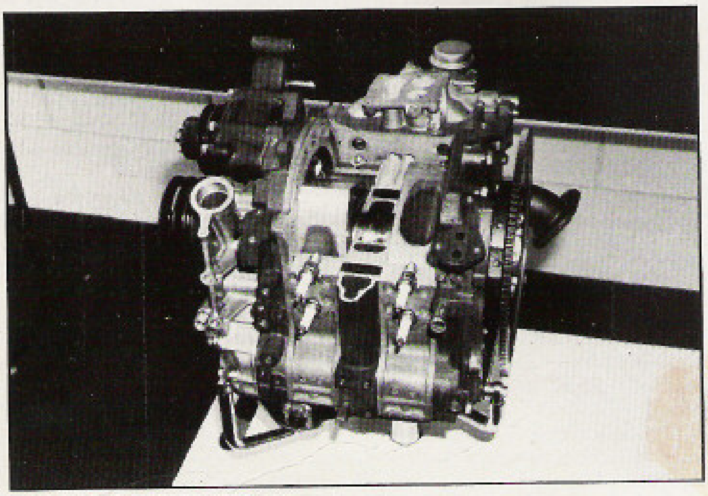
There are other worries for the poor designer. The weaker the mixture, the more slowly the flame front moves. That has become a serious issue as fuel economy and exhaust emissions have become major design targets. The option of keeping the mixture rich at all times is no longer open. Other ways have to be found of ensuring the flame front reaches all its targets.

There is also the question of basic mechanical design. The sparking plug has to be fitted where it will not get in the way of the valves and their ports. If the two valves are made large enough to get plenty of mixture into the cylinder, the sparking plug is inevitably squeezed away to one side. That lengthens the flame front▶

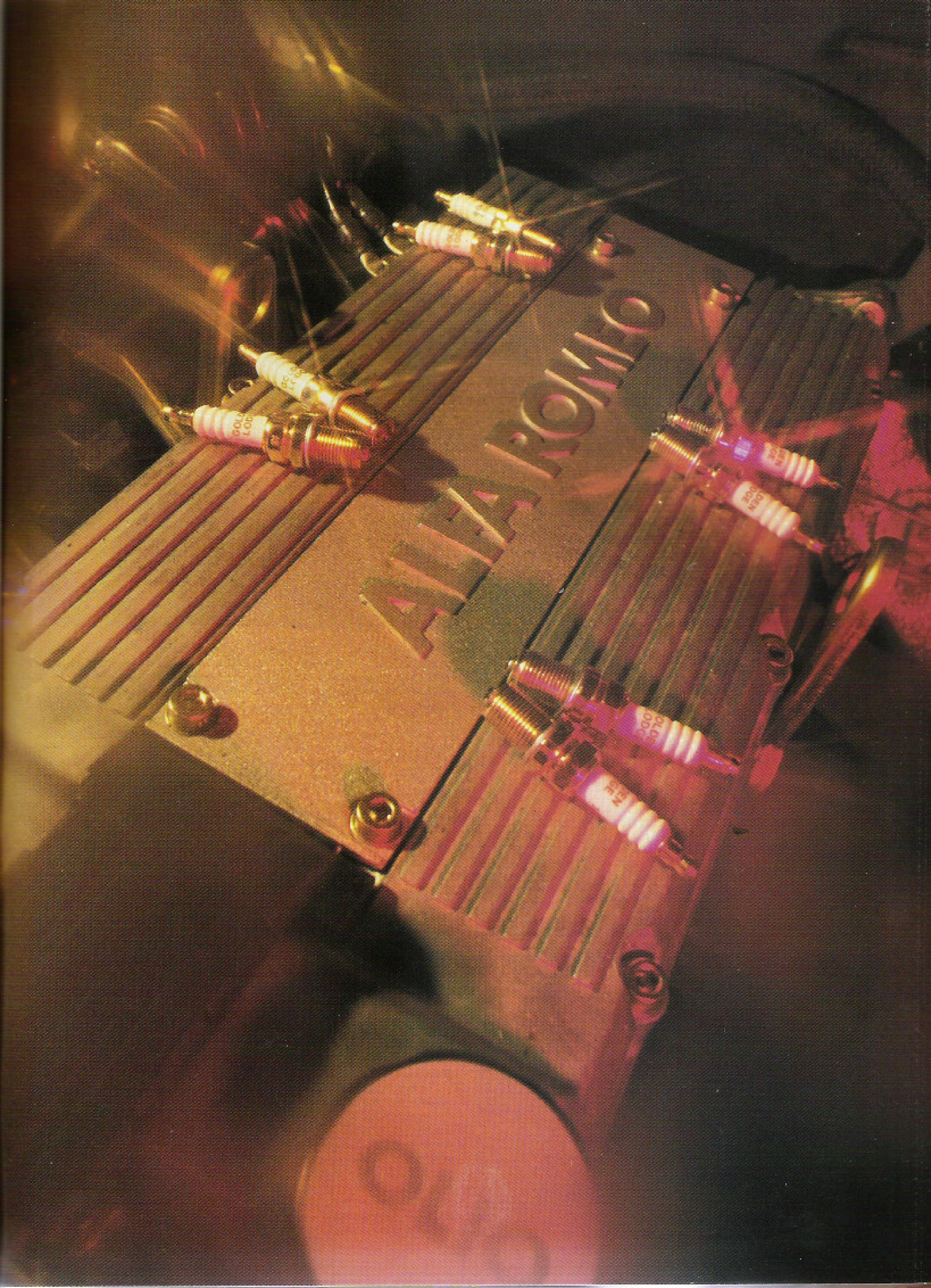




Alfa's Twin Spark *engine and its combustion chamber (above left and above). The two plugs allow the flame front in the combustion chamber to travel more quickly, leading to fuller combustion, particularly of the weaker fuel/air mixtures that more stringent emissions standards dictate*



Rotary engines, *like Mazda's twin rotary from the RX7 (left), have long flat combustion chambers ideal for twin plugs*


ALFA ROMEO

path to the farthest 'target', and ensures that burning is of necessity asymmetric — not a happy state of affairs.

Those, then, are the main pressures on engine designers seeking to create a high-output two-valve engine running lean enough mixtures to meet current exhaust emissions standards and to be reasonably economical.

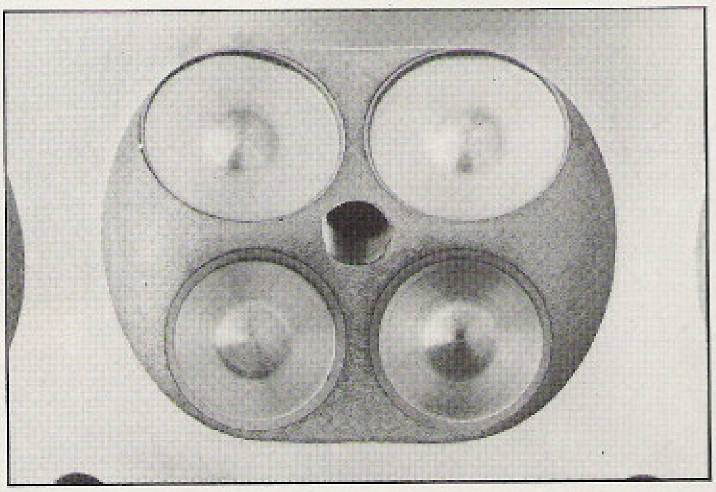
For the past decade, engine designers have lived with these pressures largely by accepting swirl and squish however much they may dislike them, and by employing combustion chamber shapes which channel the compressing mixture towards the sparking plug. Harry Weslake's chamber for the BMC A-series engine was one of the pioneers of this approach, and one which was successful enough to keep the A-series competitive for many years more than it might otherwise have been.

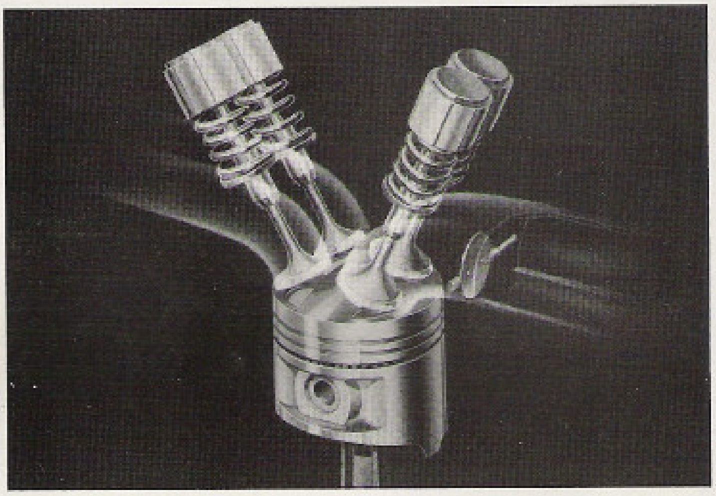
There are two more purist options, however. The first is to use four valves per cylinder. This greatly increases the possible valve area within a cylinder of given size, and frees the dead-centre spot for the sparking plug, thus equalising and minimising the flame front path in any direction.

The other option is to retain two valves but to employ two sparking plugs, symmetrically placed on the axis at right-angles to the valve axis within the cylinder. In the simplest terms, each plug look after half the combustion chamber. With good positioning, the maximum flame front paths should be even less than from the single central plug of a four-valve engine.

Just why a manufacturer should choose one solution rather than the other is a matter for debate. Alfa Romeo has bucked the current trend by going to twin-plugs, but you can hardly argue with the results. The previous 2-litre Alfa Romeo twin-cam engine produced 130bhp at 5400rpm and 130lb ft of torque at 4000rpm. The twin-spark engine, with the same 84mm bore and 88.5mm stroke, produces 148bhp at 5800rpm and 137lb ft at 4700rpm. What is more — and this is highly significant — the 2.0 Twin Spark 75 is substantially more economical than the single-spark 1.8 in identical test conditions. At 75mph it manages 47.1 instead of 40.4mpg; in the EEC urban cycle it achieves 28.5 against 23.5mpg.

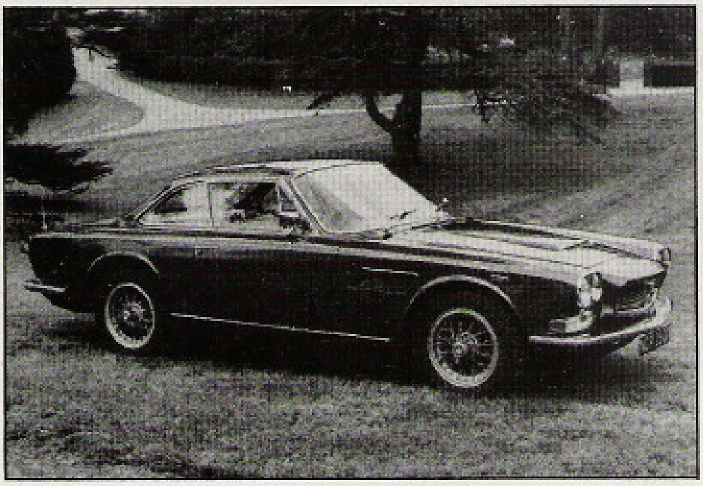
The increase in torque is significant because normally it is much more difficult to improve an engine's torque, without enlarging its capacity, than it is to improve its power. Power can be increased by running the engine faster and ensuring the flow of mixture through it is enough

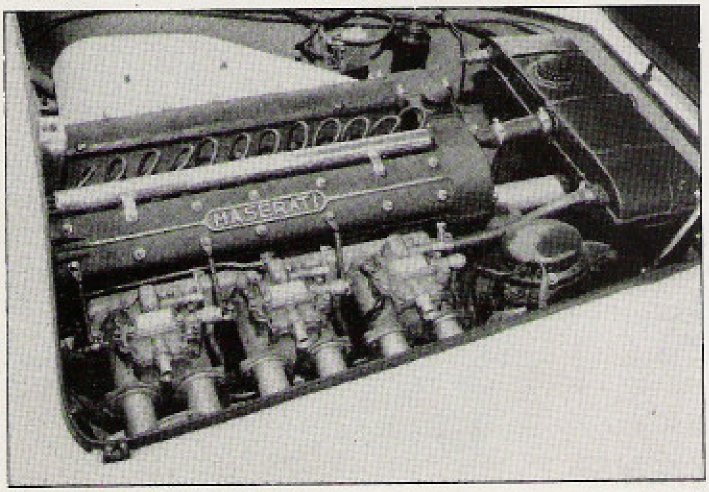




Alfa's twin-spark *system is a low-cost alternative to the now common four-valve per cylinder system that does allow a central spark plug*

Maserati Sebring *(below) used a 3.5-litre straight-six (bottom), in injection form which produced 235bhp at 5500rpm*





to take advantage of the higher speed. Torque is a measure of the pressure exerted by the expanding gas on the piston during the power stroke, and all that happens in conventional power-tuning is that the peak torque occurs at higher speed.

Alfa's improved torque indicates that the average pressure on the descending piston (the brake mean effective pressure, BMEP) has been usefully increased. This is at least partly a result of retiming the valves and ignition to take advantage of the greater latitude conferred by the twin-plug layout. It should also be noted, though, that the design of the combustion chamber and cylinder head as a whole has been changed. The original Alfa Romeo engine has a classical hemispherical chamber with the valves opposed at an included angle of 80deg. It is generally assumed that this shape gives very efficient combustion because of its small ratio of surface to volume, which minimises heat losses. However, if the engine runs a tolerably high compression ratio, the effect is badly spoiled by the need to use a high-domed piston.

The new Alfa's combustion chamber still has opposed valves operated directly by twin overhead camshafts, but the valve angle has been narrowed to 46deg and the pistons are only slightly domed, even for a compression ratio of 10-to-1. The plugs are set completely upright on the centre-line of the cylinder head, and a fair distance apart. It certainly seems they have been positioned to keep the flame path travel as short as possible. One set of plugs is fired from the 'original' distributor, skew-gear driven from the crankshaft. The other set takes its spark from a second four-contact distributor on the end of the exhaust camshaft. The inlet camshaft retains its variable inlet valve timing arrangement which allows the valve overlap to be varied according to engine speed. This has particular benefits in idling and slow-speed operation.

The twin-spark engine's much improved economy comes without doubt from its ability to run leaner mixtures with reliable firing. The second sparking plug overcomes the former problem that lean mixtures might slow down the flame front too much to allow complete burning at high speed. Alfa Romeo has not given specific exhaust emissions levels for the engine but claims it to be notably superior to the old one.

It remains to be seen whether Alfa Romeo will be a twin-plug voice in the four-valve wilderness. The company argues that the twin-spark layout avoids one of the four-valve's problems, that its high power is produced at higher engine speed with the risk of greater internal power losses. That is a contention that will doubtless be argued by some, especially perhaps by Jaguar whose AJ6 four-valve engine peaks at modest rpm.

The fact remains that the Alfa 2.0 Twin Spark is a formidable car to produce as evidence, and may give othe engine designers pause for reflection. ■