THE ARRANGEMENT of

Cylinder Head Designs which Depart from Conventional Practice—their Advantages and Drawbacks

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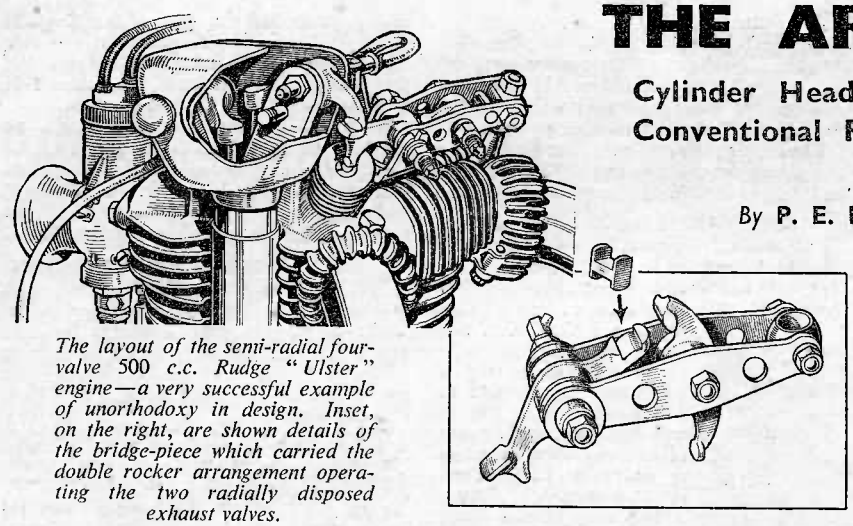


The layout of the semi-radial four-valve 500 c.c. Rudge "Ulster" engine—a very successful example of unorthodoxy in design. Inset, on the right, are shown details of the bridge-piece which carried the double rocker arrangement operating the two radially disposed exhaust valves.

THE revival of the three-valve layout by A.J.S. early this year has evoked memories of many other cylinder-head designs embodying more than the simple pair of valves which, up to now at any rate, has always been able to stave off the challenge of other systems, albeit after something of a struggle at times.

The largest valves which can safely be accommodated in a two-valve layout occupy only about one-third of the internal area of the head; thus, long ago, it occurred to some designers that a much greater valve area could be obtained by using a larger number of smaller valves. In fact, one inventor took out several patents for heads with no fewer than eighteen, which one cannot help feeling was going a trifle too far! Another inventor proposed to use concentric valves, the outer one almost as big as the cylinder bore and with a large, hollow stem which acted as a port for the inner valve. Lots of these schemes can be found in the Patent Office files by those gifted with sufficient patience.

"Pent-Roofs"

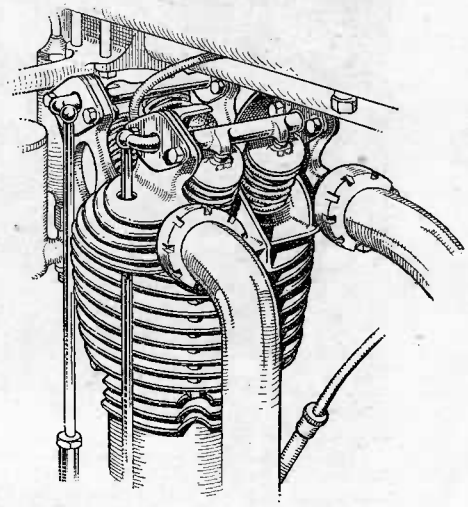
Among the more rational schemes, the most frequently used alternative to the two-valve system has been the four-valve, "pent-roof" layout, so called because the internal shape of the head is composed of two inclined surfaces in each of which a pair of valves is seated. The pent-roof or gabled shape so formed is blended into a circle of roughly the same diameter as the barrel, although in some car designs with high stroke/bore ratios the length of the pent-roof is considerably greater than the bore diameter to accommodate the largest possible valves. A section taken through the centre-line of one of each pair of inlet and exhaust valves looks very similar to the equivalent section of a two-valve head and, considered from the purely mechanical viewpoint, there is room for valves each of which is about three-quarters of the diameter of the largest which could be squeezed in with the two-valve arrangement.

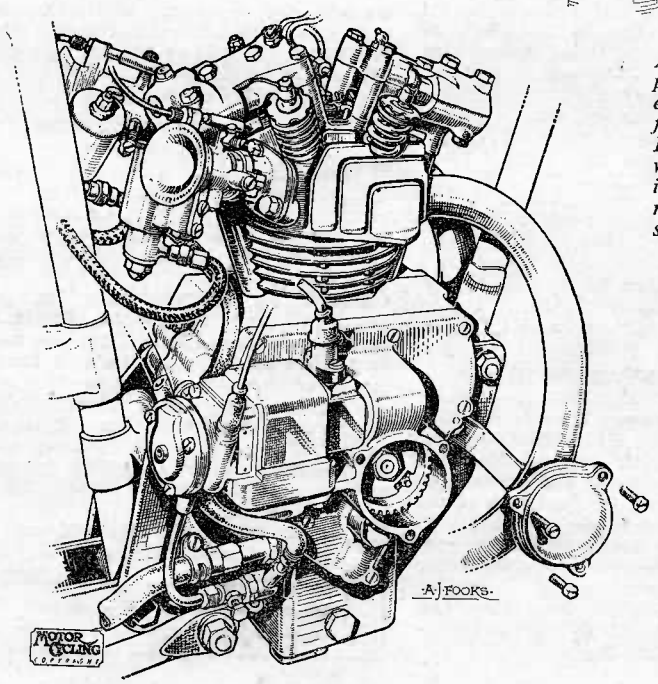
To quote concrete examples, the early pent-roof head 85 mm. x 88 mm. "Ulster" Rudge inlet-valve heads were 1⅜ in. diameter, the valve throats being 1¼ in. diameter, whilst the Vincent unit of 84 by 90 mm., and thus of comparable proportions, has a single inlet valve of 1.8 ins. diameter with a throat diameter of 1$\frac{11}{16}$ in. The total circumference of the Rudge valves, measured at the throat, was 7.8 ins., whilst that of the Vincent is only 5.8 ins. Thus at the port-lifts, which constitute a greater proportion of the total opening period than the time spent at or near full lift, the breathing capacity of the pair of valves would seem, on the face of things, to be much greater than that of the single valve. It might with safety be possible to increase the size of the latter by, perhaps, ⅛ in., but the disparity in favour of the former is still so great that its attraction is very understandable.

Volumetric Efficiency

Put another way, the size of one Rudge inlet valve is almost exactly the same as the single valve of a 250 c.c. Guzzi "Albatross," and as the latter has a cylinder capacity half that of the Rudge, one might expect that, so far as volumetric efficiency is concerned, the Rudge should be capable of the same r.p.m. as the Guzzi.

On the exhaust side, two valves possess the advantage that their ratio of area to circumference is only half that of a single valve. Comparing two valves, each ⅜ in. diameter, to one of 1½ in., the total circumferences are identical but the area of the single valve is double that of the pair. This means two things; the force required to

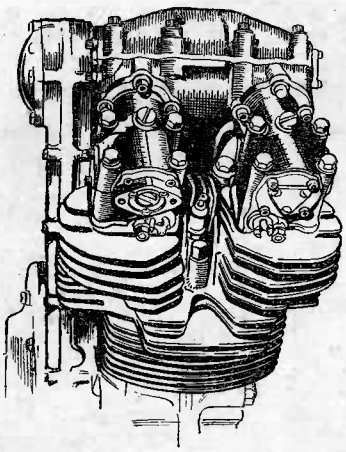




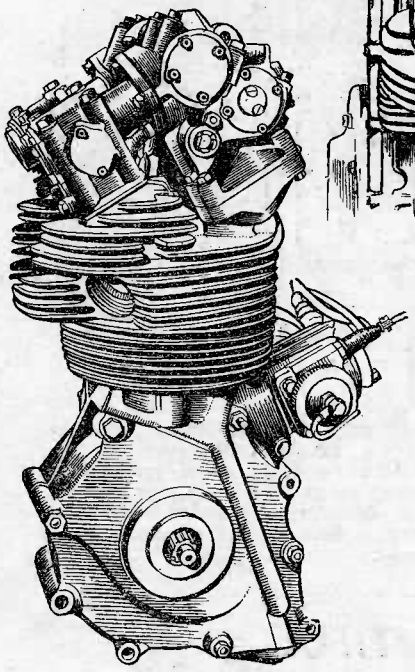
An early design incorporating double inlet and exhaust valves was the four-valve Triumph Ricardo—a famous model which was first introduced in 1922 and of which a number of examples are still giving excellent service.

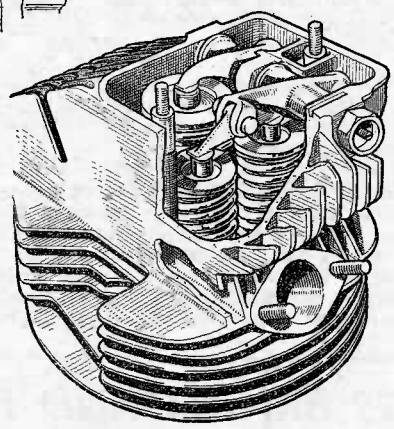
On the left is shown the o.h.v. 250 c.c. four-valve Excelsior "Mechanical Marvel." Making its debut in the 1933 T.T., it won the Lightweight Race fitted in a machine ridden by the late Sid Gleave.

f VALVES



On the left are two views of the 1952 350 c.c. racing A.J.S. unit, employing an ingenious system whereby a single inlet valve and twin exhaust valves are operated by three separate camshafts, chain-driven in the traditional "Ajay" manner.





The interesting 1935 Royal Enfield design which employed one exhaust and two inlet valves, the latter being actuated by a rocking beam as shown above.

overcome the residual gas pressure in the cylinder—some 80 lb. per sq. in.—is halved, and so is the area exposed to heat. As this heat has to escape partly through the faces and partly through the stems, it is reasonable to suppose that the maximum head temperature of the small valves will be much lower than that of the large single valve, leading to a reduction of detonation or the ability to use a higher compression ratio. Four valves also permit the sparking plug to be placed in the ideal position in the centre of the head, provided that the valve gear is arranged to give sufficient working clearance around the plug.

In the motorcycle field, many four-valvers have been constructed, some well-remembered examples being the 500 c.c. Ricardo Triumph, notable more for its smoothness and good fuel economy than for sheer power, the 1,000 c.c. V-twin Anzani, the "Sloper" 500 c.c. Ariel and, among transatlantic models, the racing Harley-Davidsons and Indians. The latter were built as 1,000 c.c. twins and 500 c.c. and 350 c.c. singles, and were very doughty performers although actually slow-revving units which pulled very high gear ratios in light frames. In 1926 Moto-Guzzi startled the Island with Pietro Ghersi's 500 c.c. four-valve o.h.c. model.

The most famous English design was the Rudge-Whitworth, which after a few years' mediocrity suddenly sprang into prominence in road racing and for a long while was invincible in the 350 c.c. and 250 c.c. categories, and an even-money chance in the Senior class. The Senior model, which was the forerunner of the others, originally had a pent-roof head, but one inherent snag of this design is that it is not nearly so compact as the conventional hemispherical two-valve head; the shape, at T.D.C., of the combustion chamber which results from the use of a piston with a crown high enough to get a respectably high compression ratio in a fairly short-stroke engine is such that combustion efficiency is not the best, even with a central plug position. For this reason, a better performance was often obtained with a compression ratio lower than that at which the regulation fuel could be run without detonation though, of course, this entailed a loss in relative power output.

Twin-Valve Snags

A pair of inlet valves, moreover, despite their larger area, are not so efficient volumetrically as a single valve, due partially to the bifurcation of the inlet port and partially to conditions inside the head. Gas issuing from a single valve meets practically no internal obstruction and is swept cleanly round into the cylinder by the spherical head formation, but the outer sides of twin valves are necessarily somewhat shrouded by the "corners" of the pent-roof and on the inner sides the two gas streams converge, thus interfering with each other to some extent. Also, by the time a poppet valve has lifted a distance equal to one quarter of the port diameter the circumferential gas flow area is equal to that of the port; thus as this amount of lift is approached, the advantage which the two small valves possess at low lifts is diminished and finally vanishes.

Exhaust conditions are much better, so far as outward gas flow is concerned but unless separate and widely splayed ports are used the thin bridge of metal between the valves runs at a high temperature, causing local seat distortion and a serious tendency towards cracking between the seats, whilst the valve-guide cooling is likely to be inadequate. In an endeavour to overcome most of these defects, the late John Pugh invented the highly ingenious "fully-radial" Rudge head employing three rockers to each pair of valves, the story being that he arrived at the Coventry works one day bearing a cardboard model of the device, which he commanded to be instantly drawn and made. Be that as it may, the scheme was good, despite its complexity, and really put the Rudge racers on the map, to stay there for some years.

Rudge Experiments

However, the inlet port required to feed the radial inlet valves was an even worse shape than before and a reversion was soon made to parallel inlets on the 500 c.c. heads, which were then dubbed "semi-radial," though on the 350 c.c. and 250 c.c. editions the full-radial design was retained. After that, a two-valve head was introduced on the 250 c.c. Rudge "Rapid" for touring use, as being much less costly to manufacture, and it is interesting to note that the Pike brothers have since developed the two-valver to a pitch which exceeds the best performances of its four-valve predecessors.

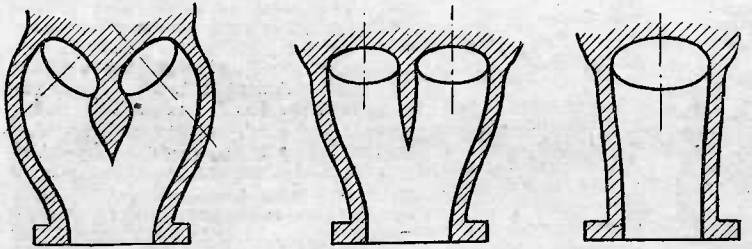
Although it did not have such a run of successes as the Rudge, the Excelsior "Mechanical Marvel" which won the 1933 Lightweight T.T. was a more advanced design; all valves were radially disposed, each pair being operated by rockers actuated by inclined push-rods from separate transverse camshafts situated behind and ahead of the cylinder. Each valve has its own port, the exhausts being widely splayed for good cooling, whilst two carburetters supplied the mixture. Later on, the standard production two-valve Excelsior "Manxman" was fitted with a four-valve head, and was the last British engine to be so constructed.

4-Valve Guzzi

Two years ago Guzzi experimented with a four-valve 350 c.c. model, which made a brief appearance in practice in the Isle of Man, but little has been heard of it since. This year, experiments were conducted with four-valve 250s in the Island, but they were not used for the race. Taken all in all, it seems that the four-valve head is not any better, or even as good, as the two-valve in "square" or nearly square engines, in which there is room for a large single inlet valve, though it may be an advantage in long-stroke engines, where head space is restricted, or in blown engines, where valve area is of greater importance than unobstructed passages giving good streamlined flow.

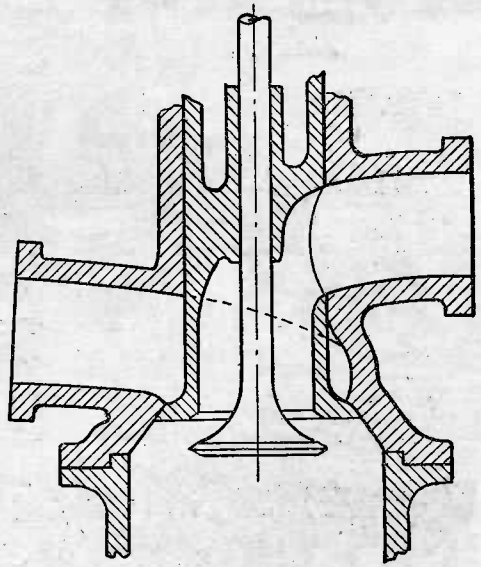
The presence of the valve stem right in the centre of the inlet port is a major obstacle to smooth gas flow, giving rise to the thought that a better arrangement would be furnished by using two carburettors, mounted on separate ports splayed at about

THE ARRANGEMENT of VALVES—Continued



(*Above*) *Three different inlet port designs, shown in diagrammatic form. That on the left is for radial valves, that in the centre for parallel valves in a pent-roof head, and that on the right for a single valve.*

On the right is shown a cross-section of a concentric "inlet-within-exhaust" valve layout.



20 degrees, and each feeding one-half of the valve. The idea was tried out experimentally by Velocette, and in the 1935 T.T. by J.A.P.s, but without success, partly because it was almost impossible, on the J.A.P.s at any rate, to tune the two carburetters to give correct mixtures at all throttle openings.

Four, or three?

As an alternative to four valves, three-valve heads have been propounded, and some years ago a 350 c.c. Royal Enfield was produced with two inlets and one exhaust valve, a layout which had most of the disadvantages and few of the advantages of four valves.

The latest A.J.S. idea of using a single inlet and two radially-disposed exhaust valves is, however, quite a logical development, for it permits the use of a very large inlet valve with reduced danger of mechanical interference with the exhaust valves during the overlap period. However, the two small-diameter exhaust valves should keep very cool. The exhaust ports are short and of small diameter, thus excessive feed-back of waste heat into the head (a bad feature of some four-valve designs) is avoided, whilst the plug position is very good. On the debit side, there is a considerable degree of added mechanical complexity and weight brought in by the use of three camshafts, but in racing complexity is of little moment provided the end justifies the means.