MOTORCYCLE ENGINEERING—25

Cooling the Multi-cylinder

Airflow interference, distortion and other problems

By PHIL IRVING

IN some respects, a multi-cylinder engine is better off than a single in the matter of cooling. Broadly speaking, for any given capacity it presents a greater area of wall on which fins can be placed; small cylinders are easier to cool than large ones anyway; and when the cylinders are spaced wider apart, as in a transverse horizontal twin, a 120° twin or even a conventional V-twin with an included angle of around 50°, there is no or little interference by one cylinder with the other and they can be designed on straightforward lines.

Even the three-cylinder D.K.W. racing two-stroke enjoyed the last of these advantages by virtue of its unique layout, and it shared with the wide-angle twin Guzzi the distinction of having the horizontal cylinder equipped with radial fins. Laying the D.K.W.'s centre cylinder down flat helped to make a compact unit but was not really a good arrangement, because there was a heavily shielded area between the downward-facing exhaust port and the crankcase which could be a source of trouble; the two upright cylinders with circular fins were much better in this respect and were well out in the breeze.

The V-twin

Although the cylinders of a 50° twin are wide apart, the rear cylinder is shielded by the front one at speed and what air it does get is already heated to some extent. At one time it was usual to point the rear exhaust port backwards, partly, one supposes, because it looked symmetrical and partly to get out of the difficulty of making the rear exhaust pipe miss the front head. It is hardly surprising that engines built in this way, particularly those with side valves which are prone to run hot in the exhaust-port region even at the best of times, were unable to stand up to long periods at full power except under racing conditions when alcohol fuel could be used.

It is, in fact, rather strange that in the heyday of the big twin nobody ever installed one of these engines with the rear cylinder vertical as in certain early NSU twins. This would be good for cooling and was considered as a possibility during the gestation period of the post-war Vincent "Rapide." In the event, the more conventional arrangement previously used in the pre-war edition was adopted, but with both exhaust ports facing forward and the rear cylinder offset by 1¼ in. to the right of the front one. In practice, both cylinders appear to be cooled equally well.

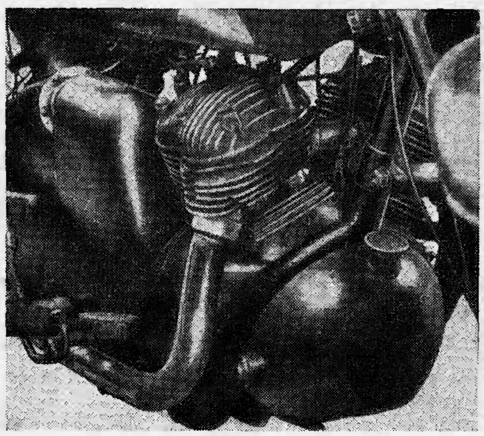
This installation, however, serves to show that one cannot be too dogmatic about cooling, nor can theory be applied too rigidly because of the unknown and variable factors which abound. At speeds around the three-figure mark there is actually a *forward* current of air in the region of the front head—a fact which became known only when oil leaking from a loose valve-cap during Clubman's T.T. practising spread along the top of the front mudguard. A similar phenomenon was observed on the flat-engined 250 c.c. Guzzi, where oil was carried across a gap of several inches between the rocker-gear and the guard.

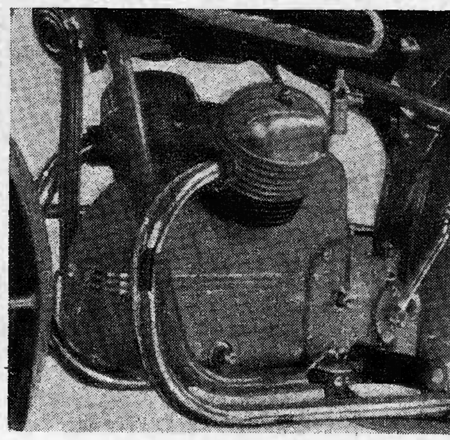
A V-twin placed with its cylinders transversely should not suffer from such capricious behaviour of the air, and symmetrical engines of this type have performed very well in three-wheelers when placed at the front. Although the arrangement appears to be very attractive for a two-wheeler also, it has been tried and dropped by several English factories, partly because it has inherent transverse out-of-balance forces which, though not very large, operate at a point where the frame is most susceptible to vibration.

The most common layout today is another which was tried and dropped several times before it was finally accepted both for touring and racing. This is, of course, the conventional parallel twin with the crankshaft at right-angles to the frame, an arrangement which is intrinsically good for cooling because it moves each cylinder out towards the regions of high-speed air.

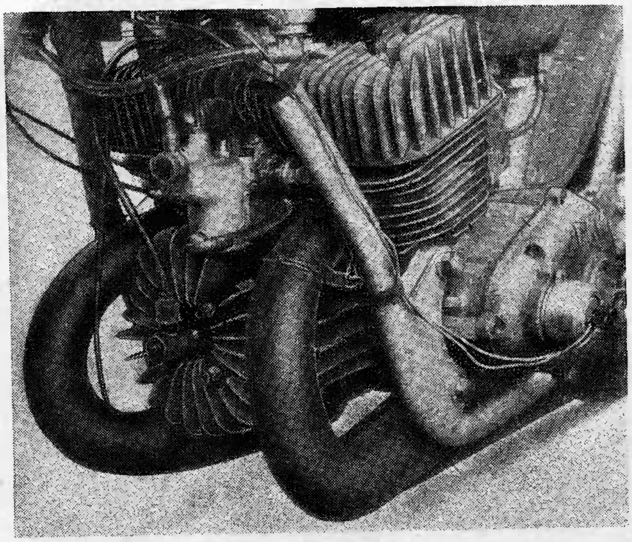
This virtue existed to an even greater extent in the geared Velocette racing and touring engines (strictly "one-off," each variety) in which the crankshafts lay fore-and-aft and were coupled by spur-gears very similar to those used in the Ariel "Square Four." The crankshafts were necessarily over 5 in. apart, which, besides moving the cylinders outwards, provided plenty of space between them. This space was still further increased in the touring version by offsetting each one by a quarter of an inch in relation to its crankshaft. There was then enough room available, without too much restriction of airflow, to locate the push-rods in a central integral housing which was almost undetectable unless its position were known.

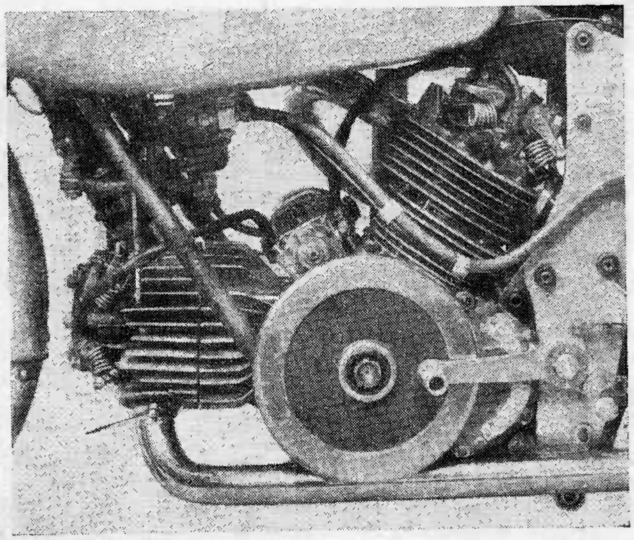
Inter-cylinder spacing is different in the conventional layout with a single two-bearing crankshaft because, in the interests of rigidity of this component, it is essential to have the cylinders very close together. The alternative is to gain more air space by using a three-bearing shaft, a most costly





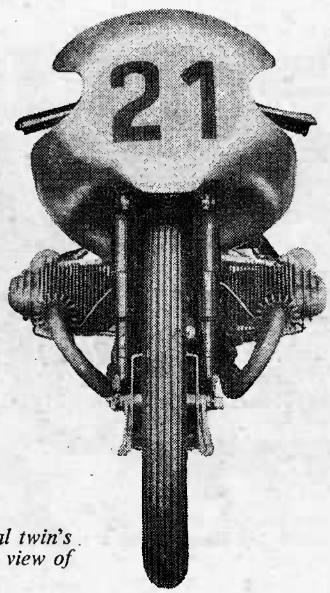
The transverse V-twin—British and German. A Brough Superior prototype of 1937 (left) and a production tourer, the 1951 Victoria "Bergmeister."





Horizontal front cylinders, radially finned, on two Continental racers, the 1954 three-cylinder D.K.W. two-stroke (left) and the "wide-angle" Guzzi twin of 1950.

More uniform temperature distribution is the object of the side-mounted exhausts of the R.C.A. twin two-stroke.



Full exposure of the horizontal twin's cylinders is well shown in this view of a 1954 B.M.W. racer.

arrangement which is currently found only on A.M.C. products and, of course, on twin two-strokes, where a centre bearing is essential in order to separate the two crankcases.

In this connection, the R.C.A. engine is interesting. Realizing that the inner cylinder walls will be hotter than the outer walls and, as a consequence, the cylinders will tend to distort into the shape (though not quite to the same extent) as a banana, the designer has moved the exhaust ports from the front round to the side in an endeavour to equalize the temperature and so eliminate such an undesirable effect, though possibly at the expense of creating a hot area just abaft each port.

With the close cylinder spacing essential if a two-bearing shaft is used, it is necessary to form both cylinders in one block, otherwise the fins would be of such a pronounced D-shape that distortion would be almost inevitable. The standard practice is to continue the fins across the narrow gap, and as the inter-cylinder space is roughly of venturi shape, the air collected at the front will pass through the centre at a fair velocity and in close contact with the surfaces. So although the actual area presented is small, the heat removal will be effective—provided, of course, that neither the entry nor the exit is badly obstructed.

Modern Parallel Twins

The Triumph design, to which must go the credit for the resurgence of the parallel twin, has the push-rods enclosed in a pair of small tubes, nestling in deep slots in the fins ahead of and behind the block. This idea would appear to entail the loss of some fin area and obstruction to the flow of both entering and leaving air, but since it has been retained for many years on several editions, it is not presumably, a source of trouble in practice.

In B.S.A. twins, all four push-rods are grouped in a single integral tunnel at the rear of the block, so that there is no obstruction to entering air but some on the exit side. On the Ariel twins, the least obstructed passage of all was obtained by running the push-rods through holes drilled in bosses at the four outer corners of the block—positioning which would be difficult to improve, because the bosses interfere little with the barrel cooling and they also act to stiffen the base flange, which, as in all the others with block cylinders, is retained by a number of small bolts.

The A.J.S. and Matchless twins, as we have seen, have a centre bearing which permits the cylinders to be spaced farther apart. Although the fins are of a distinct D-shape, separate barrels are used with long bolts running through the separate heads. An unobstructed central airflow is obtained by housing the push-rods in holes in the cylinder walls, and with this construction either cylinder is free to expand without disturbing the other.

When both cylinders are cast in one block, any tendency for one cylinder to distort along the common centre-plane through thermal expansion is resisted to an equal extent by a similar tendency in the other (as long as the temperatures of both are equal), so in general there is less liability for "monobloc" cylinders to go oval in this direction than there is with separate cylinders. But either might distort in a fore-and-aft direction due to circumferential expansion of the hot centre walls being greater than that of the cooler outer portions. In practice there appears to be little to choose between the two designs on this score.

The original design of the A.J.S. twin racer was intended for supercharging; the cylinders were almost flat, being inclined at 15° from the horizontal, and the inlet ports lay between the valves (rather in the manner of the Bristol car engine) so that fresh charge would blow directly into the barrels with less chance of driving straight out of the exhaust valves during the overlap period. Since this was a double-o.h.c. design with the rocker-boxes running from the offside right across both heads, the barrels could only receive whatever air managed to squeeze between the rocker-boxes, the inlet ports and the major diameter of each head—a condition which obviously left the inner sides of the barrels in jeopardy.

"Porcupine's" Quills

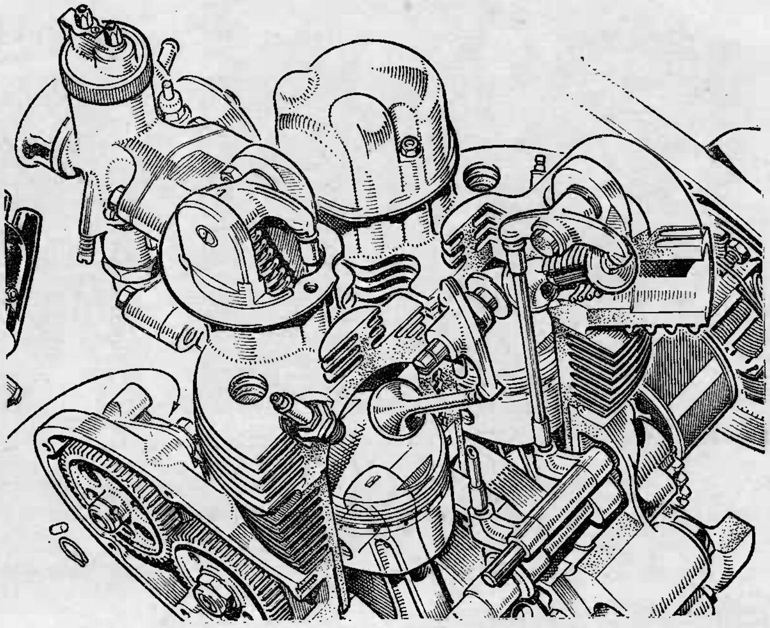
Radial finning all round was not much good, because the adjoining central fins would simply form pockets with no exits; and circular fins could only work by the inadequate means of natural convection. So a compromise was made by designing spiral fins which could receive air at the upper ends and screw it out, in a manner of speaking, into the open again lower down the barrels. Unfortunately, it seemed that casting such fins was not possible, so they were broken up into a number of radial sections, rather like turbine blades and giving somewhat the same effect. Hence the soubriquet of "Porcupine" which, like many inaccurate nicknames, has remained long after its origins have been forgotten. In later editions of this engine, normal radial finning was used (see illustration in No. 22 of this series, Feb. 4 issue), but only after the overhead inlet ports had been discarded in favour of normal ones to suit atmospheric induction.

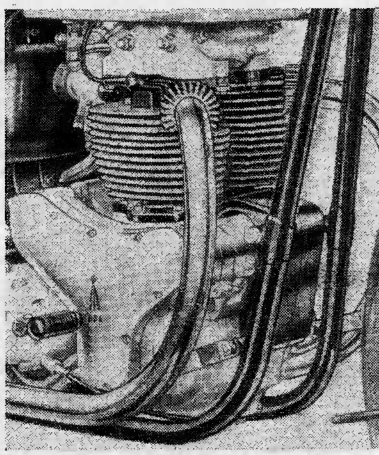
The head of this model was a one-piece casting, and the obvious course was to use continuous transverse fins, which then lay almost edge-on to the air-stream. However, as they were several inches deep measured along the central plane, their root-thickness at the joint-face was so great that there was very little space for air to get through into the danger area between the barrels. One (unused) suggestion was to cast-in a block of sheet copper fins, .030 in. thick and .140 in. apart, which would have doubled the fin surface while offering very much less restriction in area. In the upshot, and again after the inlet ports had been moved out of the way, normal finning broken up by a large number of slots was used.

In any event, this is not an easy type of engine to cool and is not nearly so simple in this respect as a horizontal single, in which the rocker boxes obstruct only half the head area.

Using the Rocker-box

In vertical push-rod twins the rocker-box, if common to both heads, can be turned to good effect by contouring its lower surface so that air is collected and diverted into the central space, and the head-finning can then be arranged to take advantage of the flow so created. A good application of this principle is to be seen on B.S.A. designs in which the vertical fins on the upper surface of the head are curved outwards at the rear, following the contour of the Y-shaped inlet pipe which otherwise would constitute a severe obstruction. The separate exhaust and inlet rocker and valve housings used on A.M.C. engines preclude this treatment, but it is notable that the greater part of the finning is concentrated on the exhaust side, where it should be.





Modern parallel-twin practice. Push-rods are located within the cylinder walls of the A.M.C. engine (above) and centrally behind the cylinders in the B.S.A. (left).

Recently, it has become a trend in racing design to construct tiny twins as two separate single-cylinder engines attached to a central component containing the primary drive and (in four-strokes) the drive to the valve-gear. This is of particular advantage for cooling in such designs as the twin 250 c.c. M.Z., and is still useful in the case of a four-stroke, though to a lesser extent because of the presence of the drive housing between the barrels. Since overall width-reduction is not vitally important, adequate air spaces can be provided and at least the drive-housing is cooler than the cylinders and can therefore receive radiant heat, which is then carried away internally by the oil.

This scheme can be considered in some ways as a derivative of the arrangement introduced on the four-cylinder Rondine and retained on its ideological descendants, the Gilera and M.V. fours. M.V. cylinder blocks, however, contain all four bores, plus an integral camshaft-drive tunnel in the late models, whereas the Gilera, at different stages of development, used either the block system or four separate barrels with long through-bolts.

In the block system there is not much air space between the tunnel and the bores on each side of it, though there is sufficient between each of the two outer pairs of cylinders. All the barrel fins are horizontal and continuous and are made of aluminium alloy; any tendency towards unequal cooling is largely ironed out by conduction.

The lower half of each cambox, though integral with the one-piece aluminium head, is kept sufficiently far away to allow air to pass through the fins which connect the two —a valuable contribution to cooling which is possible because, with such a short length from crankshaft to head-joint face, there is plenty of room above the head to elevate the camboxes just that little bit which makes all the difference between getting some air-flow and none. Of course, the transverse mounting of the block is almost ideal for utilizing the model's forward speed effectively, and these engines can function satisfactorily with less weight of fin per horsepower than any other design.

With more than four cylinders, however they are arranged, the matter becomes almost insufferably complicated unless fan cooling, with its attendant bulk and power loss, is employed. In fact, when Moto-Guzzi constructed a V-8, they simply went straight to liquid cooling, since it would have been impossible to cool the rear bank of cylinders adequately by natural airflow.

NEXT WEEK

The question of engine balance.