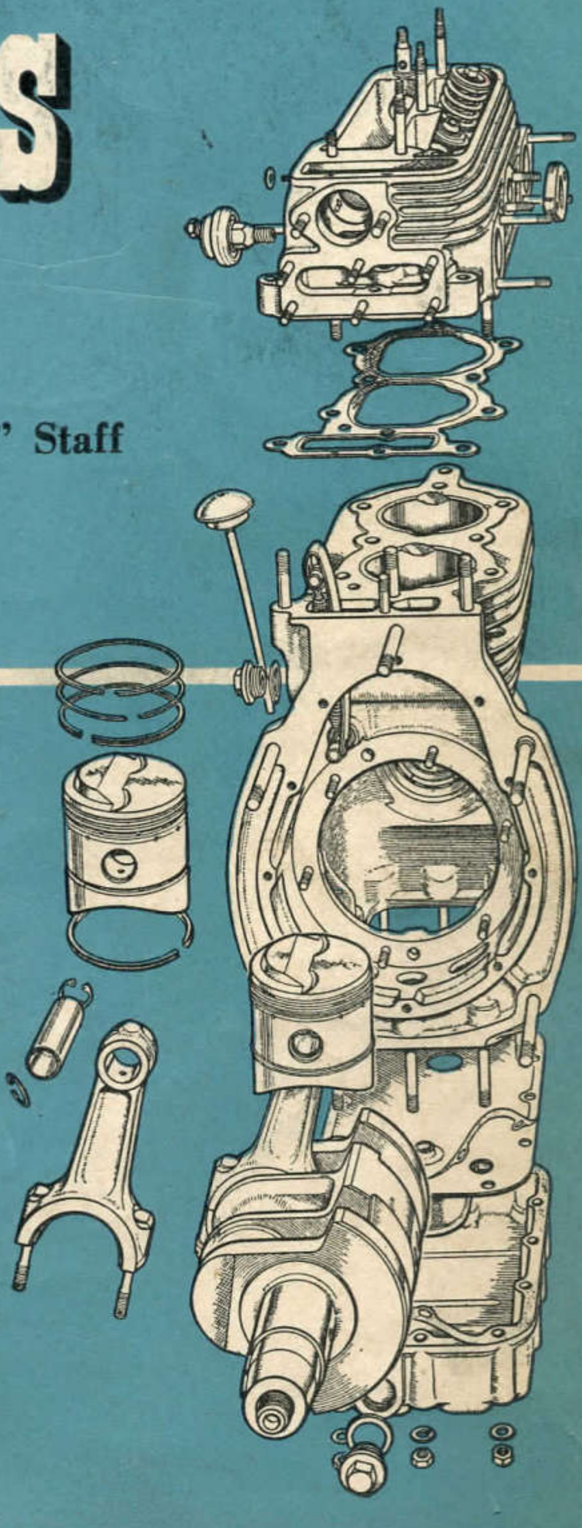
MOTOR CYCLE ENGINES

Famous British Power Units

Analysed by "The Motor Cycle" Staff

in Words and Drawings



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MOTOR CYCLE ENGINES

Famous British Designs Analysed: Details of Modern Power Units: with Unique Explanatory-type Drawings

By

THE STAFF OF

"THE MOTOR CYCLE"

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FOREWORD

EVERY keen motor cyclist, every budding engineer, all who are technically inclined, yearn to know the whys and wherefores of design. *Why* did the designer adopt that particular arrangement—what were his reasons? *Why* did he choose different materials for the exhaust-valve and inlet-valve seats? *Why*...? *Why*...? *Why*...? There are hundreds, perhaps thousands, of questions which enthusiasts would love to put to the designers of motor cycle engines.

If only it were possible to beard these designers—to get round the table with them and discuss the engines, their design and constructional features, point by point . . .

This is the aim behind the material which comprises this book. For the birth of the idea it is necessary to go back to just previous to the war. In our handbook "Motor Cycles and How to Manage Them," we had evolved a method whereby readers were led, step by step, to understand the construction of engines. In special series of illustrations, parts were shown in their correct relative proportions and in their proper relative positions; thus it was easy to comprehend how everything fitted together and to understand the manner in which the completed component functioned. Why should not this idea be developed and applied to complete engines? *The Motor Cycle* staff artists were enthusiastic. Theirs had been the honour—many, many years previously—of producing the first perspective drawings of sectioned motor cycle engines and the first drawings showing the internal mechanism of a complete motor cycle. Thus what we term the "Modern Engine" type of drawing was born, a form of drawing which, during the ensuing war, was to be copied almost the world over for instructional purposes on guns, aircraft, vehicles and all manner of other equipment.

This special explanatory type of drawing was essential to our main theme which was not merely to disclose the detail construction of engines but also to reveal the underlying reasons for the various features, whether of design or choice of material. Would manufacturers be willing to co-operate? The scheme was explained to them. It was pointed out that the whole basis was question and answer —complete, accurate answers. In direction after direction, 100 per cent co-operation was promised. Thus the "Modern Engine Series" began. Such was its success—its continuing success—that the numbers in which the articles have appeared have frequently been out of print as soon as published.

Now, to meet the oft-expressed wish, a first selection of the articles has been compiled in the form of this book. Apart from their value to the technically inclined and to owners of engines similar to those depicted and discussed, some of the articles have a special historic interest in that they reveal the thoughts and beliefs of the designers at the period when their now famous engines first took shape —*vide* the KTT Velocette and the late Harold Willis' remarks, the "Speed Twin" Triumph, first of the modern vertical-twins, and the overhead-valve Ariel Square Four; slight modifications have been made to some of the designs shown in this book in the interim, but so slight as to emphasize the remarkable skill displayed in the original conceptions.

ARTHUR B. BOURNE,
Editor, *The Motor Cycle*.

Dorset House,
Stamford Street,
London, S.E.1.

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The 348 c.c. Overhead KTT VELOCETTE

The Whys and Wherefores of a Famous Engine Designed Specifically for Road Racing

By "UBIQUE"

EVERYONE knows that, for years, the KTT Velocette was unique in being the nearest possible thing to a genuine T.T. model which was available to the public. It was, in fact, designed and intended for road racing, and this must be remembered when considering the following notes.

Looking at all the parts neatly laid out on sheets of brown paper, I was at a loss to know where to begin. Finally, after discussing the point with Messrs. Percy Goodman and Harold Willis—now, unhappily the late Harold Willis—I decided to start at the top and work down, yet in actual practice my first question dealt with the cylinder barrel. "What are the materials, and how are they mated?"

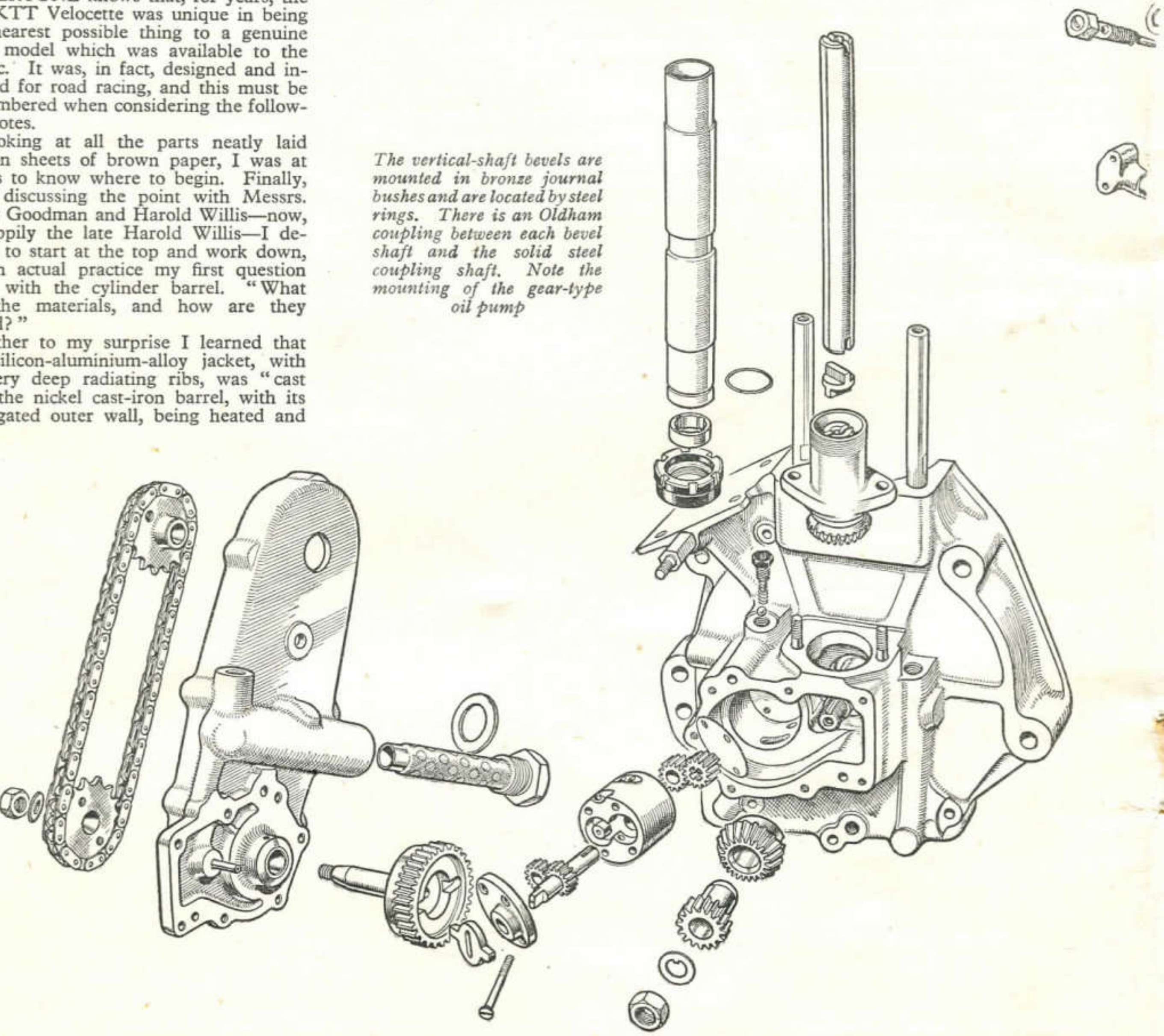
Rather to my surprise I learned that the silicon-aluminium-alloy jacket, with its very deep radiating ribs, was "cast on," the nickel cast-iron barrel, with its corrugated outer wall, being heated and placed in the mould before the alloy was poured.

Mr. Willis did not think there was much to choose between this practice and that of pressing-in a liner or shrinking-on a jacket, but actually Velocettes, he said, had had slightly better results with the practice outlined; it prevents the possibility of the liner "creeping."

The head, I gathered, was of heat-treated "Y"-alloy, a metal chosen for its light weight, strength and high thermal conductivity. The head ribs of the KTT are roughly 9in square in plan view, and the camshaft casing and the boxes for the enclosure of both valves and their double hairpin valve springs are cast with the head, so you can judge the importance of a lightweight material.

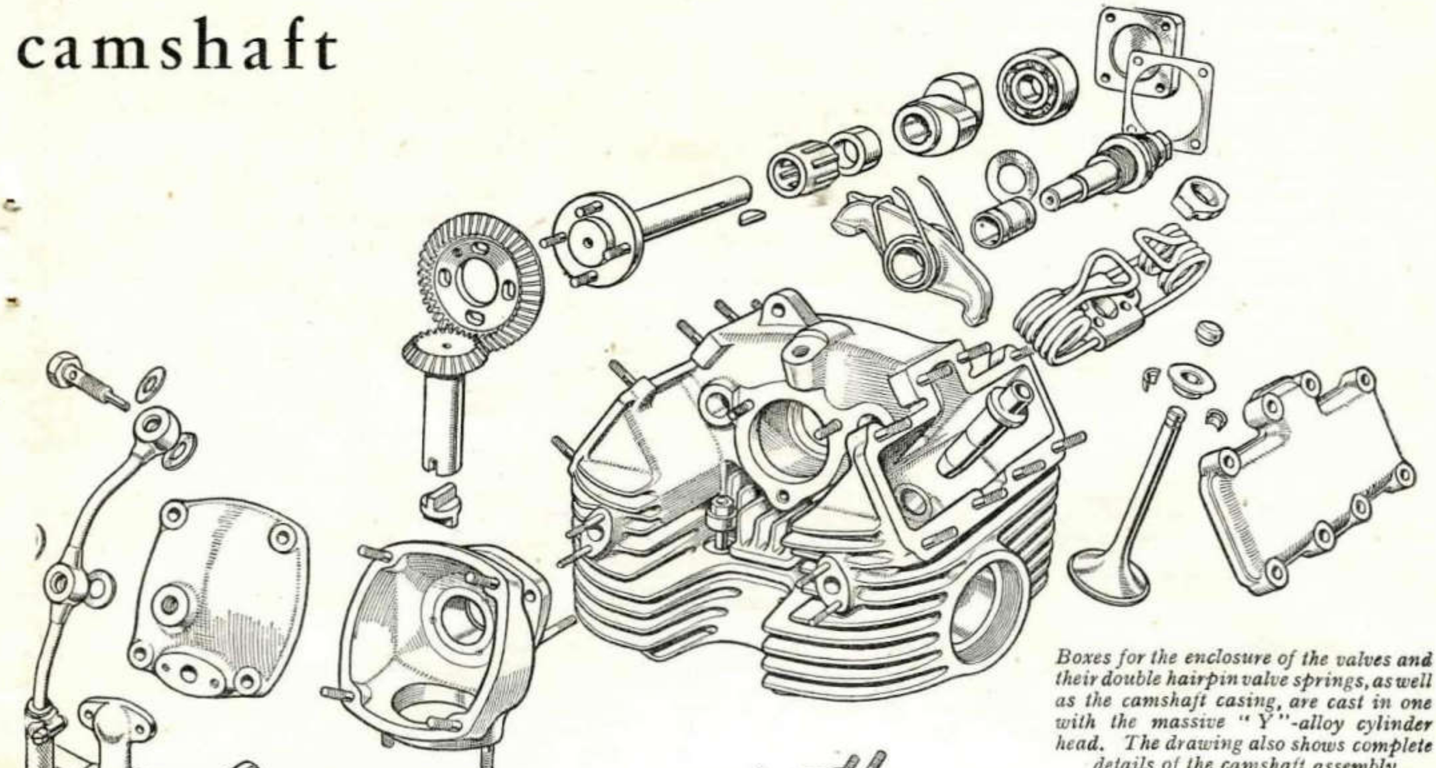
Of course, I asked why these huge cooling fins were employed, suggesting that it must be almost impossible for a considerable draught of air to reach the rib roots.

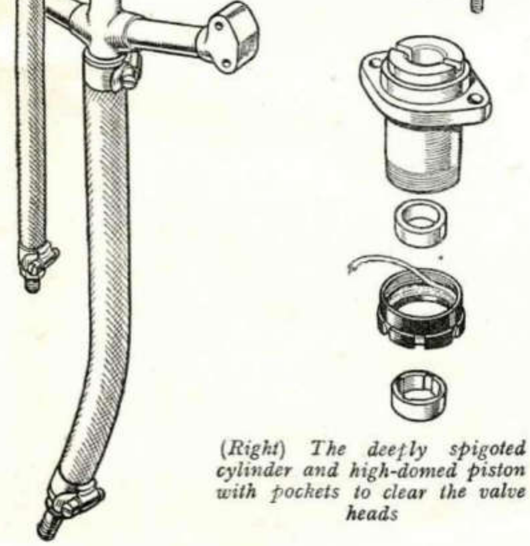
In this matter Mr. Willis told me I was correct, but that careful tests showed that it was of greater importance to get a big cooling surface right out into the



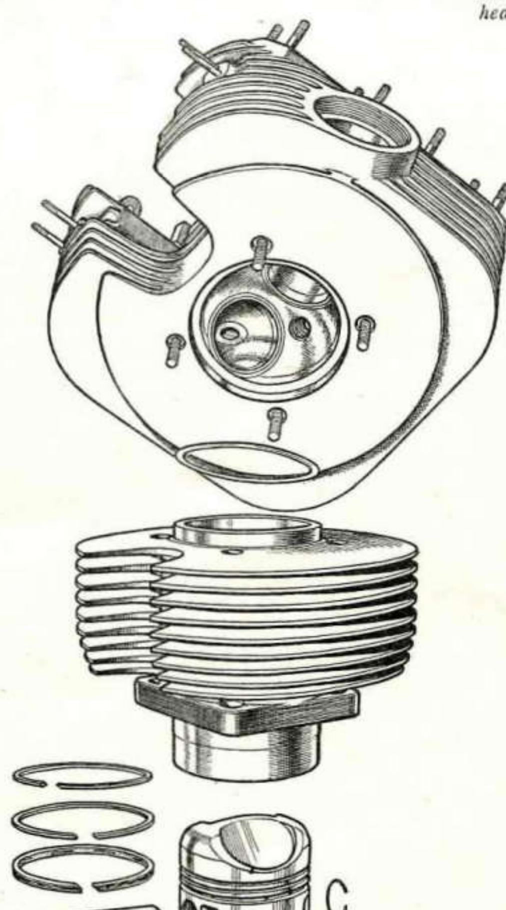
The vertical-shaft bevels are mounted in bronze journal bushes and are located by steel rings. There is an Oldham coupling between each bevel shaft and the solid steel coupling shaft. Note the mounting of the gear-type oil pump

camshaft





Boxes for the enclosure of the valves and their double hairpin valve springs, as well as the camshaft casing, are cast in one with the massive "Y"-alloy cylinder head. The drawing also shows complete details of the camshaft assembly



(Right) The deeply spigoted cylinder and high-domed piston with pockets to clear the valve heads

draught than to rely on such air as might possibly pass the front wheel, mudguard, fork, frame, etc., reaching the roots of the fins. That explains the importance of high conductivity, does it not?

Again, he pointed out that the joint between the head and barrel, at the top of the spigot, consisted of a laminated copper washer. Each of the four laminations is about 0.009in thick, and this arrangement makes a very satisfactory job with direct metal-to-metal contacts throughout.

Internally, the head is approximately hemispherical, the long-reach 14mm plug being placed high up and screwed directly into the head.

My next question was, "Why do you employ different materials for exhaust and inlet valve seatings?"

"A hard aluminium-bronze alloy is used for the exhaust seat, because the high conductivity of this metal helps to keep the exhaust valve cool and, incidentally, its high coefficient of expansion helps to maintain good contact with the head casting at high temperatures.

"For the inlet valve, the seat of which is apt to be damaged by grit, a nickel cast-iron is employed on account of its hardness."

Pressed-in Seatings

"How are the seatings held in position?" I then asked.

"The head is heated in an electrical furnace to a temperature of 200 degrees C., and the seatings previously mounted on special jigs, are pushed home very quickly. Speed is essential in this process, for as soon as the seatings come in contact with the hot head, they also expand and lock in position."

The pale gold of aluminium-bronze valve guides next caught my eye. The high heat conductivity and high coefficient of expansion, plus the fact that this material is an excellent bearing metal, make it very suitable for the purpose. Add to this, ample lubrication from the cam-box and the very high finish of the valve stems and guides, and I was not surprised to hear that wear at this point is negligible over long periods.

Incidentally, the valve stems work with quite close clearance limits, the actual figures being 0.0015in for the inlet and 0.003in for the exhaust.

"Why is the inlet valve of larger diameter than the exhaust?" Both my mentors answered this question. Perhaps I may summarize their remarks by saying that it is far more difficult to fill a cylinder by atmospheric pressure than to empty it when the piston pushes behind and there is help at certain vital speeds from a specially designed exhaust pipe.

"The valves themselves? Well, the inlet is made of a cobalt-chrome steel having high tensile strength and hard-wearing surfaces. It has a throat diameter of $1\frac{9}{16}$in, and the stem is reduced to the smallest possible diameter consistent with safety, so as to reduce port obstruction. K.E.965 steel was chosen for the exhaust valve because it retains great strength at the very high temperatures at which it is called upon to work."

Valve Timing

The port diameter of the exhaust valve is $1\frac{7}{16}$in, and the stem is approximately $\frac{1}{16}$in larger than that of the inlet, and the lift of both valves is $\frac{3}{8}$in. Both have moderately recessed heads, but whereas the end of the inlet stem is hardened, the material of the exhaust is unsuited for this purpose, so a hardened end-cap is used.

I asked if the valve timing were a secret, but it was given me without the slightest hesitation. Checked with a tappet clearance of 0.020in in each case, the timing is as follows: inlet opens 55 degrees before top dead centre, and closes 65 degrees past b.d.c.; exhaust opens 75 degrees before b.d.c. and closes 45 degrees after t.d.c.

One hundred degrees of overlap. Think of it! That ought to get the inlet gas column moving and ensure that the valves are well open when they will do most good!

The correct running tappet clearances are: inlet 0.015in, exhaust 0.025in.

Even the details of the valve spring cup and collet are of unusual interest. It was pointed out that the groove in the top of the valve stem is extremely shallow in order to reduce the strength of the stem as little as possible. To make up for this the split collet is so designed as to grip the stem, and under the wedging action of the spring cup this grip is almost sufficient without the groove.

Free to Rotate

The item which corresponds to the usual spring cup (and is described as such above) does not, in fact, form a direct thrust face for the hairpin springs, the looped ends of which are hooked on to a separate steel spring abutment, loosely mounted round the "spring cup." Thus, at the expense of a little extra reciprocating weight, the valve is free to rotate, a most desirable feature.

At their lower ends the valve springs are tucked into longitudinal holes drilled in a steel plate which surrounds the upper part of the valve guides. and these plates have, at each end, a tapped hole to carry the fulcrum of a spring removing tool.

"What spring pressures are necessary for this engine?" I asked.

"Measured with the valve closed, a pressure of 110lb, plus another 25lb for the return spring on the rocker, the latter an important point which we will discuss when we get there."

"Does the total enclosure of the valve gear cause any kind of trouble in the way of overheating?"

"No, the valve boxes have a large external area exposed to the draught and the interior is cooled by a liberal circulation of oil."

"Some years ago you used a two-camshaft racing engine," I said. "Why, in this engine, have you reverted to the single-camshaft type?"

"I was about to mention that very point," said Mr. Percy, "as it is a matter of some historical interest. The twin-camshaft job, in spite of its theoretical advantages, presented certain practical difficulties. [Since overcome as recent Velocette racing engines have demonstrated.—Ed.] It was difficult to provide reasonably accessible tappet adjustment, and to enclose the mechanism—a point which, as you know, we consider to be important. Further, for the first time we had trouble with the vertical shaft drive, which could be traced indirectly to the upper works of the valve gear."

Mr. Willis continued: "After much experiment we found that the best all-round results could be obtained from a single-camshaft engine if the rockers could be held in constant contact with the cam. This led to the powerful hairpin rocker return spring which you are examining. At first this spring caused scoring and rapid wear of the rocker heels and cams, and we found it necessary not only to provide a jet of oil directly on to the point of contact between cam and rocker, but also to face the heel of the rocker with Stellite. These precautions have been completely successful.

Floating Bushes

On inquiry, I found that these rockers are made from stampings of air-hardening, nickel-chrome steel of 100-ton tensile test. Between each rocker and its massive eccentrically mounted pivot-pin is a bronze floating bush.

"Why are the cams made separate from their shaft?"

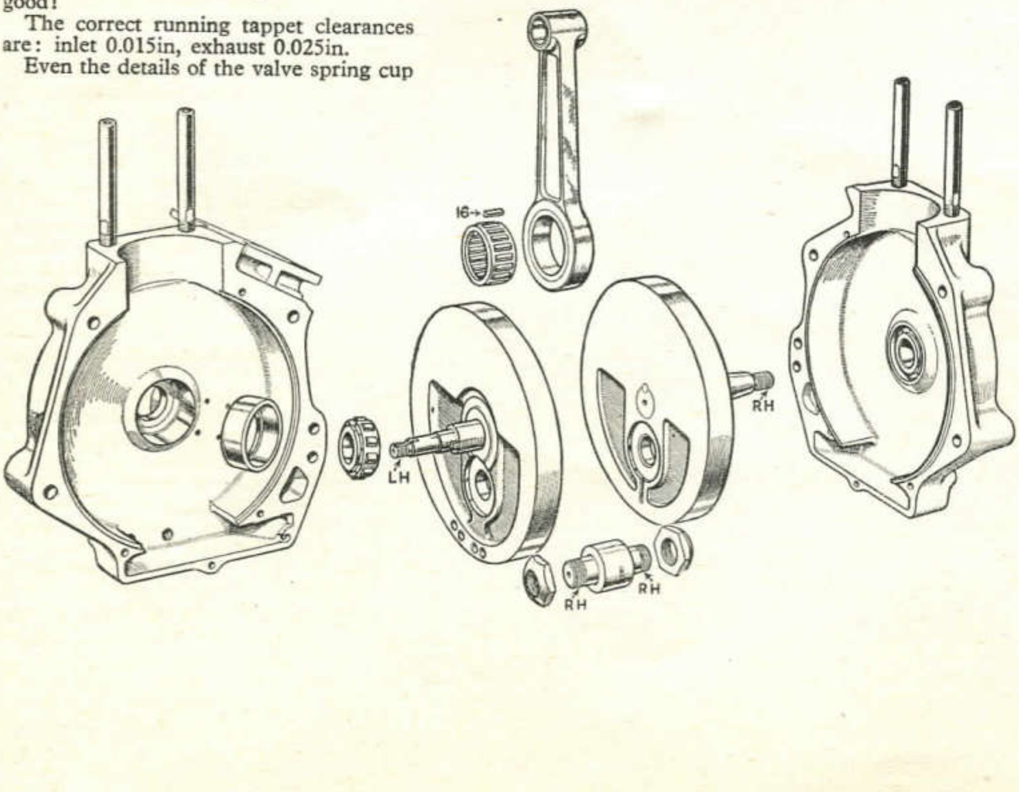
"Well, the cams, which are designed to give constant valve acceleration and deceleration are of a straight carbon-steel, deeply cased, and have 1 per cent carbon in the case. The shaft is of 3 per cent nickel steel, case-hardened so as to form a track for the driving-side roller bearing. The cams are pressed and keyed on to the shaft. The rollers on the drive side are caged and a ball-bearing on the other end of the shaft takes the end-thrust from the bevel gears."

"What about the vertical-shaft drive?"

"Most of it is standard, including the upper pair of bevels. The crown bevel is bolted to its back plate by four bolts, and the bolt holes are elongated to provide a half tooth adjustment for timing. The lower bevels have been strengthened to withstand the extra strains imposed by high speed and heavy valve springs."

"Why the lower bevels and not the upper ones?"

"Because the shape of the small-diameter bevels of approximately equal size is not so favourable to tooth strength."



(Left) Immense rigidity is a feature of the crankshaft assembly and of the unusually narrow crankcase. The flywheels are made of heat-treated carbon steel. while the crankpin has a diameter of no less than $1\frac{3}{8}$in. Big-end rollers measuring 9/16in × 3/16in are located in a Duralumin cage

"I note you retain the hunting tooth."

"Yes, the odd teeth in the vertical-shaft drive distribute the loading as evenly as possible. The vertical-shaft bevels are mounted in bronze journal bushes, the thrust being taken on the end faces. Steel rings are lightly pressed on to the shafts to locate the bevels length-wise in their bearings. There is an Oldham coupling of oil-hardened nickel-chrome steel between each bevel shaft and the solid steel coupling shaft. This coupling shaft is mounted in plain bearings in its enclosing tube, and the tube is held at each end by asbestos-packed gland-nuts, and although it appears to be quite rigid, there is just a trace of intentional flexibility in the mounting."

The unusually narrow aluminium-alloy crankcase is noticeable without need of questions, and the single-row caged roller bearings on each side are supported directly under the massive walls in which the main strength of the crankcase lies. The only additional stiffening is provided by shallow webs on the outside of the drive side. As in other Velocette models, the primary drive lies inside the final drive, and therefore the engine sprocket is close up to the main bearing. Thus, there is very little overhang and no need for a multiplicity of crank bearings.

Immense Rigidity

A glance at the compact and immensely rigid crank unit with its single-row big-end and comparatively narrow ($\frac{13}{16}$in) flywheels, also at the smooth, web-less interior of the crankcase, shows how that effect of slimness is attained, but here more questions were necessary.

"What are the flywheels made of?"

"Heat-treated carbon steel."

"Why heat-treated?"

"To prevent stretch in the shaft holes."

"How are the crank axles fixed in the flywheels?"

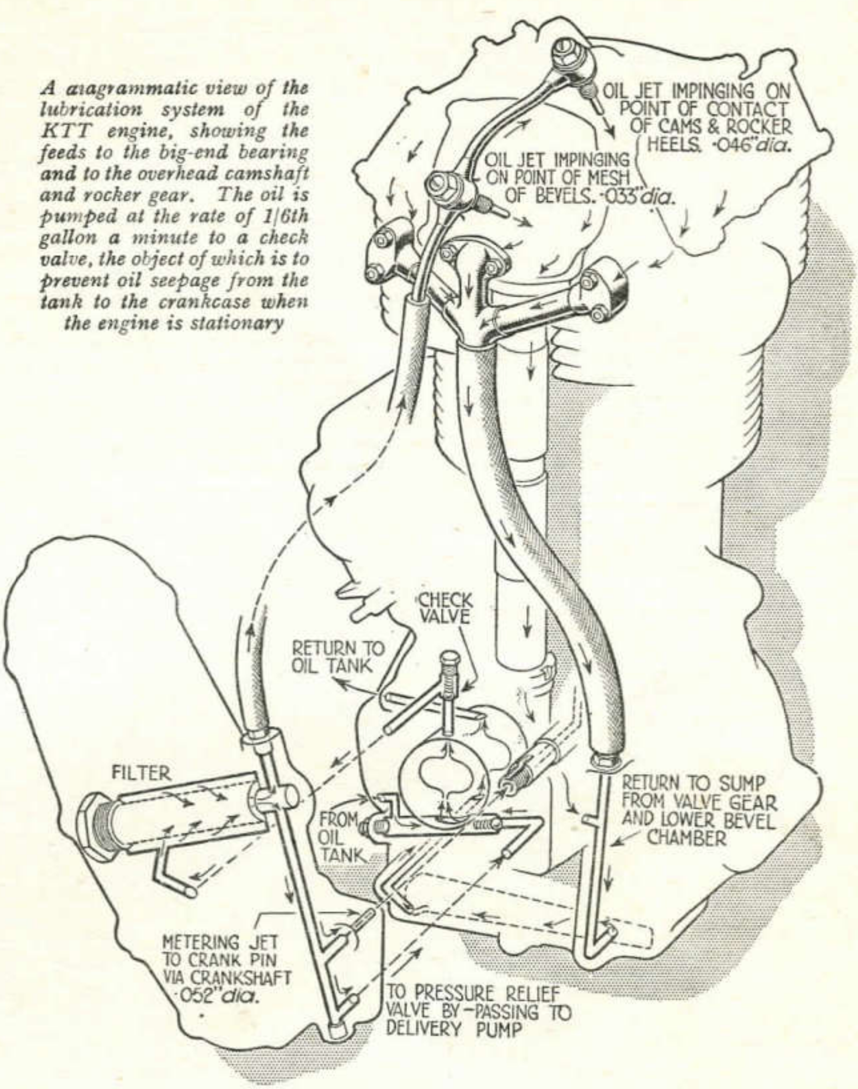
"Just pressed in, and located by a pin.

"The pin is really a screw lying parallel with the shaft, partly in the shaft and partly in the flywheel boss. These shafts, of 3 per cent nickel steel, are very slightly tapered so that the inner races of the main bearings are securely locked when pushed home. The outer races are shrunk into the crankcase, so that they also are firmly held."

Then I asked about that massive crankpin, which adds so materially to the rigidity of the crank unit. It is made of nickel-chrome steel, case-hardened to form the inner race of the big-end bearing. The main diameter is $1\frac{1}{8}$in, and the ends are very slightly tapered and pulled into the flywheels against wide shoulders. The nuts which fix it are of heat-treated nickel steel.

Rollers of $\frac{9}{16}$in × $\frac{3}{16}$in are employed in the big-end bearing. These rollers are located in a Duralumin cage, the bars of the cage being relieved on their inner surface so that only the end rings of the cage bear on the crankpin.

The reason for this is that the Duralumin cage is apt to wear the hardened crankpin, and the relief of the bars prevents damage to the roller track. This, of course, is a fact, though it may seem hard to believe that more wear is caused by the light-alloy cage than the heavily loaded rollers. The outer race of the bearing is pressed into the connecting rod big-end and a bronze bush into the small-end.



A diagrammatic view of the lubrication system of the KTT engine, showing the feeds to the big-end bearing and to the overhead camshaft and rocker gear. The oil is pumped at the rate of 1/6th gallon a minute to a check valve, the object of which is to prevent oil seepage from the tank to the crankcase when the engine is stationary

The massive forged connecting rod is made from an oil-hardening nickel-chrome steel, heat-treated to about 80 tons tensile. "Of course," said Mr. Willis, "we could use a steel with higher tensile strength, but tensile strength is not the only necessity, for great toughness is also required. The rod is machined all over and polished on the outside. This is not only useful for removing surface scale and weight, but also tends to reveal surface cracks or flaws."

Of case-hardened nickel-chrome steel, the gudgeon pin is no less than $\frac{13}{16}$in diameter; it is hollow and is taper bored at the ends to reduce weight. It floats in the little-end of the connecting rod, and is retained in the piston bosses by spring-wire circlips. As was pointed out, the outer extremities of the gudgeon pin are so chamfered that any tendency for the pin to move endways tends also to jamb the circlips in their grooves, rather than to displace them.

In order to provide the standard compression ratio of approximately 10.9 to 1, the piston head must be steeply domed. It is! So much so, indeed, that circular pockets are formed in the sides of the dome to clear the valve heads. The skirt is of slipper form, and the whole is made of heat-treated "Y"-alloy, sand-cast.

"Why sand-cast?" I asked.

"Because it has given us better results that way," was the reply.

There are small, vertical ribs from the gudgeon-pin bosses upwards, and there is a circular rib at the level of the boss centres for maintaining the shape of the slippers. Two narrow pressure rings of Wellworthy "Thermocrom" (heat-formed, not hammered) and a slotted scraper ring are fitted.

"Each engine, individually, is adjusted by shims under the cylinder base so that the cylinder head capacity is 35 c.c.," said Mr. Willis.

This 348 c.c. engine develops 27 b.h.p. at 6,500 r.p.m. It may be run at 7,000 r.p.m. in the normal course of events, and may be run with safety up to 7,500 r.p.m. for short periods, and *will* run up to 8,000, though this is considered to be beyond the limits of reasonable safety.

498 c.c. Triumph Speed

Underlying Design Features of a Famous Vertical-twin Engine, Leader of a Modern Trend

By "UBIQUE"

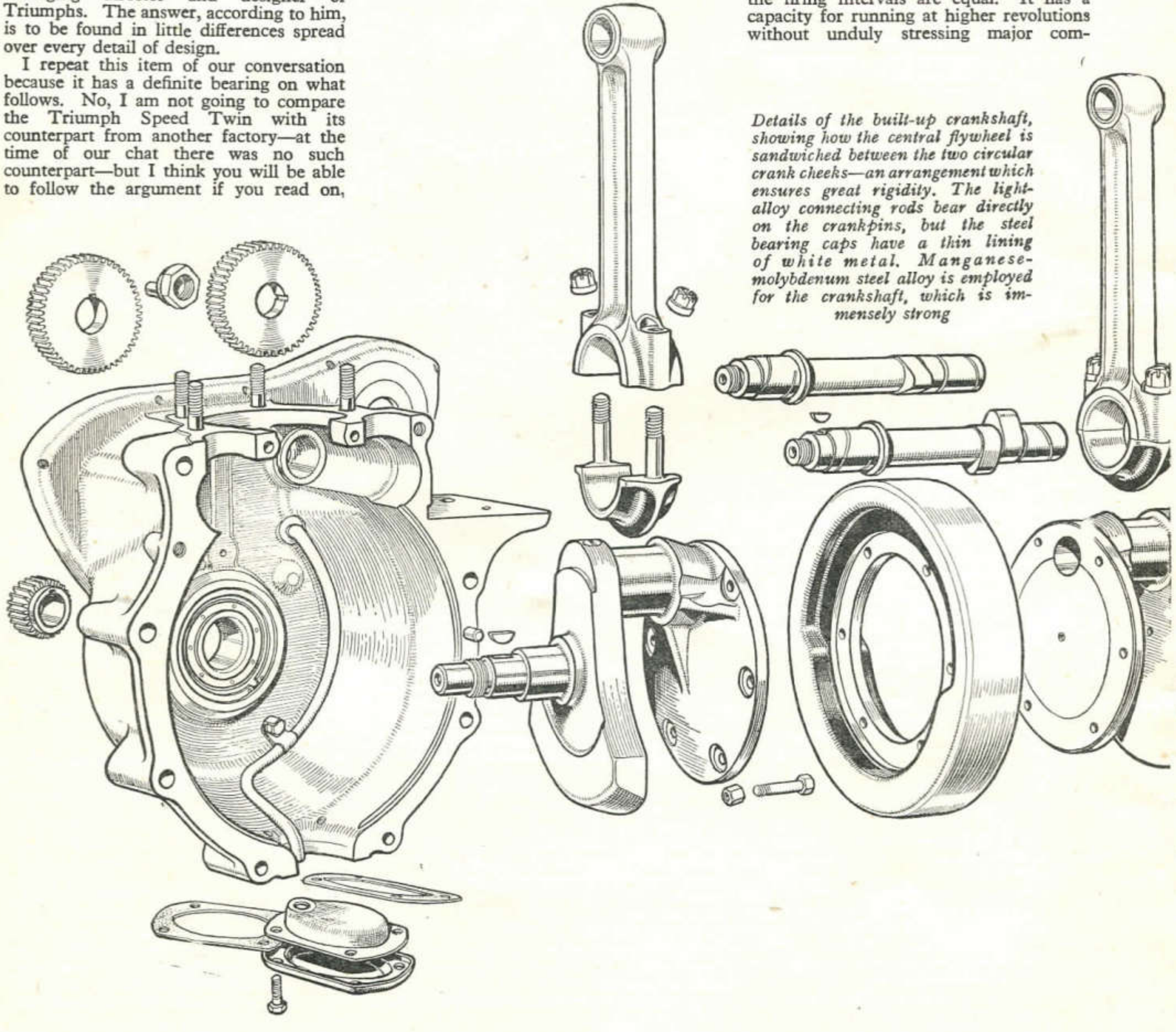
"HAVE you ever wondered why it is that of two machines having almost identical specifications, but designed and made by different factories, one may be a very ordinary performer and the other have outstanding qualities?" I was asked this question by Mr. Edward Turner, managing director and designer of Triumphs. The answer, according to him, is to be found in little differences spread over every detail of design.

I repeat this item of our conversation because it has a definite bearing on what follows. No, I am not going to compare the Triumph Speed Twin with its counterpart from another factory—at the time of our chat there was no such counterpart—but I think you will be able to follow the argument if you read on, and you will realize also that no single part of an engine is unrelated to the design as a whole.

The Speed Twin was obviously Mr. Turner's pet, because it was his latest and most up-to-date design, but most of his answers to my queries referred just as well to the "Tiger 100," which is, of course, a sports edition of the Speed Twin.

My first "Why?", rather an obvious one, concerned his choice of a twin instead of a single for an engine of 500 c.c.

"A twin," he said, "gives better torque —twice as good, in fact, if, as in this case, the firing intervals are equal. It has a capacity for running at higher revolutions without unduly stressing major com-



Details of the built-up crankshaft, showing how the central flywheel is sandwiched between the two circular crank cheeks—an arrangement which ensures great rigidity. The light-alloy connecting rods bear directly on the crankpins, but the steel bearing caps have a thin lining of white metal. Manganese-molybdenum steel alloy is employed for the crankshaft, which is immensely strong

Twin

ponents, and on account of its even torque it pulls better at low speeds. It starts more easily and requires no exhaust lifter. It is easier to silence, has better acceleration, better fuel consumption for the same power, increased reliability and durability, and it is better cooled. In fact, it is a much more agreeable engine to handle."

These, I was assured, were only some of the reasons. However, I thought they were enough to go on with, and asked for further information in regard to certain of the points mentioned.

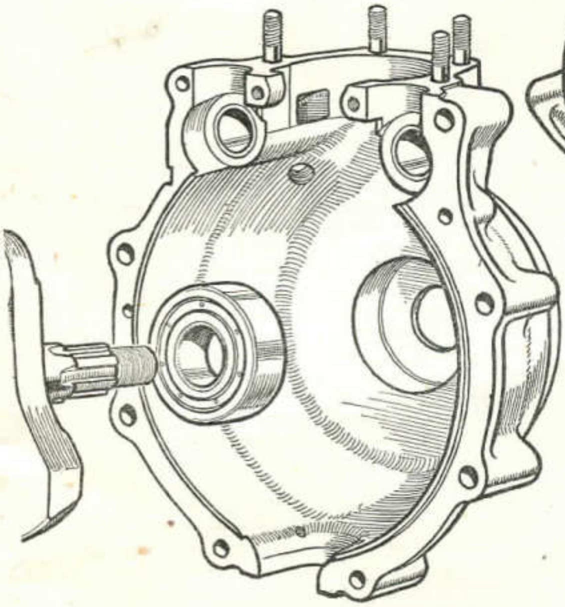
"With regard to fuel consumption," I said, "is not the result rather unexpected? Is it not true, in theory, that the single is the most economical form of engine?"

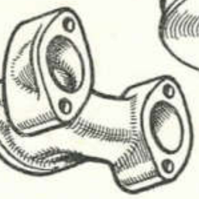
"Yes," was the reply. "On the face of it perhaps this is so, but in practice, with this particular type of engine and induction manifold, the depression is more constant and blow-back is diverted from the carburettor to the other cylinder by the design of the inlet pipe.

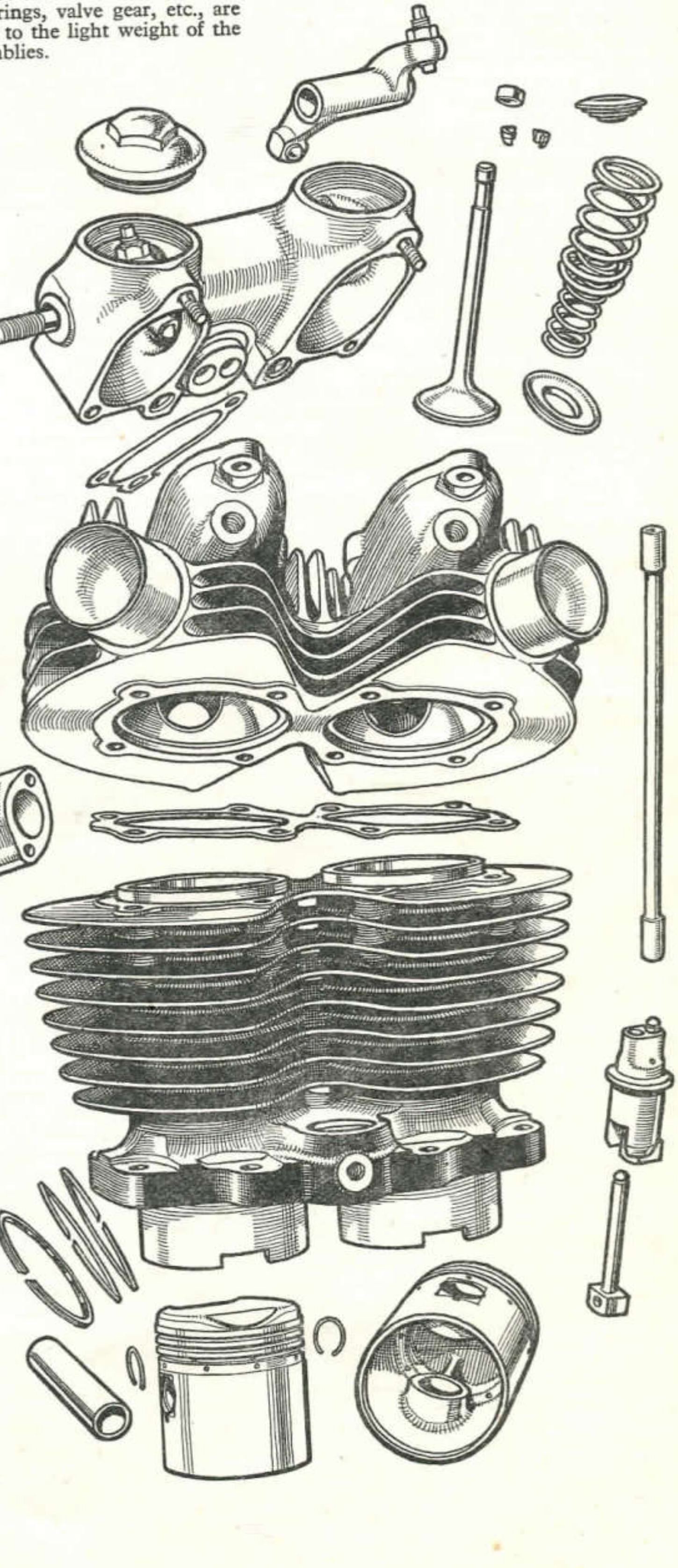
"Further, for a given power output it is possible to use a far smaller choke, which implies better vaporization and atomization." Mr. Turner quoted figures for an output of 27 h.p., saying that whereas a single would require a 1¼in diameter choke, the twin would need a diameter of only 1⅜in.

Greater reliability and durability go hand in hand, and they are inherent in the twin design, since the stresses on the connecting-rod bearings, valve gear, etc., are far lower owing to the light weight of the individual assemblies.

I was informed that in actual practice the weight of the two pistons, rods, etc., is no greater than that of the single assembly which they replace. In fact, since







(Right) Great rigidity is also a feature of the upper half of the engine. The one-piece cylinder casting has an unusually massive base and is attached to the crankcase by eight studs. The drawing clearly shows the air space between the two cylinders

there is no considerable difference between the gear ratios of the twin and single, it is almost fair to say that, for the performance of a 500 c.c. single, the majority of the stresses of a 500 c.c. twin are equivalent to those of a 250 c.c. single. Perhaps I should add at this point that the inertia stresses brought about by stopping and starting the piston at the top and bottom of each stroke may be by far the most important in the whole engine. Hence the importance of light moving parts.

Expressed in figures, the inertia loading and centrifugal loading on the big-end of the single at top dead centre of the exhaust stroke is approximately 4,800lb at 6,000 r.p.m., and that on each big-end of the twin only 2,300lb at the same revolutions.

My next question was, "Why was the vertical-twin chosen from so many possible types?"

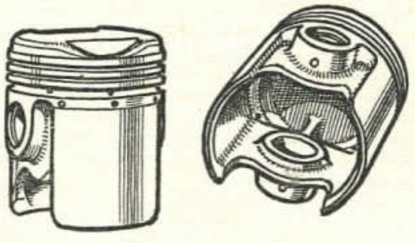
I was told that this matter had received the most careful consideration, and that the vertical-twin with cranks at 360 deg. (in line) was chosen as the best all-round layout for the following reasons:—It has the best carburation possibilities of any type of twin owing to its even firing impulses and short induction pipes. It is the most easily cooled of any type with the exception of a flat-twin set across the frame, and in the opinion of Mr. Turner this latter arrangement allows less latitude in design of many parts if unwieldiness is to be avoided. It can be laid out as a straightforward manufacturing proposition, and it can be made extremely rigid. This last feature was stressed as being of the highest importance, and it is certain that rigidity has been studied in every detail of the design under discussion, from the sturdy barrel-shaped crankcase to the monobloc cylinder casting with its heavy eight-stud fixing flange. Rigidity of internal parts is of equal importance, and this point has not been overlooked, as I will reveal later on.

Crank Arrangement

I put a question with regard to the arrangement of the cranks, although I knew the answer. "Why not cranks at 180 degrees?" The answer is twofold. First, the advantages of even firing intervals would be lost, and the carburation would be correspondingly less satisfactory. Secondly, although the primary balance would be better, a serious couple would be introduced on the whole. Thus, the advantages would be outweighed by the disadvantages.

In regard to this matter of balance, I was told that the balance of the 500 c.c. twin with crankpins in line was slightly better than that of the corresponding single, for although the total weight of the parts to be balanced is the same, the stroke is less, and the counter-weighting necessary to produce the best results is slightly less than in the case of the single.

On the question of the built-up crankshaft construction (the subject of a patent) Mr. Turner had much of interest to say. There are good reasons for the absence of a middle bearing, since with comparatively close cylinder centres it would be difficult to provide an adequate bearing and to ensure correct alignment without adding very considerably to the cost of manufacture.



Forged-type pistons of slipper design were adopted for the original Tiger 100, which is the super-sports edition of the "Speed Twin." It had a rather higher compression ratio

Also, a middle bearing might have involved an outside flywheel, and extra width and conflicting torsion effects between the flywheel and the mass of the internal balance weights.

The central flywheel system has, therefore, distinct advantages, and the method of sandwiching it between two circular crank cheeks ensures great rigidity. Incidentally, it is stated that the space contained between these crank cheeks and the inner periphery of the flywheel flange forms a useful centrifugal oil cleaner. Of a manganese-molybdenum steel alloy, the crankshaft is very strong and the big-ends are toughened by a special process. The advantages of this steel are ample strength and rather lower cost than a suitable nickel-chrome steel. Above all things, the stiffness and rigidity of the crankshaft construction are emphasized, and careful measurement has shown no material deflection at running speed.

Rigidity again is the reason for the use of a light alloy for the connecting rods, for although it would be possible to produce steel rods of no greater weight, the extra mass of metal available with the light alloy helps to stiffen the beam to a marked degree. There is another valuable feature in that the light alloy conducts the heat away from the bearings at a higher rate than would be possible with a white-metalled steel rod. The material employed for the rods is R.R.56—forged and having a tensile strength of 32 tons per sq in.

A bronze bush is used for the gudgeon pin, because the comparatively high coefficient of expansion of the alloy might cause excessive clearance and hammering of the bearing when hot if the cold clearance in the unbushed small-end were great enough for freedom.

The patent construction of the big-end is unusual in several respects. The rod bears directly on the crankpin, but the steel bearing cap has a thin lining of white metal. This arrangement takes advantage of the high heat conductivity of the light alloy, while the white-metalled cap acts as a safety valve since in the unlikely event of oil failure the metal would flow and prevent a seizure.

The big-end bolts are forged in one piece with the bearing cap and project upward, the nuts being above the centre line of the big-end instead of below. This arrangement saves weight and, of greater importance, it enables the diameter of the crankcase to be reduced and thus increases rigidity. A nickel-chrome steel of 100 tons tensile strength is employed for the combined cap and bolts.

A full-skirt type of piston is employed, and this is normal except for the internal webs designed to increase the rigidity of the gudgeon-pin bosses and conduct away heat from the middle of the piston crown. In the case of the Tiger 100, slipper pistons giving a higher compression ratio are used.

Questions about the lubrication system revealed its extreme simplicity, which in itself is a good guarantee of reliability. One side of a double-plunger pump delivers oil to the crankshaft via a small bronze bush which exists only for the purpose of guiding the oil into the shaft. Oil is delivered through the shaft to the big-ends at a pressure of about 60lb per sq in and at a volume which is ample for the needs of the big-ends and pistons.

A relief valve at the end of the shaft permits the remainder of the oil delivery to fill the timing gear cover to a predetermined level, after which it overflows to the crankcase and is returned to the tank by the scavenge pump.

The difference between oil pressure and volume was stressed and, although no figures were mentioned, I think it may be taken that the volume in the case of the Triumph Speed Twin is sufficient to do rather more than just lubricate the parts. The oil is filtered on both sides of the return pump—on the suction side through a gauze strainer, and on the delivery side through a felt filter.

Rigidity of Block

Concerning the cylinder block there are two points to be mentioned. The first is the great rigidity imparted to the whole construction by the one-piece casting with its massive base attached to the crankcase by eight studs. The second concerns the air space between the cylinders, which might appear to be inadequate, especially as it is shielded to some extent by a push-rod enclosure tube. It was pointed out, however, that a partial vacuum is formed behind the cylinder block by its passage through the air, and this depression is sufficient to induce a draught through the inter-cylinder spaces. A nickel-chrome cast iron is used for the block and provides high conductivity, a hard bore and high resistance to corrosion.

The cylinder head formation is good, and the valve gear, it was remarked, is neat and convenient for this particular layout. Inlet valves of "Silchrome" and exhausts of an austenitic steel are used. The latter material is self-hardening and has extraordinary tensile qualities at high temperatures.

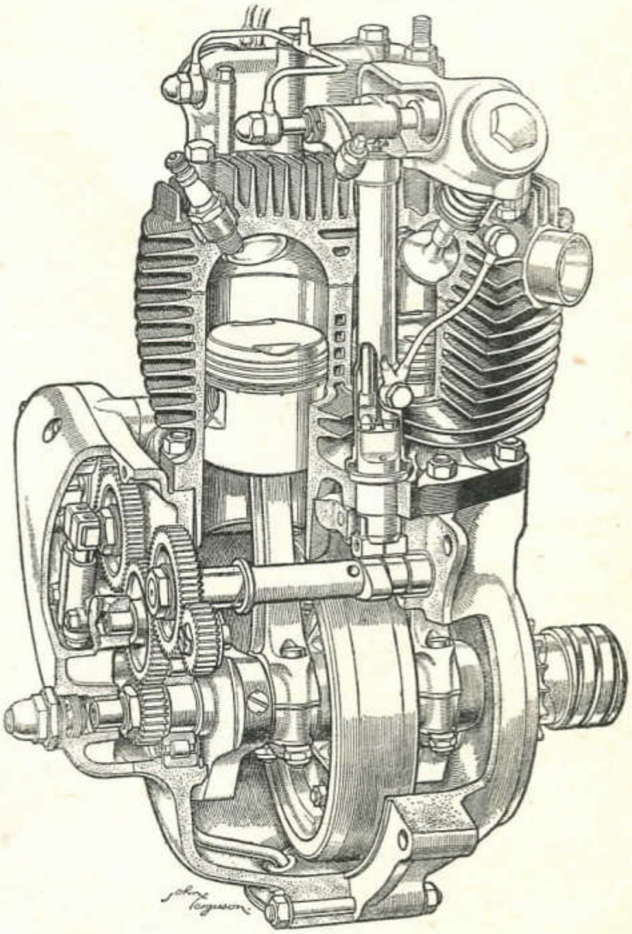
A few further inquiries elicited the fact that the cams are by no means designed for maximum efficiency; in fact, the cam forms are identical for inlet and exhaust valves. They are just a good compromise between efficiency, quietness and reliability.

The camshafts are located so high up that the engine may be regarded as of the high-camshaft type, and the enclosed push-rods are of Duralumin in order that the high coefficient of expansion may help to minimize any increase in valve clearance as the engine warms up. The timing gears are cyanide-hardened, a modern process as applied to small gears by which hardness can be obtained with close control of distortion.

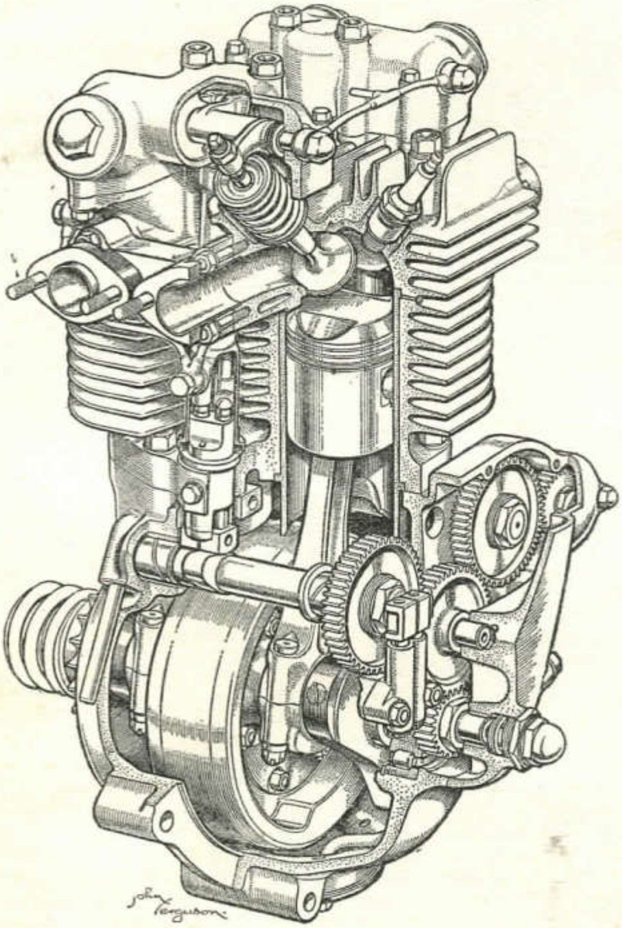
A point of unusual interest is that the rocker boxes are made of heat-treated "Y" alloy. The reason given for this is that the boxes are subject to considerable stresses and to frequent temperature changes. The material chosen is resistant to deformation in these circumstances, and so a good oil joint is retained between the box and the cylinder head.

Finally, I asked if there was much difference between the weight of the twin and its equivalent single, and was told that there is practically no difference, but that a slight advantage lies with the twin.

Triumph Grand Prix and Thunderbird

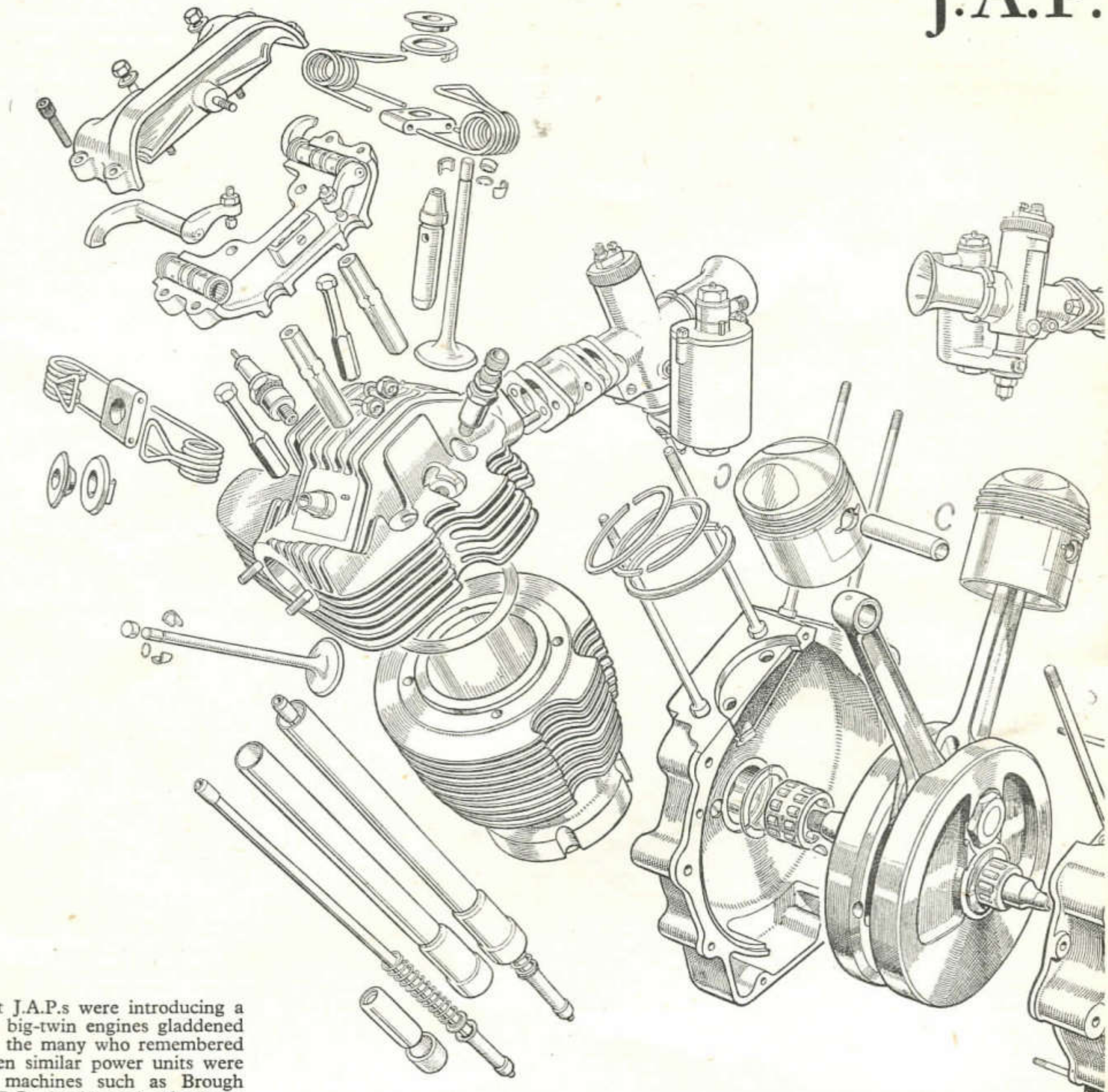


Called the Thunderbird, the 650 c.c. Triumph engine is a development of the Speed Twin and is notable for its high torque at comparatively low r.p.m. Bore and stroke are 71 × 82 as against 63 × 80 for the Grand Prix, Speed Twin and Tiger 100. Specially strong connecting rods, in R.R.56 light alloy, are fitted



The 498 c.c. Triumph Grand Prix engine was designed for racing only. While based on the existing Tiger 100, the power unit is special throughout. The large dimensions of the central flywheel will be noted. Each combustion chamber has a high-expansion, cast-iron insert, which provides both valve seats and sparking-plug boss

J.A.P.



NEWS that J.A.P.s were introducing a range of big-twin engines gladdened the hearts of the many who remembered the days when similar power units were popular for machines such as Brough Superior, O.E.C., Zenith and, of course, the famous Morgan three-wheelers. For 12 or 15 years the resources of the J.A.P. factory at Tottenham, London, had been largely devoted to stationary engines, and to speedway engines supreme on tracks throughout the world. However, to meet an undoubted demand for large-capacity vee-twins for both racing and touring purposes three new units have been designed.

Mr. S. M. Greening, A.M.I.Mech.E., Chief Engineer, and Mr. J. P. Bolando, Chief Draughtsman, took me to a small experimental shop at the factory where components of one of the new engines were laid out for inspection.

"How has this latest engine been evolved?" I asked, as a kick-off. "It has been developed," came the answer, "from the 8/80 o.h.v. 998 c.c. twin used in the Brough Superior, in speedway cars and, lately, in the Cooper racing car. It is evolved from the engine with which Eric Fernihough broke records."

"I hear there are to be several versions," I said. "What are they?"

"There are to be three engines—a 998 c.c. overhead-valve, a 998 c.c. side-valve, and a 1,096 c.c. overhead-valve."

"What are their purposes?"

"Both the overhead-valve engines are essentially for racing, but the larger one is for cars and the smaller for motor cycles. However, there will be a special low-compression version of both, suitable for 'Pool' petrol and ordinary road use. The side-valve is, of course, for road use in motor cycles running on 'Pool.'"

"Generally speaking, what is there new about the latest engines?"

"We now use an 'Elektron' crankcase, light-alloy cylinder barrels cast with cast-iron liners, and light-alloy cylinder heads with, of course, valve-seat inserts.

998 c.c. Overhead-valve Vee-twin

E. A. SITWELL Records, in Question and Answer Form, Design Details of the Latest J.A.P. Engine

Instead of a wet-sump, we now have a dry-sump system of lubrication; and instead of being 'straight-through,' the carburettor is of the Amal needle type, which allows a better and cleaner mixture at all r.p.m. Bore and stroke of the 1,096 c.c. engine are 84 × 99mm respectively, and of both 998 c.c. engines, 80 × 99mm. All three engines weigh about 125lb.

"Can you enumerate," I asked, "the main differences, otherwise, between the three engines?"

"Yes; the two o.h.v. engines differ only in the size of their bore. Bottom halves of the side-valve and o.h.v. engines are the same, but the side-valve has coil ignition and only one carburettor. Twin magnetos and twin carburettors are used on the overhead-valve engines."

"I suggest, then," I said, "that for the purpose of this article we deal from now on almost entirely with the 998 c.c. overhead-valve engine, since it is essentially a motor cycle engine and serves as a base for the side-valve version as well; but, first, why continue with a vee-twin, when the modern tendency is towards vertical, parallel twins?"

"Well, we are tooled up for vee-twins, for one thing. In any case, we wanted a 'thousand,' and a 1,000 c.c. vertical, parallel twin would be rather cumbrous. Moreover, we are the instigators of the vee-twin."

"Have you ever had any difficulty in cooling the rear cylinder?" "No, never. In fact, with this present engine, the rear cylinder seems to keep almost too cool!"

"Getting down to details," I said—"Why do you now use an Elektron crankcase?"

"For lightness combined with strength."

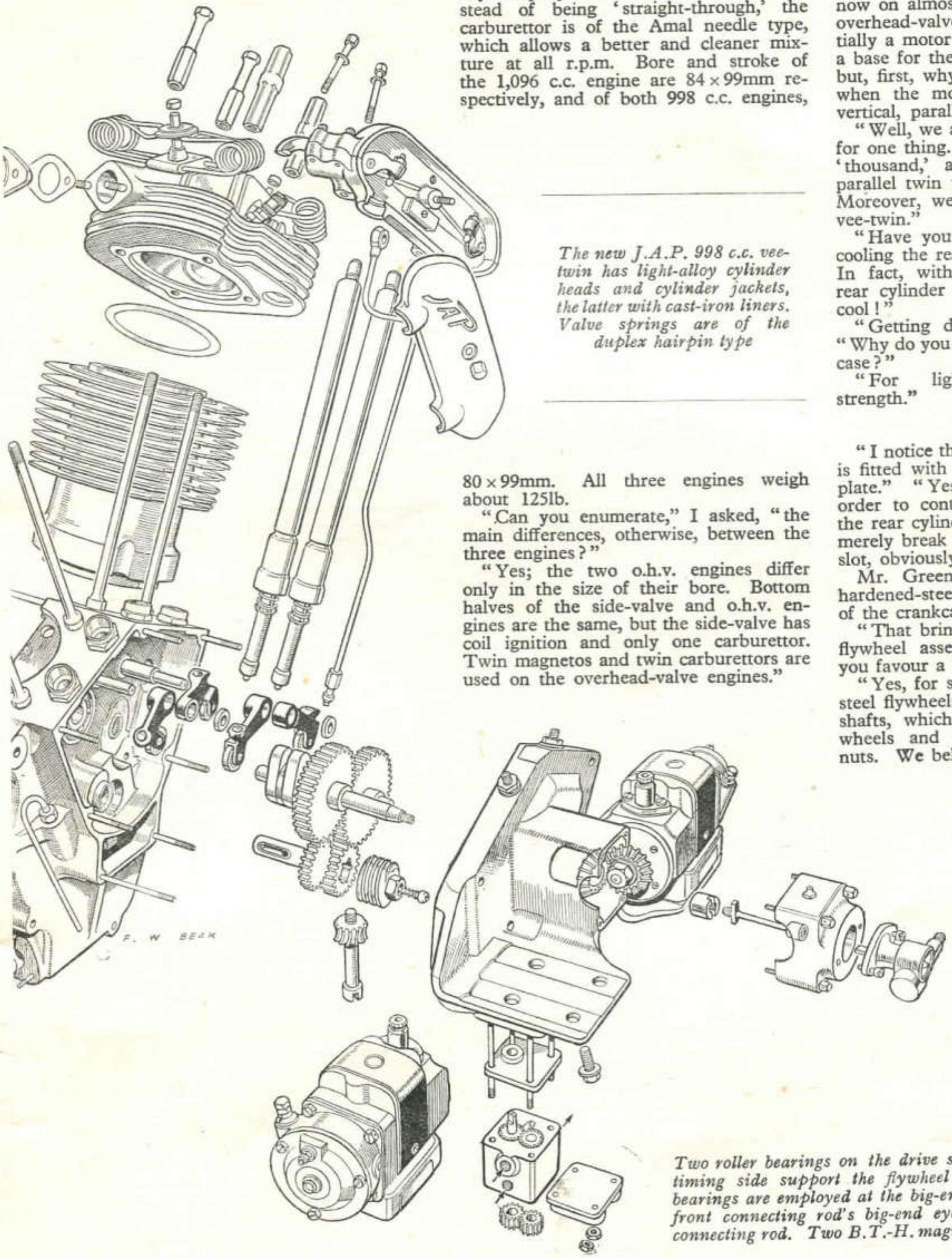
Oil Control

"I notice that the rear crankcase mouth is fitted with a slotted and drilled baffle plate." "Yes, the mouth is baffled in order to control the lubrication bias at the rear cylinder. The four drilled holes merely break up the baffle a bit, and the slot, obviously, is there for the con-rod."

Mr. Greening then pointed out the hardened-steel liner shrunk into each half of the crankcase for the main bearings.

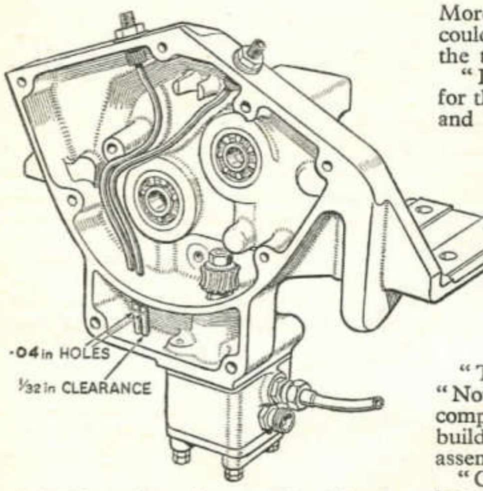
"That brings us to the crankshaft and flywheel assembly," I said. "I notice you favour a built-up assembly."

"Yes, for strength. We use high-duty steel flywheels and high-duty steel mainshafts, which are pressed into the flywheels and secured by large-diameter nuts. We believe in a parallel mainshaft



The new J.A.P. 998 c.c. vee-twin has light-alloy cylinder heads and cylinder jackets, the latter with cast-iron liners. Valve springs are of the duplex hairpin type

Two roller bearings on the drive side and one bearing on the timing side support the flywheel assembly. Two separate bearings are employed at the big-end (also see page 15). The front connecting rod's big-end eye is forked round the rear connecting rod. Two B.T.-H. magnetos, bevel driven, are fitted



A double-acting oil pump is driven by worm gear

assembly—that is to say, the shafts are not a taper fit—for the sake of rigidity. The recesses you see in the flywheels are for balance."

"What are the diameters of the mainshafts?"

"Timing side is 1in, and drive side $1\frac{5}{16}$in. Carrying the bigger load, the drive side is made larger in diameter."

"And the main bearings?" "On the timing side we use roller bearings size ¼in diameter by ½in long running in a Duralumin cage. This size is chosen with particular regard to the load and convenience for design. On the drive side we have a double-row roller bearing—size, $\frac{5}{16}$in diameter by $\frac{5}{16}$in long—also running in a Duralumin cage. This bearing will stand up to the bigger load on the drive side, and it, too, is convenient for the design."

"Why use Duralumin for the cages?" "For lightness: inertia fling with, say, bronze cages would cause wear on the mainshafts."

"And these washers?" I asked, pointing to two washers on the mainshafts, one on each side of the flywheel. "They are phosphor-bronze thrust washers," was the answer, "put there to locate the flywheels in the crankcase. They act as distance pieces, and there is a minimum of 10 thou play for the assembly to float endways. Each washer, as you see, has four little oil-grooves on each side for lubrication purposes."

Accent on Rigidity

"I suppose you use a parallel fitting for the crankpin, too?"

"Yes, for accuracy and rigidity. Each flywheel bolts up against a large-diameter shoulder machined on the pin, and the pin is secured by large-diameter nuts which face against the outside of each flywheel. The accent is on rigidity."

"I see there is no locking device for these nuts—nor for those that secure the mainshafts."

"No, the nuts and faces are made dead true, and the nuts will not come loose. We do not advocate locking devices, or it would be difficult to know when to stop. Moreover, centre punching, for instance, could spoil either the head of the nut or the thread on the pin."

"I see that you use double-row rollers for the big-ends. Why are they staggered, and what is their size?" "They are staggered in order to strengthen the cage and the size is ¼in diameter by ½in long."

"Why use rollers, and not plain bearings?"

"Plain bearings would not stand up to the load at high r.p.m. if we retained this size of big-end assembly."

"That seems quite clear," I said. "Now we come to something a bit more complicated. Can you please describe the build-up of the two big-ends into an assembly?"

"Certainly. As you see, one of the rods has a fork end, and the two are assembled together. The inner rod runs on 58 needle rollers, ⅛in diameter × ⅝in long, positioned endwise by two hardened-steel washers which are peened on to a hardened-steel liner pressed into the big-end eye. These needle rollers in turn run on the outside of a hardened-steel sleeve pressed into the eye of the forked rod. The assembled rods run on the rollers in the Duralumin cage already mentioned, which is, of course, positioned on the crankpin. These caged rollers actually bear on the inside of the hardened-steel sleeve. You will notice that the fork end is bridged for added rigidity. It should be pointed out, too, that the hardened-steel sleeve has three different diameters in order to avoid distortion of the rod and damage to the race when fitting. Outside diameter of the sleeve on its bearing surface is $\frac{27}{32}$in."

Why Forked?

"What is the advantage of this forked-rod arrangement?" "It obviates the necessity for offsetting the cylinders, and therefore the engine can be less bulky."

"Anything special about the con-rods?" "They are made of high-duty steel and are highly polished to make sure there are no cracks or defects."

"Couldn't you use light-alloy rods—say R.R.56?" "We should have to have much larger rods if we used that material, in order to make sure they were sufficiently strong."

"Now we have arrived at the small-ends and pistons," I said.

"Yes; each small-end has a pressed-in phosphor-bronze bush. Fully floating, circlip-located gudgeon pins are employed. The pistons are made of low-expansion aluminium alloy, and their skirts are machine-tapered. Internally, the gudgeon pins are taper-ground. Each piston has two compression rings and one scraper. Bosses inside are webbed to the crown for strength. For suitable compression ratios, the pistons are domed in shape, and they have machined flats for valve clearance."

"What are these compression ratios?" "For alcohol fuel, the 998 c.c. and 1,096 c.c. engines both have a compression ratio of 14 to 1; and their ratio for 'Pool' petrol is 7.2 to 1. Ratio for the side-valve running on 'Pool' is about 6 to 1. Piston clearances are 6 to 8 thou at the bottom of the skirt when cold. Incidentally, note the drain-back oil holes below the bottom (scraper) ring and in the scraper ring groove."

"I presume you employ aluminium alloy for the cylinder barrels and heads in the interests of better heat distribution, better cooling, and lightness?"

"That is right. The barrels have large-diameter fins and cast-in, cast-iron liners. Four holding-down bolts are used, of $\frac{7}{16}$in diameter high-tensile steel, and the barrels are spigoted into the crankcase to a depth of $\frac{5}{16}$in. Integral with the crankcase, the bolts go right through the cylinder head and secure that as well, with sleeve nuts."

Timing-gear Features

"What are the main points about the timing gear?" I asked. "We'll start from the mainshaft pinion," came the reply. "This steel mainshaft pinion drives the front camwheel, which in turn drives the rear camwheel. Each camwheel deals with one cylinder and carries two cams, inlet and exhaust. The rear camwheel also drives the rotary crankcase breather valve, which we can discuss later. A Torrington, needle-roller bearing is used for the front camwheel, and a Skefko ball bearing for the rear one."

"Why different bearings?" "Simply because of the size and geometry of the design. The cams operate four roller-type cam levers, each roller running on a fully floating, phosphor-bronze bush. Their pivot pins are supported at both ends, by the timing cover and crankcase wall respectively."

I picked up a push-rod. "What can you tell me about these?" I asked. The answer was, "For lightness and strength, we use hollow, Duralumin rods. The Duralumin expands approximately with the cylinders and heads, so we are not troubled by differential expansion. Each push-rod has a hardened-steel ball-end at the bottom and a hardened-steel cup at the top. The rods are 14in long by $\frac{7}{16}$in outside diameter, and each is fitted with a return spring located by a shouldered sleeve and washer. These springs are put there to keep flutter away from the rods on their return downwards. Drawn-steel tubular push-rod covers are located over guides which are screwed into the crankcase."

I noticed that access to the inside of the aluminium-alloy rocker box could be obtained simply by removing one nut and the cover. I saw the ball-end rocker adjusters at the push-rod end of each rocker.

"What are the rockers made of?" I inquired. "They are high-tensile steel stampings running on needle-roller bearings."

"Why needle rollers?" "Because there is less friction than with a plain bearing, and needle rollers are easier to lubricate since they need less oil."

"I see you employ hairpin valve-springs; but why have them exposed when the modern tendency is towards enclosure?" "We like to expose them to keep them cool. Incidentally, each spring is located in a steel block which fits over the valve-guide extension."

"What material is used for the valves?" "K.E.965 for both valves. It is a material that can withstand both stresses and heat. Although we need not really use K.E.965 for the inlet valve, which keeps cooler than the exhaust, we do so in order to make quite certain. You will see that there is a hardened-steel end-cap on the top of each valve, on which the rocker bears. This cap is free to turn, and it is put there to prevent wear of the valve stem. Incidentally, port diameters are: inlet 1 21/32in, exhaust 1 33/64in. Stem diameter is 11/32in for both."

Seats and Guides

"Now, what about these valve-seat inserts?"

"They are shrunk in, and austenitic iron is used for the inlet, while aluminium-bronze is employed for the exhaust. Obviously we cannot use the same material for both, because of the difference in expansion that would be brought about by the different temperatures. We use phosphor-bronze, pressed-in valve guides; and the sparking plug is screwed directly into the aluminium alloy of the cylinder head."

"Please comment on the combustion-chamber shape and port arrangements."

"In the interests of efficiency, we have a hemispherical combustion chamber. The inlet ports are offset to make room for two carburettors, and the exhaust ports are also slightly offset to make room —particularly in order to dodge the frame front down-tube of a motor cycle. In the interests of highest efficiency we have two carburettors on the o.h.v. engine. The overhead-valve engine is designed primarily for racing. Moreover, if you had only one carburettor with such a tall, twin-cylinder engine, the difference in expansion between the induction manifold and the cylinders might cause trouble with leakage. One carburettor is entirely suitable for the side-valve version, since the engine is not so tall and we do not want the last ounce of power from it. A single carburettor has the obvious advantage of being less costly than two."

"Good. Now let's tackle the lubrication system, which, as you have already said, works on the dry-sump principle. Can you please describe the cycle of events?"

"Certainly. First, it must be pointed out that the oil is circulated by a double-acting, gear-type pump driven off the timing-side mainshaft pinion by a worm gear. From an external tank, the oil falls by gravity to this pump, whence it is pumped via the timing-side mainshaft and a drilling in the flywheel to the crank-pin, where it bursts out to lubricate the big-ends. From the big-ends, the oil is released to lubricate the pistons. Then it falls by gravity into the sump from where the return side of the pump takes it back to the tank. That is the main part of the system."

Rotary Breather

"And it seems perfectly clear; but what about rocker lubrication, etc?"

"Ah—to understand the system of rocker lubrication we must go back first to the rotary crankcase-breather valve. Driven by the rear camwheel, this valve operates on the down-stroke of the pistons. A ported bush pressed into the timing half of the crankcase mates with a port in the rotary valve. The 'release' is led into a small compartment in the crankcase, and thence some of it is piped to the rear chain for lubrication purposes. You appreciate, of course, that the 'release' contains a certain amount of oil.

"In this small compartment, pressure is set up. Practically all the air 'breathed' will go out to the atmosphere, with a little oil for the rear chain. The remaining oil, and a little air, will collect on the lower part of the compartment, from which a pipe is taken to each rocker box. The lower ends of these pipes have a 1/32in clearance above the bottom of the compartment, to pick up the oil. In order to prevent the oil from attaining a continuous stream upwards, a small hole (40 thou) is drilled in each pipe ⅜in above the lower end. Each little hole effectively breaks the column of oil.

"Once inside a rocker box, the oil, discharged from the pipe, is split by a projection or boss. Part of the oil now passes along galleries and through drillings to each rocker bearing, and the remainder drops into a small reservoir which distributes the lubricant to the valve stems. Ball ends of the rockers are effectively lubricated by oil mist. Now the oil drains back through the push-rod tubes into the timing chest, where it lubricates the timing gear, and thence into the crankcase. The push-rod tubes are made oil-tight by synthetic-rubber seals at their lower ends and a close fit at the top. Incidentally, with this system, the rocker box must be air-tight, and, indeed, it is air-tight."

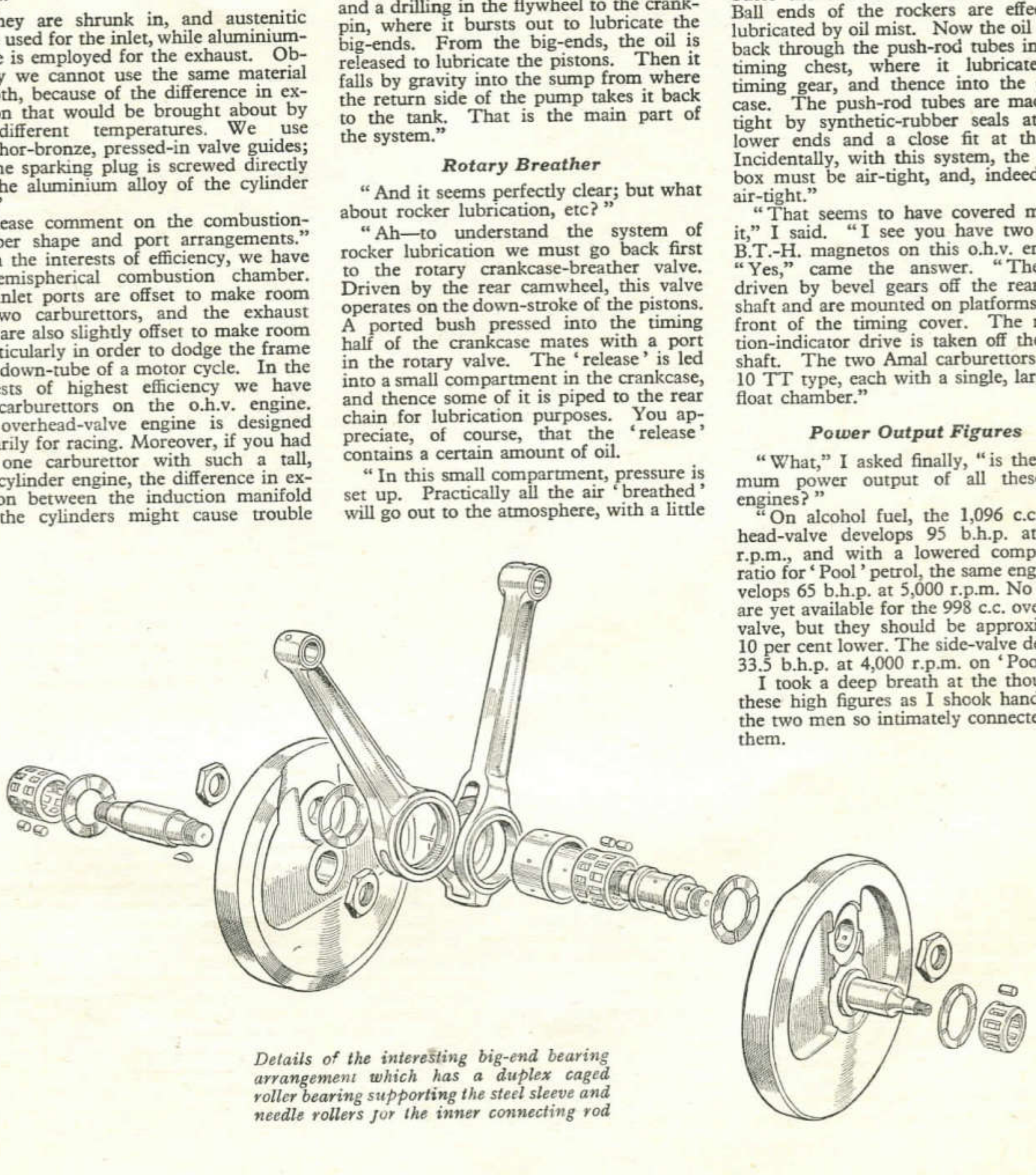
"That seems to have covered most of it," I said. "I see you have two single B.T.-H. magnetos on this o.h.v. engine." "Yes," came the answer. "They are driven by bevel gears off the rear camshaft and are mounted on platforms at the front of the timing cover. The revolution-indicator drive is taken off the same shaft. The two Amal carburettors are of 10 TT type, each with a single, large-size float chamber."

Power Output Figures

"What," I asked finally, "is the maximum power output of all these new engines?"

"On alcohol fuel, the 1,096 c.c. overhead-valve develops 95 b.h.p. at 6,000 r.p.m., and with a lowered compression ratio for 'Pool' petrol, the same engine develops 65 b.h.p. at 5,000 r.p.m. No figures are yet available for the 998 c.c. overhead-valve, but they should be approximately 10 per cent lower. The side-valve develops 33.5 b.h.p. at 4,000 r.p.m. on 'Pool'"

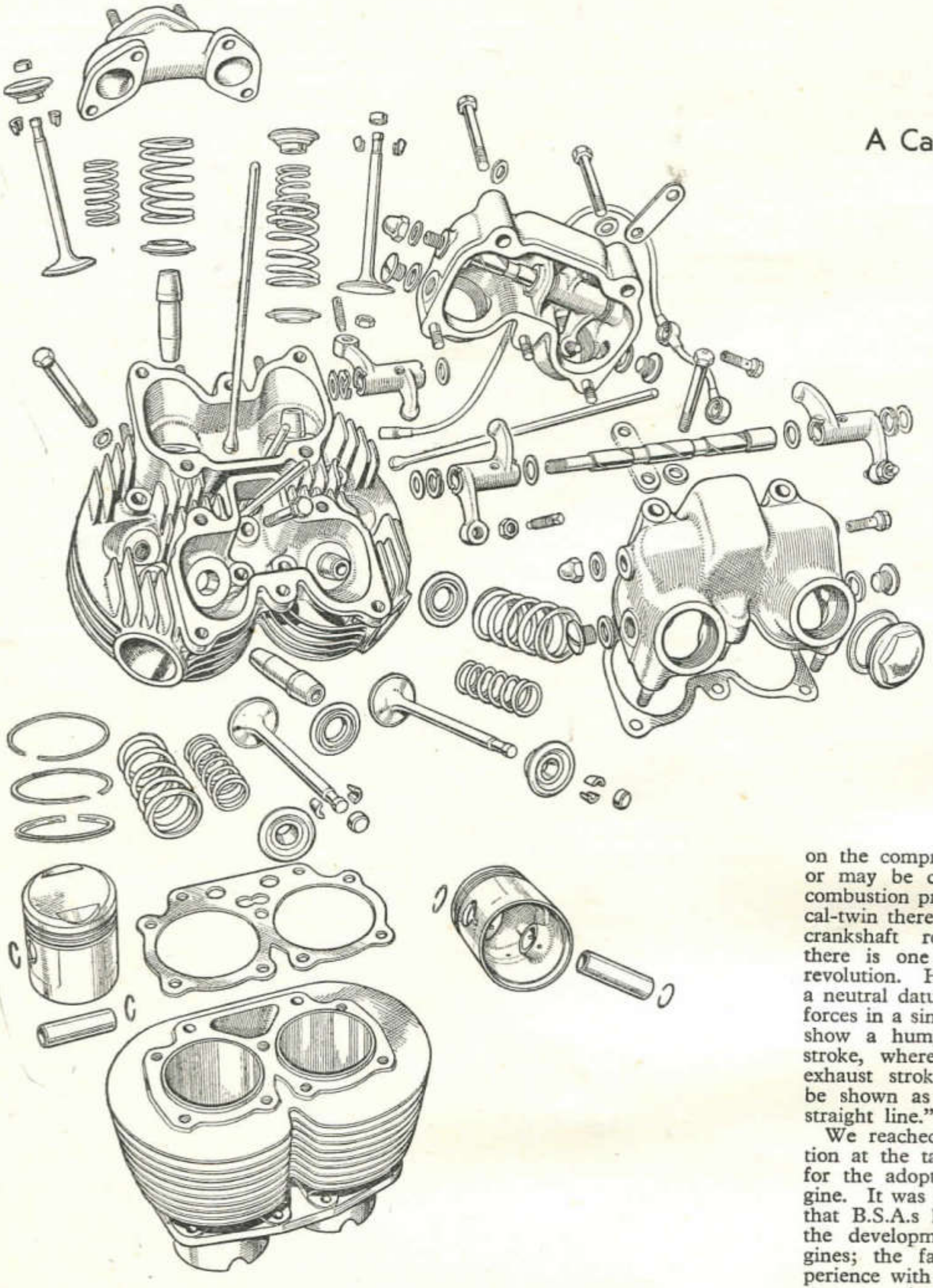
I took a deep breath at the thought of these high figures as I shook hands with the two men so intimately connected with them.



Details of the interesting big-end bearing arrangement which has a duplex caged roller bearing supporting the steel sleeve and needle rollers for the inner connecting rod

B.S.A.

A Catechism on an Established



Two separate valve-spring wells, with an air space between them, are formed in the cylinder-head casting. The head is retained by nine bolts, one of which is in the middle to prevent distortion and give a good joint seal. Light-alloy rocker boxes are bolted independently to the head. Rockers operate direct on the steel spindles

THE afternoon's discussion promised well. In the airy B.S.A. office was a wealth of technical experience. At the head of the table was Mr. H. Hopwood, Chief Designer (Motor Cycles), who was "in" on the designing of the highly successful vertical-twin that started the trend in 1938. And it was a vertical-twin—the B.S.A. Model A7, introduced in 1946—I had journeyed to the Small Heath works to discuss. Supporting Mr. Hopwood was Mr. H. Perkins, Assistant Chief Designer; he laid down the A7 engine and it was, in Mr. Hopwood's words, "Mr. Perkins' baby." Further support came from Mr. D. W. Munro, M.I.Mech.E., of the Technical Department, who has a reputation for his technical writings and his predilection for technical chit-chat.

Mr. Munro was not long in propounding a theory that deserved a verbatim note. "I maintain," said D.W.M., with eyes a-twinkle, "that the balance of a vertical-twin is better than that of a single. True, the two types of power unit are identical in *dynamic* balance. But in a four-stroke cycle, the inertia loading on the compression stroke is minimized or may be completely opposed by the combustion pressures. Now with a vertical-twin there is a firing stroke for every crankshaft revolution; with a single there is one firing stroke every *other* revolution. Hence a graph curve about a neutral datum showing the unbalanced forces in a single-cylinder machine would show a hump indicating each exhaust stroke, whereas in a vertical-twin the exhaust strokes would, by comparison, be shown as a lesser variation from a straight line."

We reached that stimulating observation at the tail-end of a list of reasons for the adoption of a vertical-twin engine. It was pointed out by Mr. Perkins that B.S.A.s had been following closely the development of multi-cylinder engines; the factory had had much experience with twins, and engines of that type were in production during the first World War. It was foreseen that while the single-cylinder engine was far from on its way out in public favour, there was increasing demand for engines that were smoother and quieter in operation.

The vertical-twin has those merits. "And," added Mr. Hopwood, "it is neat and compact and will fit comfortably in a conventional frame; it can be cooled adequately and gives good accessibility for maintenance."

Then emerged another consideration connected with inertia loading. Mr. Hopwood pointed out: "Though the

Model A7 Twin

Power Unit, With Answers from B.S.A. Technicians. By HARRY LOUIS

actual weight of the two pistons complete with rings and gudgeon pins, plus that part of the connecting rods assessed as reciprocating motion, might be higher than with a single-cylinder engine of similar capacity, the inertia loading will be lower by reason of the shorter stroke of the twin."

Next, I asked the reason for the semi-unit construction achieved by bolting the gear box to the rear of the crankcase. "That arrangement gives a compact unit," said Mr. Perkins, "and makes for the utmost rigidity. Hence there are lower mechanical losses in the primary drive." Mr. Hopwood pushed the point further: "There is also the attraction of weight saving by the elimination of engine plates between crankcase and gear box and by the reduction in the frame member lugs." Maintenance was easier because a primary chain adjustment could be made very quickly by resetting a slipper, which did not mean the rear chain had afterwards to be readjusted as with a separate gear box design.

"Did you encounter any snags with this bolted-up arrangement during the development stages? For instance, did any bother arise in connection with heat transference to the clutch; did you find that the engine and transmission noises were accentuated?" The answer was, "No, trouble with heat transference never arose and, on the subject of noise, well, the A7 has gained a high reputation for quietness."

The crankshaft is a one-piece forging in 65-ton, 3½ per cent nickel, toughened steel. The crankshaft has integral bob-weights and a flange in the middle to which the flywheel is bolted. Formed with the flywheel are additional bob-weights. On the drive side at the main bearing, the shaft measures 1⅛in diameter, the timing-side bearing journal measures 1⅜in diameter, and the big-end journals are 1.46in diameter. Each crankshaft assembly is individually balanced within narrow limits; the big-end journals and the timing-side crankshaft journal are induction hardened, and ground and polished to a superfine finish.

Oil hardening, high-carbon, nickel-steel, H-section connecting rods, with conventional split big-end eyes, are employed. Big-end bolts are in high-tensile nickel-chrome steel. Bearing liners are steel-back, lead-bronze, with indium flash. At this point Mr. Munro chipped in. "We shouldn't overlook the importance of the indium flash—indium is nearly as expensive as gold, by the way—which is diffused into the surface of the lead bronze. It provides an amazingly high resistance to instantaneous overloading and it is therefore particularly advantageous during running-in of a new engine."

Gudgeon pins measure $1\frac{1}{16}$in diameter, are taper bored, and are in nickel-chrome steel, case hardened and tempered; they are of the fully floating type retained by wire circlips. Pistons are of B.S.A. design and are cast in silicon-alloy, which has a very low cœfficient of expansion. Each piston has two compression rings and one slotted scraper ring. Compression ratio is 7 to 1. On the Star twin it is 7.5 to 1.

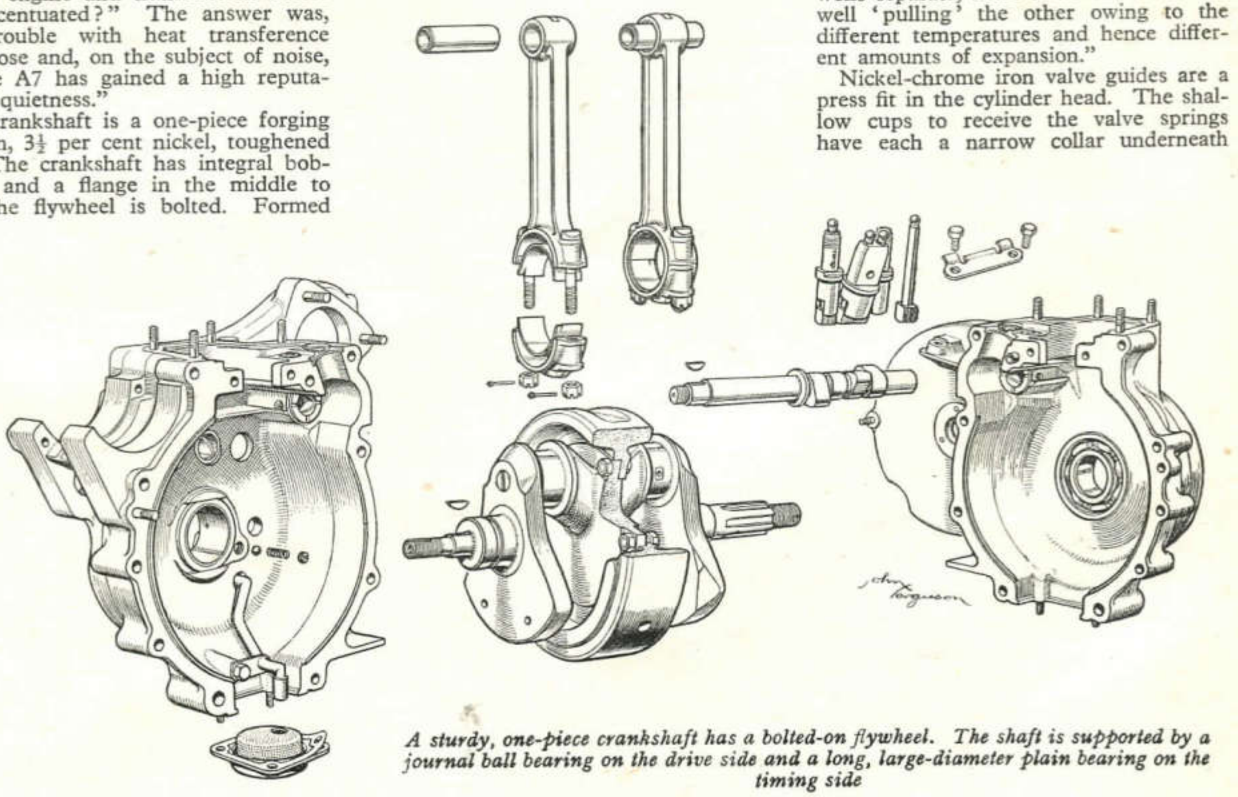
"This monobloc cylinder casting is unusual in the arrangement of the push-rod tunnel," I observed. "Would you give me the considerations that led up to that layout being adopted?"

"Oh, yes," volunteered Mr. Perkins. "The idea of the push-rod tunnel at the rear was to obviate any obstruction to cooling air impinging on the cylinders. There is adequate air flow between the two bores with outlets round the sides of the push-rod tunnel. The one-piece casting gives rigidity and is eminently sound practice providing the design allows good cooling. Incidentally, the material used is iron, as you can see, and the bores are hone finished."

"And arising from this layout, is the attraction to be able to employ a single camshaft with a resulting simplification of the timing gear?" I queried. "Agreed," came the reply.

The iron cylinder-head casting includes the valve-spring wells on which fit the light-alloy rocker boxes. Mr. Munro added, "You will note that those wells are distinct and separate from each other with a lateral air space between them. That is important; the air space ensures proper cooling, and since one well is for the exhaust valves and the other for the inlets, the temperatures of the wells will be vastly different in normal running conditions. By keeping the wells separate, there is no chance of one well 'pulling' the other owing to the different temperatures and hence different amounts of expansion."

Nickel-chrome iron valve guides are a press fit in the cylinder head. The shallow cups to receive the valve springs have each a narrow collar underneath



A sturdy, one-piece crankshaft has a bolted-on flywheel. The shaft is supported by a journal ball bearing on the drive side and a long, large-diameter plain bearing on the timing side making contact with the head. "Thus," said Mr. Perkins, "the cups are clear of the head and less heat is conducted to the valve springs."

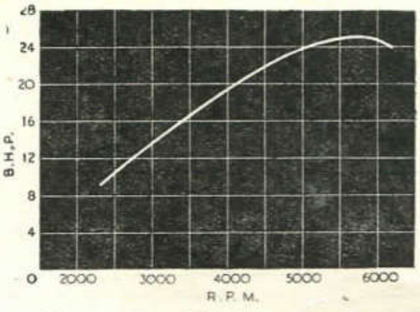
Inlet valves are in 3⅜ per cent nickel-steel with a high carbon content. Jessop G2 nickel-chrome austenitic steel is employed for exhaust valves. The coil valve springs exert 90lb pressure with the valves fully open—that is, with $\frac{5}{16}$in lift. Springs are retained by a collar and split, taper collets. Valve stems are fitted with hardened steel end-caps on which the adjustable rocker ball-ends bear.

"You will have seen," said Mr. Perkins, "that the head is held down by nine bolts. The rocker boxes are independently bolted to the head so that the nine bolts have one job—to hold the head firmly and squarely on the cylinder block." Then Mr. Munro added, "And one of the bolts is plumb in the middle of the head; it is an important bolt because it prevents the chance of distortion and plays a big part in making a good joint."

"You employ separate light-alloy rocker boxes," I observed. "Why not rocker boxes integral with the cylinder head, so eliminating joints between boxes and head and also, possibly, obtaining a stiffer ensemble?"

"Integral rocker boxes may seem an attractive proposition," said Mr. Perkins, "but adequate cooling can be difficult to achieve; furthermore, the differences in thicknesses of metal inevitable in such a casting might encourage distortion."

Manganese-carbon, case-hardening steel is used for the ½in diameter rocker spindles; each spindle is supported not only at the ends, but also in the middle by a ribbed boss in the casting; the boss separates the two rockers. Very stiff, yet light in weight, the 3 per cent nickel, case-hardening steel rockers operate directly on the spindles (in other words, there are no rocker bushes). "The best possible bearing," said Mr. Hopwood.



Power curve of the 495 c.c. A7 twin

Ends of the rocker arms are cupped to receive the solid steel push-rods. "Is there no difficulty with lubrication of those 'upside down' cups?" I queried "No. The contact surface gets adequate lubrication and an advantage is that the cups will not hold water that might arise from condensation; hence there is no chance of sludge—or even rust—formation," said Mr. Perkins. He went on to mention that the absence of a cup on the push-rod and a ball end on the rocker meant a saving in weight.

A specially interesting point is that in the sides of the rocker boxes are detachable Duralumin plugs—one for each valve—to allow a feeler gauge to be inserted between adjuster and valve-stem end cup. There are, of course, screw caps to give access to the lock nuts and adjuster heads.

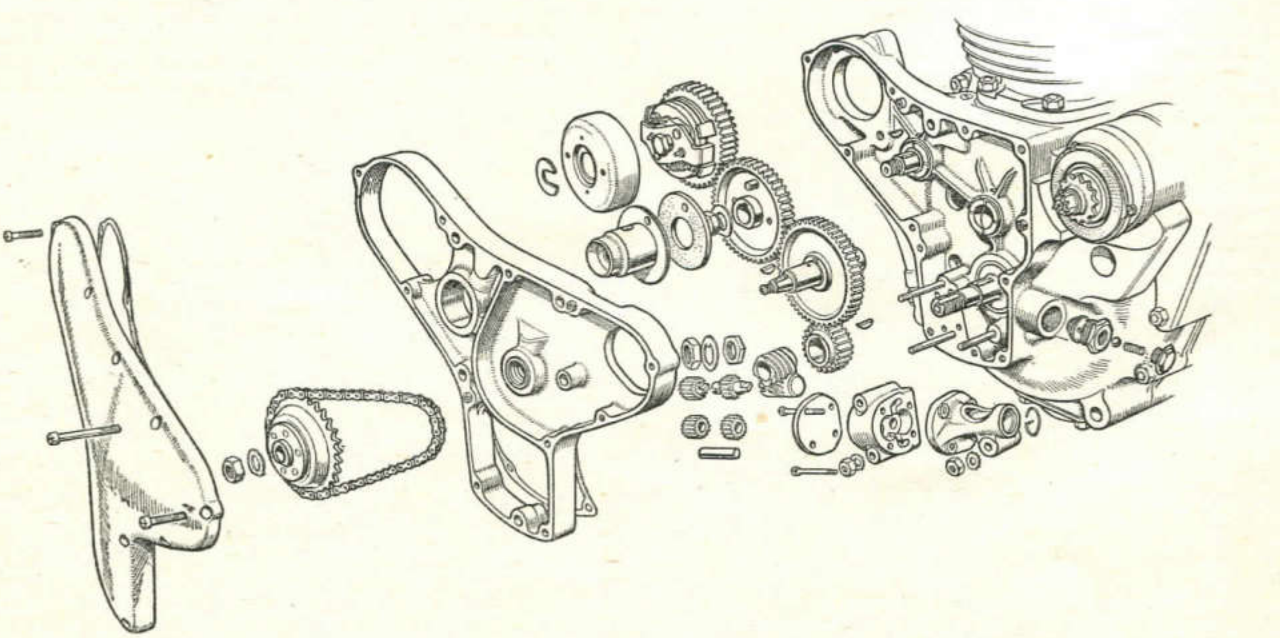
The crankcase is an extremely robust aluminium-alloy casting. The crankshaft is carried and located by a large deep-groove, ball journal bearing on the drive side. On the timing side there is a steel, white-metal-lined bearing, 1¼in in length; the bearing area is thus 1¼in long by 1⅛in diameter.

"That long, plain bearing gives good support to the crankshaft," I observed. "Yes," agreed Mr. Perkins, "that's its charm. You will note, too, that the crankshaft pinion is as close as possible to the bearing, which ensures accurate running of the pinion. The main oil feed to the big-end bearings passes through this crankshaft bearing, which is thus almost awash with oil. This attention to rigidity and lubrication pays dividends in quiet timing-gear operation. Concentration on eliminating even a minor source of noise in the timing gear is well worth while, because the train of pinions tends to magnify or 'throw up' noise."

Spur pinions of the timing gear are $\frac{7}{16}$in wide. Meshing with the crankshaft pinion, and positioned above it, is the intermediate pinion, the spindle of which is supported by phosphor-bronze bushes ¾in long by ¾in in diameter; one bush is in a crankcase boss strengthened by webs in the casting, and the other bush is housed in the inner timing cover which thus forms an outrigger plate. The pinion spindle protrudes through the bush and carries the dynamo driving sprocket.

Meshing with the intermediate pinion is the camshaft pinion which, in turn, drives the magneto with its auto-advance mechanism.

"Special attention has been given to obtaining a rigid camshaft," mentioned Mr. Hopwood. Then Mr. Perkins added, "The material is manganese, case-hardening steel and the shaft and cams are in one piece. There are three ¾in × ¾in



A train of pinions drives the camshaft and the magneto. The inner timing-chest cover provides an outrigger bearing for the intermediate pinion. Fitted to the camshaft pinion is the breather operating in the inner cover boss. Chain drive to the dynamo is in a separate compartment phosphor-bronze bushes supporting the camshaft. The tappets and guides are in similar material to the camshaft. A ball-end is formed at the top of each tappet, which operates in the cup forged in the lower end of the solid push-rod."

Fitted on the outer face of the camshaft pinion and turning with it is a breather valve which operates in a boss in the inner end-cover of the timing chest. "This looks a rather more elaborate breather than on many engines," I suggested. "Why?"

"We wanted a really effective breather and were prepared to go to some trouble to get it," said Mr. Perkins. "Not only was the A7 to be a smooth, quiet engine, but also it was to be clean, which means oil-tightness. How far we succeeded with this breather can be gauged from the fact that even at maximum crankshaft revolutions, there is still a depression in the crankcase—something of an achievement. The engine has gained a reputation for oil-tightness."

Then we started to discuss the chain dynamo drive; this drive is enclosed by the outer timing-chest cover and is remote from the timing chest proper with its camshaft and magneto driving pinions.

"Why the separately enclosed drive and why chain drive?" was my next question.

Mr. Perkins replied: "With a high-performance engine such as the A7, the precisely accurate timing given by gear drive is desirable for camshaft and magneto. The same accuracy is not necessary for driving the dynamo. To have employed gear drive for the dynamo would have increased the chance of operating noise in a design on which considerable pains to secure silence had been expended. Another point is that the chain is lubricated by grease, and thus the possibility of oil from a timing chest reaching the dynamo is eliminated."

"This layout makes it necessary to have both inner and outer timing covers," I observed. "Presumably the added cost and complication are worth while?"

"Certainly. The outrigger support that the inner cover gives to the intermediate pinion is, in our view, essential for quiet operation. The outer cover takes no load; in fact, the engine can be run without the cover."

"And now for the lubrication system," I suggested to Mr. Perkins. "You mentioned earlier that the oil feed to the big-ends passed first through the timing-side crankshaft bearing. I take it that, from the big-ends, the oil is flung out to lubricate the pistons, small-ends, and so on?"

"Quite right," concurred Mr. Perkins. "At the same time the cams and tappets are lubricated because these components are not in a separate compartment—they are exposed to the crankcase as in car practice."

"What pressure is maintained for the main and big-end bearings?" I inquired.

"The pressure release valve—detachable, by the way—at the front of the timing chest is set to pass oil at 55lb/sq in when the oil is hot. As you might expect, the gear pump creates a far higher pressure than 55lb, and the oil by-passing the valve flows into the timing chest."

"What is the capacity of the pump?"

"At 5,000 r.p.m. the pump passes 126.6 pints an hour," said Mr. Munro, after consulting a chart. "And the return pump will pass 177 pints an hour at a similar crankshaft speed."

The rockers and valve gear are lubricated from a tapping off the return pipe to the tank. Oil is fed along the rocker spindles and emerges through a hole under each rocker arm to lubricate the valve guides. Surplus oil drains down the push-rod tunnel past the tappet guides into the crankcase.

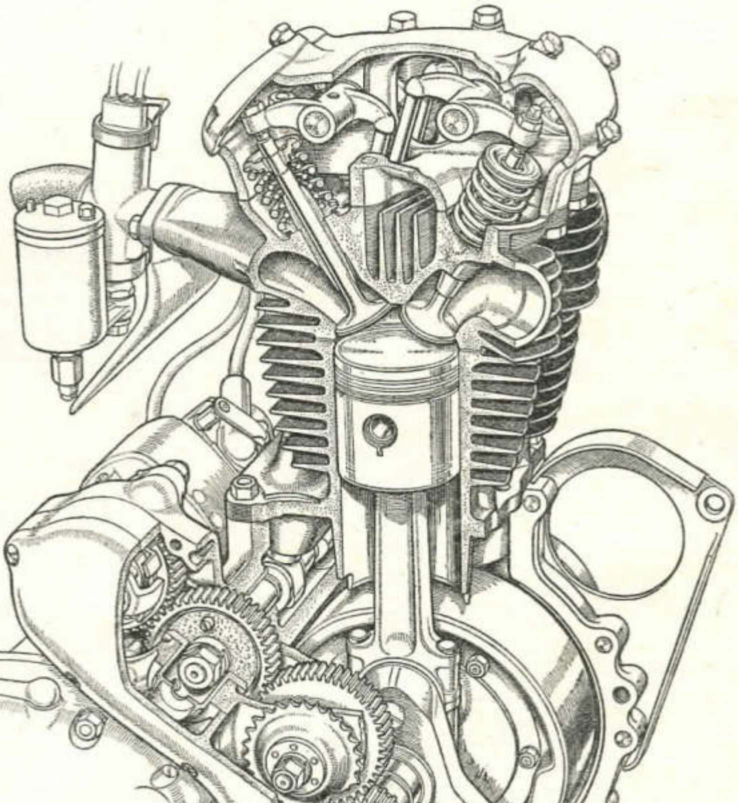
When examining this arrangement, I said, "Would one not obtain a more positive supply of oil by taking a by-pass off the feed side of the pump?"

"Theoretically, yes," agreed Mr. Munro, "but the amount of oil required 'upstairs' is not very great and the present system does the job admirably with the utmost simplicity. Can one ask for more?"

"What does the power curve of this fine engine looks like?" was my final question.

"Here's the graph," said Mr. Munro. "Take it away with you—the figures are no secret!"

650 c.c. B.S.A. Golden Flash



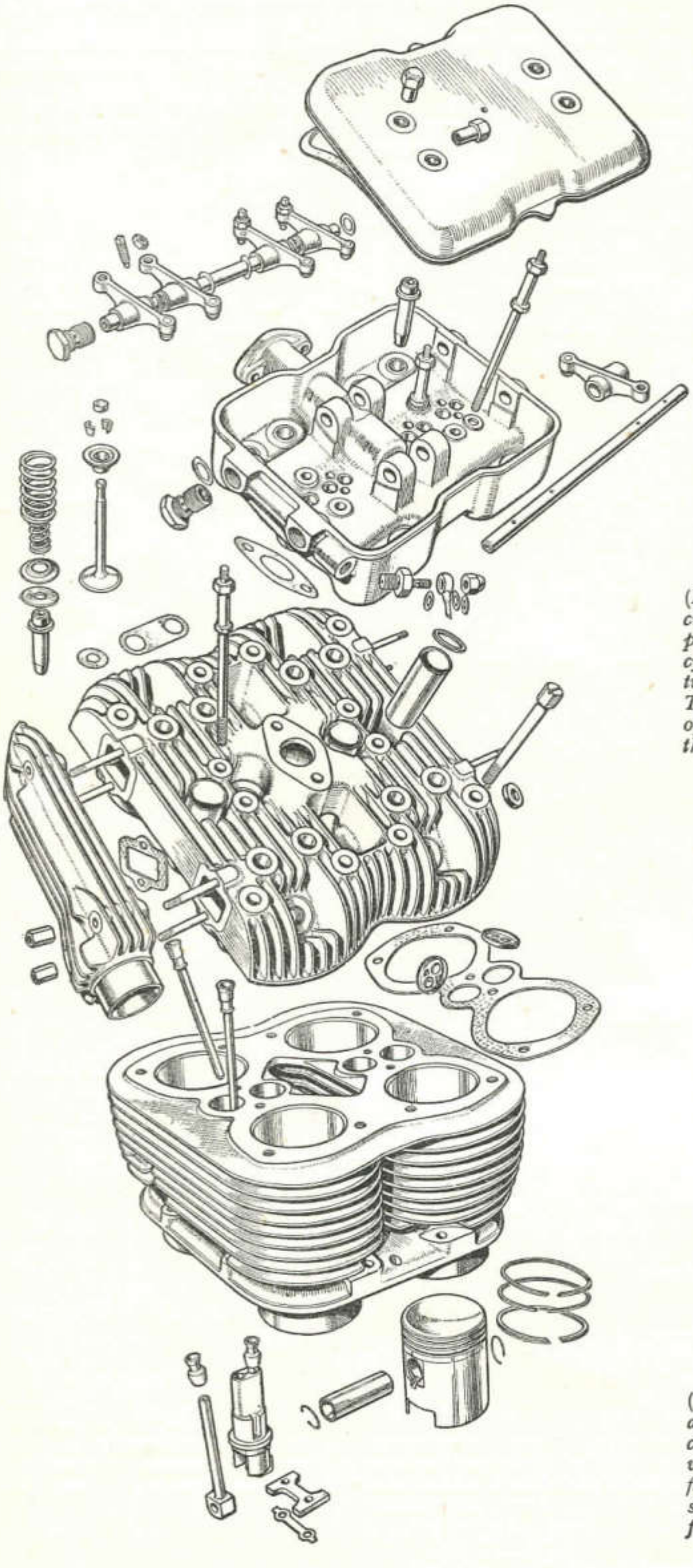
Big brother of the 500 c.c. A7, the 650 c.c. (70×84mm) B.S.A. Golden Flash engine has larger diameter timing- and drive-side shafts and, also in keeping with the greater engine capacity, even more effectively cooled cylinder heads. Connecting rods are of light alloy. Unusual nowadays, the pistons have concave crowns. The tappets are of barrel type with chilled rubbing surfaces

997 c.c. Overhead-

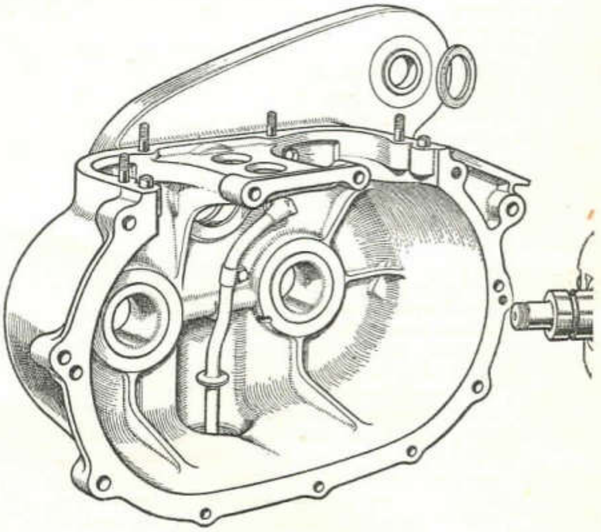
BEFORE I start describing in detail the construction of this fine but unusual engine, allow me to give a brief survey of its history and development. Mr. Edward Turner, now managing director of the Triumph Engineering Company, joined the Ariel staff in the early part of 1929, and started to design and to build the prototype "square-four." At the time there were no British four-cylinder motor cycles on the market, though a few large American straight-fours were imported.

While big engines of this type can be made to provide good results, largely because they are seldom driven at wide throttle openings, it was decided to try something smaller and more efficient.

The "square" arrangement appeared to be promising, since it was possible to space the cylinders widely and so to obtain good cooling, to set the crankshafts across the frame so as to obtain a normal type of drive, and because (in the original design) the overhung cranks permitted the employment of roller big-ends.



(Left) The one-piece cast-iron cylinder block is deeply finned circumferentially and there is an ample air space between each pair of cylinders. A one-piece iron casting is also used for the cylinder head, but in this case the fins are vertical and set longitudinally. Separate finned exhaust manifolds are employed. The valves are enclosed within the light-alloy rocker box and are operated by short Duralumin push-rods. Cast integrally with the rocker box is that part of the induction pipe which connects the carburettor with the centre of the cruciform manifold



(Above, right) The aluminium alloy crankcase is split vertically and the halves are dowelled together. Each crankshaft has a centrally disposed, bolted-on, steel flywheel, and steel balance weights are dovetailed and bolted to the outer crank cheeks. The flywheels are mounted on opposite sides of the flange of each crank, so that they overlap each other. Plain bearings are employed for the big-ends and also for the timing side of the crankshafts

valve Square four Ariel

Constructional Details of an Interesting and Most Successful Multi-cylinder Design

By "UBIQUE"

It is not everyone who knows that the prototype embodied unit construction of engine and gear box, the clutch housing being driven directly from the rear crankshaft gear. This arrangement appeared to be highly satisfactory, but at the time it was considered undesirable to try too many experiments at once, and the design was modified to suit the more normal type of primary drive and separate gear box.

This original 500 c.c. Ariel was very compact. It had a short overhead camshaft which operated all eight rockers, and the arrangement of valves was such that the distribution of gas could be as nearly perfect as possible.

In the course of time a rather larger engine was required for sidecar work, hence the 600 c.c. model, and it was found that the early engines were a trifle shy on flywheels. Also, they were not easy to produce, so that when an opportunity for redesign occurred, several modifications of importance were introduced, though the main features were retained.

The geared cranks, about which doubts had been expressed in many quarters, were now a proved success, and so also was the arrangement of cylinders; it was decided, therefore, to continue these features in the revised design, but to include certain major modifications which will become obvious in the description.

Though my interview took place with Mr. Turner, the technical staff of Ariel Motors was most helpful in collecting for my inspection every single part of the engine and in explaining "the reason why." The parts were all neatly laid out, and I began my questions with the cranks. These are made of nickel-chrome, case-hardening steel, and the journals are hardened and ground.

"Why," I asked, "did you change over to plain bearing big-ends?"

"Because they are quieter, and if properly lubricated they last longer, being less sensitive to water due to condensation, and to scrubbing. Also, because I have always liked plain bearing big-ends."

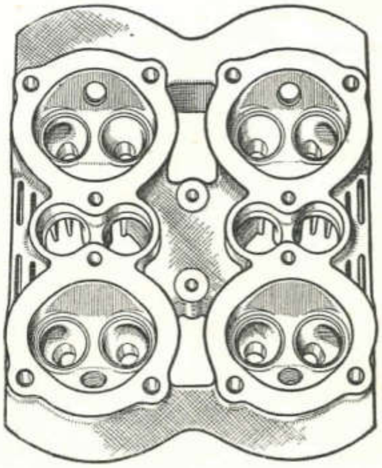
The journals are $1\frac{3}{8}$in in diameter and 1in long. On the long crank web between them is a central flange to which the flywheels are bolted. The flywheels are mounted on opposite sides of the flange on each crank. That is to say, they are staggered, and overlap each other. Each flywheel is a steel stamping of $6\frac{3}{8}$in diameter and $1\frac{5}{8}$in width. This arrangement of flywheel in the middle of the crankshaft has a counterpart in the twin Triumphs.

To each of the outer crank cheeks a steel balance weight is dovetailed and bolted. The dovetailing relieves the bolts of much of the centrifugal stress.

"Why detachable balance weights?"

"So that the flywheels can pass over the shaft."

On the timing side of the crankshaft is a white-metal-lined bronze bearing ($1\frac{3}{32}$in × $1\frac{1}{4}$in), and on the drive side a caged roller bearing. On the rear crank there is an outrigger roller bearing beyond the main gear wheel; this is not interchangeable with the main bearing, as the bore is 0.001in less in diameter. The main roller bearings carry a lip on the near side of the outer race, and the races are located by spring circlips which must be removed before any attempt is made to detach the bearings. On the outside of the plain timing-side bearings there are oil-retaining washers which must not be overlooked in the event of an overhaul.



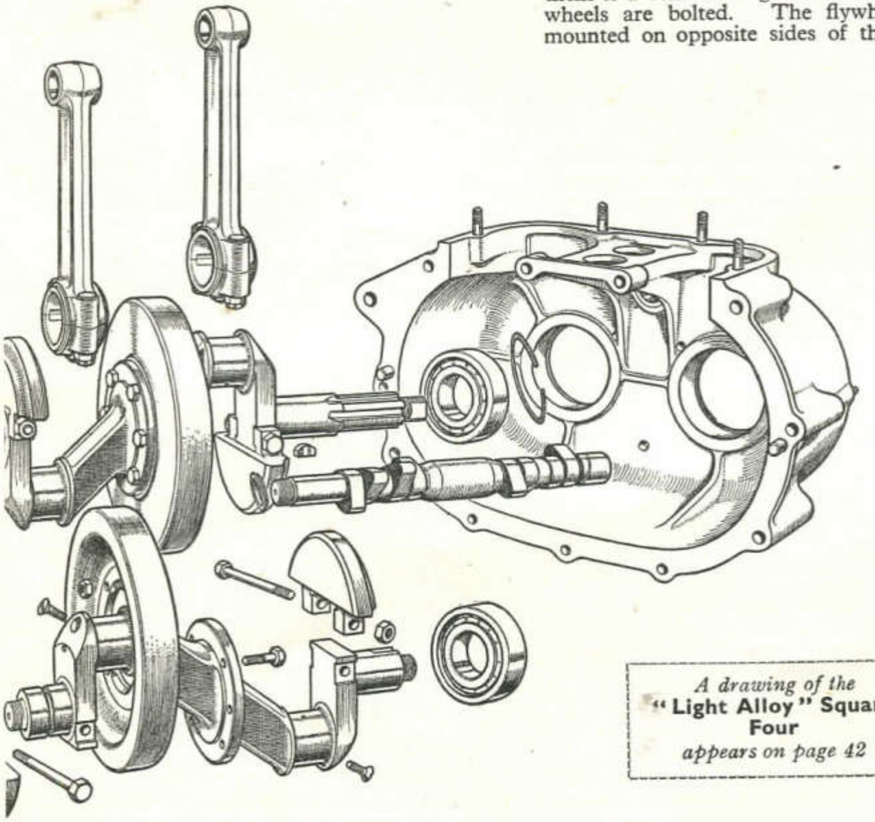
Each cylinder head is of pent-roof formation and houses two vertical valves

On the subject of the gears which connect the two cranks, Mr. Turner had much of interest to tell me.

"Do you employ a special tooth form?" I asked.

"Yes, in conjunction with the gear manufacturers we decided on a 20-degree pressure angle, and a long addendum tooth (a tooth form having the greatest practical height above the pitch centre). This form compensates for variation between centres due to expansion, with the least possible amount of backlash."

"Would not helical teeth be an advantage?"



A drawing of the
"Light Alloy" Square Four
appears on page 42

"Only if the teeth were ground, and it is not so easy to grind helical teeth as straight teeth."

"What material is used?"

"An 0.2 per cent carbon steel, because it can be treated so as to produce a very hard surface. The profiles of the teeth, of course, are ground."

Crankcase Details

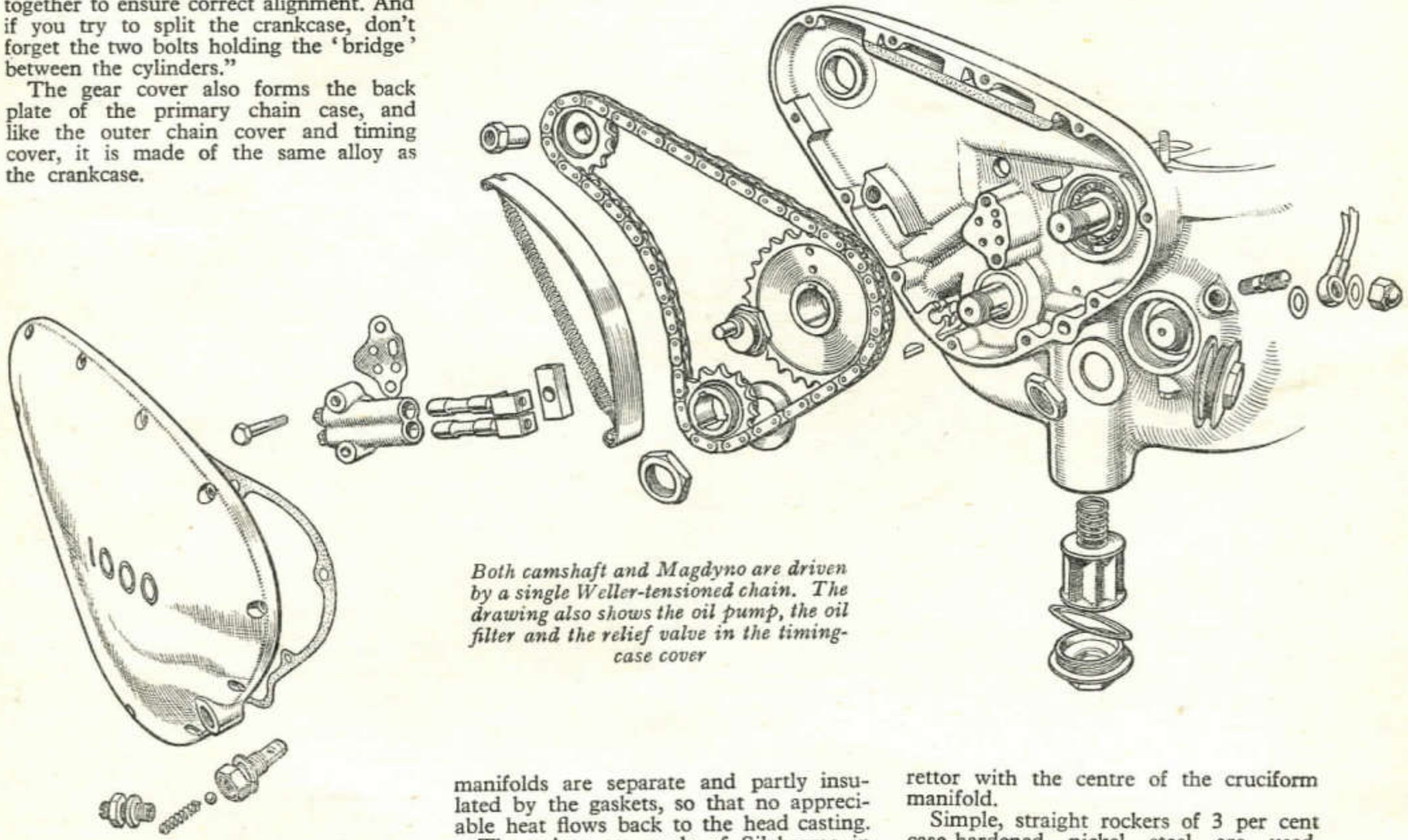
Fibre discs are pressed into the inside of the gears and riveted in position to prevent ring, and the gears are pressed on to their shafts and located by keys. Extractor threads are provided on these gears and, indeed, on all parts which may have to be withdrawn for overhaul.

Made of a normal aluminium alloy, the crankcase is split vertically in the middle.

"Are there any special features?" I asked.

"Only that the halves are dowelled together to ensure correct alignment. And if you try to split the crankcase, don't forget the two bolts holding the 'bridge' between the cylinders."

The gear cover also forms the back plate of the primary chain case, and like the outer chain cover and timing cover, it is made of the same alloy as the crankcase.



Both camshaft and Magdyno are driven by a single Weller-tensioned chain. The drawing also shows the oil pump, the oil filter and the relief valve in the timing-case cover

The cylinder block is made of a high-grade, close-grained cast iron, and is cast in one piece; it is held to the crankcase by eight ⅜in studs. The cylinder centres are approximately 4½in apart in width, and 5in in length, so that there is ample air space between.

"What made you decide on these centres?"

"Well, like all features of design, it is a compromise—in this case between cooling space and crankshaft stiffness—and I think it is a very satisfactory compromise, too."

The cooling fins are all circumferential, and extend to as much as 1½in in length. Though the cylinder walls are of moderate thickness, the head walls are about ⅜in thick and the one-piece iron casting is cooled by vertical fins set longitudinally.

Each combustion chamber is of pent-roof formation, for this, as Mr. Turner remarked, "provides a compact and easily operable arrangement for the vertical valves." It also enables the cruciform induction pipe to be cast into the head and leaves the exhaust valves at the outer corners where they are most easily cooled.

Now this cruciform manifold has an outstanding advantage in that the gas enters at the middle of the cross, and therefore has a path of equal length to each cylinder—a most important point in the attainment of equal distribution.

The cylinder head is held down by twelve studs, and the finned exhaust manifolds are separate and partly insulated by the gaskets, so that no appreciable heat flows back to the head casting.

The valves are made of Silchrome in the case of the inlets and of K.E.965 for the exhausts; they have a throat diameter of 1⅛in and a lift of $\frac{5}{16}$in.

Valve Timing

"Is this not on the small side?" I asked.

"Not for this type of engine. These moderately sized valves have the advantages of light weight and good cooling, and the performance of the engine shows them to be ample. Incidentally, I consider that many modern engines are over-valved for touring purposes." Here I agree most heartily with Mr. Turner.

Each valve has a hardened end-cap, and is seated by two concentric springs having a total pressure of approximately 90 lb (seated). The clearances, measured cold, should be: inlet 0.006in; exhaust, 0.008in.

Since the exhaust and inlet cams are identical, the actual period of opening is equal, the timing being as follows: inlet opens 25 degrees early and closes 55 degrees late; exhaust opens 60 degrees early and closes 20 degrees late. Thus the overlap is 45 degrees.

Oil-quenched cast-iron valve guides help to locate the light-alloy rocker box, and four of the holding-down bolts pass right through to locate the cover. There are washers below each lower spring cup and also at each point of contact between the rocker box and cylinder head. With the rocker box is cast that part of the induction pipe which connects the carburettor with the centre of the cruciform manifold.

Simple, straight rockers of 3 per cent case-hardened nickel steel are used. Hardened steel hemispheres are pressed in at the valve end and an adjustment is provided by a hardened set-screw and lock nut. Two long pivot pins each carry four rockers. They are centreless ground, hardened, and drilled for pressure lubrication to each bearing.

The camshaft is set across the crankcase and is carried by a ball bearing on the drive side and a plain bearing at the opposite end. It is completely hardened except for the threads. At the middle, the shaft is much enlarged "to prevent whip."

"Why did you drop the original overhead camshaft?"

"With this large engine the disadvantage of increased reciprocating weight is more than compensated by the high power output at moderate speeds. Also, with the camshaft in the crankcase it is possible to drive both camshaft and Magdyno with a single Weller-tensioned chain."

This chain, by the way, is of ⅜in pitch with straight-sided links, and a stout fibre strip is fixed to the timing box above the top run of the chain. "Why?" To prevent chain thrash.

"I should like to point out," continued Mr. Turner, "that the cams are designed for quiet operation and long life rather than for very high efficiency. A further important point is that the present location of the camshaft greatly facilitates a top overhaul."

Each pair of tappets is carried in a single circular (outside) block, the block being of a special aluminium alloy (122) to ensure long life. Each pair of blocks is held up by a common bridge-piece. The tappets have radiused feet, and are rectangular at the base to prevent turning.

Steel cups are fitted to the top of the short Duralumin push-rods, but the bottom is not covered because there is no movement or rubbing, but only a pure compression load at the base.

Split Big-ends

Light steel tubes enclose the push-rods, the upper oil joint being made by the cylinder head gasket. Besides enclosing the push-rods, these tubes act as oil return leads from the rocker box, the oil draining through the tappet blocks and falling on to the cams.

Now we come to the main insides. The connecting rods are R.R.56 aluminium-alloy forgings heat-treated to 30-ton tensile strength. This material was chosen because it provides an extremely stiff and rigid beam of light weight.

The split big-end bearing is lined with white metal, the reason being that in the unlikely event of seizure the metal would run and thus save serious damage to connecting rod and crankshaft.

Two 5/16in bolts secure the big-end cap to the rod, and these bolts are works of art. Made of 60-ton oil-hardened nickel-chrome steel, they are slightly reduced in diameter within the bolt holes to provide a small degree of elasticity without reducing the strength below that of the weakest point (the screw threads). At the entry of each hole, and in the neighbourhood of the split, they are, however, of full diameter and ground to size so as to act as locating spigots for the halves. The nuts are castellated and fixed with split pins. In length the rods are just two strokes between centres, and the small-end eye is bushed with bronze.

Hollow, taper-bored gudgeon pins of case-hardening nickel-chrome steel are located in the pistons by circlips; the diameter of the pins is 11/16in.

Compression Ratio

Low-expansion, silicon-aluminium alloy pistons with slightly concave heads provide a compression ratio of 5.8 to 1. The only internal ribs support the gudgeon-pin bosses from the crown. There are two compression and one scraper ring per piston, and the latter returns oil from the cylinder wall to the gudgeon pin through drilled leads. The piston skirt is long, but is cut away at the sides. I inquired the reason for this, and was told, "To clear the flywheels."

A double-plunger pump which circulates a pint of oil per minute at 2,500 r.p.m. is driven from the camshaft. It is capable of maintaining a pressure of 60lb/sq in after feeding two main and four big-end bearings. Oil is pumped first to the main timing side bearings, then to the main drilling in the crankshaft, whence drilled ducts lead to the inner side of the crankpins and big-end bearings. There is a by-pass to the rocker shafts through which there is pressure feed to each rocker bearing, and also to the pressure gauge.

A spring-loaded ball relief valve is located between the two plain bearings. In the body of the valve is a screw which is not intended for adjustment, and should be kept screwed home. Its object is to provide a method of removing the ball and spring for cleaning purposes. A breather pipe is located in the back of the timing case.

Oil returns to the sump via the push-rod cover tubes, and is pumped back to the tank. There is a gauze filter in the sump on the extractor side, and another filter in the tank on the suction side.

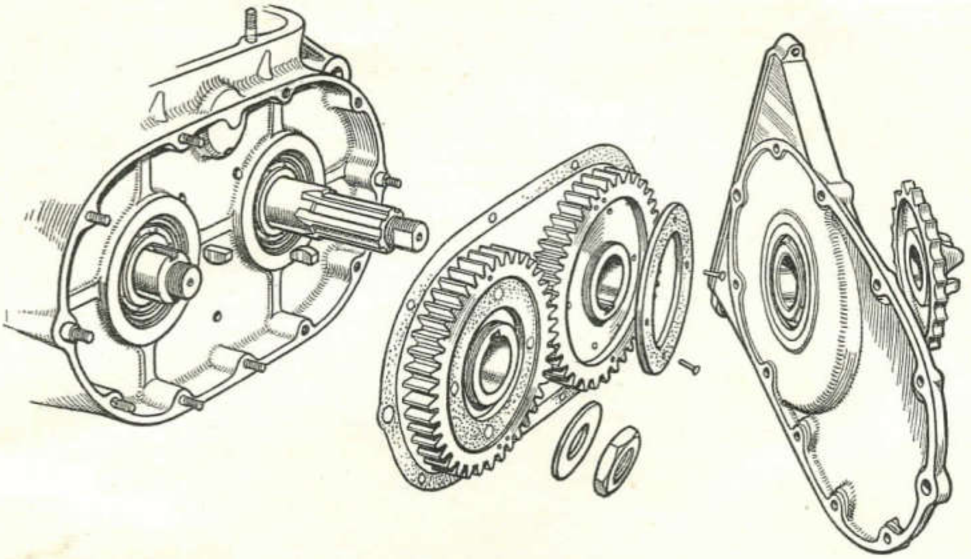
This completes the description of a remarkably fine engine—one which develops about 38 h.p. at 5,500 r.p.m. I asked Mr. Turner to give me some idea of his aims when producing the design.

He said, "The main idea was to provide a four-cylinder engine small enough for use in a solo motor cycle, yet producing ample power for a really high performance (approximately 100 m.p.h.) without unduly high compression, racing cams, or a big-choke carburettor. In fact, I was aiming at the ultimate reliability with the minimum of attention."

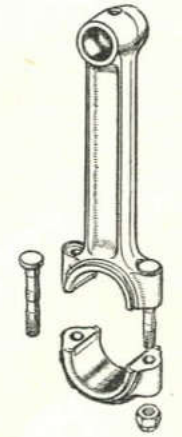
More Reliable

"Do you suggest that the four-cylinder engine is more reliable than the single, size for size?"

"Yes, for a given power output the multi is more reliable from about 350 c.c. upwards, as there is less mechanical stress, less whip, and greater area for heat distribution. The increase in internal friction is more than compensated by the increased range of r.p.m. These remarks, however, do not apply to all types of multi-cylinder engine."



The two crankshafts are geared together, and the steel gear wheels have pressed-in and riveted fibre discs to prevent ring. The gear cover also forms the back plate of the primary chain case

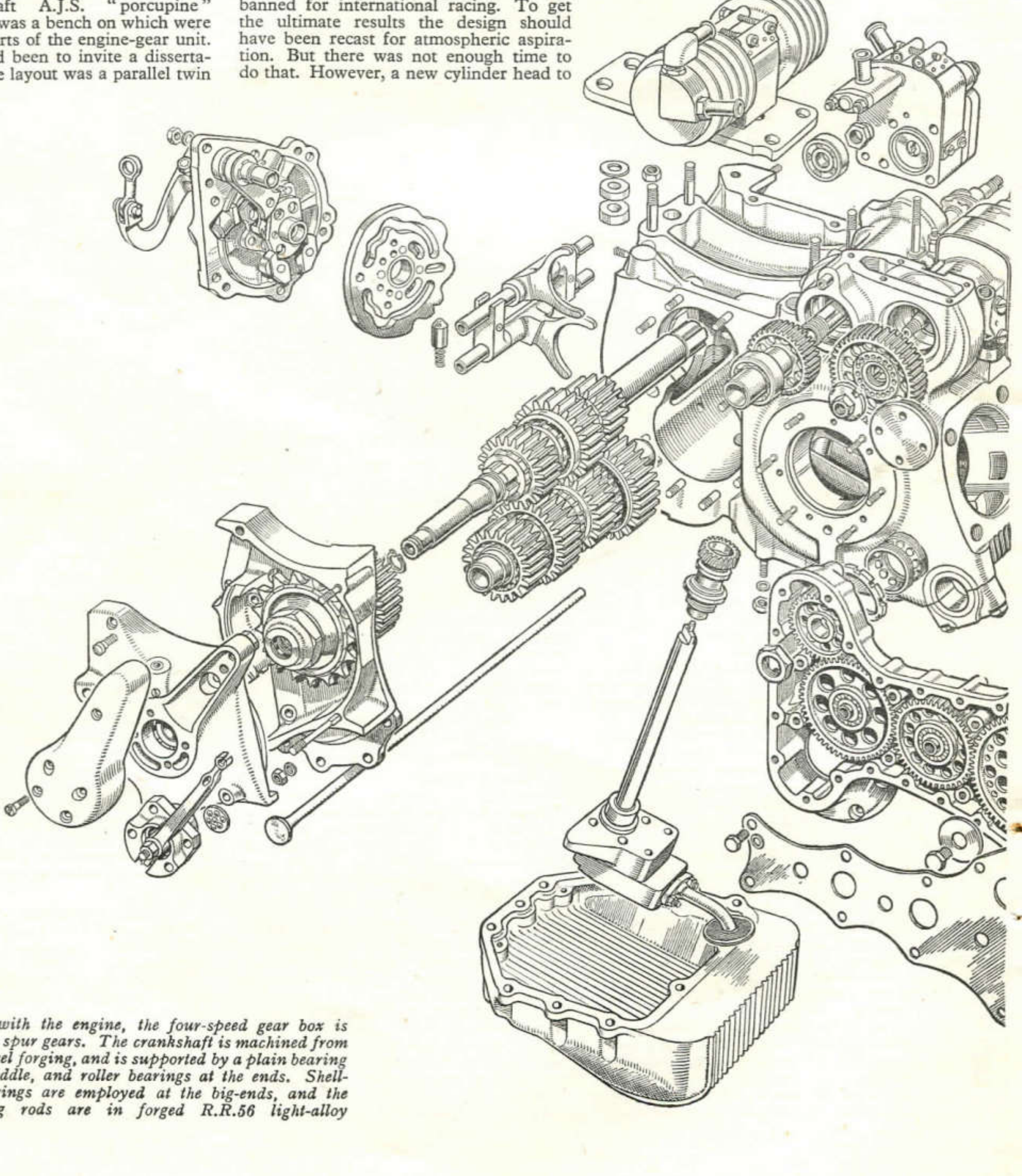


Aluminium-alloy connecting rods with white-metal-lined big-end bearings are a feature of the Square Four engine

498 c.c. Racing Twin A.J.S.

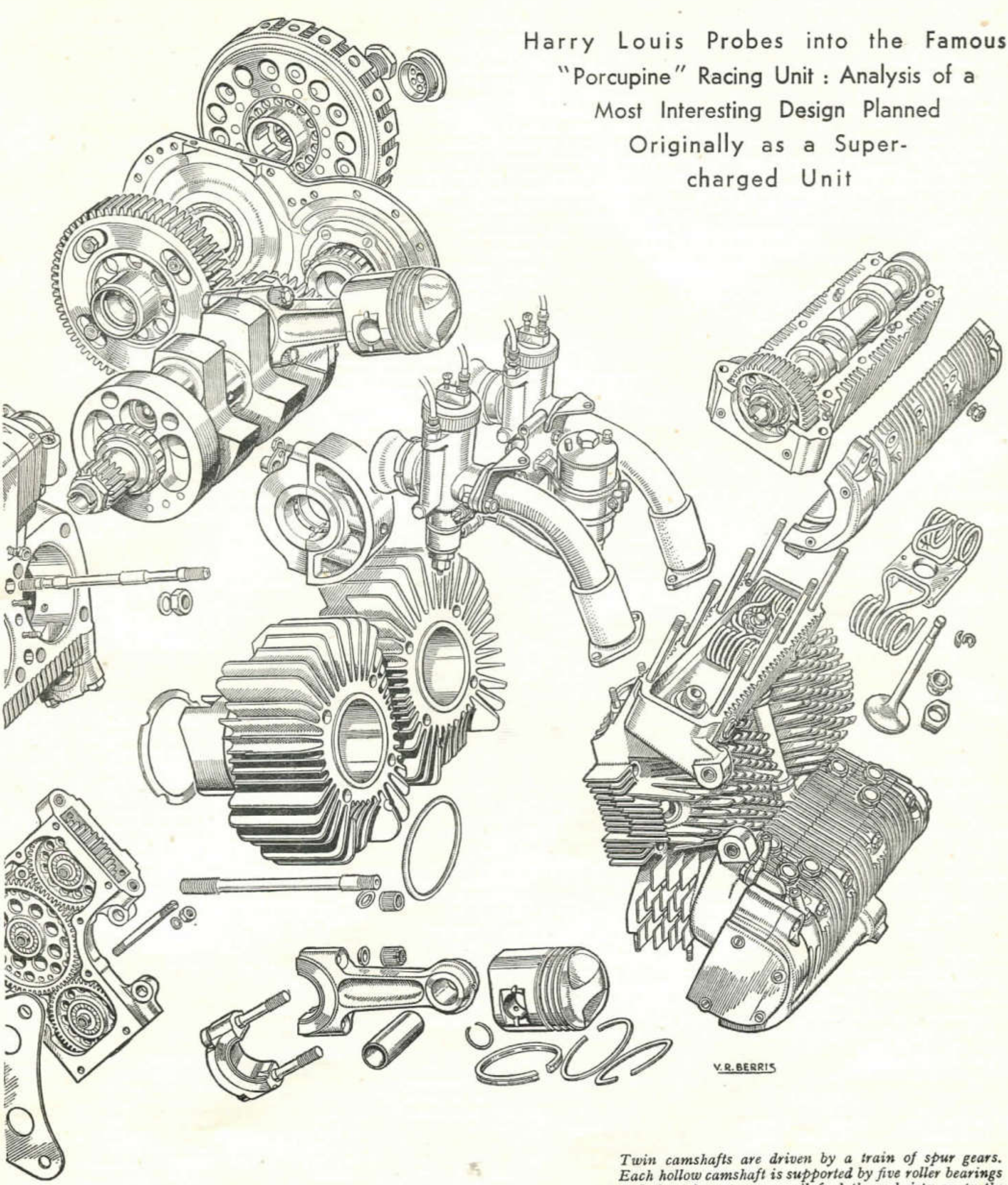
"IT must be remembered that this power unit was envisaged as a blown job," mused Jock West. We—that is Jock, the racing man and Associated Motor Cycles' sales manager, Matt Wright, chief of the racing department, and I—were standing beside the London Show model of the famous 498 c.c. double-camshaft A.J.S. "porcupine" twin. Nearby was a bench on which were lying all the parts of the engine-gear unit. My gambit had been to invite a dissertation on why the layout was a parallel twin with the cylinders set almost horizontal.

The musing continued. "The war was still cracking when the engine was roughed out mentally so to speak. With the war over, the design was laid down and a prototype made. Then in the autumn of 1946, came the F.I.C.M. decision that superchargers would be banned for international racing. To get the ultimate results the design should have been recast for atmospheric aspiration. But there was not enough time to do that. However, a new cylinder head to



In unit with the engine, the four-speed gear box is driven by spur gears. The crankshaft is machined from a solid steel forging, and is supported by a plain bearing at the middle, and roller bearings at the ends. Shell-type bearings are employed at the big-ends, and the connecting rods are in forged R.R.56 light-alloy

Harry Louis Probes into the Famous "Porcupine" Racing Unit : Analysis of a Most Interesting Design Planned Originally as a Supercharged Unit



Twin camshafts are driven by a train of spur gears. Each hollow camshaft is supported by five roller bearings and there is a pressure oil feed through jets on to the flanks of the cams. The light-alloy cylinder head casting has formed with it the valve-spring wells. Spike finning is used for the forward-facing cylinder heads give higher compression ratios was essential.

"Two main problems arise when supercharging is envisaged—accommodating the power unit in the frame and cooling the cylinder heads. A.M.C. had had considerable experience with supercharged fours—remember the pre-war 'octopus' vee-four?—and knew that, for air-cooling, the cylinder heads must have first call on all the air that's going.

"A supercharged parallel four with the crankshaft across the frame on the lines of the Gilera might be successful if air-cooled. But if the width of the engine is to be kept within reasonable dimensions, the valve-gear, cylinder head hemispheres and cylinder bores might be too crowded for adequate cooling. Remember that the pre-war blown Gilera parallel four was liquid-cooled. Now that the Gilera four is normally aspirated it is air-cooled.

Best Compromise

"So, the best compromise seemed to be a twin. And almost the best way of air-cooling the cylinder heads is to face them forward; another good point is that the weight is kept well down in the frame and the centre of gravity of the machine is thus very low, which is half the battle of good handling."

"Wouldn't a horizontally opposed twin layout with crankshaft in line with the frame give better cylinder head and cylinder cooling for supercharging?" I suggested.

"Possibly yes," replied Matt Wright, "but it is doubtful whether the weight could be got so low down as with the parallel twin, and in any case the weight would be less concentrated. It would not be 'in' the frame."

"Unit construction of engine and gear box is employed. Got any talking points on that?" I inquired.

"Oh, yes," said Jock. "With the engine lying down there's ample space for a sturdy gear box, but not for the usual gap between separate units for engine and gear box. Hence our crankcase casting embraces the gear-box shell. But the gear box is self-contained and independently lubricated."

"Gear drive between crankshaft and gear-box mainshaft, I note. The engine runs backward presumably?" was my next query. "Yes, it does," answered Matt Wright, "and gear drive is the obvious choice. The crankcase cum gear-box casting gives fixed centres apart from the expansion under heat of the Elektron, which is of no consequence from the point of view of efficiency. A chain drive would not theoretically be less efficient, but there would have to be some form of slipper adjustment which might well put the chain drive at a disadvantage. The ⅝in width spur gears are, of course, fully enclosed and run under ideal, fully lubricated, conditions."

"The difference in diameters between crankshaft and gear-box mainshaft gears is not very great," I observed. "Obviously the clutch runs at fairly rapid r.p.m. Does the high inertia ever give any bother, are there any worries with overheating due to heat transference from the crankcase, and is it not difficult to obtain the necessary overall gearing reductions by means of the gear box and rear sprockets?"

"Well," said Jock, "there was in the early stages a headache or two as a result of the clutch friction material being deformed by centrifugal force; new-type friction plates cured that. As you see, the clutch unit is remote from the gear-drive chest and well out in the air stream, so there are no overheating troubles. Answer to the final point is that we do get enough reduction by way of the gear box and rear sprockets. It is a fact, however, that the large rear sprocket approaches the maximum size permissible to avoid overstressing the chain due to 'fling.' We are within the safety limit and rear chains give good service and no trouble. But if we went up much on the diameter of the rear sprocket and used the top speeds of the bicycle, chains would be a problem."

"Now what other external features arouse queries?" I muttered. "Ah—perhaps you would run over the advantages of double overhead camshafts with spur-pinion drive."

"The best way to get the valves to follow the cam contours accurately at high revs is to keep the weight of the components operated by the cams as low as possible," said Matt. Then Jock West continued, "The weight of either an exhaust valve or an inlet valve and its tappet is approximately 100 grammes, which for an engine of this type is pretty low. On the point of the drive, the answer is that no form of gearing results in less friction than spur pinions. This method of drive is, incidentally, rather ruled out for production racing engines intended for private owners because of the difficulty of obtaining compression ratio changes.

"It might also be noted that double overhead camshafts are more or less impracticable on production engines because it is difficult to provide a means of reasonably rapid tappet clearance adjustment. On this 'porcupine' job every adjustment means removing a camshaft box, inserting or removing a shim behind the contact pad in the tappet, refitting the cambox, checking the clearance and, if necessary, starting all over again!"

"Spike finning," I observed, "is the obvious choice for the forward-facing cylinder head and the maximum cooling area for a given depth and pitch of fins is clearly achieved. Any snags involved?"

"No," replied Jock, "not if we have in mind only a 'few off' racing jobs. But, again, spike finning would be unattractive for production in any quantity. Casting is difficult and demands great care, and the spikes are very vulnerable; it is the easiest thing in the world to chip off a spike or two inadvertently when the head is being removed or is on the bench for attention."

We walked over to the bench where there was, in fact, a dismantled cylinder head and all the other major components that make up the racing power unit. "Elektron crankcase, gear case, and covers," I mentioned. "Yes," said Matt, "Greatest strength-to-weight ratio among the suitable materials available."

As I picked up the crankshaft, Jock gave a running commentary on its features. "Forged steel and machined from a solid billet. Nitrided journals for the plain indium-flash, shell bearings at the big-ends and at the middle. Caged roller bearings for the outer mains in the crankcase. The middle bearing is 1¾in diameter and 1¼in wide, is flanged, and locates the crankshaft laterally. The shaft is immensely rigid, and experience has shown that the middle bearing is only lightly stressed."

West continued. "The crankshaft is carefully balanced, of course, but final setting of the balance ratio is obtained by means of those three holes in the periphery of each bob-weight between the middle main bearing and the big-end bearings. Each hole behind its sealing Allen screw plug has detachable weights. In practice, the very best results are obtained by varying the balance ratio to suit the engine when it is bolted in the frame, notwithstanding apparently identical engines and frames. The balance alterations can be made quickly by removing the crankcase sump when the bob-weight Allen screws are exposed."

Plain bearings of similar type to that which supports the middle of the crankshaft are employed at its big-ends. Diameter is 1/16in and width is ⅞in. Connecting rods are in forged R.R.56 light-alloy and, at the small ends, operate direct on the gudgeon pins. The nuts for the big-end cap clamping bolts are splined on the outside to take a special key. "Why?" I inquired.

Smaller Cutaway

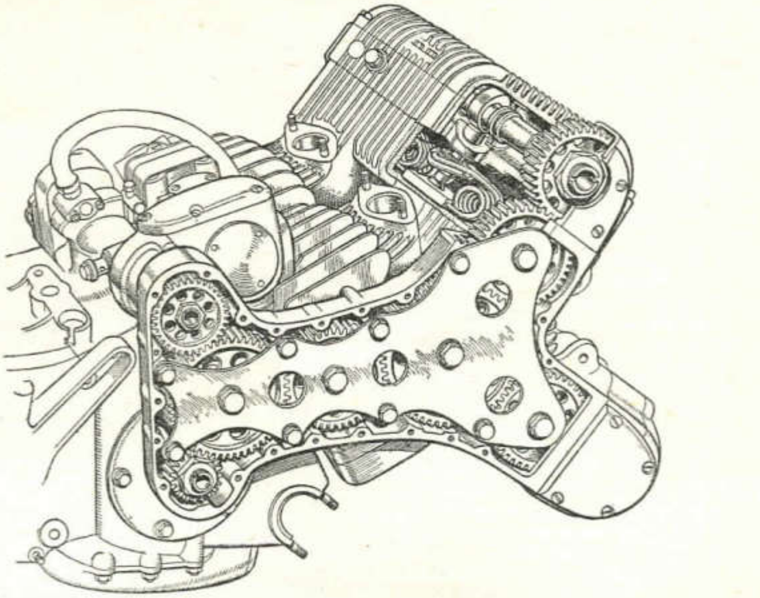
"The key is just as effective for tightening or loosening the nuts as a socket spanner on a hexagon," replied Matt Wright. "The advantage is that the outside diameter of the splined nut can be smaller for a given strength factor than a hexagon. Hence a smaller cutaway is necessary in the con-rod to accommodate the nut."

The Hepolite forged aluminium-alloy pistons have a full skirt, are domed, and provided with valve clearance flats. Each piston carries two 1/16in wide compression rings with straight-side gaps and one slotted scraper ring. Gudgeon pins are in case-hardening steel, measure ⅞in in diameter, and are taper ground internally. Round-wire circlips are employed.

A rectangular sump is bolted to the base of the crankcase. This sump is ribbed externally *and* internally to assist cooling of the oil. Cylinders are separate. Each cylinder is an aluminium-alloy casting with a shrunk-in iron liner which protrudes at the base and is sunk in the mouth of the crankcase for 1¾in of its length. There are cutaways to clear the connecting rod. Finning is longitudinal and is 2in deep at front and back (or, rather, top and bottom with the horizontal cylinder layout), but is shallower at the sides.

The cylinder head is a one-piece light-alloy casting, which includes the two hemispheres for the combustion chambers, and includes the valve-spring wells—one for the inlets and one for the exhausts. Inlet-valve seatings are austenitic iron and the exhausts are bronze; they are all shrunk in.

"That cylinder head casting is a magnificent piece of work," said Jock West. "Spike finning at the top of the head



An outrigger plate supports the spindles of the camshaft drive pinions. The gear meshing with the crankshaft half-time pinion also drives the duplex gear oil pump and magneto

gives the greatest possible surface area and is especially suitable for facing forward into the air stream. There is a ground joint between the tops of the spigots and the recesses in the head."

Exhaust valves are of the sodium-filled type, in K.E.965 steel, and have $\frac{7}{16}$in diameter stems. Inlet valves in the same material (but not sodium-cooled) are $\frac{1}{8}$in less in diameter at the stem, but are wider across the head. The bronze valve guides are a press fit in the head, and locate the valve-spring base plates. Valve springs are of the duplex, overlapping hairpin type and exert 100 lb pressure with the valve on its seat. Split collets retain a collar around each valve stem. This collar has a deeply serrated periphery, and the eight male serrations bear on another collar in which the overlapping ends of the valve springs seat; this arrangement allows the valve to turn. "This turning of the valve results in a lower mean operating temperature," explained Matt Wright.

To each valve-spring well is bolted an Elektron cam box. Mounted in five 1in diameter roller bearings with split Duralumin cages, the camshaft is turned from a solid forging in case-hardening mild steel. The shaft is hollow, and its weight is only 12 oz. "To keep this shaft rigid it is necessary to support it with five bearings," explained Jock. "To reduce the number of bearings would make it necessary to have a heavier shaft, which means higher inertia and a greater load on the driving gears—a matter of some importance."

Operating in Duralumin guides, the tappets are hollow and are specially designed for light weight. The tappets carry pressed-in, hardened contact pads, and clearance between a pad and the valve-stem is adjusted by shims under the head of the pad. The head is threaded externally to take an extractor. Clearance is measured with a gauge inserted through a hole (fitted, of course, with a detachable cap) in the wall of the cam box. Adjustment of the mesh of the driving gears is obtained by shim gaskets between the face of a cam box and the appropriate face on the cylinder head.

Camshafts' Drive

There are, in all, eight $\frac{1}{2}$in-wide spur pinions in the drive to the two camshafts. First, there is the half-time pinion on the crankshaft, then two intermediate pinions, then a larger pinion where the drive branches to the two camshafts. Meshing with this large pinion is, for each camshaft, an intermediate pinion driving the pinion on the shaft. Pinions have roller bearings which operate on spindles held by the back half of the Elektron gear cover and an outrigger support plate. Each pinion is statically balanced.

The intermediate pinion meshing with the crankshaft half-time pinion also drives yet another pinion—the one on the pump shaft. This pump is of the duplex gear type and of high capacity; it passes 45 gallons an hour at 7,000 crankshaft r.p.m. The main supply is through a Tecalemit fabric filter, thence to the middle main bearing. At the bearing, the oil enters the crankshaft and emerges through the big-end journals. Pistons and small-end bearings are lubricated by oil flung out from the big-ends. At the drive end of the crankshaft is a ported crankcase breather.

In the crankcase sump is a scavenge pump driven by a shaft and skew gear on the supply-pump shaft. This gear pump picks up the oil which drains down into the sump and returns it to the tank.

The secondary supply from the duplex-feed pump forces oil to the cam boxes. In each cam box housing is a gallery from which, through detachable jets, the oil impinges on the flanks of the cams. A vertical tube drains the oil from the upper (inlet) cam box to the lower (exhaust) cam box, from where a scavenge pump at the end of the camshaft forces the oil back to the tank. However, in the external return pipe is a banjo union above the gear box, and a by-pass with an adjuster from this union leads a supply of oil, by means of a nozzle, into an annular groove at the back of the teeth of the gear box sprocket. From this groove oil flows outward under centrifugal force through holes with outlets in the hollows between the teeth, and so lubricates the chain. "This semi-positive lubrication of the rear chain works so well," mentioned Matt Wright, "that chain adjustment is rarely necessary."

The magneto is mounted just in front of the oil-pump and is driven by a pinion on the pump shaft.

Transmission from crankshaft to gear box mainshaft is by means of $\frac{5}{8}$in wide spur gears giving a reduction of about 0.7. The gears are enclosed and lubricated; in fact, the gear cover carries the drive-side main bearing. Jock West then did some talking. "The gear box mainshaft gear has an integral shock-absorber which takes the form of curved coil springs interposed between a centre spider and the gear body. This device is a comparatively new addition, as originally the design did not include a transmission shock-absorber.

"The clutch case is machined from solid forged steel. There are 20 grooves to take the tongues of the driving plates, and 24 in the centre unit for the tongues of the driven plates. This high number of contact tongues spreads the heavy torque loading."

Six springs, by means of deep thimbles in the orthodox manner, bear on the light-alloy outer plate, which is freely drilled for further lightness. The operating thrust rod passes through the gear-box mainshaft and has a head bearing on a ball thrust race at the operating lever end.

"Yes, the gear box is more or less orthodox in design," continued West, "except for the fact that the rear-drive sprocket is on the right-hand side, and roller bearings are employed fairly freely. For example, the layshaft has caged roller bearings at both ends; $\frac{7}{16} \times \frac{1}{4}$in rollers support the mainshaft in the top-gear sleeve; needle rollers are employed for those pinions free to rotate on their shafts.

"To give rapid gear changes, alternate dogs are cut back at the ends. Gears are selected by a normal, double pawl, positive stop, foot-change mechanism."

My parting shot was definitely fishing, I know, but it had to come. "I see the top of the gear-box casing is cradle-shape. Obviously that cradle was intended to house a supercharger driven from the gear-box mainshaft gear. Wouldn't it be fun to clamp a blower on and have a crack at a few more track records—you know, those that are pretty well impossible with an 'atmospheric' engine?"

"Yep, it would be fun all right," agreed Matt. "But they tell me there's a T.T. in June . . . ."

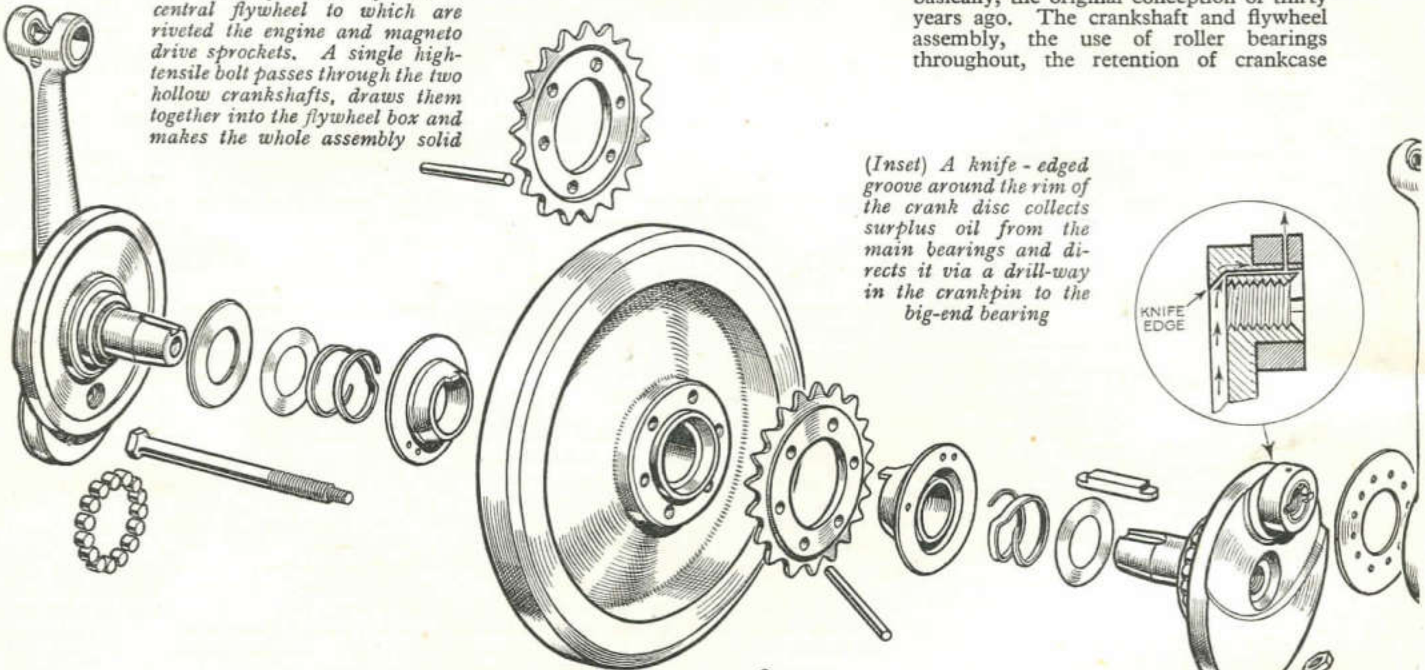
596 c.c. Twin-

Constructional Details of an Unconventional Engine

TO many people the internal workings of the Scott engine are something of a mystery, because the mechanical design is quite unconventional. Moreover, in a three-port two-stroke engine, using crankcase compression, the crankcase becomes more than a mere box to hold the crankshaft and its bearings. It is a functional part of the engine and its design enters very largely into the question of volumetric (or pumping) efficiency.

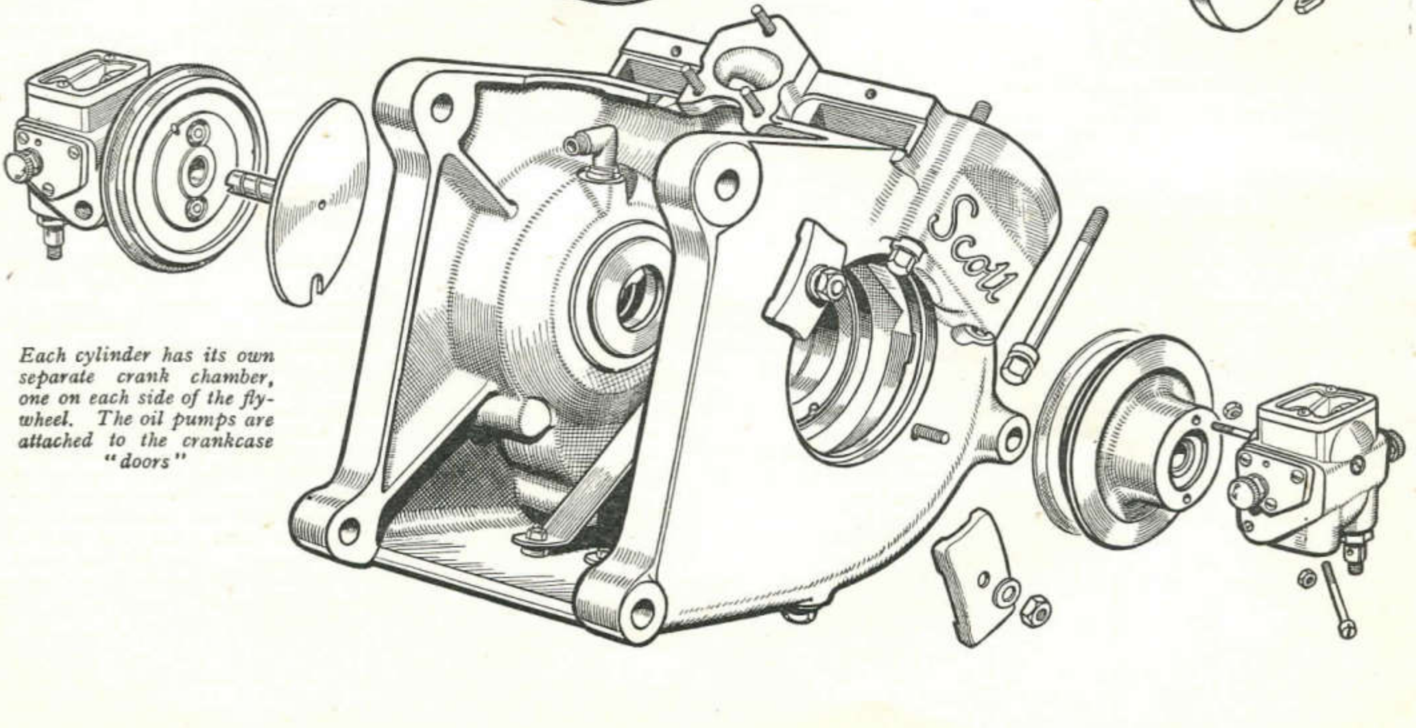
Again, the ports in the cylinder and the passages in the crankcase, in conjunction with the piston, are, in effect, the valve gear; in consequence, the piston must of necessity be of the correct design for this essential part of its work, as well as for its normal duty. Simple as the three-port two-stroke engine is in principle, it calls for very great care in design and construction if really good results are to be attained.

Mechanically the Scott engine is also very remarkable in that it follows today, basically, the original conception of thirty years ago. The crankshaft and flywheel assembly, the use of roller bearings throughout, the retention of crankcase



The built-up crankshaft has a central flywheel to which are riveted the engine and magneto drive sprockets. A single high-tensile bolt passes through the two hollow crankshafts, draws them together into the flywheel box and makes the whole assembly solid

(Inset) A knife-edged groove around the rim of the crank disc collects surplus oil from the main bearings and directs it via a drill-way in the crankpin to the big-end bearing



Each cylinder has its own separate crank chamber, one on each side of the flywheel. The oil pumps are attached to the crankcase "doors"

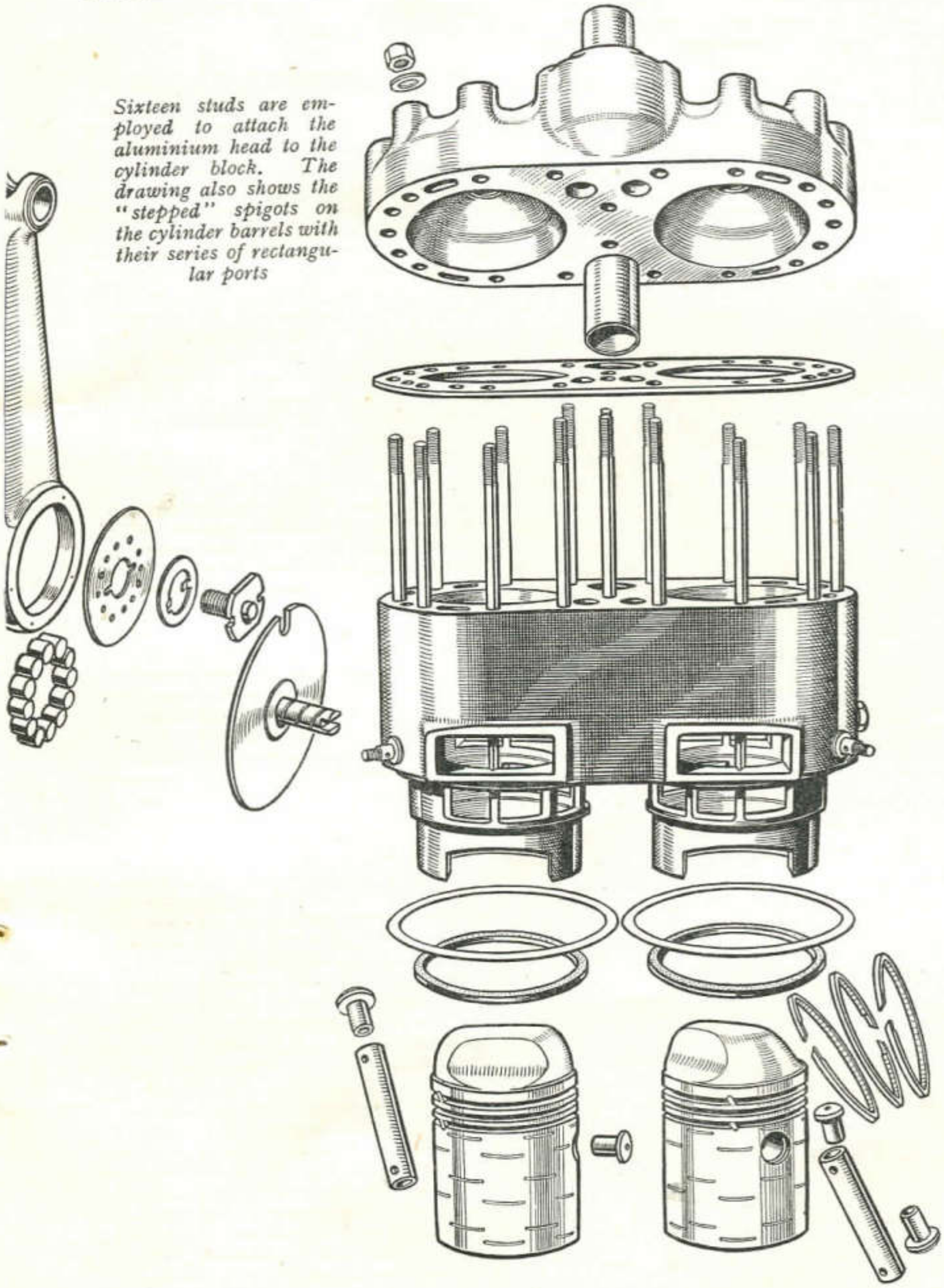
cylinder Scott

How it Operates

By "WHARFEDALE"

compression by specially designed glands, and so on, remain a tribute to the brilliance of the late Alfred A. Scott. Time has not changed the mechanical layout and it is only in detail and materials that improvement has been possible.

With compression-tight main roller bearings, built-up crankshaft, central flywheel and roller bearing big-ends, a very high degree of precision is called for, and when one reflects that the original design was laid out at a time when precision machining and standardized bearing assemblies were almost unheard of in commercial productions, the daring of it all becomes apparent; there was every justification for the slogan "years ahead."



Sixteen studs are employed to attach the aluminium head to the cylinder block. The drawing also shows the "stepped" spigots on the cylinder barrels with their series of rectangular ports

This necessity for really accurate workmanship accounted for the excellence of the Scott engine. "Made to limit gauge" was a proud trade-mark for many years in a period when fine measurements were less common than they have since become.

The performance of a two-stroke engine is determined more by the original design and construction than by subsequent "tuning," and that, by the way, is a point that Mr. Harry Langman made when he was showing me the components of the "Clubman's Special" engine. "First and last," he said, "it is accurate workmanship that controls the results. You cannot tinker with a two-stroke like you can with a four-stroke." Harry, incidentally, has grown up in the Scott tradition. He was one of the original staff in Alfred Scott's time, and apart from an Army interlude (when he and I, so it chanced, were in the same unit) he has been associated with the Scott continuously as tester, trials rider, solo and sidecar T.T. racer, and latterly factory executive.

Applicable to All

The "Clubman's Special" has certain modifications from standard, and has a higher compression ratio, but otherwise the general description is applicable to all models.

The engine size now standardized measures 73mm × 71mm (596 c.c.) and the water-cooled cylinders with detachable aluminium head are inclined forward. The cylinder block is bolted to an aluminium casting generally referred to as the "crankcase," although the term is not exactly correct without explanation.

A two-stroke engine using crankcase compression requires that each cylinder shall have its own separate crank-chamber, and in the Scott the flywheel is located between the two chambers so that, to a certain extent, the engine may be regarded as two quite separate single-cylinder units, one on each side of the common flywheel. Thus the "crankcase" is a large box enclosing the flywheel and forming an undershield, and at the same time incorporates the two crank chambers and the primary drive. The simile of two separate single-cylinder engines breaks down when we come to consider the induction system.

The carburettor is bolted to a flange on the crankcase casting in communication with a space which surrounds the lower part of the cylinder barrels, so forming a kind of manifold. This manifold space in the crankcase is very important, for its design has great bearing upon efficiency; its walls are highly polished and there are no pockets for obstructions to the gas flow. Unlike the manifold of a more normal type of engine, the whole interior of the intake system is exposed when the cylinders are removed.

Four power impulses in two revolutions of the crankshaft are given by the twin two-stroke, and the torque effect is similar to that of a four-cylinder-in-line four-stroke engine. For each power impulse there is a corresponding intake, so that the engine is drawing on the carburettor far more constantly than is the case with a 180-degree twin four-stroke. Moreover, as compression occurs in one crank chamber the other is drawing in, with the result that any blow-back as the inlet port closes on the one is taken by the other, and so on.

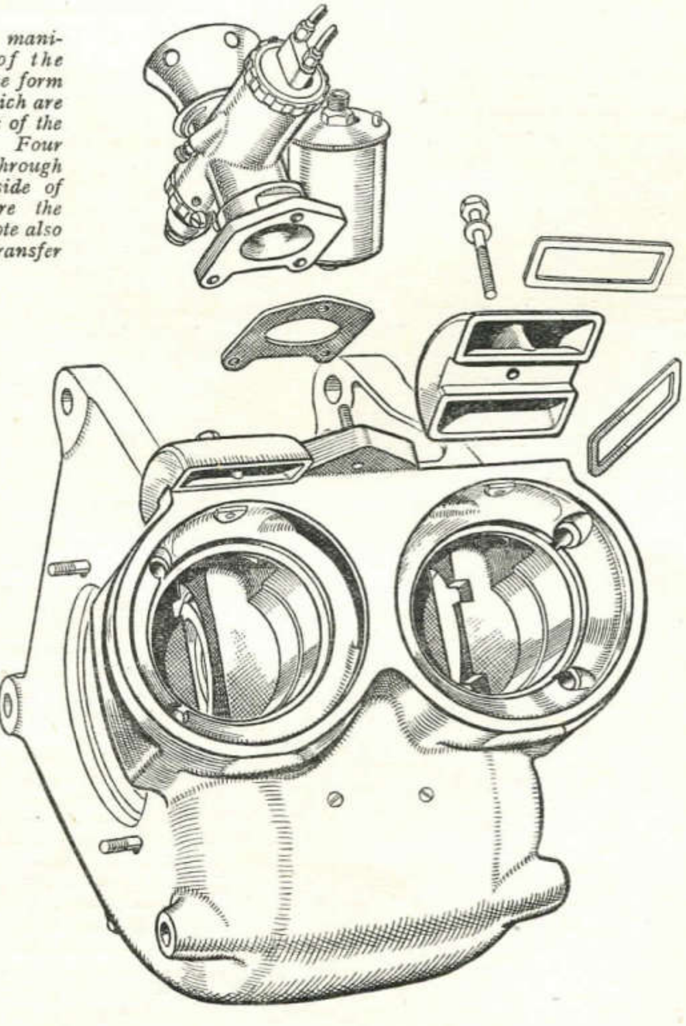
This "induction manifold" portion of the crankcase is quite deep, in the form of wells which receive the long projecting spigots of the cylinder barrels; the base flange of the cylinder block (below the water jacket) rests on the top surface and is pulled down by four bolts which are passed upwards through bosses on each side of the casting. The projecting parts of the cylinder barrels are turned to two external diameters, the lower portions being spigoted into the crankcase wells, while at the "steps" formed by the sections of larger diameter (in which the inlet ports are cut) square-section rubber rings are fitted, linen rings being placed on the upper portions close up against the base flange.

When the cylinder block is tightened down the linen rings seal the joint between the base of the block and the crankcase, while the rubber rings are compressed against corresponding registers inside the wells, so sealing the annular manifold space.

Through the upper part of the projecting barrels, which coincide with the manifold, are six rectangular ports extending more than half-way round the wall, the clear inlet area being equivalent to nearly 40 per cent of the cylinder bore. These ports face mainly inward towards the centre line.

When the piston rises the ports are uncovered by the bottom of the skirt and gas passes through from the carburettor to "fill" the depression in the crank chamber. The big inlet area is essential for efficiency, as the period of full opening is brief, the piston beginning to uncover the port at about 58 degrees before top dead centre and finally closing it again 58 degrees after t.d.c., or about 120 degrees of crank movement as against 190 or more degrees in the case of a four-stroke. Rate of port opening is a function of piston speed and it cannot be altered, unlike the valve lift of a four-stroke which can be varied by cam design irrespective of engine r.p.m.

As the piston descends the gas is compressed in the crank chamber, while the upper part of the piston begins to uncover the transfer port about 66 degrees before bottom dead centre. Gas is forced into the cylinder above the piston via the transfer passage, which is a detachable casting connecting the crank chamber (below the manifold portion, which, it will be remembered, is sealed by the rubber base-ring) with the transfer port about a third of the way up the working portion of the cylinder barrel. The exhaust port is directly opposite but slightly deeper than the transfer port ($\frac{15}{16}$in against $\frac{5}{8}$in). It is in the forward side of the cylinder wall and is, of course, uncovered by the piston at the same time as the transfer port, although, due to its greater depth, it opens earlier in the cycle of operations and closes later. But more on this point anon.



The "induction manifold" portion of the crankcase is in the form of two wells in which are located the spigots of the cylinder barrels. Four bolts passing through bosses on each side of the casting secure the cylinder block. Note also the detachable transfer castings

Port Design

To digress a moment. Most two-stroke engines have the ports and transfer passages cast integrally in the cylinders, and as large ports (of great relative width, to give quick opening) weaken the barrel, the size has more often been determined by the structural strength than by efficiency. Additionally, integral casting makes the openings and passages inaccessible to machine tools. The Scott cylinder design permits all the ports to be machined to precise limits, so that accuracy of port timing is assured. All roughness can be removed, and as the downwardly projecting cylinder barrels extend well below the holding-down flange the inlet port dimensions do not affect the strength.

Since the exhaust and transfer ports are open at the same time, and as they face each other, the incoming gas would immediately shoot across and out of the exhaust if its flow was not controlled. This control is effected by the deflector top piston. Designing the "hump" on the piston crown is a highly critical matter, and whereas there are certain things that obviously must be avoided (like sharp angles or pockets), the ideal shape for any given engine is achieved only by a long process of experimenting.

As already mentioned, the exhaust port begins to open somewhat in advance of the transfer one, so that the pressure of the exhaust gas is reduced and its flow towards the port is initiated. When the transfer port opens the fresh cold charge from the crank chamber is shot up the side of the cylinder wall towards the head by the deflector and it tends to displace the hot exhaust gas rather than to mix with it, although, of course, some intermingling is unavoidable. This is one of the reasons why all two-stroke engines of the ported cylinder, piston-controlled type have a lower thermal efficiency than four-stroke engines of corresponding size.

The new gas above the piston is compressed and fired in the usual way and the cycle is repeated, there being a power impulse each time the piston comes to the top. Mechanically the design is so closely associated with the functional working of the two-stroke cycle that it is necessary to explain the engine in terms of this relationship so that the reason for many of the details shall be evident. With the main outline disposed of, however, it is possible to look more closely into the mechanical details.

By arranging the flywheel and primary drive between the two crank chambers, a compact self-contained layout results. On the other hand, the transverse "couple" peculiar to two-cylinder engines with the cranks set at 180 degrees increases as the distance between the cranks increases. Some slight reduction of this width could be secured by having the flywheel elsewhere, but the Scott engine suffers remarkably little from this particular force.

It is not obvious why the engine is so free from vibration. But one cannot overlook the possibility of the large central mass of the flywheel resisting the effect of the rocking couple in much the same way as a brick will absorb a hammer blow without passing it on to the hand that holds it.

Location of the bearings may have an important influence on the matter, too. The mainshaft runs in two roller bearings and the crankpins are overhung, but the flywheel and the primary drive are supported *between* the bearings; the whole assembly is exceedingly stiff and compact in spite of the fact that it is necessarily built up from separate components.

Each crankshaft comprises a tapered stub which carries the inner race of the main roller bearing and engages with the flywheel centre. The web is a disc, thickened at one side for balancing purposes, and having a small boss to receive the inner race of the big-end roller bearing. In the crank chambers are pressed the outer races of the main roller bearings, and these are firmly fixed by means of locking rings which are shrunk in around the housings; definite location is assured by four countersunk screws. This positioning is necessary because small oil ports in these bearing shells have to be "timed," as will be explained when we consider the lubrication system.

Since a two-stroke crank chamber must be compression tight, and as a roller bearing is anything but that, the problem is overcome by the use of spring-loaded glands. The rollers are assembled on the crankshaft race and faced by a ground disc or collar which slides on the mainshaft; this collar is backed by a spring.

The centre boss of the flywheel, on which the driving and magneto sprockets are riveted, is taper bored from each side. A keyway is cut straight through this double taper hole and a long key is fitted which registers with keyways in the tapered ends of the mainshafts projecting from the crank discs. The accuracy of these keyways in relation to the crankpins is most important, since the precision of the port timing is wholly dependent upon them.

A single high-tensile bolt through the two hollow crankshafts draws them together into the flywheel boss and makes the whole assembly solid; the workmanship here has to be above question, since the slightest malalignment would throw both the main and the big-end roller bearings out of truth.

The nickel-steel connecting rods are of oval section, and they are as thin as possible to obviate large empty spaces in the crank chambers; the small-ends are offset to a slight extent. Oil-hardened roller races are pressed into the big-ends, a feature of which is the unusually large diameter in relation to the width.

Bronze bushes are used in the small-ends, and to those unfamiliar with the Scott engine the large amount of metal taken out of the top of the bearing is unusual, but it has to be recollected that there is explosion pressure on the piston at every downward stroke, so that the upward inertia pressures on the upper half of the bearing are cancelled out in a way which does not obtain in a four-stroke engine.

Fairly long pistons of heat-treated Y-alloy aluminium are used, and as they are also the "valve gear" the clearances have to be set to very close limits, and to ensure the best results each piston is pronouncedly tapered or, more correctly, each part of it has its own diameter. There are four different diameters, ranging from 0.004in clearance at the skirt to 0.009in above the top piston ring. Replacement pistons turned parallel are a frequent cause of poor running, lack of power, and seizure. Short oil-distribution grooves are cut in the piston skirt, and there are three very narrow compression rings at the top.

Dividing Bars

Light hollow gudgeon pins float in the piston bosses. Obviously, since both the rings and the pins pass the cylinder ports, provision has to be made to prevent them catching. Dividing bars cross the exhaust and transfer ports, and for the same reason the large inlet port is divided into six sections. Stops are fitted in the ring grooves to prevent the ring gaps working away from the unported outer sides of the cylinder bores.

End movement of the gudgeon pins is prevented by the use of large, domed bronze buttons riveted into the outer ends of the pins; these buttons fit into recesses in the piston wall and prevent the pins working across to the inner sides and fouling the inlet ports.

Lubrication is effected by two duplex Pilgrim pumps fitted on the crankcase "doors," which is the name given to the discs that close the outer sides of the crank chambers and through which the crankshafts and big-ends are assembled. Main lubrication is provided by the pump on the off side, which delivers oil to recesses behind the shells of the mainshaft roller bearings. Ports in the inner faces of the shells coincide with ports in the spring-loaded packing glands, which themselves are definitely located in relation to the crankpins by tongues on their collars engaging with the keyway in the flywheel boss. These ports in the glands and bearing shells are timed to register at the point of maximum crankcase depression so that oil is sucked through, lubricating the glands and the main bearings. Oil escaping from these is thrown across the face of the crank disc into a knife-edged groove around the rim, from which it goes owing to centrifugal force through a drilled hole into the crankpin to lubricate the big-end bearing.

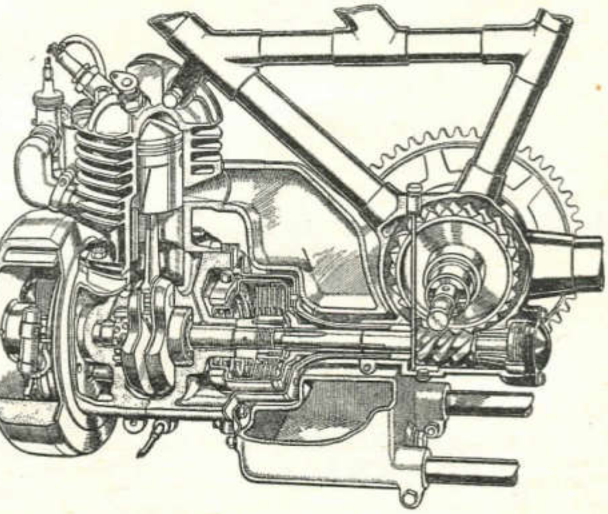
The other pump delivers a limited quantity of oil via small-bore pipes to oil grooves in the cylinder bores between the inlet and transfer port levels, thus directly feeding the piston skirts.

Water-cooling is on the thermo-syphon system and both connections are made through brass pipes fixed in the cylinder head, which, incidentally, is held down by nuts on 16 high-tensile steel studs in the cylinder block; a copper and asbestos gasket makes both the water and compression joints.

From the union at the rear of the head the water rises to the radiator header tank, while the cool water from the base of the radiator passes down through the tube in the front of the head. This tube extends well down inside the water jacket and is chamfered off at its end so as to direct the flow of water on to the cylinder walls in the region of the exhaust ports.

It will be realized that the all-round performance of a two-stroke engine such as the Scott is dictated almost entirely by (a) the possibilities of the original design, and (b) by the accuracy of manufacture. In short, such an engine is rarely susceptible to amateur "tuning." The Scott engine is one that is not excessively stressed mechanically, hence its well-known and quite remarkable longevity.

SCOTT 98 c.c. CYC-AUTO



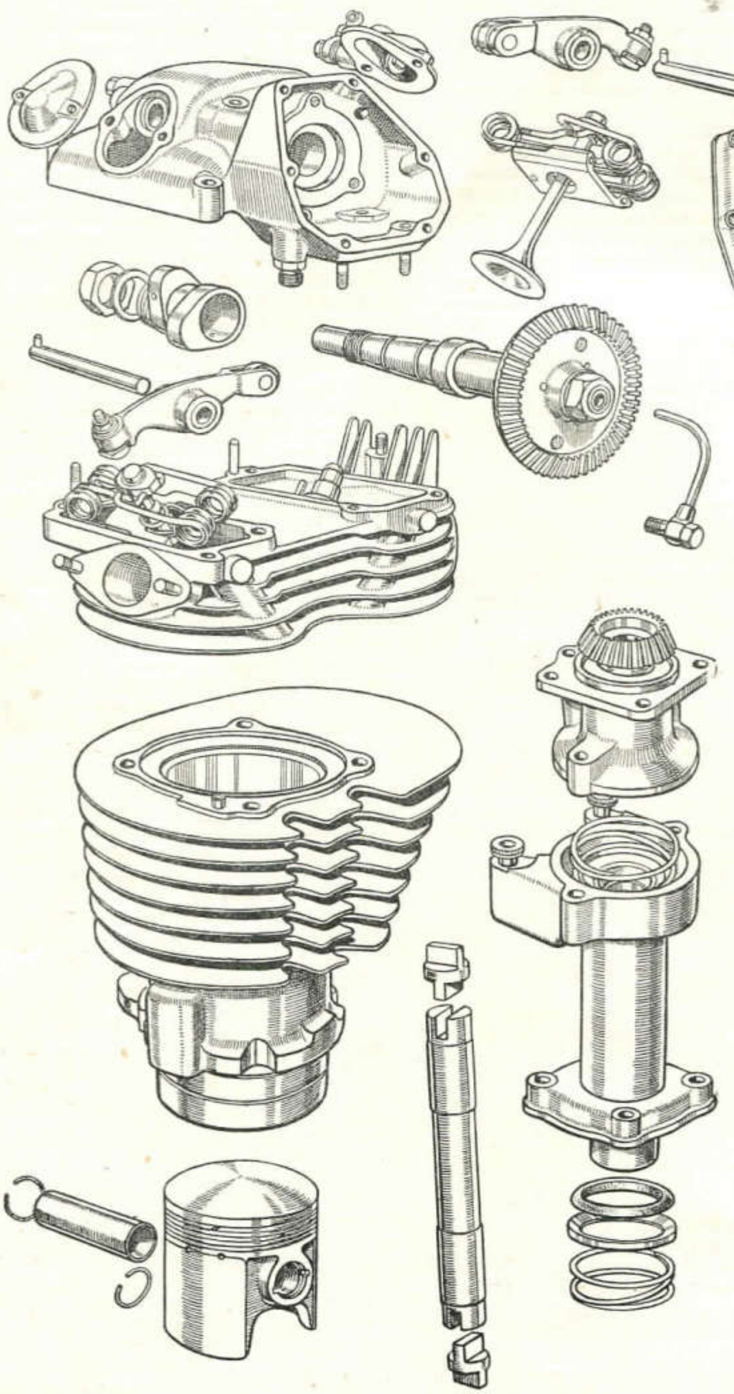
A multi-plate clutch, worm drive and a transmission brake are employed in this ingenious Cyc-Auto unit

Excelsior Manxman

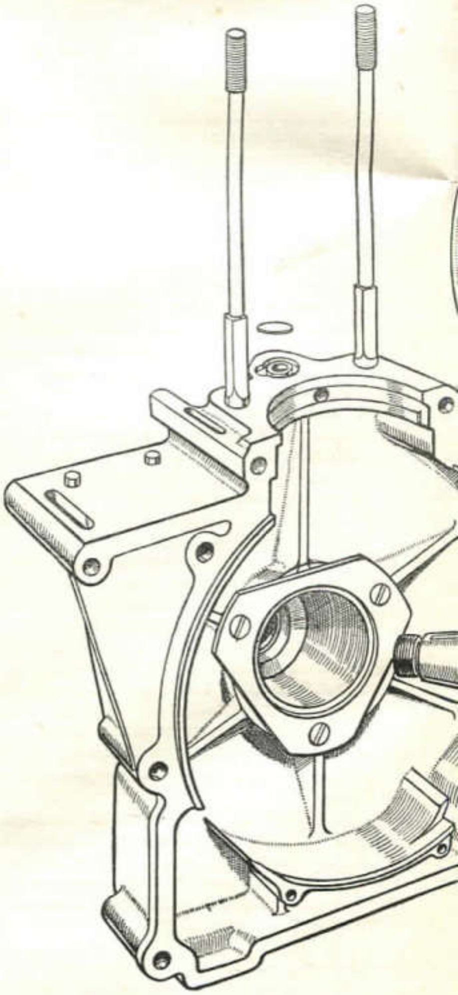
Tourist Edition of a Famous Racing Engine. By "UBIQUE"

THE Excelsior folk are well known in both racing and tourist fields, and when I visited them for the purpose of the series dealing with outstanding designs I was not surprised that they suggested what might be described as a tourist edition of a racing type of engine. By this I mean that overhead-camshaft engines are seldom found outside the racing class, but that the advantages of the type are very attractive, if, as in this case, the engine can be modified so as to provide the motive power of a magnificent fast touring mount selling at a reasonable price.

One of the features of the "Manxman" engine is the extreme rigidity of the crankshaft unit, so I began at that point.



The cylinder finning of the "Manxman" engine is unusually deep and widely pitched. There is a positioning dowel for cylinder to head and cylinder to crankcase, the latter forming an oil lead to the rear of the cylinder. The drawing also shows the "overlapping" hairpin valve springs and details of the overhead camshaft gear



"Of what are the flywheels made?"

"High-tensile steel stampings, because, as you see, the crank axles are formed integrally with the flywheels."

"What proportion of the reciprocating weight do you balance?"

"On this particular type we have found that 0.6 is the most suitable figure."

"What about that huge crankpin?"

"It is $1\frac{7}{16}$in in diameter, and is dead hard on the roller tracks. The ends, however, are not hardened, and it is hollow—to form a sludge trap—the ends being plugged with aluminium."

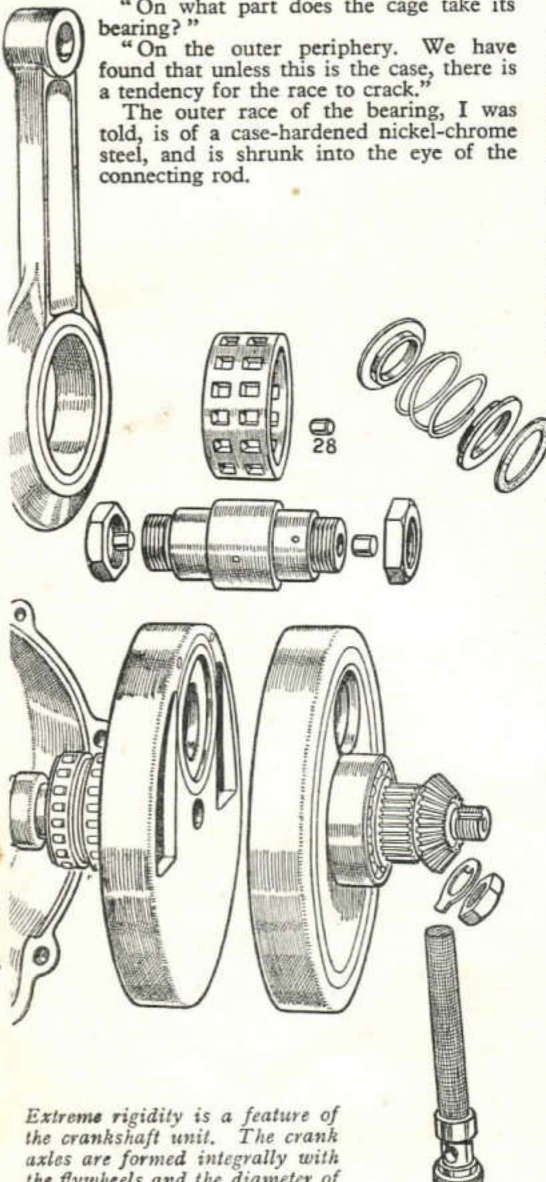
"How is it fitted?"

"The ends taper to the extent of 0.001in in their own length, they are pressed into position, and afterwards locked up by nuts. There are 28 rollers of $\frac{5}{16}$in × $\frac{1}{4}$in, disposed in two rows in a cage made from R.R.56 drawn bar—not tube. This point is important in view of the improved results obtained."

"On what part does the cage take its bearing?"

"On the outer periphery. We have found that unless this is the case, there is a tendency for the race to crack."

The outer race of the bearing, I was told, is of a case-hardened nickel-chrome steel, and is shrunk into the eye of the connecting rod.



Extreme rigidity is a feature of the crankshaft unit. The crank axles are formed integrally with the flywheels and the diameter of the crankpin is no less than $1\frac{7}{16}$in

"Why this tremendous con-rod?" I next asked.

"It is made from R.R.56 light alloy, and is not so heavy as it looks—try it for yourself."

I tried it, and found the rod surprisingly light for its size. "The proportions are designed to promote great rigidity, and the deep web round the big-end makes a sound seat for the outer race. Incidentally, the rod is heat-treated to a Brinell hardness of 121 or over, as we find that at any lower figure there is a tendency to stretch.

"There is no bush in the small-end eye, and the $\frac{7}{8}$in diameter gudgeon pin bears directly in the rod. This pin is hollow and bored taper at each end. It is made of a nickel-chrome steel, and is lightly case-hardened on the bearing surface only. The ends are slightly chamfered externally and it is located by circlips."

"What about the piston?"

"It is made of Y alloy, and is die-cast and heat-treated. As you will see, it is very slightly domed, although the compression ratio is 7 to 1. The skirt is diamond turned, oval and taper, to provide for expansion, and there are two narrow piston rings and a single stepped scraper ring."

Next we passed on to crank bearings, and I was told:—

"The shaft diameter on the drive side is $1\frac{1}{8}$in and there are two separate caged roller bearings carried in a single outer race. A special gland nut working in a bonded cork packing ring serves also to lock the inner races on the shaft. The outer race is shrunk into the crankcase and locked by a steel plate.

"On the driving side there is a double-row self-aligning ball bearing, locked on both the shaft and in the crankcase for locating purposes."

"The crankcase appears to be a sand-casting," I said.

"Yes," came the reply, "the design does not lend itself particularly well to die-casting. The alloy is rather special, for since almost all the oil leads are internal there must be no trace of porosity. Of course, each case is pressure-tested before erection."

I noticed that the crankcase proper is divided from the oil sump by a partition having large openings at each end. At the front end of the partition and at a point behind the partition on the crankcase wall are "scrapers" to deflect oil from the flywheels into the sump; there is also a small sludge trap at the lowest point of the sump.

The timing side of the crankcase is adequately stiffened by cast-in oil leads, the timing-gear case and one external web, but on the driving side there are several internal webs.

"Do these webs cause loss of power through oil drag?" I asked.

"Definitely, no," was the reply. "It is our experience that, provided there is ample clearance between flywheels and crankcase, oil drag is not likely to occur to any serious extent."

Two other points should be mentioned before leaving the crankcase. First, the halves are held together by four bolts, quite distinct from the frame-holding bolts. Secondly, crankcase pressure is allowed to pass to the timing case, and to escape to the oil-tight chaincase through a disc valve and through a groove in the top of the crankcase, which, with a corresponding groove on the cylinder spigot, forms an annular passage.

"The cylinder fins are rather widely pitched, are they not?"

"Yes, the pitch is $\frac{1}{2}$in, and we have found it the best compromise for all-round purposes. You will see that the upper ribs are much deeper in front than elsewhere. This helps to get the heat away from the exhaust side, maintains an even temperature and prevents cylinder-bore distortion. There is a single vertical rib at this point to prevent 'ring.' Notice also that there is a positioning dowel for cylinder to head and cylinder to crankcase. Both dowels are hollow, and the lower one forms an oil lead to the back of the cylinder."

In a recess in the cylinder lies a solid copper joint washer 0.050in in thickness.

In section, the combustion chamber forms a fairly shallow arc, which accounts for the low dome of the piston. The head is of cast-iron and has circumferential ribs, with vertical ribs at the front of the exhaust port. A 14 mm plug is located as near the middle as possible, and the lower part of the valve boxes with their draining passages are formed with the head.

"How is the head held down?" was my next question.

"By long bolts having heads within the crankcase and screwing directly into the head casting, for which purpose the bolts have square shanks where they emerge from the crankcase."

As regards the bronze valve guides, there is little to be said except that they are chamfered at the top (outside) to prevent excessive lubrication.

Valve Sizes

Here are some particulars about the valves: inlet valve made of K.E.805, stem dia. $\frac{5}{16}$in, throat dia. $1\frac{27}{64}$in, rocker clearance (cold) 0.008in. Valve opens 38 to 40 degrees before t.d.c.; closes 60-62 degrees after b.d.c. Exhaust valve made of K.E.965, stem dia. 0.350in, throat dia. $1\frac{21}{64}$in; rocker clearance 0.015in. Valve opens 60-62 degrees before b.d.c.; closes 35-38 degrees after t.d.c.

"How would you describe your valve springs?"

"We call them overlapping hairpins, and the reason for the overlap is to save width without reducing spring length."

For description I will refer you to the drawing of the engine, as it would probably need a page to describe this ingenious arrangement in words!

"The lower ends of the springs are tucked into holes in a bottom collar stamped from R.R.56, and the upper ends hook directly under the top collar and to the valve via the usual split cones."

"The valve, then, cannot revolve?"

"No, and, oddly enough, we get better results when it does not do so. Why, I don't know, but it is so."

"Why do you use hairpin springs?"

"Because with a 20 per cent reduction in spring pressure over the coil type we can run at still higher speeds without loss of valve control."

End-caps for the valve stems are made of a very special drawn steel bar, and are hardened on the upper surface only.

Before dealing with the rockers and camshaft we must have something to hang them on, so let us examine the combined camshaft case and rocker boxes.

This item, I was told, is of the same light-alloy as the crankcase. It has two positioning dowels, and is held down by six set pins. Further, a trough is formed for the camshaft, and the walls of the trough control the supply of oil to the valve gear. At each end of the trough are large bronze bearings for the camshaft; that at the driving end is carried in a thick light-alloy housing "purely to facilitate manufacture." The bearing at the opposite end is mounted in a detachable end-plate.

The camshaft, to which the crown bevel is secured by key and nut, is nickel-chrome steel cased on the bearing surfaces only. In the middle the shaft is tapered, and on this taper fits the cam block consisting of two cams hardened on their working faces. A nut and tab washer hold the cams on the taper; there is no key. The cams have an easy take up and take off for silence, but in between they are of the reasonably "hot" type, and the total lift is 0.36in. An end-float of 0.005in, measured cold, is allowed for the camshaft, a hardened-steel thrust washer being provided.

Valve Rockers

"Is there anything unusual about the rockers?"

"There is, indeed. They are made of a 90-ton steel, case-hardened in the bore and on the inside faces of the fork which carries the roller cam follower. This roller runs on a floating bronze bush with a hardened pivot pin."

"Why do you use a roller?"

"For two reasons. First, it would be difficult to obtain a glass-hard surface on a steel which is suitable for the rocker arm, and the roller is glass-hard. Secondly, much quieter operation can be obtained from a rolling motion as opposed to a skidding motion.

"Exactly the same practice is employed on a larger scale for the rocker pivot, but in this case the central pivot pin is carried in bronze bushes shrunk into the case. The pins, however, are fixed, and do not rotate."

"Why, then, the bronze bushings?"

"Merely to prevent the pins hammering loose in the comparatively soft alloy case."

A hardened heel-pad over the valve-stem cap is of curved formation and cannot rotate. It is adjusted by a screwed sleeve and locknut for clearance purposes. There is an extension on the exhaust rocker, which is engaged by an exhaust lift cam carried in the rocker cover plate.

"Will you please explain the sequence of the vertical-shaft drive parts?"

"The top bevel is made in one piece with its shaft journal, then comes an Oldham coupling, the vertical shaft (hollow), another Oldham coupling, and the lower bevel, which is similar to the top bevel. Plain bearings are used throughout, one for each bevel and two for the vertical shaft, which is hardened on the bearing surfaces. Adjustment of mesh for the top bevels is by a hard-steel thrust washer, various thicknesses being available. At the lower end there is additional adjustment by means of shims behind the crankshaft bevel. The hunting tooth system is employed, the gears from top to bottom having teeth as follows: 52, 27, 27, 26."

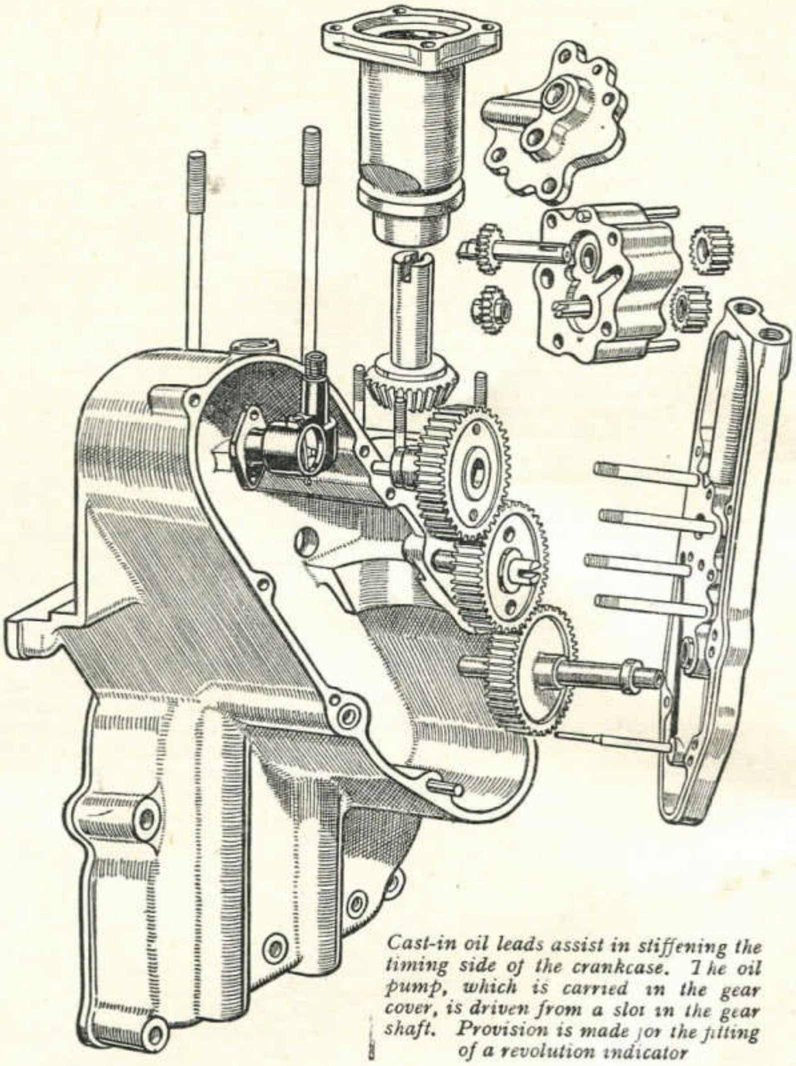
The vertical drive is, of course, enclosed, the enclosing tube (aluminium) being secured by spring-loaded gland nuts and oil-resisting rubber rings. It was pointed out that the lower part of the upper gland housing carries two hollow spring-loaded thimbles with fabric end-faces. These press against the oil drains from the rocker boxes and lead the oil to the vertical shaft. The bottom bevel with its bearing is carried in a detachable housing.

Now for a description of a rather complicated lubrication system. First, all oil leads but one are internal. Next, the feed gear pump circulates 14 gallons per hour at 6,000 r.p.m. and the return pump has a capacity six times as large.

Oil seepage while the engine is stationary is prevented by a spring-loaded plunger at the inner end of the indicator rod. There is always enough oil in the pump lead to ensure priming.

When the pump is started, the piston is forced outwards, thus uncovering delivery leads to (1) a jet within the hollow crankshaft and thence to the big-end, (2) through a flexible pipe to the camshaft housing, thence to the bevel teeth, the camshaft bearings and the lift faces of the cams. The return from the upper works is through the spring-loaded thimbles, already mentioned, to the vertical-shaft bearings and to the timing case, then to the sump; (3) a lead to a point on the piston about ⅛in below the scraper ring. The scavenge pump draws from the sump and delivers to the tank through a filter in the timing-case cover. Metering holes are employed to ensure the correct proportions of flow.

As regards performance, the engine which I examined had just come off test. At the start of the test the figures given were: 13.2 h.p. at 4,000 r.p.m., 16 at 4,500, 19 at 5,000 and 20.5 at 5.500. After eight hours' running, the corresponding figures were: 13.6, 16.41, 19.7 and 21.2. The engine peaks at 6,000 r.p.m., and at that speed gives from 23.5 to 24 b.h.p.



Cast-in oil leads assist in stiffening the timing side of the crankcase. The oil pump, which is carried in the gear cover, is driven from a slot in the gear shaft. Provision is made for the fitting of a revolution indicator

Royal Enfield Vertical-twin

E. A. SITWELL Elicits the Whys and Wherefores

WHY does a manufacturer choose to build a particular type of engine? That seems to me a natural starting point in analysing the design of any power unit. Accordingly, the first question I put to Mr. E. O. Pardoe (chief draughtsman) and Mr. R. A. Wilson-Jones (technical manager) at the Royal Enfield factory was: "Why make a 500 c.c. upright, parallel twin at all? Surely not merely to be in the fashion!"

Mr. Wilson-Jones and Mr. Pardoe smiled. The two-man team shot out the answers with what seemed almost firing-interval regularity: "Even torque and easier starting are two advantages. Moreover, a shorter stroke and lighter reciprocating parts mean more r.p.m.; therefore, there is more power. Better cooling is obtained with a vertical twin than with a one-behind-the-other vee-twin, and more even firing. The vertical-twin engine fits conveniently into the conventional type of motor cycle frame. A theoretical disadvantage lies in balance, but the balance of a 500 c.c. vertical twin is better than that of a single of the same capacity, because of the shorter stroke of the twin. Smoothness is ensured by the use of light-alloy con-rods, a stay for the cylinder heads, etc."

Mr. Wilson-Jones added: "I have always found that a smooth-running engine gives more speed for the same power. . . ."

My next question was: "Why are two entirely separate cylinder barrels and heads used?"

"That layout eliminates distortion," answered Mr. Pardoe, "since there is a better cooling space between the cylinders and because the heads are not tied together. Servicing is easier, as the barrels are interchangeable. Incidentally, you will see that the crankcase provides an uninterrupted joint face for each cylinder base."

"Why is a one-piece casting used to form the dynamically balanced crankshaft and flywheel ensemble?"

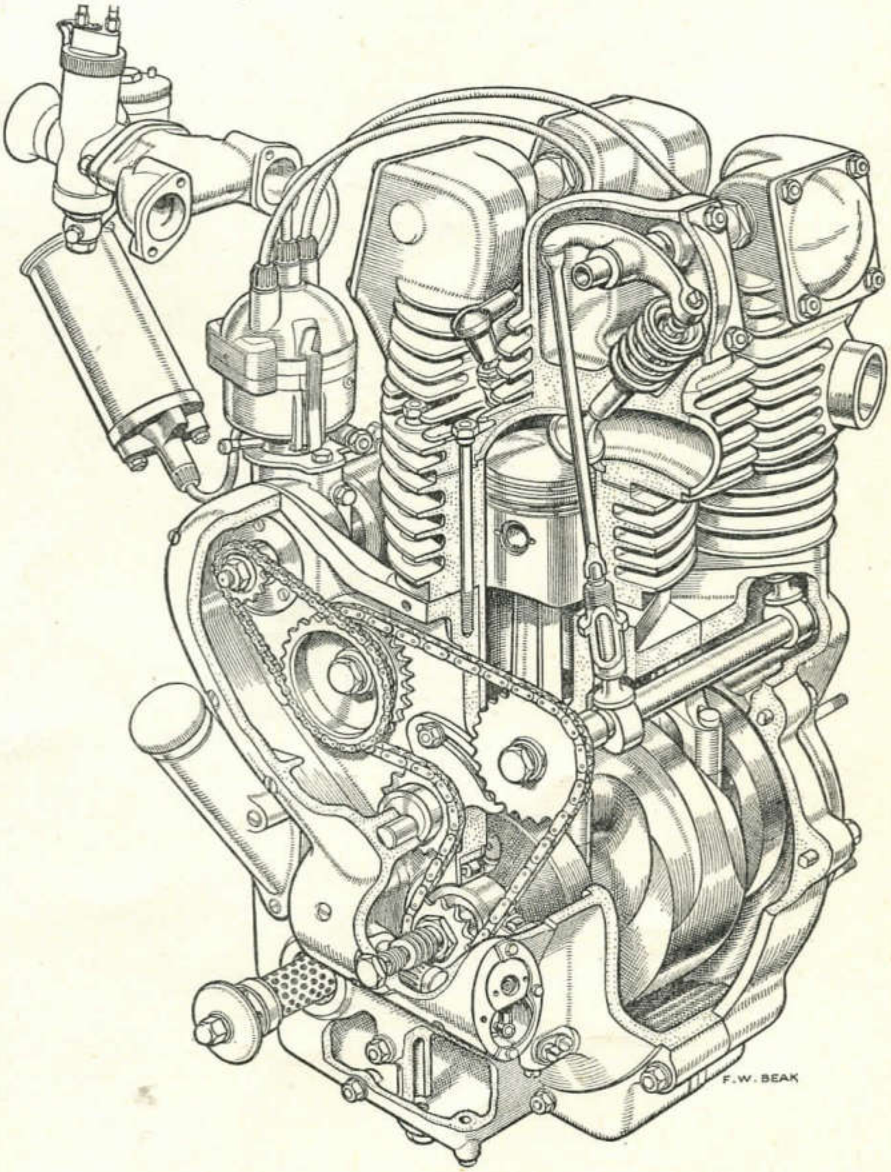
"One reason, of course, is to ensure dead truth in running," came the answer. "Also, since the flywheel is part of the crankshaft, there is no chance of its coming loose, and the number of parts is reduced. Alloy-iron is employed, as it is a material recommended by the people most experienced in casting shafts. Choice of material is a question of strength, bearing qualities, and the certainty of obtaining sound castings. Our tests have shown that the material we have chosen is excellent in all these respects."

Views of Mr. Wilson-Jones on three-bearing crankshafts interested me, since only two main bearings are used in the Royal Enfield twin.

"A three-bearing shaft appears at first sight to have advantages," he said, "but only if you can ensure that the three bearings and their housings remain in line under all conditions, and if the shaft is not weakened torsionally. Justification for the two-bearing shaft, however, lies in its simplicity. It is a matter of compromise whether one or two throws are used between bearings. A three-bearing shaft has, of course, only one throw between each bearing and the next one. Usual car practice is to employ two throws, and experience has shown that two main bearings, with two throws between them, provide ample rigidity for high-speed motor cycles."

Both main bearings are of the same diameter, since there is virtually the same load on each. The single-row ball bearing on the driving-side locates the end of the crankshaft, and the roller bearing on the timing-side allows sliding to occur on the rollers should there be any differential expansion between the case and the shaft. In the hollow driving-end of the crankshaft there is a non-return, disc-type valve, which communicates with an external pipe and forms the crankcase breather. Crankpins are cored, and steel discs, closing the holes at each end, are held in place by circlips. A small, spring-loaded, oil-release ball valve is fitted to the disc on the timing side in order to prevent excessive pressure from building up when the oil is cold. Outlet holes for feeding oil to the big-ends are at 90 deg to the crank throw.

Keyed into the end of the shaft, the timing chain sprocket is held against a



taper by a bolt running through it and engaging a knurled nut in a recess on the inner face of the crank web. A rod, passing radially through the web, locks the nut in position. This rod is held into the nut by a grub screw at its outer end, and the grub screw is itself locked by centre punching.

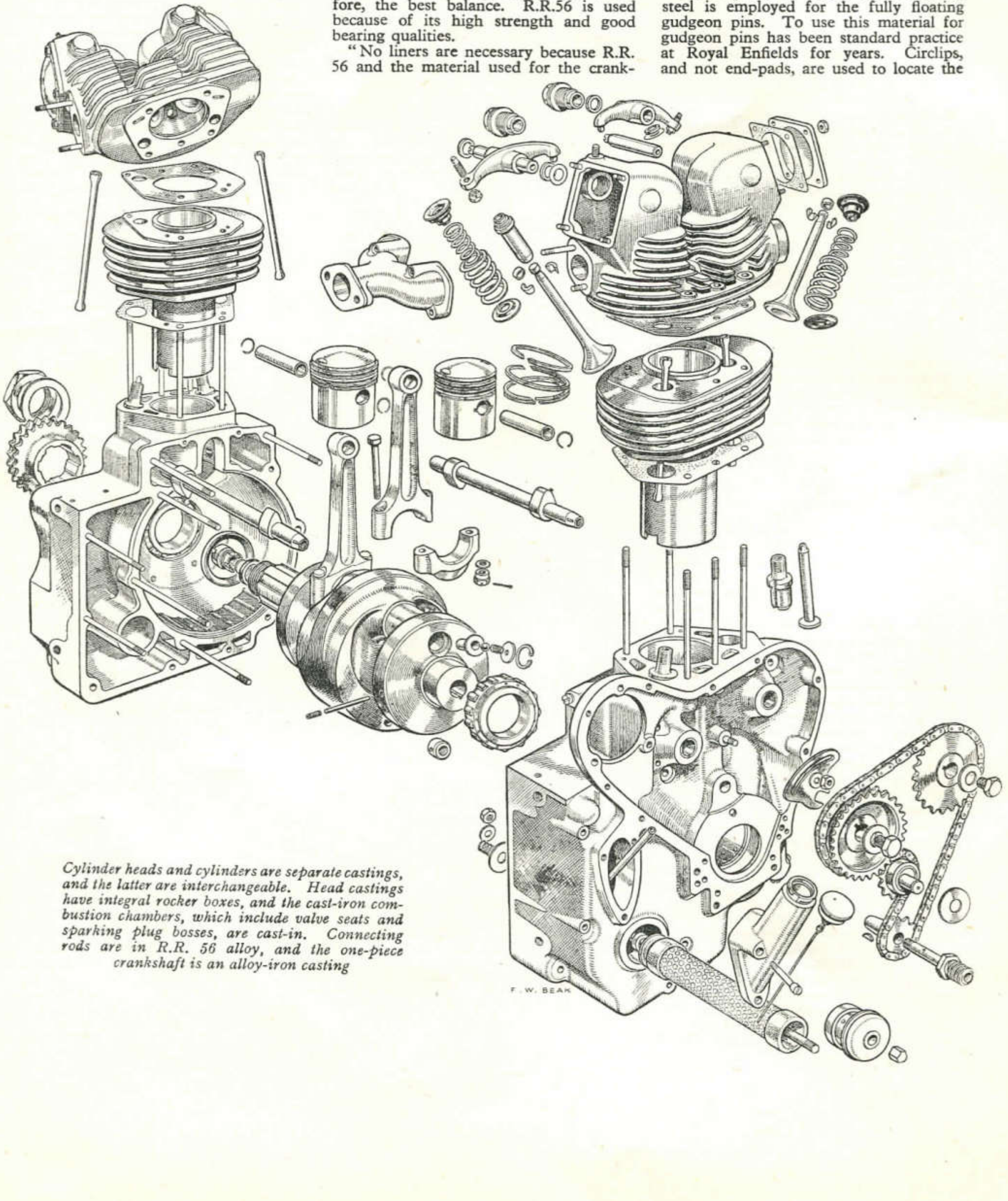
I saw that the bolt holding the timing chain sprocket against its taper fulfilled other useful functions as well: **the head** of the bolt carries the worm drive for the cross shaft that drives the two, double-acting, oscillating, plunger-type oil pumps. Moreover, the bolt is hollow and takes the oil-feed to the big-ends.

"Split, plain big-ends are used," I said, "and you tell me that the con-rods are made of R.R.56 alloy. Why this material, and why no liners for the big-ends?"

"We use a light-alloy," was the answer, "because it provides the lowest possible reciprocating masses and, therefore, the best balance. R.R.56 is used because of its high strength and good bearing qualities.

"No liners are necessary because R.R. 56 and the material used for the crankshaft are together first-class bearing metals. Provision of liners would necessitate either increasing the diameter of the bore of the con-rod's big-end, or reducing the diameter of the pin, or doing both these things, with consequent loss of strength. Servicing is just as easy as with loose bearings, and there is a reduction in the number of parts. Plain bearings have been standard practice on our singles since 1939."

Three per cent nickel case-hardening steel is employed for the fully floating gudgeon pins. To use this material for gudgeon pins has been standard practice at Royal Enfields for years. Circlips, and not end-pads, are used to locate the



Cylinder heads and cylinders are separate castings, and the latter are interchangeable. Head castings have integral rocker boxes, and the cast-iron combustion chambers, which include valve seats and sparking plug bosses, are cast-in. Connecting rods are in R.R. 56 alloy, and the one-piece crankshaft is an alloy-iron casting

¾in pins because end-pads, with pins of this size, might have a tendency to score the cylinder walls. End-pads are more suitable for very small engines.

Silicon-aluminium-alloy, with a coefficient of expansion of 0.000017 per degree Centigrade, is used for the pistons. This low expansion rate, combined with a taper oval form, minimizes the risk of seizure when running at low clearances. Minimum piston clearance when cold is 3 thou, the measurement being taken at the bottom of the skirt fore and aft. Slightly domed, the pistons give a standard compression ratio of 6.5 to 1. Mr. Wilson-Jones said : "We think this ratio is as high as we can go on pool petrol for comfort and without pinking."

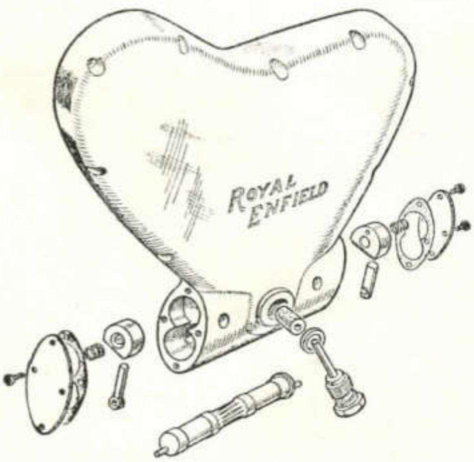
Looking at the cast-iron barrels and aluminium-alloy cylinder heads, I saw that provision was made for five through-studs to fulfil the dual function of holding the heads to the barrels and the barrels to the crankcase. The deeply spigoted construction ensures that the studs are kept as short as possible; they are only 3in long. Having them so short helps to reduce the difference in expansion between the stud and the cylinder. This difference in expansion is further reduced by the fact that each stud passes through the actual cylinder casting and is not exposed to the air. In order to allow a certain amount of elasticity, the plain portions of the studs are reduced in diameter.

"Why is aluminium-alloy used for the cylinder heads?"

"For lightness and better cooling. There are four integral rocker boxes, each with its separate cover. The cast-iron combustion chamber inserts, which include, of course, valve seats and plug bosses, are cast-in, and not shrunk-in, in order to save space; thus the valves can be closer together. You will see that cast-in steel exhaust stubs are employed."

"Why are there two camshafts instead of one? And why have a chain-driven timing-gear?"

"Use of two camshafts in this engine allows the push-rods to be disposed so that there is an uninterrupted flow of air between the cylinders. Light, short push-rods, all the same length, can be employed; and so there is a minimum number of different kinds of parts in the mechanism.



"With the chain, it is as easy to drive two camshafts as one. Reason for using a chain is that the camshafts are high up, and would otherwise need very large pinions or a large number of them. Of ⅜in pitch and 0.225in width, the single-row chain is amply strong for the job and has been very well tested. Exactly the same type of chain is used today for the primary drive of the 125 c.c. two-stroke Royal Enfield, and was used for the primary drive on the pre-war 150 c.c. overhead-valve machine, which developed about 7 b.h.p. Chain tension, as you see, can be adjusted by moving a jockey sprocket running on an eccentric."

"What about cam form?"

"Both inlet and exhaust have slow acceleration ramps which take up the tappet clearance quietly. Cam lift is $\frac{5}{16}$in."

Standard, flat-base tappets are employed, with nickel-chrome, cast-iron guides; and the push-rods, each of which is 5½in long and weighs about 1⅛oz, are made of solid steel rod with integral cups top and bottom.

I asked for information about the valves. Their sizes, across the port diameters, are $1\frac{3}{16}$in inlet and 1⅛in exhaust. A smaller exhaust valve runs more coolly than a bigger one, and leaves room for the larger inlet valve needed for letting the gas in quickly. Austenitic steel—actually, K.E.965—is used for the exhaust valves, since it is a material that maintains strength at high temperatures. Inlet valves are of Silchrome. Valve-guide material is phosphor-bronze, on account of its high coefficient of expansion; thus the guide is kept tight in the head when the head expands.

Valve Geometry

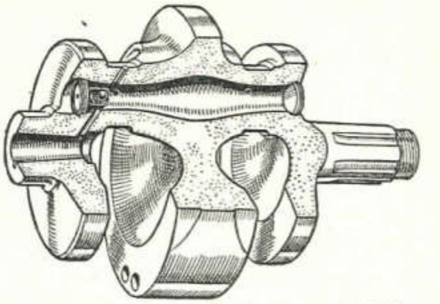
"What about valve geometry, tappet adjustment, etc.?" I asked.

"Angle between the valves is 80 deg. which is wide enough to provide a good flow and, at the same time, a compact combustion chamber. Valve springs are of the standard, double-coil type. Note the tappet adjustment, which is provided in the valve end of each rocker. Each lock-nut, being underneath the rocker-end and having a conical seating and a shallow saw-cut, is self-tightening. Each rocker spindle floats in the rocker and also in the end bearings, thus giving a kind of fully floating gudgeon-pin effect and spreading the wear. The rocker spindles are hollow, of course, to carry oil."

Discussion turned to the transmission, and I was told that, with the gear box bolted to the back of the engine there was, of course, all the advantage of unit-construction, but at the same time the box and the engine could be serviced as two separate units; also, since the primary drive centres were close, the wheel-base could be kept short in spite of the pivoted-fork type of spring-frame that tended to lengthen it.

"Why is a duplex primary chain employed?"

"Chiefly because it is particularly adaptable for the slipper tensioner used with that type of bolted-on gear box. A good point is that the tensioner is not sprung against the chain; oil will not, therefore, be kept out of the links. The chain is a ⅜in duplex and thus is quieter than would be a ½in single-row chain. It has straight-side links to suit the tensioner. Although the crankcase breathes through the timing-side mainshaft, the breather exit is outside the primary chain-case and so will not pass moisture into the case itself."



The one-piece alloy-iron crankshaft. Steel discs close the ends of the coring through the crankpins, and one of the discs incorporates a spring-loaded oil-release ball valve

"What about the lubrication system?"

"It is designed so that oil is fed positively to the big-ends, cylinder walls, valve rockers, cam tunnels, and timing case. Included in the system on its return side is a large, felt, full-flow filter. Instead of an external oil-tank, there is a ½-gal oil compartment in the rear of the crankcase."

Mr. Wilson-Jones pointed out that, because of this internal compartment, not only was there quicker warming up of the oil and therefore a full rate of circulation sooner, but also there was a complete absence of external oil-pipes.

At the bottom of the crankcase is a sump which the scavenge pump, of course, keeps dry. This sump is separated from the rest of the crankcase by a two-piece gauze screen—corrugated to provide a greater area and in order that flywheel draught will tend to push the oil through the gauze. Object of the gauze screen is not only to filter the oil, but also to prevent disturbance of the oil in the sump by flywheel draught.

"Why do you use coil ignition?"

"Coil ignition provides easier starting," was the answer. "Moreover, we wanted automatic advance and retard, and so a Magdyno was ruled out. We prefer coil ignition with a distributor to a separate magneto and dynamo because the former combination simplifies the timing gear and gives a more compact engine. If the engine was wanted for racing, it could be provided with a magneto. In fact, later a specification will be available that includes a base-mounted magneto, high-compression pistons, extra strong valve-springs, and high-lift cams without slow acceleration ramps."

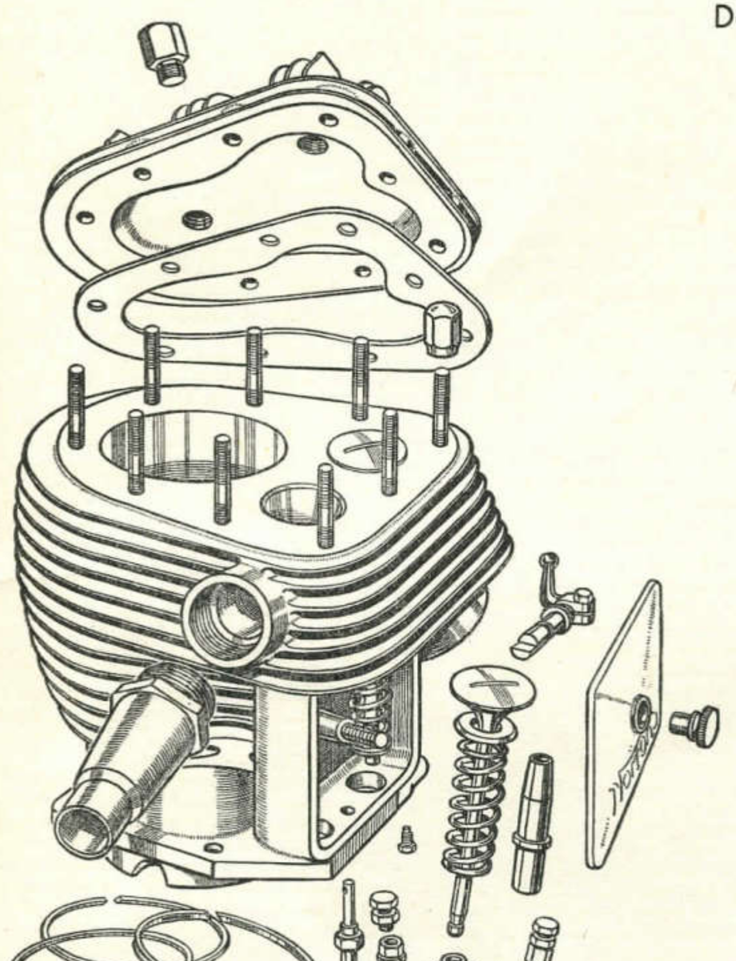
Having been told all these details of design, I said: "This twin of yours—it has a capacity of 496 c.c., and its bore and stroke are 64mm and 77mm respectively. What is the power output?" Mr. Wilson-Jones gave me the figures immediately. "The power output from the standard engine," he said, "is 25 b.h.p. at 5,500 r.p.m."

490 c.c. Model 16 H

Design Features of an Engine of Which Tens of Thousands Are in Use

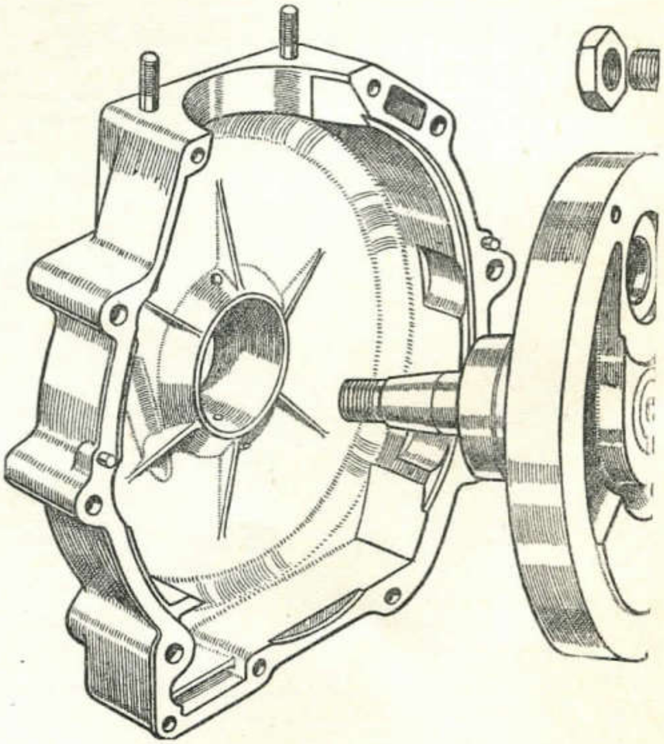
By "UBIQUE"

On page 41 willl be found illustrations of the post-war 16H



(Left) The cast-iron cylinder has a detachable head and is held to the crankcase by five studs. The drawing also shows the slightly domed alloy piston and details of the valve gear

(Below) Unusually large-diameter flywheels are a feature of the 16H engine. The crankcase castings are correspondingly large to provide ample clearance. Note the double gear-type oil pump, which is driven by a worm on the crankshaft



Side-valve Norton

MY first question to Messrs. W. Mansell and Gilbert Smith before I went to see the 16H engine in pieces was, "When did the type originate?" And then and there I put my foot in it, for none of us knew!

In the subsequent conversation, which wandered over many subjects, I don't think we ever established quite the exact date. However, there is no doubt that the parent "Model 16" existed prior to the 1914-18 war and, like the famous B.S. and B.R.S. models, it had a side-valve engine of the same bore and stroke and some of the features of the modern 16H.

We moved to a secluded office where we found an engine completely dismantled and Mr. E. M. Franks quite prepared for all my questions. I began, as usual, with the lowest part of the insides.

"I suppose those big flywheels account for the smooth, steady pulling of the 16H?"

"Yes, partly. They are 8in diameter and 1in thick at the rims. They are cast from a special grey iron having a fine grain, and we balance the rotating and 0.6 of the reciprocating weights."

"How are the mainshafts fitted?"

"Just pressed in on a very slight taper (0.003in per inch) and keyed."

"They look pretty hefty."

"Yes, they are 1in diameter, and are made of nickel steel, case-hardened."

"But you use 'complete' ball and roller races on the shafts, so why case-hardened?"

"To prevent any chance of wear or hammering between the inner races and the shafts."

On the drive side there is first a ball bearing (at the outside), then a spacing ring, and next a caged roller bearing. An identical roller bearing supports the timing side.

"Are there any special thrust washers?"

"We use pen-steel washers as shims to limit the total side-play to 0.005in."

"What an immense crankpin!"

"Yes, the roller track is $1\frac{7}{16}$in diameter and it is of $3\frac{1}{2}$ per cent nickel steel deeply case-hardened. The ends are slightly tapered—0.0015in per inch—and pressed into the flywheel bosses, where they are locked by nuts which, in turn, are locked by set screws."

It was then pointed out that the crankpin had no drilling for lubrication, but that the oil was flung by centrifugal force from a lead drilled in the flywheel directly into the end of the roller race. Of course, I said "Why?" And the answer was, "To prevent any chance of the surface 'picking up' at the orifice of the drilling."

"You see," I was told, "we employ a double-row crowded roller race with no spacing."

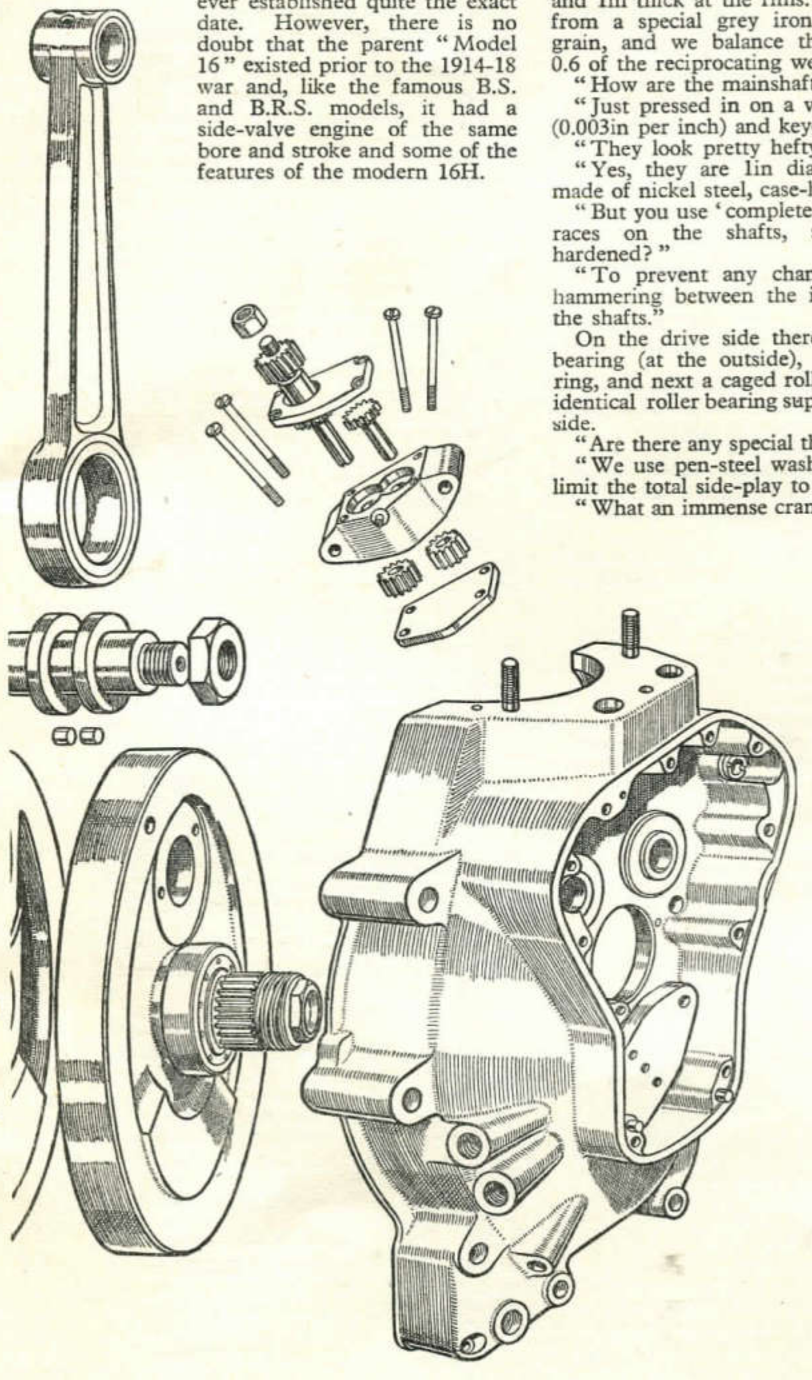
I did not ask why this system was used, because if Nortons adopt a mildly unusual practice, you may take it that the main reason is that it works!

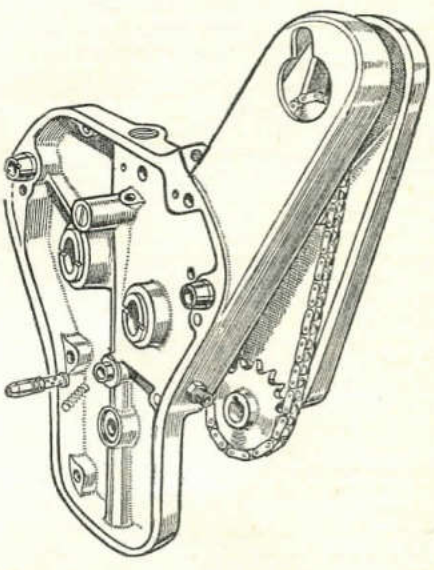
"Now what about the connecting rod?"

"It is a nickel-chrome steel stamping of about 70-ton tensile strength, and is just over two strokes length between centres."

"I see a separate outer race for the big-end is pressed in, and that the small-end eye is bushed, but is it fair to call it a *small*-end?"

"Well, the hole in the bush is $\frac{7}{8}$in diameter, and the bush itself is made of chill-cast phosphor-bronze, which has a





A spring-loaded gland in the timing-gear cover plate is a feature of the lubrication system. By means of this gland, oil is forced along the crankshaft into the big-end bearing very good grain. Actually, we use this material in all important plain bearings."

In this small-end fits a case-hardened nickel-chrome steel gudgeon pin, taper bored to save weight. It has a lapped finish and is located in the piston by spring-steel circlips.

As soon as I saw the piston I thought of the first Norton I had owned—a B.R.S.—for there were the same type of oil distributing grooves in the skirt and there were the close gudgeon-pin supports—not now brought close in by a deeply waisted piston, it is true, but by concave walls which also provide a surface relief round the gudgeon-pin bosses. Nor, of course, are the modern pistons of cast-iron, but of a low-expansion aluminium-alloy having a high silicon content. The piston head is slightly domed (as were the old ones) to give a compression ratio of 5 to 1, and there are two narrow pressure rings and a "Superslot" scraper ring.

The halves of the crankcase are die-cast in a suitable aluminium-alloy, and as they have plenty of clearance from the big flywheels the castings are large and hefty.

"How thick are the walls?" I asked.

"The thickest part is round the bearing bosses, but the walls taper to $\frac{7}{32}$in at the thinnest part near their maximum diameter."

"I see that there are internal webs from the bearing housings to the walls. Do they cause oil drag?"

"No, there is plenty of clearance, and anyhow there is no oil worth worrying about near the centre of the case."

"How are the halves held together other than by the frame bolts?"

"They are positioned by a register and two dowels, and are held by three small bolts and a set screw."

"Why those cut-out segments?"

"Just to save weight. You will see, also, that below the sump there is a small sludge trap which can be drained by removal of a set pin."

"What is that hole below the drive-side bearing housing?"

"It registers with a corresponding hole in the crankshaft when the piston is descending, and thus forms a timed breather, the vapour escaping to the atmosphere."

"Now for the cylinder. Is there anything special about the material?"

"It is just a good close-grained iron casting with a Brinell hardness of from 200 to 210."

"Are the walls very thick?"

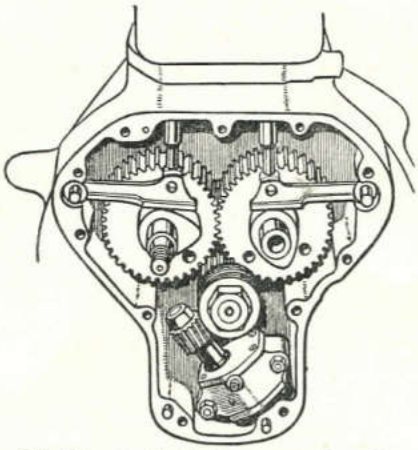
"About $\frac{1}{4}$in near the base, but thicker near the top, so as to provide a good heat path. The fins, pitched at $\frac{3}{8}$in, are about $1\frac{1}{2}$in deep near the top."

"I see that the valve-spring enclosure box is cast with the cylinder; do you find it has any marked effect on cylinder temperature?"

"No, if you look you will see there is an air space between the box and the walls."

The cylinder is held down by five studs, one of which lies inside the valve-enclosure box, and is formed with an extension so drilled that jets of oily vapour are blown on to the valve stems from the timing case.

Before leaving the cylinder casting I should mention that the spigot is cut away to clear the swing of the connecting rod, and that the bore has a honed finish. The valve ports are ground out, largely, I was told, to simplify decarbonization, though the process certainly helps to promote a smooth gas flow as well.



The drive for the timing gear is from the crankshaft to the exhaust camshaft and thence to the inlet camshaft. A worm drive is used for the oil pump

The broad, flat faces, surface ground, between the cylinder and head are separated by a composite joint.

"What is the joint made of?"

"Graphited asbestos reinforced by thin steel plate and having a thin copper flange on the top."

"Why on the top?"

"To prevent the gasket sticking to the head and thus being damaged during a 'decoke'."

"What about the cylinder head?"

"It is made of the same material as the cylinder barrel, and is held down, as you see, by nine $\frac{3}{8}$in studs."

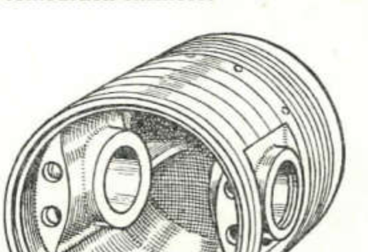
"Why so many and so large?"

"In joining two faces of irregular outline and subject to varying temperatures it is almost impossible to have too many fixing points if distortion is to be avoided."

"Why are the tips of the vertical head ribs ground flat?"

"Purely for location when machining."

"What is special about the formation of the combustion chamber?"



This view of the alloy piston shows how the casting is relieved at the bosses. Two narrow pressure rings and a scraper ring are employed

"Well, the piston has only a working clearance from the head, so that the main part of the chamber is above the valves, and in the throat."

An 18 mm plug is placed over the inlet valve, and there is a compression plug in the middle of the head, which enables a rod or wire to be introduced for timing purposes.

"What valve steel do you use?"

"Jessop's H.3—a material which is highly resistant to oxidization at high temperatures and also retains a high tensile strength in the same circumstances. The inlet and exhaust valves are identical in design and material."

The valve heads are slightly domed and the big radius below the heads is followed by a gradual taper which merges imperceptibly into the valve stem at the level of the top of the valve guide. The guides are made of oil-hardened cast-iron, the bores being lapped and the outer surface ground from the bore to ensure concentricity. They are lightly pressed into position, but are additionally retained by the valve springs, which butt against a collar shouldered on to the guides. The collars keep the valve springs clear of the cylinder casting, and thus avoid unnecessary heat. The usual type of split collet holds the spring cup, but only one spring per valve is used.

"Why only one spring?" I asked.

"There is no need for two on a side-valve engine since in a case of spring failure the valve cannot drop into the cylinder."

"What spring tension is used?"

"About 65 to 70lb with the valve seated."

Each valve has a throat diameter of $1\frac{1}{2}$in, and a seat width of $\frac{3}{32}$in. The timing is: Inlet opens 25 degrees early; closes 45 degrees late. Exhaust opens 60 degrees early; closes 30 degrees late. The ignition setting is 35 degrees early at full advance. The lift of the cams is 0.339in, and the tappet clearances (cold) are: Inlet 0.002in, exhaust 0.004in.

Tappets of K.E.2301, which are hardened and ground to $\frac{1}{4}$in diameter, work in chill-cast phosphor-bronze guides and contact with internal rockers stamped from the same material, hardened on the working faces only. The pivot pins on which the rockers swing are also hardened and ground, and the centre portion of each pin is serrated and pressed into the rocker eye.

I noticed that the rocker bushes in the timing cover are unusually thick and tapered, so asked the reason.

"These bushes serve as locating dowels for the cover plate," I was told, "and are assisted by two plain dowel pins lower down the cover plate."

The faces of the rockers which contact with the cams are flat and, with the special cam forms, provide an approximation to constant acceleration and deceleration of the valves.

"Are the cams separate from the shafts?"

"Yes. Each cam and gear wheel is made in one piece from K.E.2301 and hardened, and the shafts, also case-hardened and ground, are pressed in and keyed."

"Why the holes in the gear wheels?"

"You will notice that they are on the same side as the cams, thus removing weight on that side and helping to balance the cam lobes. Both the shafts are hollow, and they rotate in large chill-cast phosphor-bronze bearings."

"I see that the drive is from the crankshaft to the exhaust camshaft, and thence to the inlet camshaft. Is that arrangement preferable to a direct drive to each shaft?"

"Yes, we find that it is distinctly less noisy owing to the more continuous loading of the gears. Also, we use wide gear wheels—half-inch—which reduces noise and provides long life."

On the end of the inlet camshaft is a taper and keyway for attachment of the Magdyno drive sprocket. The chain employed is of ⅜in pitch and ⅛in wide.

Now for the lubrication system. The 2-to-1 wheel on the crankshaft is held in place by a nut (left-hand thread) on which is formed a three-start worm for the purpose of driving the double gear-type oil pump. The pump is entirely enclosed in the timing-gear chest, and all leads are internal except for those to and from the oil tank.

I asked the capacity of the pumps.

"The delivery pump circulates one pint per minute at 4,500 r.p.m., and the capacity of the scavenge pump is just twice as large."

"How is the oil filtered?"

"There is a gauze filter in the oil tank on the suction side of the delivery pump, and that is all that is necessary."

I asked a lot of questions about the oil circulation system, but for the sake of simplicity I am going to try to give a summary of the answers in consecutive form.

Piston Lubrication

Oil is pumped through a nozzle on the pump-body casting to the timing-gear cover, the joint being made by a fibre washer or washers so arranged as to stand proud of the face of the timing chest by about 0.015in. Thus, when the timing-gear cover plate is bolted home the joint is under pressure and there is no leakage.

Having reached the cover plate, the oil enters a short main lead from which the various feeds branch at convenient intervals. First, oil enters the timing side of the crankshaft through an ingenious spring-loaded gland. The central part of this gland consists of a bronze jet having a $\frac{3}{64}$in hole and a nose machined to the same angle as the seat in the crankshaft, against which it is held by a light spring. This jet is free to rotate in a steel nut screwed (left-hand) into the cover plate. Thus oil is forced into the crankshaft through the web of the flywheel and into the big-end, as explained earlier.

Another lead passes back to the crankcase casting, through the base of the cylinder to a hole drilled in the wall just below the travel of the lowest piston ring, thus providing direct lubrication for the thrust side of the piston. The supply of oil to this point is metered by the size of the holes and no adjustment is needed.

From the main lead, also, there is a direct feed to a ball release valve from which excess oil escapes to the timing gears. The adjustment of this release valve is set at the factory and should not be altered. The ball-valve release is in the face of a rectangular pad cast with the cover plate, and so arranged as to clear the timing wheels by a matter of a few thousandths of an inch only. Thus the released oil feeds to the point of mesh between the inlet and exhaust camwheels, and cannot readily escape without lubricating the gears most thoroughly.

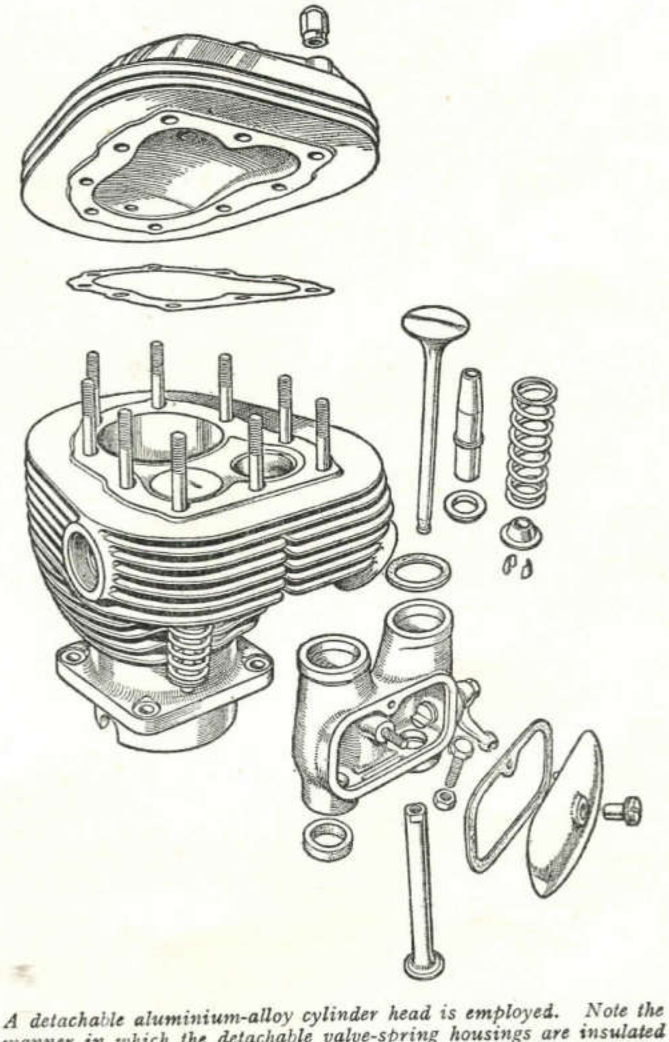
Oil is allowed to accumulate in the timing case until it reaches the level of the crankshaft, so that the crankshaft pinion and the oil-pump drive are partially submerged. After reaching this level it overflows to the crankcase and to the sump. The scavenge pump draws oil from the sump at a point above the sludge trap, and returns it to the tank through an external lead.

And now for a last look round to see if I have missed anything. Ah! There is that nicely tapered induction pipe, screwed into the cylinder casting. It is there primarily so that the carburettor may clear the Magdyno, but it serves another purpose in that it provides a gradual taper from the carburettor choke to the inlet port. I also like that highly polished timing cover, because it is so much more easy to clean and thus it is practical as well as ornamental.

Power? Well, Nortons are notoriously modest about the power output of their engines, but I was told that the sustained power of the engine was well up to that of equivalent side-valve engines and that the machine had a maximum performance of 65 to 68 m.p.h. That, after all, is plenty fast enough for most folk who place railway-train reliability before all else.

Incidentally, the engines of the Norton machines supplied to the Army in such large numbers are based on this type; the differences are very slight indeed.

THE LATEST 16H

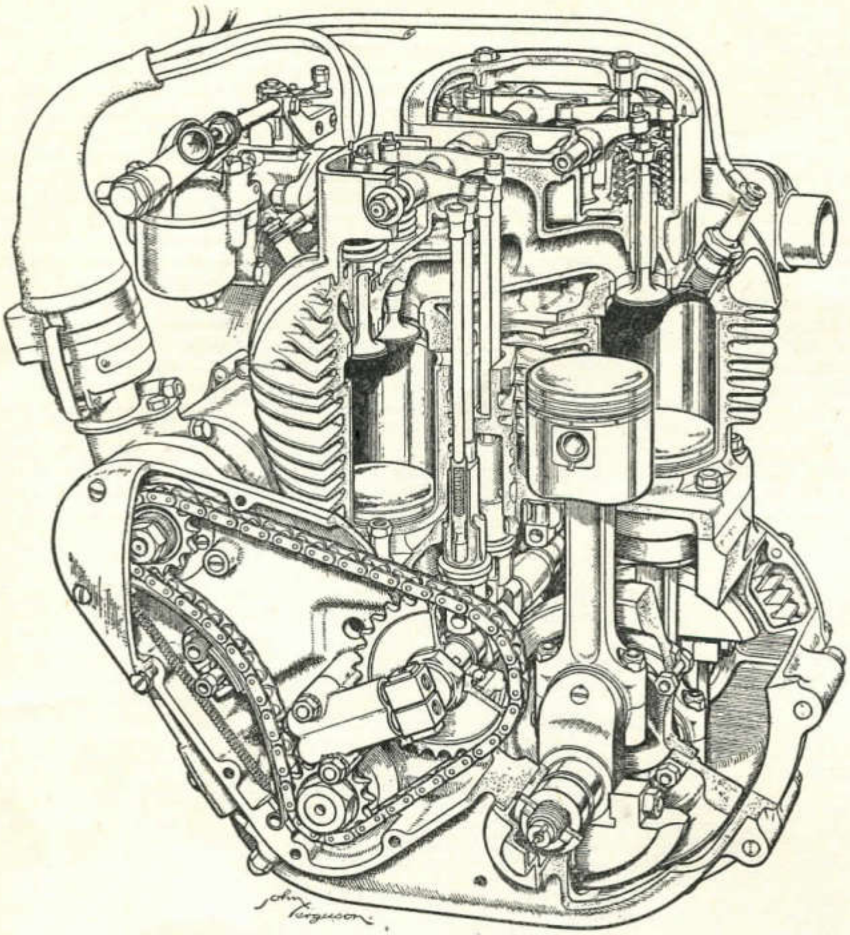


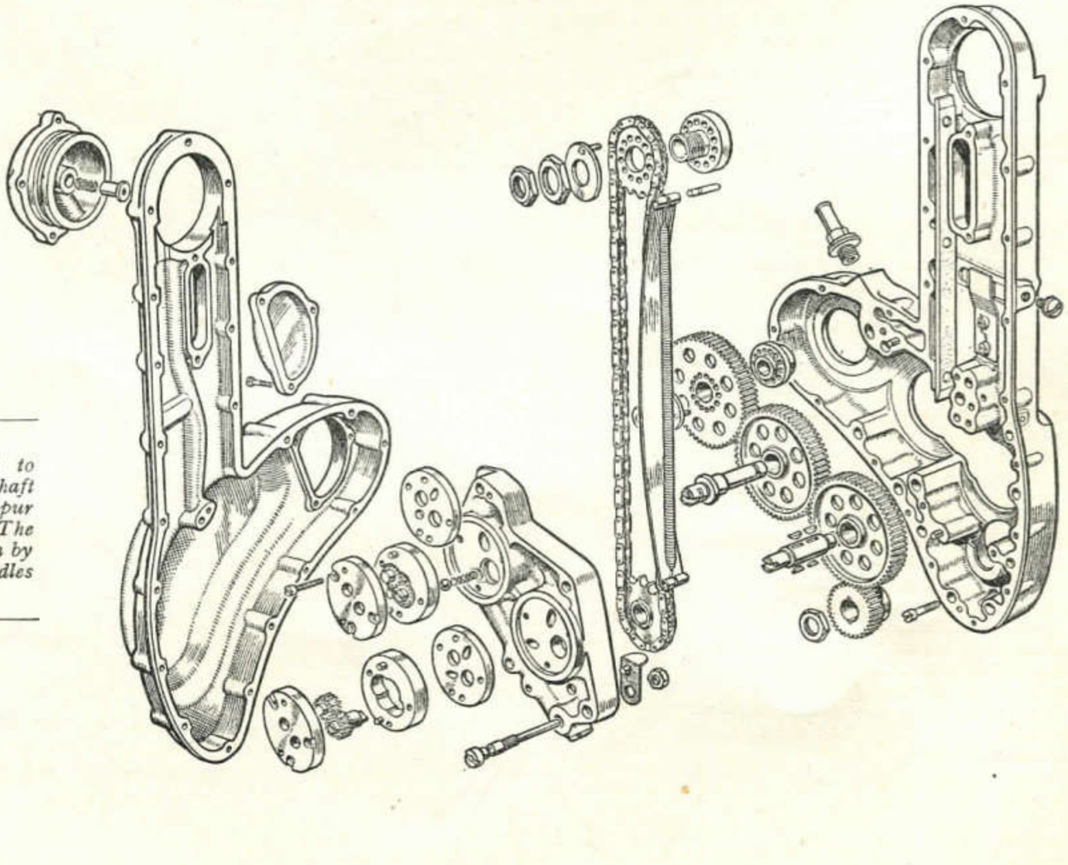
A detachable aluminium-alloy cylinder head is employed. Note the manner in which the detachable valve-spring housings are insulated from the cylinder and the division between exhaust- and inlet-port finning

"Light Alloy" Ariel Square Four

Revised Version of Engine Discussed on Page 20

In the redesigned Ariel Square Four engine, extensive use has been made of light alloys. This and the change to coil ignition have resulted in a saving of nearly ½cwt. over the earlier model (pages 20-23). Cylinder block and cylinder head casting are both in aluminium-alloy ; each cylinder has an iron alloy liner The rocker boxes are integral with the head casting

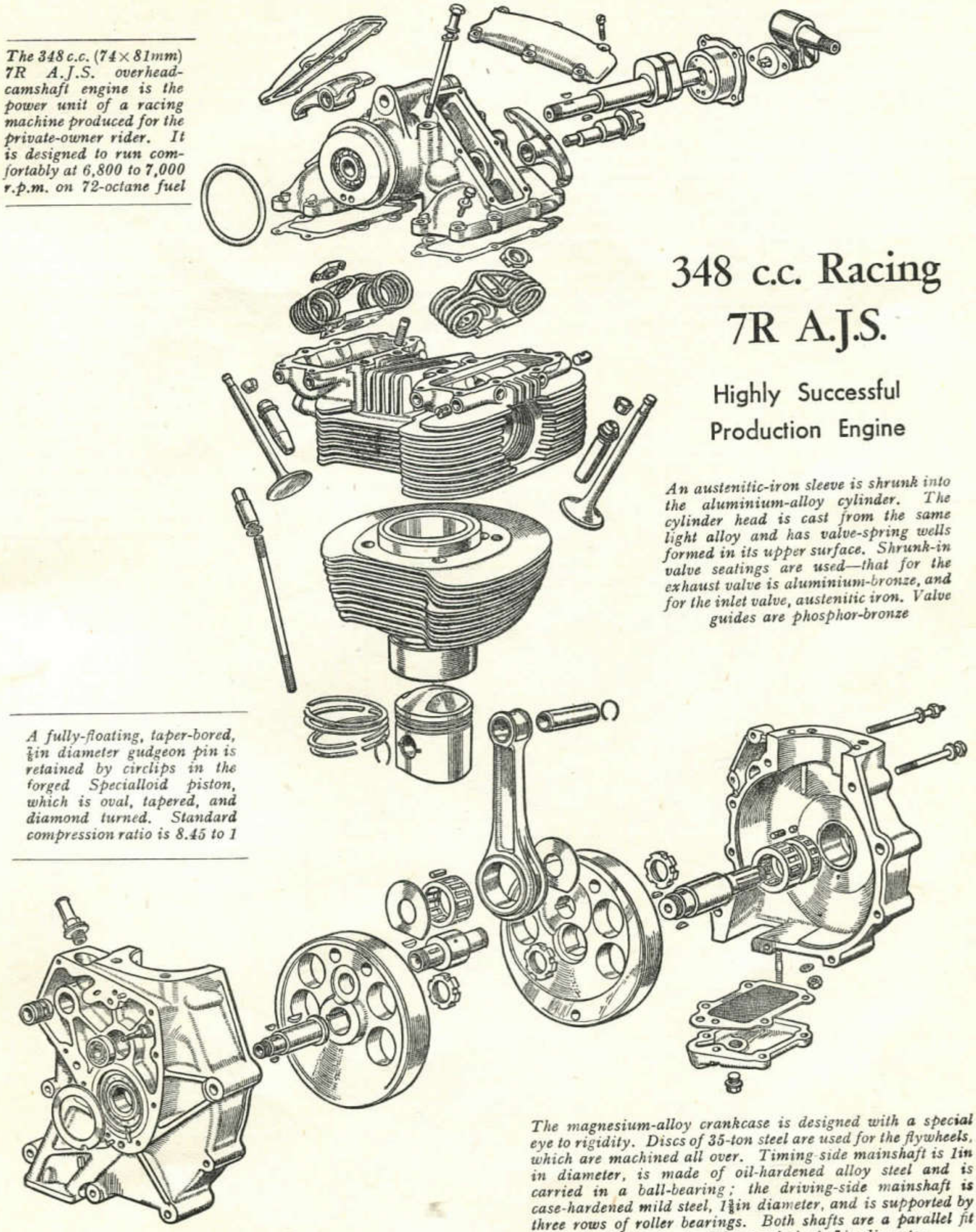




A chain is employed to drive the overhead camshaft of the 7R A.J.S. and spur gears for the magneto. The two oil pumps are driven by the timing-pinion spindles

348 c.c. Racing 7R A.J.S.

Highly Successful Production Engine



The 348 c.c. (74 × 81mm) 7R A.J.S. overhead-camshaft engine is the power unit of a racing machine produced for the private-owner rider. It is designed to run comfortably at 6,800 to 7,000 r.p.m. on 72-octane fuel

An austenitic-iron sleeve is shrunk into the aluminium-alloy cylinder. The cylinder head is cast from the same light alloy and has valve-spring wells formed in its upper surface. Shrunk-in valve seatings are used—that for the exhaust valve is aluminium-bronze, and for the inlet valve, austenitic iron. Valve guides are phosphor-bronze

A fully-floating, taper-bored, ⅞in diameter gudgeon pin is retained by circlips in the forged Specialloid piston, which is oval, tapered, and diamond turned. Standard compression ratio is 8.45 to 1

The magnesium-alloy crankcase is designed with a special eye to rigidity. Discs of 35-ton steel are used for the flywheels, which are machined all over. Timing-side mainshaft is 1in in diameter, is made of oil-hardened alloy steel and is carried in a ball-bearing; the driving-side mainshaft is case-hardened mild steel, 1⅜in diameter, and is supported by three rows of roller bearings. Both shafts are a parallel fit in the flywheels. The crankpin is ⅞in diameter

Model LE

GEORGE WILSON Probes into the "Reasons Why" of the Lightweight Mount—and CHARLES UDALL, Devel

"THE component parts of the LE engine are all straightforward. It is the fact that they have been 'gathered together'—shall we say?—in the way that they have that makes the machine appear unorthodox. It is true to say that in the complete machine not a single departure has been made from what is regarded to-day as normal engineering principles; obviously to depart from these would have spelt trouble—in large capital letters!"

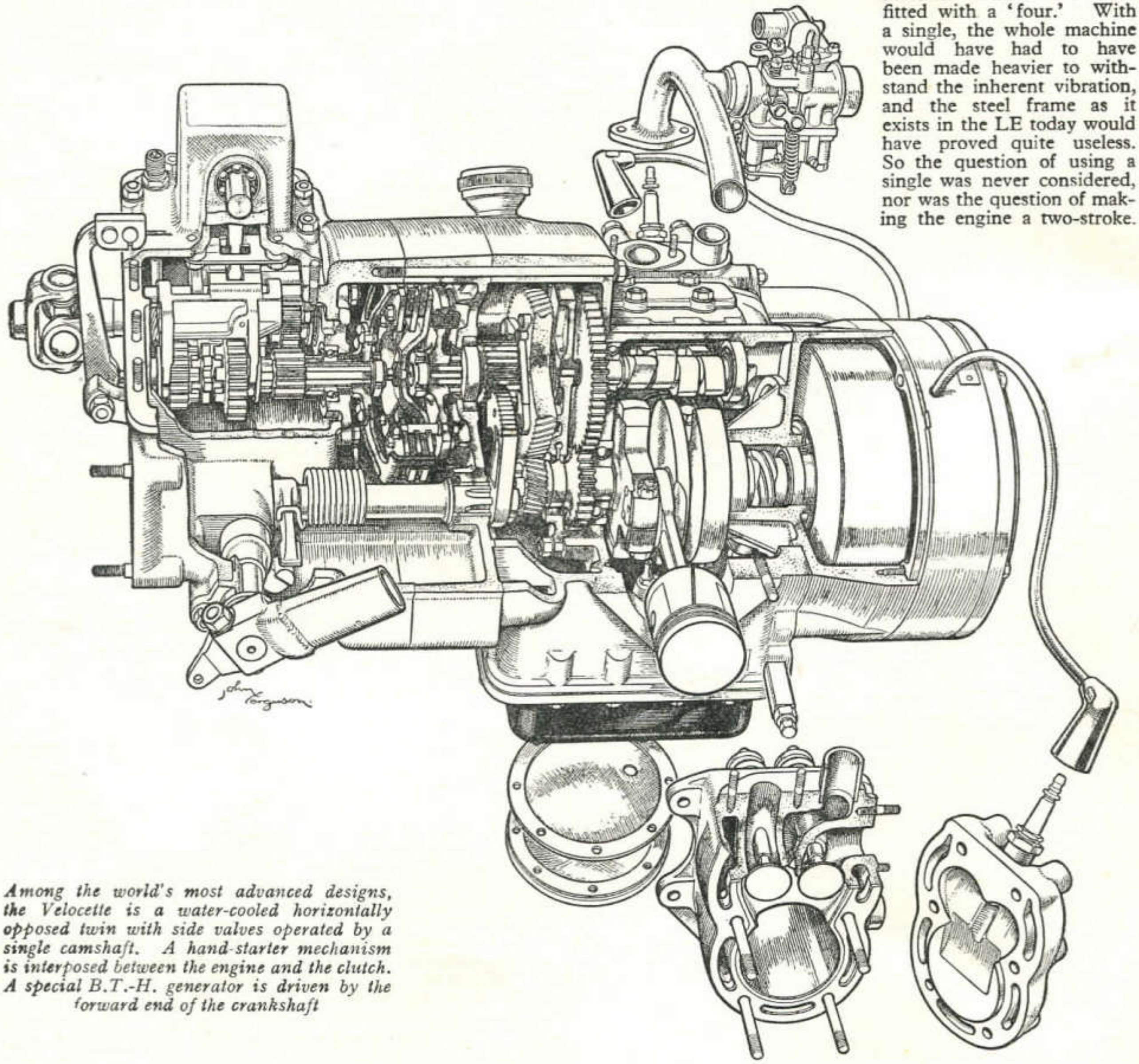
Thus spoke Mr. Charles Udall, Velocette Development Engineer, when I called at the works to discuss the whys and wherefores behind the ingenious design of the 150 c.c. LE Velocette—the most revolutionary lightweight of the day.

"In discussing the LE unit," he continued, "I'm afraid that it may be necessary to depart from the strict confines of your 'Modern Engines' series. You see, the LE is a conceived-as-a-whole design. The engine, gear box, propeller-shaft, and bevel box all form an integral unit; an entity; a single unit designed to do a specific job. And it is impossible to discuss one 'section' of the unit without bringing in a sister section."

From this stimulating gambit we passed on to a discussion that carried us non-stop through an absorbingly interesting afternoon.

My first question was a multiple one: "Why did you decide on a flat-twin and why, indeed, on a twin at all? Did you ever consider employing a single—a two-stroke, for instance?"

"Well, first of all," replied Mr. Udall, "one of the primary aims was the elimination, in so far as was possible, of all forms of vibration. There are only three types of engine which could be considered, and of those only the flat-twin is really suitable for use in a small-capacity motor cycle. The four-cylinder engine also, of course, eliminates vibration, but obviously the LE is not the sort of machine which could be fitted with a 'four.' With a single, the whole machine would have had to have been made heavier to withstand the inherent vibration, and the steel frame as it exists in the LE today would have proved quite useless. So the question of using a single was never considered, nor was the question of making the engine a two-stroke.



Among the world's most advanced designs, the Velocette is a water-cooled horizontally opposed twin with side valves operated by a single camshaft. A hand-starter mechanism is interposed between the engine and the clutch. A special B.T.-H. generator is driven by the forward end of the crankshaft

Velocette Twin

Velocette Design—the 149 c.c. Model, Forerunner of the Similar 192 c.c. opment Engineer, Provides the Answers

"Again," Mr. Udall continued, "we come to my point about one thing leading to another. Since one of the chief aims, as I have said, was the elimination of vibration, a flat-twin was decided upon. Since the unit had to be as simple as possible, and large mileages with a minimum of attention were an important proviso, side-by-side valves were preferred. An objection to overhead-valves was that even in a small-capacity engine, the width would be considerably increased, making the engine much more vulnerable. The cylinder heads, in fact, would probably have projected beyond the legshields.

"Linked with the question of ease of maintenance was the decision to use shaft-drive. True, shaft-drive is more expensive than chain. But having a shaft greatly simplifies maintenance for the non-mechanically minded rider, who may be using the machine every day. And the chief aim, after all, was to provide for low maintenance cost as opposed to the lowest production cost.

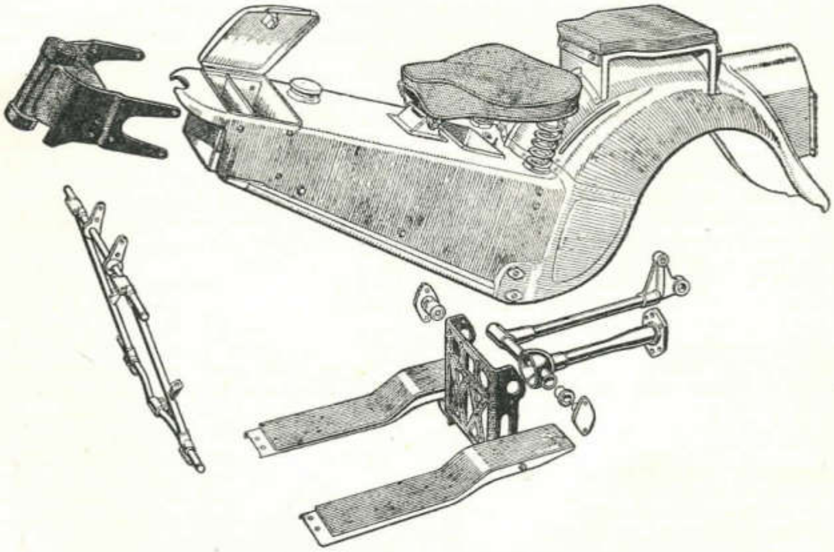
"The decision to employ shaft-drive arrived at, mounting the engine transversely in the frame was a *sine qua non.* Cooling? Water-cooling was the obvious answer for two reasons: the first was that it is possible to obtain a much higher degree of mechanical quietness when the cylinders are shrouded by water jackets. Taking the conception of the machine as a whole again, legshields must be regarded in the light of essentials, and if air-cooling had been employed, gaps in the shields for the air stream would have been necessary. And that, of course, would have affected weather protection. Another point was that the engine temperature of a small side-valve unit is more easily controlled by means of water-cooling."

Going into his last point in greater detail, Mr. Udall pointed out that had air-cooling been employed, it would have been next to impossible to incorporate air passages round the exhaust ports.

"The manufacture of engine, clutch, gear box, and final drive as a single unit promised simplification in assembly and manufacturing problems which could not be ignored. Hence the unit construction."

In one fell swoop, as it were, Mr. Udall had answered about a dozen of the points listed on the rough questionnaire I had prepared. I decided I had better scrap it right away, and deal with each field of inquiry as it cropped up!

Leaving generalities, Mr. Udall went on to point out that the crankshaft is of the two-throw type with the cranks at 180 deg. Since the aim was to keep the offset on the cylinders as low as possible in order to reduce the out-of-balance couple to a minimum, it was desirable to keep down the width of the big-ends. Thus roller-bearings were used. Had plain bearings been adopted, the cylinders would have required to be considerably more offset than they are now, since, in order to achieve the desired load-carrying capacity, considerably wider bearings would have been needed.

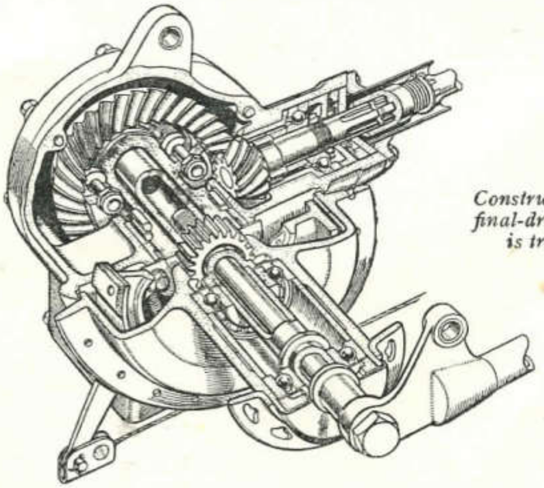


Main backbone of the frame is a 22-gauge sheet-steel pressing, to which the wide rear mudguard is welded

The rollers in the big-end bearings are uncaged. There are 28 rollers per bearing. The size of the big-end track on the crankpin is 1in dia. When talking of the big-end track, Udall was referring not to the crankpin itself, but to the hardened sleeve which is pressed on the crankpin.

The obvious question to all this was: "But why use these sleeves at all—why not a plain, hardened pin of larger section and grind the bearing surface?"

"Ah!" said Charles, "that requires some explanation. As you can see, the crankpins and crank discs are a one-piece forging. The metal used is a 3½ per cent nickel steel, in fact, B.E.S.69. This is a steel with a high tensile strength and one that it also quite ductile. In order to minimize the risk of fracture, and avoid cracks in the angles formed by the pin and disc, these corners have to be radiused. And, of course, since a roller bearing cannot bear on a surface with radiused ends, the big-end tracks, or sleeves, have their inner ends likewise radiused to allow them to be pressed up close to the cheek of the crank disc. An incidental point is that even if it were possible to have the bearings running



Constructional features of the compact final-drive unit. Drive to the rear wheel is transmitted by a series of dogs direct on the crankpin, it would not be possible to use B.E.S.69, since the material cannot be hardened to the necessary degree."

"I see, and what is the material used for the tracks?"

"It is carbon-chrome steel, turned from bar material, heat-treated and then ground. Incidentally, the sleeves are approximately ⅛in thick."

I drew Mr. Udall's attention to the crankshaft bob-weights and asked: "Why are bob-weights fitted since, surely, with this type of engine, the primary out-of-balance forces are nil?"

"A good point," answered Charles with a smile. "I grant you that, as the piston and connecting rods in a flat-twin move at the same speed in opposite directions, their inertia forces cancel each other out. But owing to the fact that the cylinders are offset in relation to one another, there exists a slight out-of-balance couple. And this *can* be reduced by adding bob-weights to the crankshaft. The effect is to reduce the couple in the horizontal plane and introduce a rather higher couple in the vertical plane; but since a motor cycle is very much stiffer in the vertical plane, its effect is nothing like so marked. In other words, it is much better to have the couple in the vertical plane than in the horizontal."

"And how are the bob-weights fitted to the crankpins?" I asked.

"The pins are a push fit into the bob-weights. They are locked up by a clamp bolt and lock nut. Then the pins and bob-weight are drilled in position and round, hardened dowels pressed in."

"With this layout the attractions of adopting the car practice of a combined flywheel and clutch at the rear of the engine seem too good to miss, yet you have ignored them. Any special reason for doing so?" I asked.

"The present arrangement with the flywheel at the front is much better, since, with the existing layout, there is a primary reduction gear between the mainshaft and the clutch. With the clutch running at roughly one-third engine speed, we have a slow-running gear box. This reduces the inertia of the clutch and other rotating parts and makes the gear-change easier."

"Fair enough. Is there anything extraordinary about the main bearings?"

"No, they are perfectly standard ball bearings at both ends with a plain, steady bearing on the driving shaft. It was decided to use ball bearings so that there would be the minimum resistance to starting. The diameter of the ball journals is ¾in."

"What material is used for the pistons?"

"They are Y-alloy die-castings; rather unusual in so far as they use a one-piece core in the die. Normally a piston is constructed as a die-casting with anything up to nine separate pieces in the core. Because of the shape of the bosses, the core has to be collapsed when the piston is cast. The LE pistons are made in such a way that the bosses are 'Dee'd' up the piston crown."

I noted that the gudgeon-pin bosses were situated roughly half-way down the piston skirt. "Why is that?" I asked.

Charles replied: "In order to get a proper distribution of load on the piston skirt. If the gudgeon pin is carried high up in the skirt immediately below the slotted oil-control ring, there is intense pressure just at that point and it *can* lead to seizure. Redistribution of the load makes it possible to use smaller clearances. We use 1½ thou. at the skirt."

"Is the camshaft a forging?"

"Yes, it carries four integral cams. The material is ordinary, case-hardening mild-steel and the cams are case-hardened. The shaft is carried on a ball journal at each end. Diameter of the bearings is $\frac{5}{16}$in bore."

I picked up one of the tiny 10-mm sparking plugs and inquired: "Why use such small plugs?"

"The reason is that you can get better water passages round a small plug than you can with a large one, and also they are more in proportion with a small head."

"I note that the plugs screw directly into the aluminium-alloy head. Why use light-alloy heads when the engine is water-cooled?"

"It is generally agreed that light-alloy heads give improved cooling. One can use a slightly higher compression ratio than with an iron head and, of course, there is the advantage of the weight-saving."

I remarked on the fact that the valves were inclined to the bores. Was that as a result of using only a single camshaft or was it also, perhaps, done purposely, in order to get more water round the valve seats?

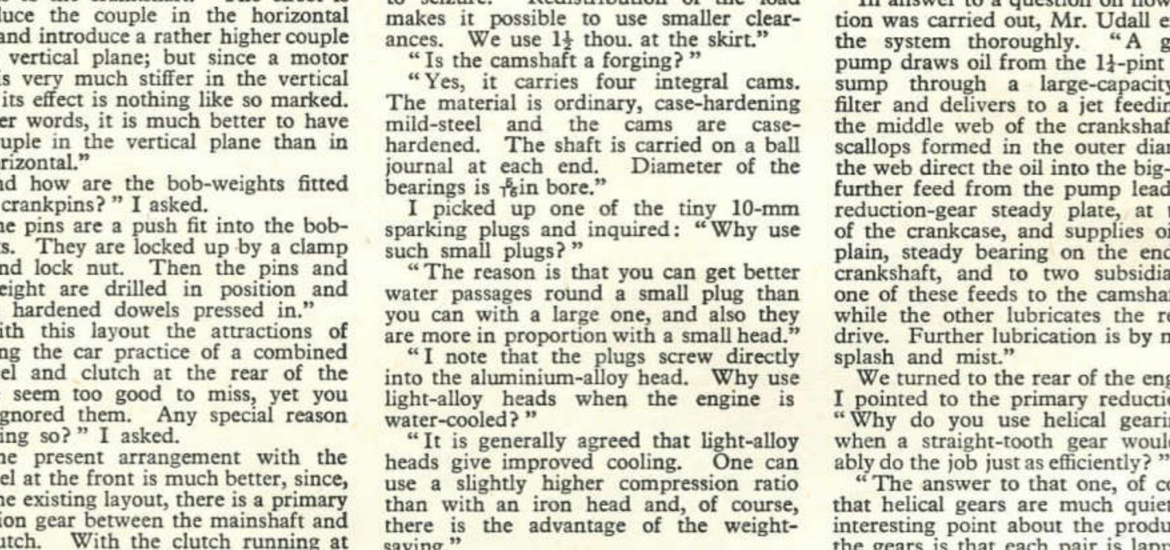
"Yes, those are the answers. The valve seats are machined in the cylinder casting. Valve-guide material? Plain cast-iron, pressed in. The material used for the valves is normal Silchrome valve steel. Inlet and exhaust valves are made from the same material and the sizes are identical, diameter across the heads being $\frac{13}{16}$in. The compression ratio is 6 to 1 Valve springs are of ordinary helical type of 35lb seated strength. Cotters are of the straightforward split type of orthodox design.

"Long tappets of square section with radiused ends are used, and tappet bushes are of sintered cast-iron pressed into the crankcase. Why square-section tappets? Because we wanted to use the widest tappets and cams possible in order to reduce wear to a minimum."

In answer to a question on how lubrication was carried out, Mr. Udall explained the system thoroughly. "A gear-type pump draws oil from the 1¼-pint capacity sump through a large-capacity gauze filter and delivers to a jet feeding oil to the middle web of the crankshaft. Two scallops formed in the outer diameter of the web direct the oil into the big-ends. A further feed from the pump leads to the reduction-gear steady plate, at the rear of the crankcase, and supplies oil to the plain, steady bearing on the end of the crankshaft, and to two subsidiary jets: one of these feeds to the camshaft gears, while the other lubricates the reduction drive. Further lubrication is by means of splash and mist."

We turned to the rear of the engine and I pointed to the primary reduction gear. "Why do you use helical gearing here when a straight-tooth gear would probably do the job just as efficiently?" I asked.

"The answer to that one, of course, is that helical gears are much quieter. An interesting point about the production of the gears is that each pair is lapped on a special machine. This ensures the high degree of accuracy which is essential to



Layout of the hand-starter, clutch, gear box, shaft and bevel pinion really quiet running. It is a procedure used quite a lot in the car world."

"What material is used for the gears?"

"It is a 3 per cent nickel-chrome-molybdenum steel of 70-80 tons tensile strength."

"Is it used because of its toughness?"

"The answer to that is 'yes'—partly; but the real reason it is used is to give a high-core strength to the teeth."

"With this method of unit construction," I asked, "do you have any troubles owing to the heat transference to the clutch?"

Charles answered that he had experienced none at all. The friction plates themselves are of a high-fade-point material—one which, in other words, can withstand very much higher than normal temperatures before it loses its frictional properties.

"What is the material?" "It is a Ferodo material known as V.M.41."

"I note that you have interposed the starting mechanism between the clutch and the engine. Why?" "The real reason for that, of course, is to make control easy in difficult circumstances. For instance, if, with the normal starter, the engine stalled during a get-away, it would mean selecting neutral, starting the engine, then re-engaging the gear before getting under way. In this case, all that is necessary is to lift the clutch lever, start the engine and set off."

"How is the reduction helical fitted to the mainshaft? Is it keyed or fitted on a taper?" I asked.

"It is actually pressed on to the present shaft, but it used to be held by splines. It is now pressed on to a very much larger shaft."

"What is the interference?" "1-1½ thou." "How is it pressed on?" "There is a very slight taper in the bore of the gear and on the shaft, which means that the two can be pushed together so far, and then the operation is completed in a press."

Pointing to the clutch, Mr. Udall continued, "The clutch, on the other hand, is fitted on splines on the end of the reduction gear shaft and the shaft is carried in one ball journal and one plain bearing."

"You use a two-plate clutch," I cut in. "Is there any special reason for that?"

"Well, yes," he replied. "A single-plate clutch of this dimension would have required a much heavier spring pressure to transmit the power. This, of course, would have meant very much heavier clutch operation, and the idea was to get the operation as light as was humanly possible. We found that with the two-plate clutch we had the ability to transmit all the power we wanted with the desired lightness of operation."

"What are the outstanding features of the gear box?"

"Well, it is a constant-mesh, offset box of normal type, but not, of course, a normal gear box as we know it in the motor cycle world. It is one in which the drive is taken in on one shaft and the output taken from the other; in other words, it is not a straight-through box, and the drive is always transmitted by one pair of gears only in any gear."

"Yes, I see that," I replied, "but is there any reason for using an offset box apart from that of achieving the necessary offset required for the shaft-drive?"

"Yes," Mr. Udall pointed out, "there is the additional advantage of low frictional losses since, in the indirect ratios, the power is being transmitted, as I have said, through only one pair of gears—as opposed to two pairs in the normal type of box."

"What material do you use for the gear pinions?" I asked.

"It is nickel-chrome steel, exactly as used for the reduction helicals, and it is used for the same reasons."

"What are the shafts made of?" "It is a nickel-chrome case-hardening steel, known as E.M.39." "Any special points about its heat-treatment?" "None whatever. It is a perfectly normal case-hardening steel, chosen for its high-tensile strength."

Asking what material was used for the propeller shaft, I was told that it was nickel-chrome oil-hardened steel, also employed because of its high tensile strength—which is about 65 tons per sq in. The shaft operates between a Hardy-Spicer, needle-roller universal joint at the front end, and a splined muff-coupling at the rear.

"What size of bearing is used for the bevel pinion?"

"It is a ¾in duplex type; a special thrust bearing carrying thrust in both directions. Normal spiral bevels are employed."

"How is the bearing locked?" "Quite simply," I was told. "It is shrunk into the housing and locked in position by a screwed ring. The bevel pinion is also carried by a needle roller bearing situated as close up to the teeth as it will go."

"Any special points about the spiral-bevel crown wheel?"

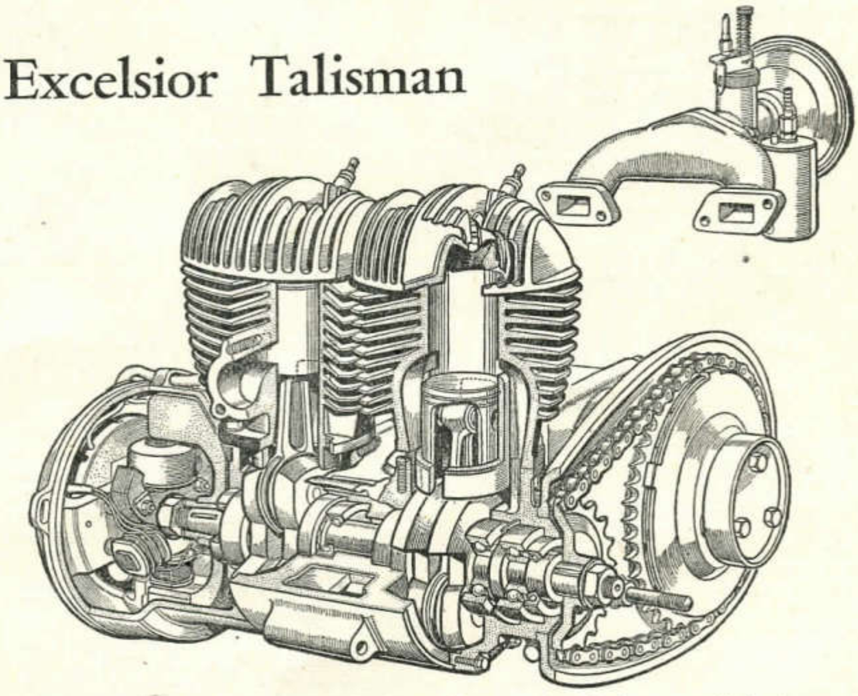
"Not really. It is a perfectly normal type, carried by one needle roller bearing and one ball bearing. There is provision for adjustment in the mesh, which is carried out at the factory. What might be described as an unusual feature is that, since it has a fairly high ratio, it is possible to use a very small bevel box. Drive to the rear wheel is transmitted by a series of dogs."

All that remained to discuss was the ignition and carburettor.

Dealing with the ignition set first, it will be recalled that a B.T.-H. generator is employed. Situated immediately forward of the forged-steel, dished flywheel, and partly shrouded by the dished portion, the generator unit is driven on a forward parallel extension of the tapered shaft by a Woodruff key. The casing is held by four bolts extending from the flywheel housing and easily accessible from the front of the engine. In the casing are contained the D.C. generator, h.t. coil, distributor, contact-breaker and auto-timing device, cut-out and condenser—all compact, all concealed, all accessible in a single compartment.

The carburettor? It had to be one that would provide the perfect tickover. The engine must spring to life at the lighest pull on its starting handle, and it must respond to the most ham-fisted opening up. The result is the special fixed-jet carburettor. It contains only one moving part—a butterfly throttle, and it features a separate starter jet system with in-built push-pull operation. This furnishes the correct mixture for starting and dispenses with the need for a tickler.

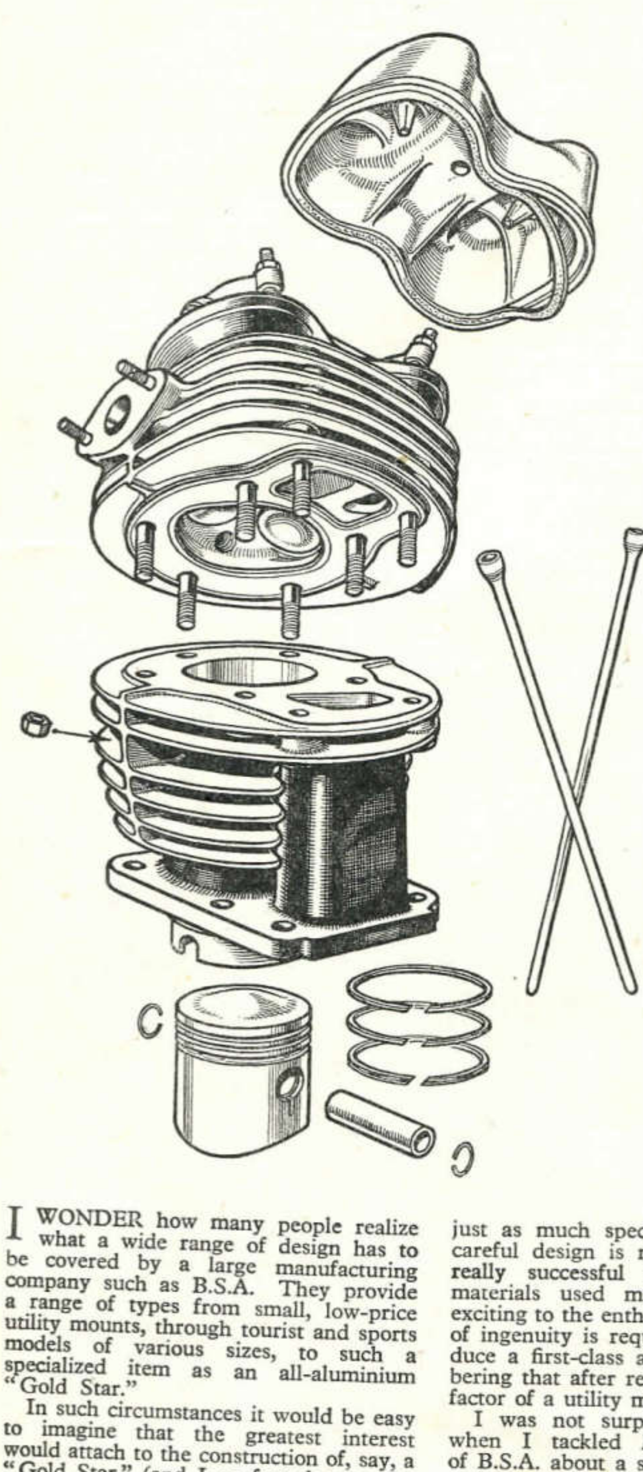
Excelsior Talisman



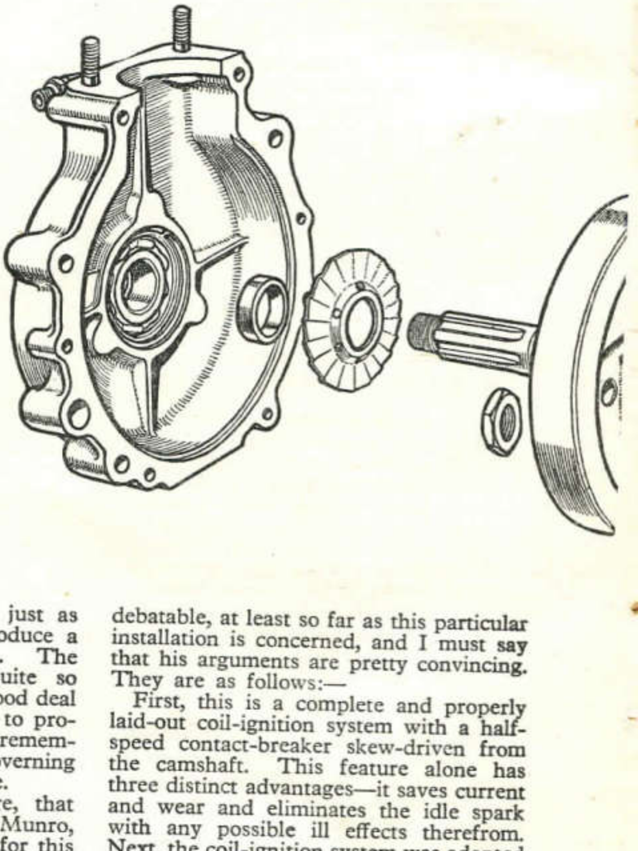
Of 244 c.c. (50 × 62 mm), the Excelsior Talisman twin cylinder two-stroke has two entirely separate cylinder barrels and cylinder heads. Each piston operates above its own crankcase. Crank throws are set at 180 degrees to provide the torque of a four-cylinder four-stroke. Five bearings support the crankshaft

Model C11 250 c.c.

A Utility Two-Fifty With a High



(*Left*) *A copper-asbestos washer is used between the cylinder and head; the latter has a seven-stud fixing. The cone-shaped projections in the valve cover are breathers*



I WONDER how many people realize what a wide range of design has to be covered by a large manufacturing company such as B.S.A. They provide a range of types from small, low-price utility mounts, through tourist and sports models of various sizes, to such a specialized item as an all-aluminium "Gold Star."

In such circumstances it would be easy to imagine that the greatest interest would attach to the construction of, say, a "Gold Star" (and I confess that on the occasion of this visit to the B.S.A. experimental shop my eyes kept wandering to some lovely light-alloy bits and pieces which were lying about). Nevertheless, just as much specialization and just as careful design is required to produce a really successful utility engine. The materials used may not be quite so exciting to the enthusiast, but a good deal of ingenuity is required in order to produce a first-class article, always remembering that after reliability the governing factor of a utility machine is price.

I was not surprised, therefore, that when I tackled Mr. D. W. Munro, of B.S.A. about a suitable model for this series he suggested the C11.

Now Model C11 is a rather unusual machine. It has a capacity of 249 c.c. and is designed for utility purposes; that is to say, although it must sell at a modest figure, it must run for long periods without skilled attention or replacements, and it must be economical, easy to start and easy to service. Those, I think, are the main attributes of the ideal utility machine. It was considered, however, that there was room for a utility machine which embodied all these features plus a "little something that the others had not got" in the way of performance.

Hence the 249 c.c. overhead-valve B.S.A., with a maximum speed around 60 m.p.h., a fuel consumption of 100-120 m.p.g., and a solidity of construction and simple straightforward design that became apparent during our conversation.

The machine has coil ignition and automatic advance spark mechanism, two features which are apt to cause discussion, so it was natural that I should tackle Mr. Munro on these subjects first of all. He would not admit that the subjects are debatable, at least so far as this particular installation is concerned, and I must say that his arguments are pretty convincing. They are as follows:—

First, this is a complete and properly laid-out coil-ignition system with a half-speed contact-breaker skew-driven from the camshaft. This feature alone has three distinct advantages—it saves current and wear and eliminates the idle spark with any possible ill effects therefrom. Next, the coil-ignition system was adopted deliberately, not because it was cheaper, but because it was considered to be better for this type of machine.

In combination with the automatic advance it provides about the nearest

Overhead-valve B.S.A.

Performance

By "UBIQUE"

thing to perfection in the way of easy starting. There is never a kick-back, and there is always a good fat spark, so that a first-kick start is normal and not exceptional.

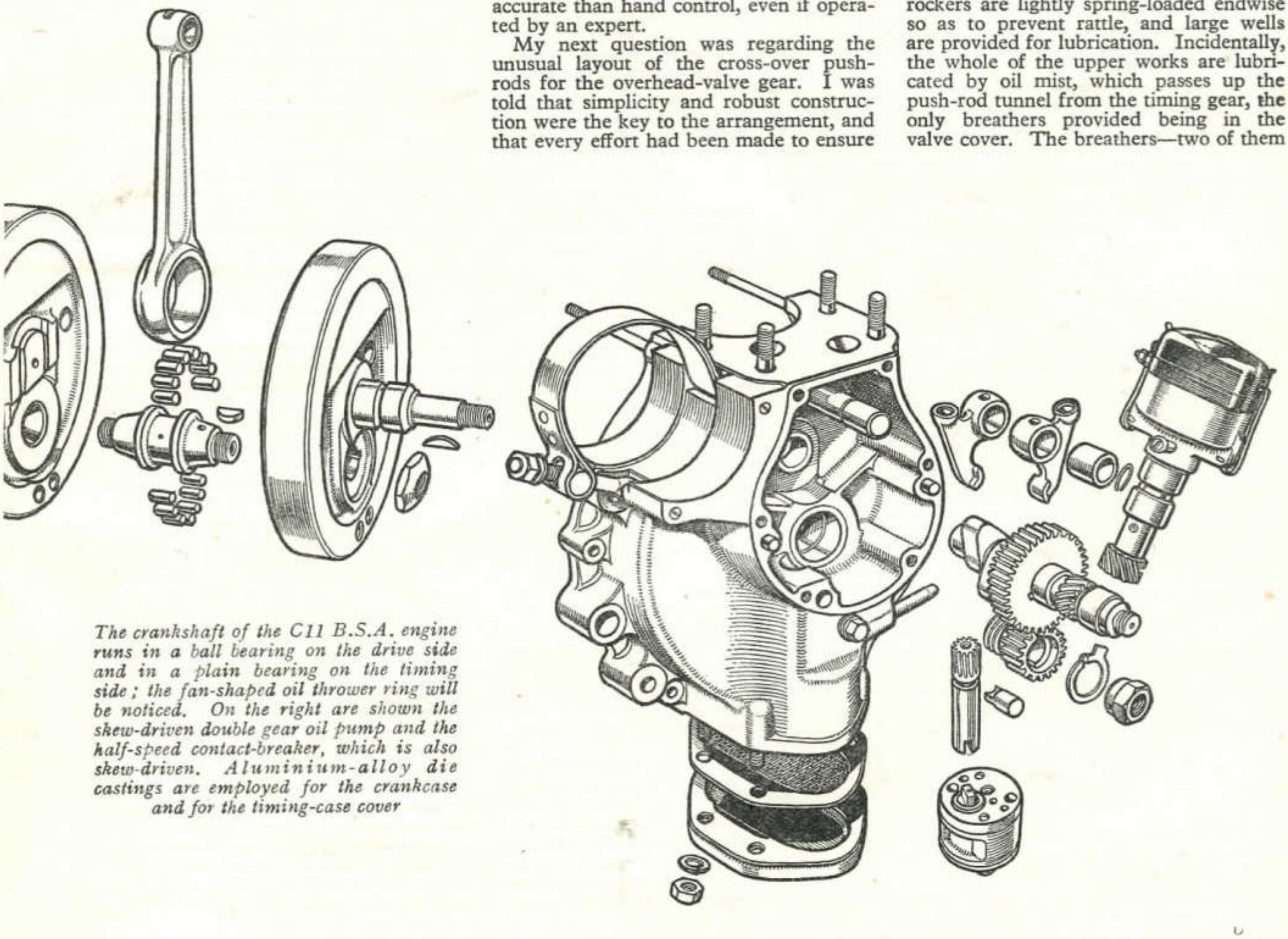
With automatic voltage control there has been no trouble with batteries, but careful tests have been carried out for both starting and running with deliberately discharged batteries. From these it has been determined that the engine will run on a voltage as low as 3, and start quite satisfactorily on 4 volts. Since the accepted figure for a fully discharged two-volt cell is 1.4 volts, and there are three cells to the battery, there will always be available current that is at least at 4.2 volts, unless the battery is damaged. It should be added that this easy starting is obtained without an exhaust-valve lifter. Thus, two control levers—spark advance and exhaust lifter—are eliminated from the handlebar.

Now as to the automatic advance. The advance curve is carefully matched with the power curve of the engine, and the mechanism is not just a "two-position" device, i.e., full advance and full retard. In fact, the advance of the spark is imperceptible to the rider. Tests have been carried out with fixed spark, hand-controlled advance and automatic advance, and in every case the automatic advance has scored in the matters of acceleration, smooth running and absence of pinking. Further, the sparking plug and probably the valves retain their condition longer, since they are not subjected to excessive heat due to over- or under-advanced ignition. There is no doubt, said Mr. Munro, that an automatic advance device, if designed for the particular engine on which it is used, is far more accurate than hand control, even if operated by an expert.

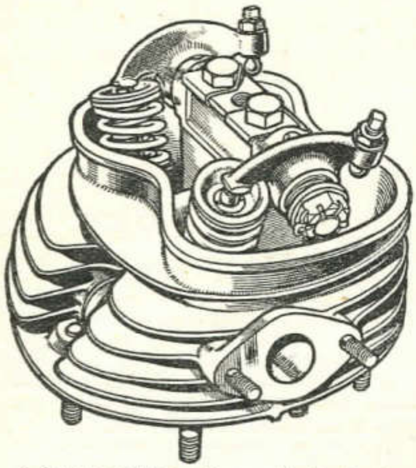
My next question was regarding the unusual layout of the cross-over push-rods for the overhead-valve gear. I was told that simplicity and robust construction were the key to the arrangement, and that every effort had been made to ensure long life of valves and valve gear with a minimum of attention. The valves themselves are made from an austenitic steel, and they are mounted in alloy cast-iron guides, which provide a hard bearing surface. The comparatively small included angle (35 degrees) between the valve centres provides that the push-rods shall be parallel to the valve stems, and thus avoid side thrust on the valve guides and rocker bearings.

The valve guides are long and the spring cups deep so as to ensure the longest possible springs in a given space. There are two concentric springs for each valve, the main reason for which is the provision of a reserve spring on which the rider could get home in case of spring fracture, but which also guard against periodic valve float.

Hardened-steel rockers bear directly on massive pivot pins, and these pins are part and parcel of a single forging held to the cylinder head by two bolts. The rockers are lightly spring-loaded endwise so as to prevent rattle, and large wells are provided for lubrication. Incidentally, the whole of the upper works are lubricated by oil mist, which passes up the push-rod tunnel from the timing gear, the only breathers provided being in the valve cover. The breathers—two of them



The crankshaft of the C11 B.S.A. engine runs in a ball bearing on the drive side and in a plain bearing on the timing side; the fan-shaped oil thrower ring will be noticed. On the right are shown the skew-driven double gear oil pump and the half-speed contact-breaker, which is also skew-driven. Aluminium-alloy die castings are employed for the crankcase and for the timing-case cover



A feature of the cast-iron cylinder head is that the rocker pivot pins form part of a single forging that is bolted to the main casting

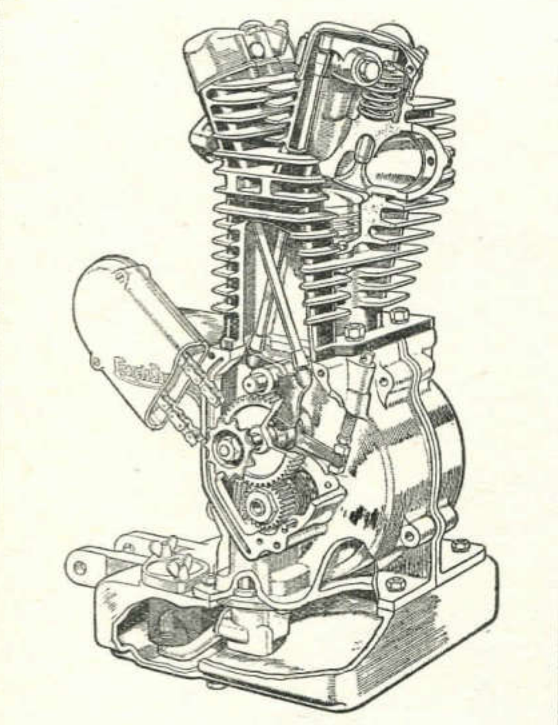
—are of some interest, for they consist only of cones containing steel wool through which air can pass with ease, but in which oil mist condenses and drips back to the valve gear. I was told that this device is most effective.

Solid steel push-rods with hardened ends socketed directly into the lower rockers are used, because they are likely to prove troublefree, and the little extra weight involved is of no great importance in an engine which is not primarily designed for constant high-speed work. I was warned, however, not to fall into the error of believing that the C11 was a sluggard, since it develops 11 h.p. at 5,000 r.p.m.

The camshaft is constructed of case-hardening mild steel, and runs in very large plain bearings. It is formed in one piece with its two cams and the skew gear for the contact-breaker drive, and the 2 to 1 gear wheel is pressed on and keyed. Before leaving the subject of valve gear Mr. Munro pointed out that all parts are accessible, and that the valve cover (a stiff light-alloy casting) is held by a single nut, yet is sufficiently rigid to prevent oil leakage at the joint surface.

Passing to the cylinder and head, I would mention that the original design was laid out for a one-piece casting, and that the first engine was so constructed. This arrangement has certain technical advantages, and I asked why it had been discarded in favour of the detachable head. I gather that public opinion and the claims of accessibility are the main causes which brought about the change. But, whatever the causes, the shape of the combustion chamber remains much as before, that is, semi-spherical, with modification to the main shape in the neighbourhood of the valves so as to provide true seatings and adequate clearance round the valve heads.

Owing to the shape of the head, which is not a true circle at the cylinder joint, no spigot is used, but the two parts are held by no fewer than seven stout studs and nuts, a copper-asbestos washer being interposed.

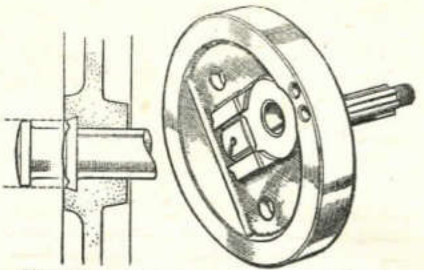


An interesting contrast with the C11 B.S.A.—the 247 c.c. (68 × 68 mm) Francis-Barnett "Stag," introduced for 1935

There is nothing special about the cast iron used for the cylinder and head castings, except that it is of high-grade quality. The fins are deep and fairly widely pitched, so that the air can flow freely to the rib roots and cylinder and head walls, and there is a single vertical fin at both front and rear to prevent "ring."

Die castings in an aluminium alloy are employed for the crankcase and timing covers as they provide a smooth finish and minimize machining.

While looking at a dismantled crankshaft, I noticed that the taper on the crankpin ends appeared to be steeper than usual, so I asked the reason. Mr. Munro stated that this was regular B.S.A. practice, as it facilitated replacement when necessary. The more usual taper—a matter of a few "thou" per inch — had been tried, and, although eminently successful in use, it had a tendency to stretch the hole in the flywheel boss and thus render replacement somewhat difficult.



How the crank axles are secured in the flywheels by means of a special undercutting process

The crankpin, of 3 per cent nickel steel, case-hardened, carries a single row of long rollers, and the connecting rod, of the same material, is hardened and ground at the big-end to form the outer race of the bearing. I was told that this practice has proved to be very satisfactory, provided that the bearing is properly lubricated.

This brought us to the question of lubrication. For obvious reasons, the double gear pump used on other B.S.A. models has been incorporated in the design. It is skew-driven from the crankshaft, and the delivery pump forces oil to the timing-side plain bearing and through the crankshaft to the big-end. There is a release valve, but this is not adjustable, and there is no tell-tale, except that the return pipe to the tank is visible when the filler cap is removed. From this there should be a good flow, as the amount of oil circulated per minute is considerable. It is not felt that any other form of indicator is necessary, and it is almost impossible for the system to fail provided that there is oil in the tank.

Mr. Munro pointed out an interesting feature which, I believe, is peculiar to B.S.A. engines. This is that the crank axles, each of which has a shallow rectangular head, are pressed into holes in their respective flywheels, the flat edges of the heads lying against corresponding faces in bosses formed with the flywheel. These bosses are undercut, and the axle heads are hammered into the undercut portion by a process similar to a chisel cut. The scheme will be clearly followed from the illustration.

There is a plain bearing on the timing side and a ball bearing on the drive side; a fan-shaped thrower ring inside the crankcase prevents direct oil leakage through the drive side.

There is not much to be said regarding the piston. It is of the plain-skirted type, has a slightly domed head and carries two pressure rings and one scraper ring. The gudgeon pin is large (¾in dia.) and hollow, and is located by circlips which permit it to float in the piston bosses, but prevent scoring of the bore. A thin bronze bush lines the small-end of the connecting rod.

I asked the special significance of the cadmium plating on all the bolts and nuts, and also on the valve spring cups, and was told that it is a particularly good rust-preventer. Cadmium, it appears, is electro-positive to iron, and consequently there is no electrolytic action in the presence of moisture.

The Speedway J.A.P.

An Engine Which Has Remained Basically Unchanged for Many Years and is Stated to Develop 40 b.h.p.

WHEN speedway racing was introduced to Great Britain in 1928, sports-type machines were employed. During the next two or three years, a number of manufacturers marketed special speedway models and it was common for as many as half a dozen makes to be competing at a meeting. However, one type of engine, the J.A.P., emerged, specially designed for speedway use, and by 1931 was easily the most popular power unit.

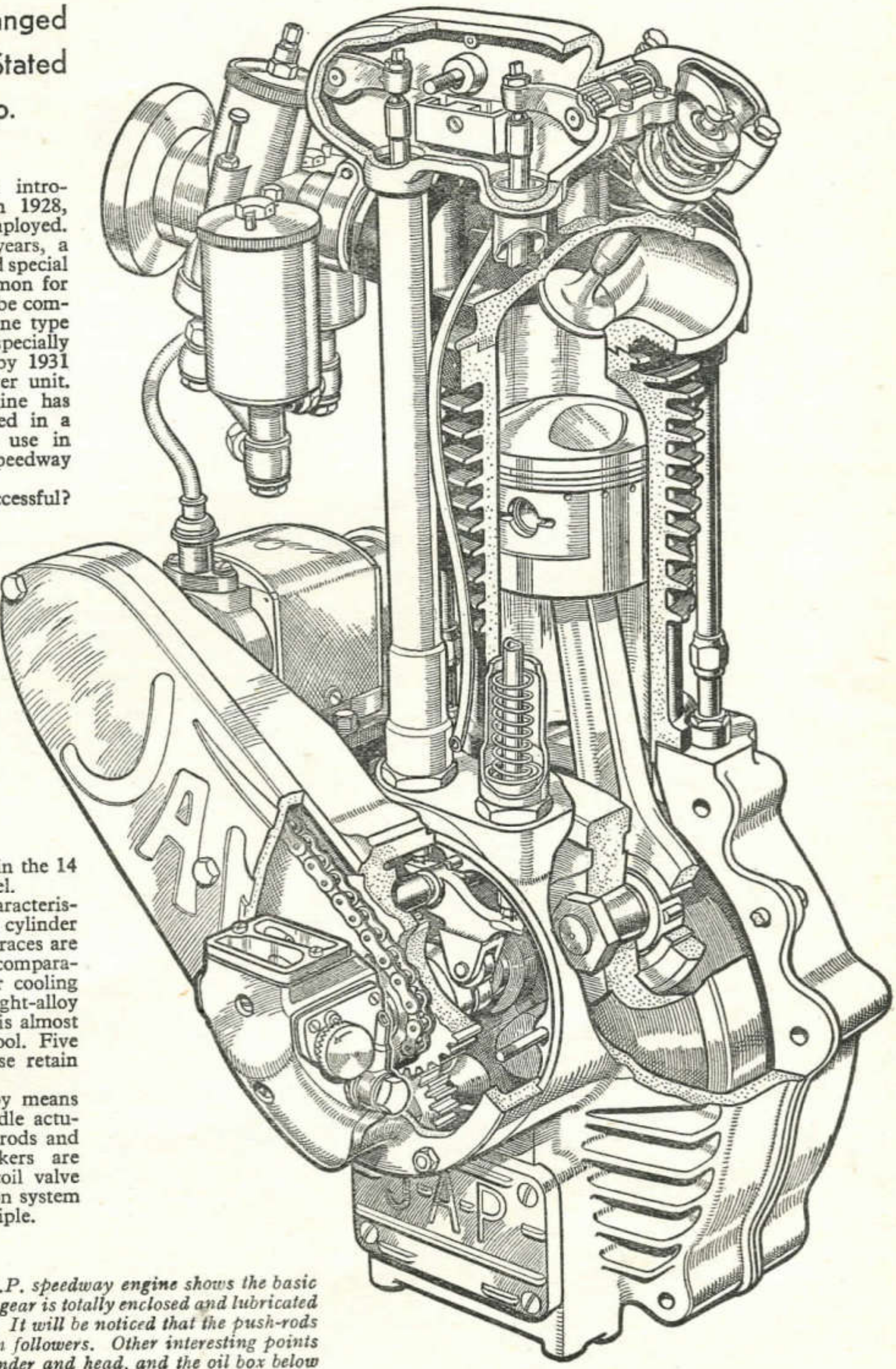
Since that time no other engine has challenged the J.A.P. which, fitted in a variety of frames, is to-day in use in almost every country where speedway racing is held.

Why is the J.A.P. engine so successful? The answer lies in its remarkably good low-speed torque coupled with over 40 b.h.p. at its 6,500 r.p.m. peak; in its high power/weight ratio; and in its simplicity and straightforward design which facilitate quick maintenance.

Large-diameter roller bearings support the flywheel assembly in the light-alloy crankcase, and caged rollers are employed at the big-end. At the small end there is a phosphor-bronze bush for the gudgeon pin retained in the piston by circlips. The piston is domed at the crown to provide a high compression ratio—ratios commonly used are in the 14 to 16 to 1 variety for alcohol fuel.

The most obvious external characteristic is the shallow finning of the cylinder and cylinder head. As speedway races are of short duration and speeds are comparatively low, wide surface area for cooling is unnecessary. Indeed, if light-alloy cylinder and head were fitted, it is almost certain the engines would over-cool. Five studs screwing into the crankcase retain both cylinder-head and cylinder.

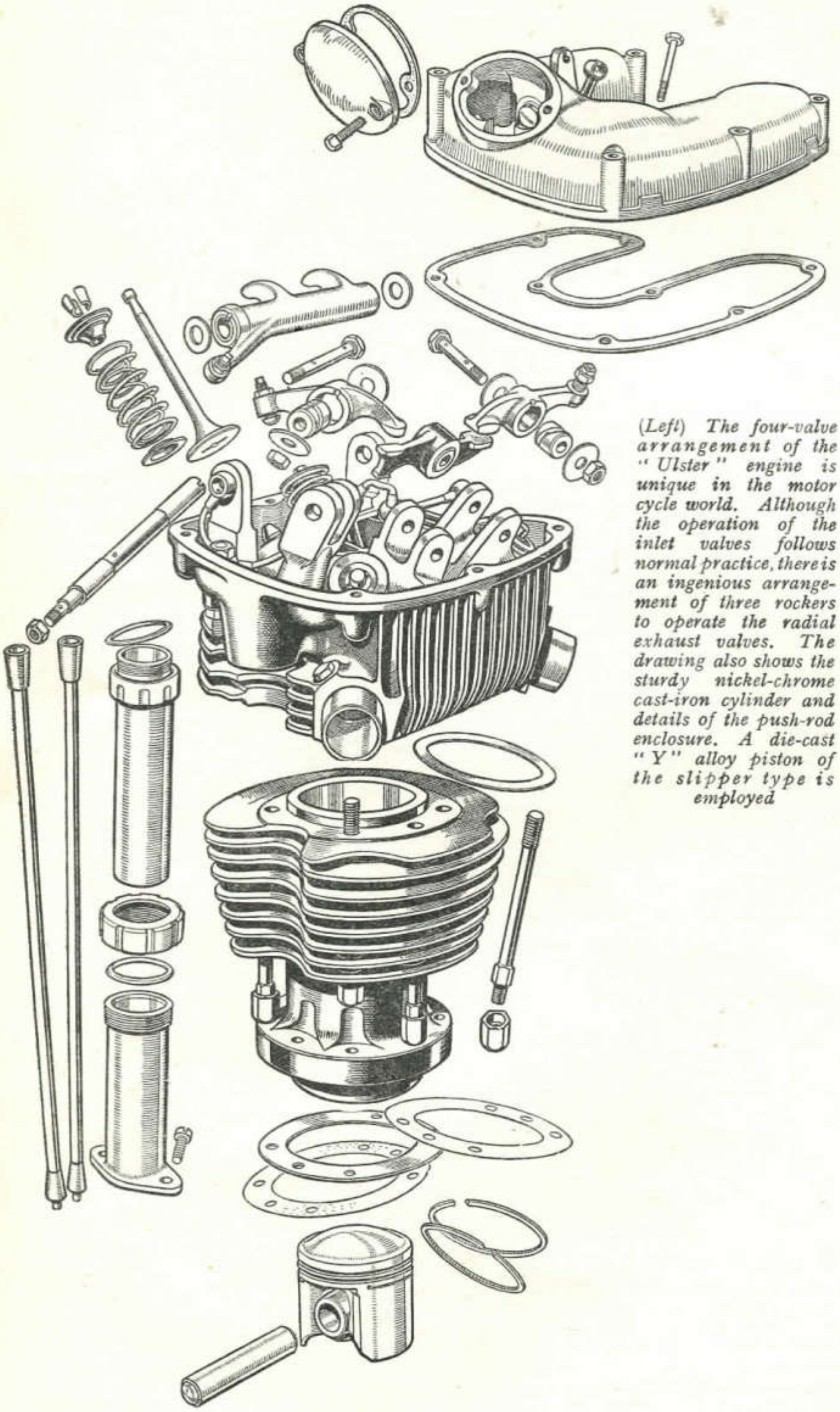
Valve operation is orthodox by means of two cams on a common spindle actuating roller-type followers, push rods and overhead rockers. These rockers are carried on needle rollers and coil valve springs are fitted. The lubrication system operates on the total-loss principle.



This sectional drawing of the J.A.P. speedway engine shows the basic simplicity of the design. The valve gear is totally enclosed and lubricated from one side of the duplex pump. It will be noticed that the push-rods bear directly on the roller-type cam followers. Other interesting points are the shallow finning of the cylinder and head, and the oil box below the timing chest into which the oil is passed from the crankcase before being discharged on to the track

499 c.c. Four-valve

Interesting Features of a Famous Pre-war High-efficiency Production



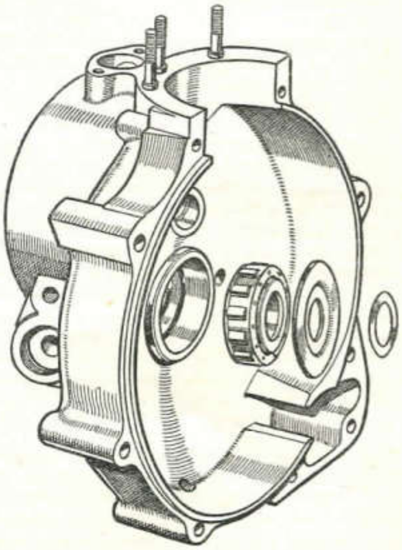
(Left) The four-valve arrangement of the "Ulster" engine is unique in the motor cycle world. Although the operation of the inlet valves follows normal practice, there is an ingenious arrangement of three rockers to operate the radial exhaust valves. The drawing also shows the sturdy nickel-chrome cast-iron cylinder and details of the push-rod enclosure. A die-cast "Y" alloy piston of the slipper type is employed

"MY first question, obviously, is, 'Why do you use four valves?' for in this your engines are just about unique." The man to whom this remark was addressed was Mr. G. L. Hack, the then head of the Rudge-Whitworth Technical Department. In front of us, laid out in sequence on sheets of brown paper, were all the parts that go to make a Rudge Ulster engine. This, we had agreed, was *the* engine in the Rudge range to discuss and to analyse as regards "whys" and "wherefores," because not only had it many interesting features, but it was the power unit of an unusually fast and lively production model.

"Yes!" said Mr. Hack, "In employing four valves we are unique in the motor-cycle world, though not in the aircraft world. There you find that for high performance four valves are almost universal. Our reasons for adopting the system are many. The most important is that with a high power output it is so much easier to obtain reliability. The two exhaust valves obviously run cooler than a single large valve, and the arrangement permits the use of a central plug without there being any risk of the cylinder head cracking. Most people, I believe, will accept the view that a centrally disposed plug, with the short distance the flame has to travel, is an advantage.

Light-alloy Head

"The arrangement of two parallel inlet valves and two radial exhaust valves is covered by a patent. We call it a 'semi-radial' head, the inlet side being flat and the exhaust side a portion of a sphere. The advantages of light valves and light valve springs in regard to reliability and freedom from bounce are more or less self-evident.



Rudge Ulster

Unit: Unusual Points of Design

By "TORRENS"

"For several years the cylinder head has been of aluminium-bronze, which is an excellent material, but we have just standardized a light alloy—R.R.50. This has better conductivity than bronze, but the great point is the big saving in weight, which is something like 10lb. In the case of the bronze head the valve seats were, of course, integral. Now we employ austenitic valve seats. These are fitted by cooling them in solid carbon dioxide and pressing them into position in the head, which is heated by being immersed in a trichlorethylene degreaser. No great pressure is required, for with these extremes of temperature the interference fit between the seats and the cylinder head is less than a thousandth of an inch. When both are at atmospheric temperature the difference is about five-thousandths of an inch.

"While we have never had a valve seat come loose, the outer edges of the exhaust seats are very slightly chamfered and we roll the head material over this chamfer just as a precaution. The five screwed bushes or thimbles into which the holding-down bolts go are of bronze and shrunk in by the same method, except that they are screwed into place, whereas the valve seats are pressed in. On two sides of each bush there is a small flat running down to a depth of about 1/10in. As a safety measure we use a Brinell hardness tester to press the cylinder-head material against these flats and thus lock the bushes in place.

"The valve guides are a hot-water fit. If they were put in by the carbon-dioxide method the owner would find that they were so tight that he could not get them out. The material is nickel-chrome cast-iron, which wears well and has the advantage that, with it, it is easy to provide a really good finish. They are, of course chamfered at the top to act as oil scrapers. This is very necessary if, as in our case, you flood-lubricate the enclosed valve gear.

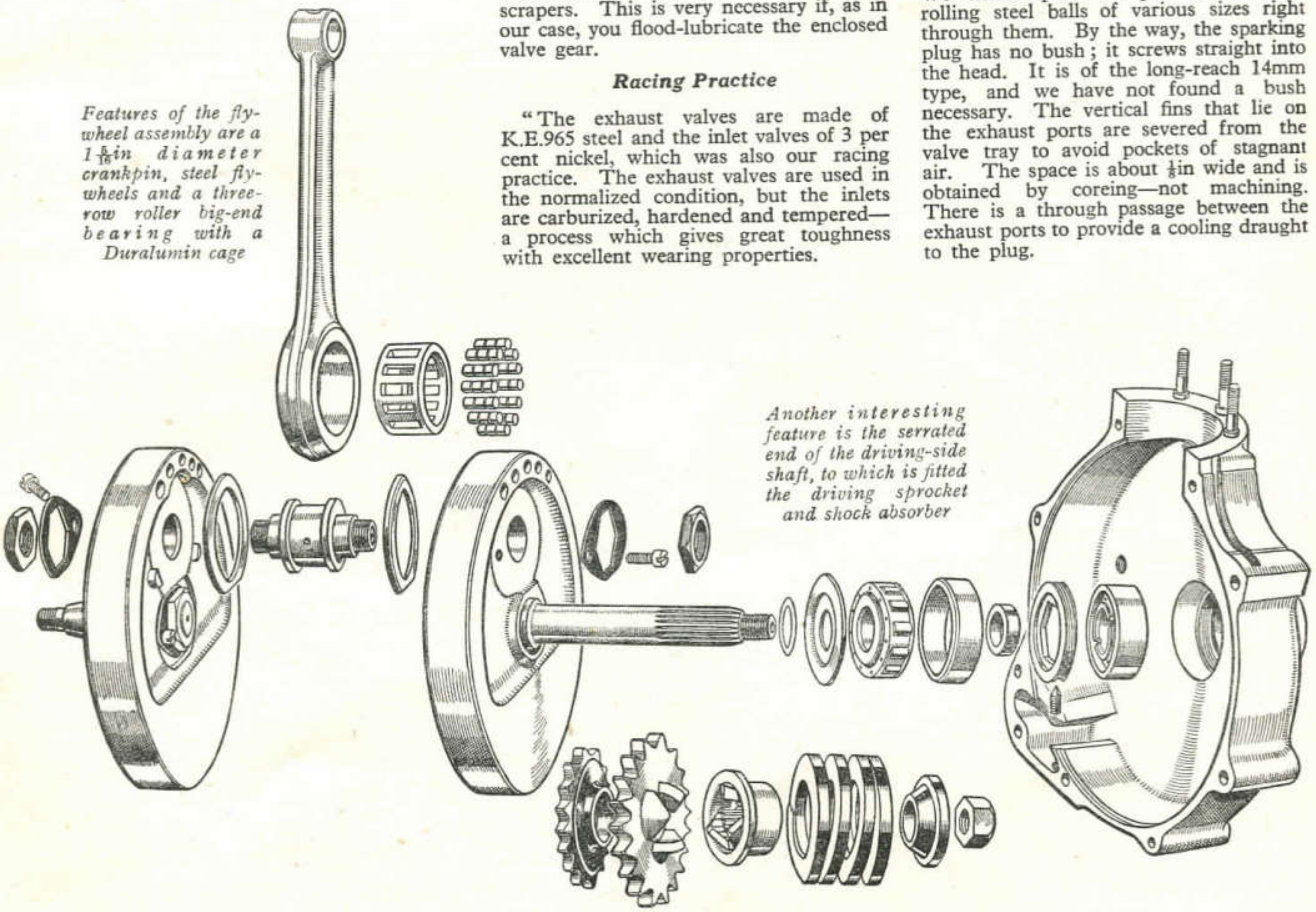
Racing Practice

"The exhaust valves are made of K.E.965 steel and the inlet valves of 3 per cent nickel, which was also our racing practice. The exhaust valves are used in the normalized condition, but the inlets are carburized, hardened and tempered—a process which gives great toughness with excellent wearing properties.

"The inlets have flat heads and the exhausts are of semi-tulip formation. The curvature of the latter mates to some extent with the cylinder head, but the important point about tulip-shaped heads is that the tulip gives the valve slight flexibility and, therefore, makes for reliability.

"With austenitic steel—of which K.E. 965 is an example—a big clearance is needed between the valve and its guide, but with our inlet valves, although the engine has a high power output, we can run with a clearance of a couple of 'thou.' A point here is that oil will not get down the guide and cause trouble; also, there is nothing like employing close clearances when you can. Yes, the stems are of small diameter; that of the inlet valves is only $\frac{1}{4}$in, while the exhausts are $\frac{5}{16}$in.

"The inlet port design is of the familiar bifurcated type with an easy sweep into the head. The diameter of each port is $1\frac{1}{8}$in, so there is a pretty hefty valve area. We check up on the port diameter by rolling steel balls of various sizes right through them. By the way, the sparking plug has no bush; it screws straight into the head. It is of the long-reach 14mm type, and we have not found a bush necessary. The vertical fins that lie on the exhaust ports are severed from the valve tray to avoid pockets of stagnant air. The space is about $\frac{1}{8}$in wide and is obtained by coreing—not machining. There is a through passage between the exhaust ports to provide a cooling draught to the plug.



Features of the flywheel assembly are a $1\frac{5}{16}$in diameter crankpin, steel flywheels and a three-row roller big-end bearing with a Duralumin cage

Another interesting feature is the serrated end of the driving-side shaft, to which is fitted the driving sprocket and shock absorber

"Both the valve collars and the valves are tapered, so the load is taken on the taper and not on the small shoulder at the end of the valve stem. The valve springs give a pressure of 83lb at half lift."

At this point I started playing with the rocker gear. The drawings show how it functions. The arrangement for the inlet valves is quite straightforward; it is in the case of the radial exhaust valves that ingenuity has had to be brought to bear. The tappet or operating rocker is carried on a bronze bush that is clamped between a forked boss which is part and parcel of the head. This presses on the upper side of the rocker for the right-hand exhaust valve; the lower side operates the valve, while the far end of the rocker presses the third rocker upwards and thus works the other exhaust valve.

"What are the rockers made of?" I asked.

"They are all of 3 per cent nickel case-hardening steel," came the reply. "This is easier to machine than nickel-chrome and proves very satisfactory in practice. There is, you will notice, a separate banjo oil union to each pivot pin and, therefore, to each bush. The base, or 'tray,' at the bottom of the rocker standards slopes towards the push-rod tube, thus leading the oil away to the timing gear and thence back to the oil tank. A graphited washer goes between the large single-piece valve cover and the head.

"For the cylinder-head joint we use a plain copper washer, which goes on the inside spigot of the head so that there is no annulus—no space to form a gas trap. The cylinder is of nickel-chrome cast-iron and finished throughout by grinding. There is no honing, the final finish being obtained by very fine grinding.

"Yes, the cylinder base is nearly ¾in thick. For the flywheels, which are 7¼in diameter and 1in wide, we employ drop-forgings. We have never yet had cast-iron flywheels in a Rudge. We use 0.35 per cent carbon steel, because with this you obtain permanence of the crankpin and axle holes—one can rebuild the engine without any trouble.

"The connecting rod is drop-forged in 5 per cent nickel case-hardening steel. There is no bush at either end; this keeps both the weight and size down. In a thin section, such as this form of rod, the tensile strength of the steel is 75 to 80 tons sq in. For such a strength after heat-treatment the machinability in the annealed condition is particularly good. The heat-treatment, too, is a simple task. After machining, the rod is case-hardened to a depth of 0.05 to 0.06in. The rod is not of a pronounced H-section; it is more a dumb-bell section—an H-section with very full flowing radii. We have always raced with this section, and I think that there is a good deal to be said in its favour; certainly it has proved very effective.

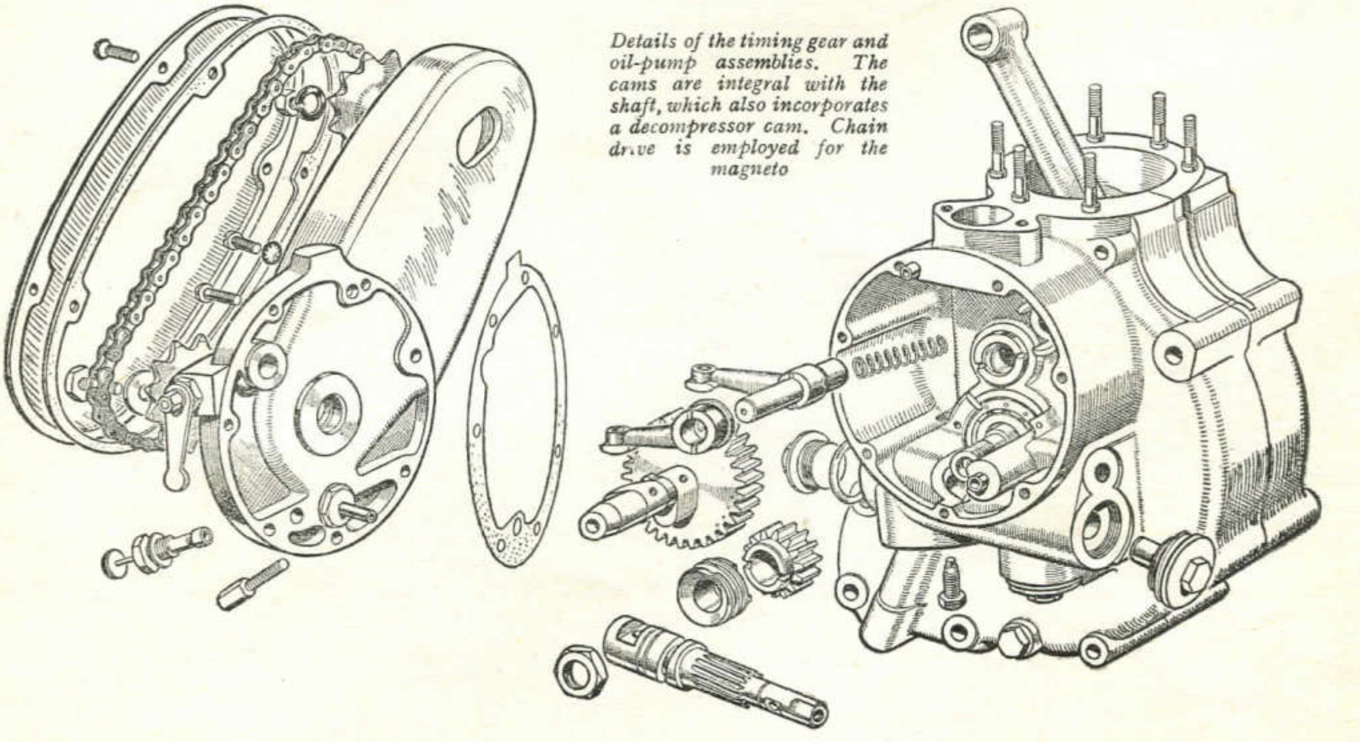
"The crankpin has two flanges, which pull up against the faces of the flywheels and provide rigidity. The diameter of the crankpin is $1\frac{5}{16}$in and of the axles ⅞in. The theory is that if the crankpin provides a really rigid junction between the flywheels there is no need for large-diameter axles, for the latter are mainly in shear. The interference fit between the crankpin and flywheels is 0.0025 to 0.0035in. That Duralumin cage for the three-row roller big-end bearing is carried on the flanges of the crankpin. Thus the actual bearing surfaces of the big-end—both the inner and outer ones—are completely clear of the cage. The cage wears the inner side of the crankpin flanges in the course of time, but this is unimportant as the bearing clearance is not increased thereby.

"A 2 per cent nickel case-hardening steel is used for the crankpin. The oil hole in the middle of the crankpin is horizontal, facing forward, when the piston is at the top of its stroke. The crankpin nuts are locked by hexagonally holed washers and set-screws. For the axles a taper fit is employed.

"On the driving side there are two bearings. First, there is a ball bearing which is fixed in the die-cast crankcase by a locking ring provided with an internal hexagon; then comes a spacing washer and finally a single-row roller bearing. This last is a Ransome and Marles with long rollers—actually 0.4in long—and is a press fit in the crankcase. The ball bearing provides positive end-location of the flywheel assembly. On the timing side there is just a roller bearing similar to that on the driving side.

"The ribbing on the crankcase wall which we had a few years ago has been discarded in favour of a smooth exterior. This is chiefly with the object of providing a crankcase that is easy to clean. The walls taper in thickness, of course; around the bearings the thickness is approximately half an inch. Those six cylinder holding-down studs are of alloy steel. The reason is that we wanted the studs to be of small diameter so that they could be set close in to the cylinder walls; the use of alloy steel enables us to do this as well as to provide threads that won't strip and bolts that won't break.

"Yes, the use of serrations on the outer end of the crank axle is unusual. The serrations are of no great depth and thus the shaft is not weakened so severely



Details of the timing gear and oil-pump assemblies. The cams are integral with the shaft, which also incorporates a decompressor cam. Chain drive is employed for the magneto as would be the case if splines were employed. The arrangement is similar to that used so successfully on the Rudge detachable car wheel.

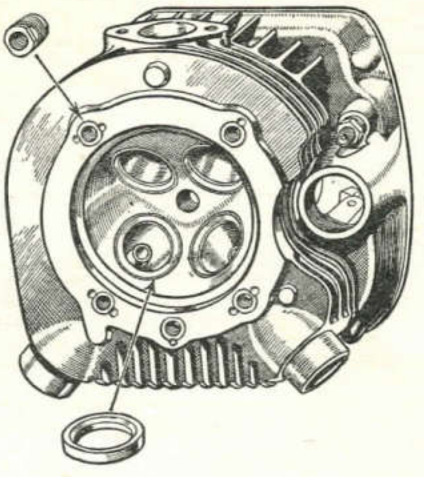
“The right half of the crankcase, as you know, contains the oil pump. The front side of the pump provides the feed to the engine. Oil is forced into the big-end bearing, to the rear of the cylinder wall and to the valve gear. When we changed over to totally enclosed valve gear we doubled the capacity of the pump. At an engine speed of 5,000 r.p.m. the delivery is now approximately half a pint a minute. The capacity of the return side is 2½ times this. With the engine hot, the oil at 5,000 r.p.m. goes to the various parts in these proportions: cylinder head, 12 pints per hour; cylinder walls, 2½ pints; and big-end, 13 pints.

“An important point is that whereas when the engine is hot the bulk of the oil divided between the valve gear and the cylinder goes to the former, when the engine is started from cold the majority is delivered to the cylinder. The reason for this desirable state of affairs is the long pipe used to carry the oil to the valve gear.

“The timing gears are ground after hardening and are fitted by selection. Manganese case-hardening steel is used for the cams, since it provides a very hard case. The cams are integral with the shaft and the latter pressed into its wheel. Our reason for this practice is accuracy of production. Cam followers are used, as you see. Incidentally, the oil-pump plunger is made of K.E.805 oil-hardening steel, which gives minimum distortion after hardening and also a very strong driving wheel.

“Aluminium (R.R.56) tubular push-rods of ⅜in diameter are used. The ends are of oil-hardened steel and, of course, are a press fit on the rods. Steel tubular rods are fitted to the ‘Special.’ With the light-alloy head fitted to the ‘Ulster,’ the R.R.56 just about compensates for the expansion. Indeed, there is remarkably little difference between the valve clearance, hot or cold. Another result in the case of such long rods (no tappets are employed) is that there is a saving in weight, though this is not so important as it might seem, since valve bounce has never been a limiting factor with the ‘Ulster.’ The push-rod enclosing tube is 1¼in diameter, so there is plenty of space for the oil to flow away from the head.

“Die-cast Y alloy is used for the slipper piston, which, as you will note, is of the circumferentially slotted type. The piston is ground elliptically—the diameter is 6-7 thou. greater across the faces than at the edges of the slipper—so there is never any trouble with four-corner seizures. A 3 per cent nickel, lapped gudgeon pin is used. This is ¾in diameter, and the distance between the gudgeon pin bosses only an inch. I am not too happy about the use of circlips for the location of gudgeon pins, since a circlip must fit perfectly and this may not be so after it has been removed and refitted a few times. What I use, therefore, are bronze end-pads. These are pressed out of bronze sheet and pushed up to a shoulder in the pin.



The light-alloy head is of the “semi-radial” type, the inlet side being flat and the exhaust side a portion of a sphere

“Those two 1½mm-wide piston rings are of the hardened type. We find that soft rings are liable to fritter away and provide a lapping powder. Hardened rings not only stand up better, but are also kinder to the cylinder barrel. No, we do not use a scraper ring.

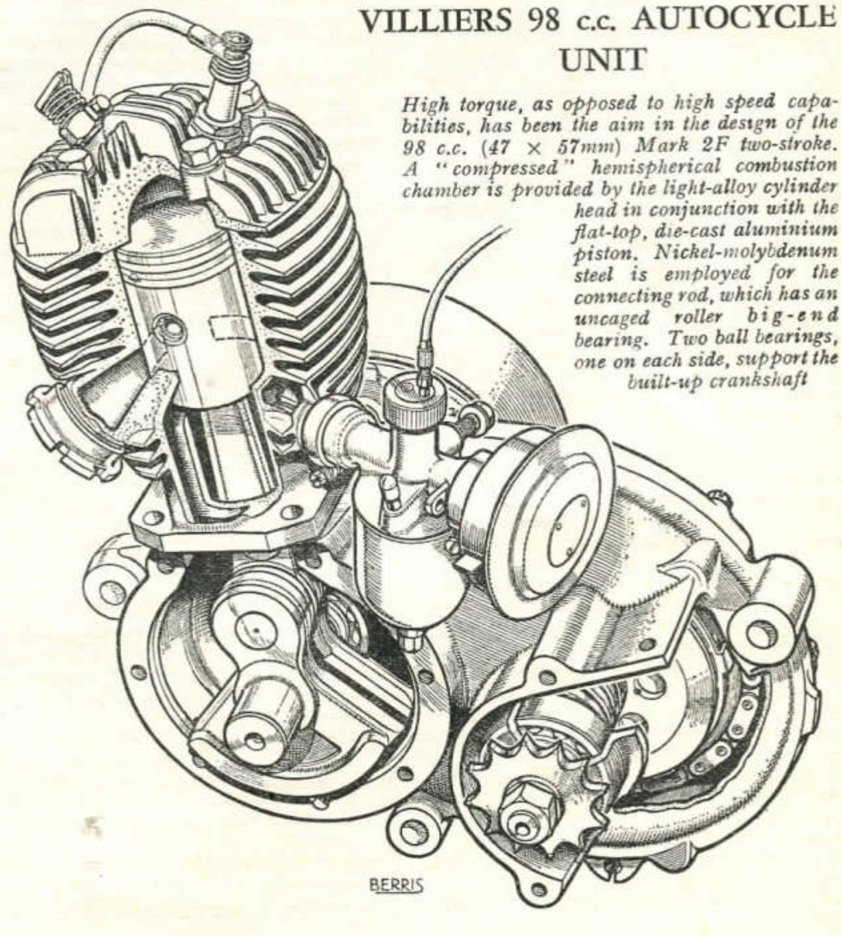
“By contemporary standards the compression ratio is low. The standard ratio is 6.8 to 1, though on the special bench-tested engines we provide a ratio of 7.25-7.5 to 1, according to the results obtained during the tuning. On these engines we fit a carburettor with a bigger choke, also racing cams. The engines, of course, are not so quiet as the standard ‘Ulster.’

“Well, that seems to cover nearly everything. Have you any other points? Cams? Yes, even though this is a high-speed engine they open and close comparatively slowly; we desire silence and longevity as well as high performance. The valve timing with a clearance of 0.02in is: the inlet valves open 10mm before top dead centre and close 13mm after bottom dead centre, while the exhaust valves open 16mm before the bottom of the power stroke and close 10mm down the induction stroke. The decompressor cam starts to raise the exhaust valves at approximately the bottom of the compression stroke and closes some 112 degrees later. Our ignition timing is 12 to 14mm before top dead centre.

“Now, then, what about coming and having a look round the factory. . . .”

VILLIERS 98 c.c. AUTOCYCLE UNIT

High torque, as opposed to high speed capabilities, has been the aim in the design of the 98 c.c. (47 × 57mm) Mark 2F two-stroke. A “compressed” hemispherical combustion chamber is provided by the light-alloy cylinder head in conjunction with the flat-top, die-cast aluminium piston. Nickel-molybdenum steel is employed for the connecting rod, which has an uncaged roller big-end bearing. Two ball bearings, one on each side, support the built-up crankshaft



Sunbeam 487 c.c. In-line

E. A. SITWELL Consults Mr. D. W. Munro on Details of the Design

IN order to begin ferreting out the whys and wherefores of the Sunbeam engine design, the first question I put to Mr. D. W. Munro, M.I.Mech.E., of the Technical Department was: "Why did you decide to make a twin?"

"Before I attempt to answer that or any other question," replied Mr. Munro, "I must make it quite clear that I personally did not design the Sunbeam. Credit for doing that must go to Mr. E. Poppe, who, as you realize, is no longer with the firm," Mr. Munro then went on, "Obviously the main advantages of a twin are silence, smoothness, and easy starting. Moreover, the modern trend is for multis, and we wanted the Sunbeam, above all, to be an ultra-modern machine without being fantastic. Besides being very up to date, it had to preserve the traditional Sunbeam dignity."

"What was the reason for building an in-line engine?" I asked. Mr. Munro answered, "In order to achieve a compact, car-type layout for a complete unit. Wide use of aluminium-alloy results in an even distribution of heat throughout the whole cylinder-block. Experience has fully justified this in-line arrangement."

Silence Question

"Surely, by its resonance, aluminium-alloy emphasizes mechanical noise? How do you get over that?"

"By the adoption of short, stiff fins giving a compact mass. Also, the camshaft has been designed with extreme care; the cams have quietening ramps which provide a slow transition for an 18-thou tappet clearance."

"With the crankshaft in the fore-and-aft position, how is the primary reduction effected?" I asked.

"Primary reduction in each gear," said Mr. Munro, "is between the mainshaft and the layshaft, the gear box being, of course, in unit-construction with the engine. In this we have departed from normal car practice."

"'Why this departure?' Because the final (shaft) drive has to be offset in order to reach the side of the rear wheel. This is the most convenient way of doing it."

"Could you not do this, yet still not have any primary reduction?"

"Well, no. We should have to have a greater secondary reduction in the worm drive at the rear wheel, with consequent higher rubbing speed in the worm gear. This would probably cause wear. We should possibly need a larger rear wheel unit, too. You see, it is possible on a car to have everything so much more massive than we can have on a motor cycle. Incidentally, the worm wheel is not bolted rigidly to the rear hub. Instead, there is a loose coupling dog interposed between the worm wheel and the wheel hub. This is put there in order to relieve the worm wheel of any stresses due to shock on the rear wheel or flexing."

"What about the clutch?" I asked. "Why only a single plate, when most motor cycles have multi-plate clutches?"

"The answer is," said Mr. Munro, "that the Sunbeam clutch operates on the flywheel at engine speed and therefore carries less torque for a given power output than the more usual motor cycle clutch that is mounted on the gear-box mainshaft and runs at about half engine speed. Therefore, a single, 7in diameter clutch plate works exceedingly well."

"Why choose to have overhead valves operated by a chain-driven overhead-camshaft?"

"We believe that a properly designed overhead-camshaft engine can be quieter than an equivalent engine with push-rods, since there are fewer contact points. Moreover, the engine can be narrower, because space is not taken up on one side by tappets, cams, and push-rods. For a given performance we can use lighter valve springs, as there are no push-rods and tappets to be returned to former positions. The advantages of lighter springs are, of course, reduced wear on valve seats and less noise. We think that an engine with an overhead-camshaft has potentially a higher maximum power output than one of the same capacity with either push-rods or, of course, side valves. Reason for using a chain and not a vertical shaft to drive the overhead-camshaft is because the chain runs silently."

"Before we get down to a more detailed discussion of the engine," I said, "I should like to ask why you have used such a short stroke and such short con-rods." (Bore and stroke are 70mm × 63.5mm respectively, giving a capacity of 487 c.c.)

"A short stroke is used," answered Mr. Munro, "in order to keep the piston speed down, which is a modern idea. Another reason is to keep down the big-end rubbing speeds. Short con-rods are employed in order to make the engine as compact as possible."

"With such short rods, is there not liable to be secondary vibration?"

"That point is looked after by the use of light-alloy rods and a special engine mounting."

"Now let us get down to engine details," I suggested. "First of all, can you please comment on the use in the Sunbeam engine of a cast-iron crankshaft?"

Mr. Munro smiled. "Well," he said, "it is not common bedstead iron by any means, you know! Actually, it is a high-grade alloy-iron of the 'Meehanite' class, possessing great rigidity and resistance to fatigue, and providing excellent bearing surfaces. Compared with ordinary cast-iron, it has great mechanical strength."

"I see that it is a single-throw crankshaft with the crank-journals separated by a massive central bobweight. Why did you not use a normal built-up crankshaft?"

Mr. Munro answered this with a counter question: "Why," he asked, "go to the trouble and complication of building up a crankshaft when split big-ends solve the problem of a one-piece shaft? . . . Incidentally, being split, the big-ends are more easily replaceable if necessary."

"Can you please give me some information about the main bearings?"

"As you see, at the rear we have a plain, white-metal-lined bearing, and in front there is a large, deep groove, ball journal bearing. The latter also takes the clutch thrust and has a large, spring-loaded oil-seal."

"Is there an oil-seal for the rear, plain bearing?"

"Not for the bearing itself, because it is an 'internal' bearing, and no special precautions against oil leakage between the engine and timing gear are necessary. There is, however, a sheet-steel partition between the timing gear and the clutch chamber, and this partition carries an oil-seal which prevents leakage on to the clutch."

"What are the bearing sizes?"

"The front bearing is 1⅜in diameter, and the rear 1½in diameter."

"Why have different kinds of bearing at the front and at the rear?"

"Well, we like plain bearings for silence, but have to have a bearing somewhere that is capable of taking thrust when the clutch is disengaged. Hence the ball journal being in front."

"What allowance is made for end play?"

"Theoretically, nil, but perhaps there is a small working clearance at the rear end."

"What about the big-ends?"

"They are of the steel-back shell-type with indium-flash lead-bronze liners. Indium is comparatively a rare metal, quite soft, but having the property, when deposited electrolytically, of becoming infused into the lead-bronze bearing, thus giving the bearing temporarily an ultra-high resistance to load. This extra load resistance is especially valuable during the running-in period of the engine, at which critical stage in the engine's life the indium effectively prevents any breakdown of bearing surfaces."

"Why use liners at all?"

"Because steel-back liners are easier and cheaper to replace than complete con-rods."

Oil-control Rings

"I notice you do not use ordinary white-metal bearings. Why?"

"Because steel-back liners do not require scraping and bedding-in like the older type of bearing, in which a thick deposit of white-metal was cast directly on to the rod."

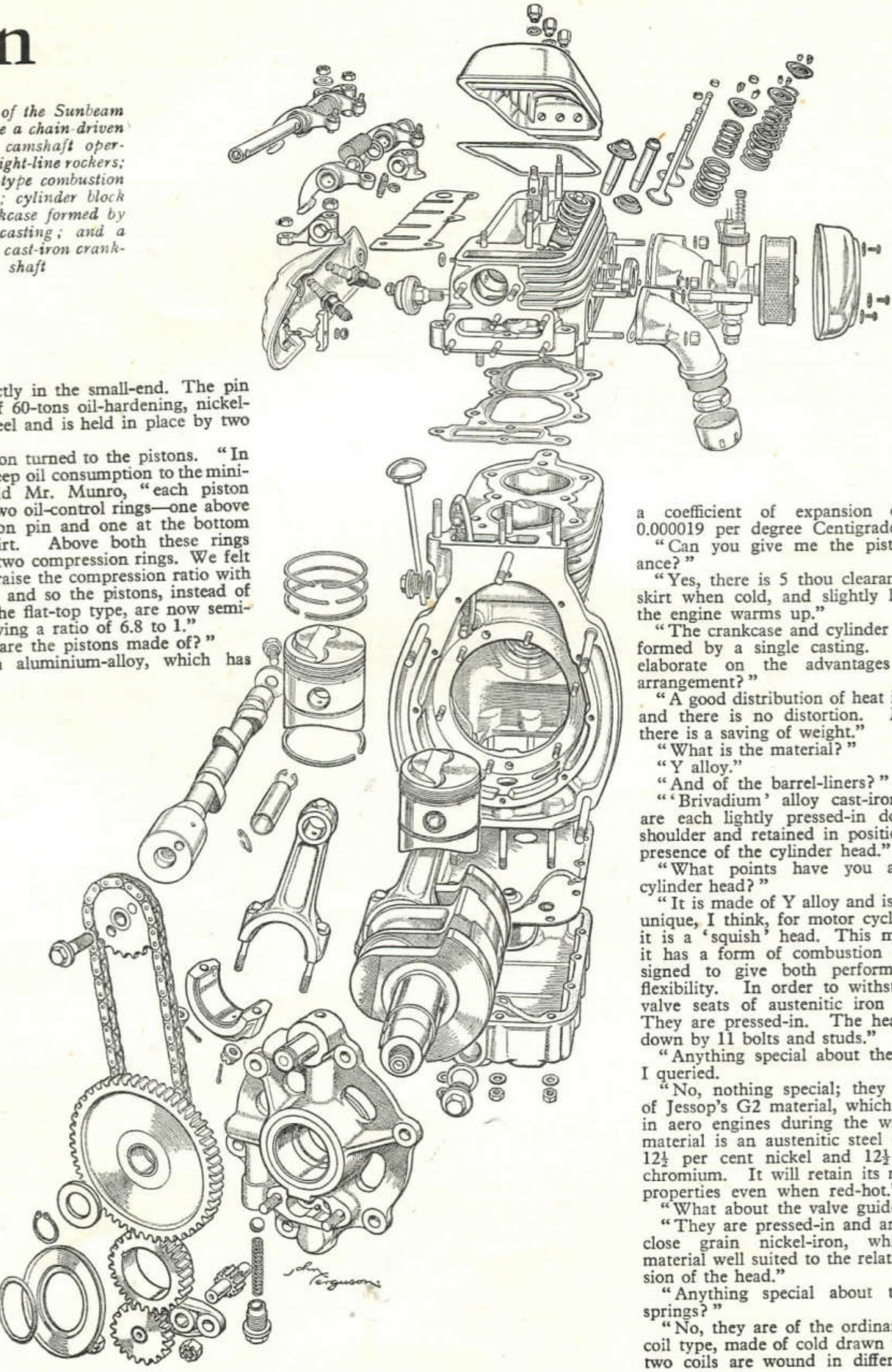
"You mentioned light-alloy con-rods," I said. "I expect the alloy used is R.R.56?"

"Yes," said Mr. Munro.

"What about the small-ends?" I asked.

"Each con-rod," replied Mr. Munro, "has a fully floating gudgeon pin oper-

Twin



Features of the Sunbeam engine are a chain-driven overhead camshaft operating straight-line rockers; "squish"-type combustion chambers; cylinder block and crankcase formed by a single casting; and a one-piece cast-iron crankshaft

ating directly in the small-end. The pin is made of 60-tons oil-hardening, nickel-chrome steel and is held in place by two circlips."

Discussion turned to the pistons. "In order to keep oil consumption to the minimum," said Mr. Munro, "each piston now has two oil-control rings—one above the gudgeon pin and one at the bottom of the skirt. Above both these rings there are two compression rings. We felt we could raise the compression ratio with advantage, and so the pistons, instead of being of the flat-top type, are now semi-domed, giving a ratio of 6.8 to 1."

"What are the pistons made of?"

"Silicon aluminium-alloy, which has a coefficient of expansion of about 0.000019 per degree Centigrade."

"Can you give me the piston clearance?"

"Yes, there is 5 thou clearance at the skirt when cold, and slightly less when the engine warms up."

"The crankcase and cylinder block are formed by a single casting. Will you elaborate on the advantages of this arrangement?"

"A good distribution of heat is effected and there is no distortion. Moreover, there is a saving of weight."

"What is the material?"

"Y alloy."

"And of the barrel-liners?"

"'Brivadium' alloy cast-iron. They are each lightly pressed-in down to a shoulder and retained in position by the presence of the cylinder head."

"What points have you about the cylinder head?"

"It is made of Y alloy and is of a type unique, I think, for motor cycles in that it is a 'squish' head. This means that it has a form of combustion space designed to give both performance and flexibility. In order to withstand heat, valve seats of austenitic iron are used. They are pressed-in. The head is held down by 11 bolts and studs."

"Anything special about the valves?" I queried.

"No, nothing special; they are made of Jessop's G2 material, which was used in aero engines during the war. This material is an austenitic steel containing 12½ per cent nickel and 12½ per cent chromium. It will retain its mechanical properties even when red-hot."

"What about the valve guides?"

"They are pressed-in and are made of close grain nickel-iron, which is a material well suited to the relative expansion of the head."

"Anything special about the valve-springs?"

"No, they are of the ordinary double-coil type, made of cold drawn wire. The two coils are wound in different directions in order to try to prevent rotation. Incidentally, there is a hardened steel thimble on the end of each valve stem to reduce wear. Car-type rockers are used, separated by springs. Tappet adjustment is at the rocker-ends."

"What is the overhead-camshaft made of?"

"Case-hardened steel. It has two large plain bearings operating directly in the Y-aluminium-alloy. It is chain-driven off an intermediate pinion, and the chain has a Weller-type tensioner which requires hardly any attention, but is accessible for assembly purposes."

"I see that an Amal carburettor is fitted," I said.

"Yes," said Mr. Munro; "it is a single-lever type with a strangler for starting."

Pancake Dynamo

"Why is coil ignition used?" I asked.

Mr. Munro said: "For easy starting and a reliable tick-over. Automatic advance is employed. The distributor is driven at half engine-speed from the rear end of the camshaft, where it is in a convenient position and is protected from the weather. There is a very small range of adjustment on the timing, because we do not wish to encourage the private owner to monkey about much in that direction.

"A Lucas 60-watt pancake-type dynamo is employed, with no separate bearings for the armature, which is carried on the front end of the crankshaft itself. With this arrangement, the yoke is accurately positioned round the armature. Another advantage is that there is no necessity for an additional drive. Also, the instrument is nicely cooled there, and, since output rises as temperature falls, the biggest possible output is obtained."

"Let us now explore some of the mysteries of the shaft-drive," I suggested. "I assume the reason you employ a propeller shaft instead of a chain is to obviate the need for messy chain-adjustment, and also because the ultra-modern design of the Sunbeam lends itself particularly well to this form of drive?"

"Quite right," answered Mr. Munro.

"What can you tell me about the shaft?" I asked.

"First of all," said Mr. Munro, "it is 11½in long between the centres of the two universal joints. It is made of Hardy Spicer, medium-carbon, chrome-molybdenum steel, suitably heat treated. It is a forging and runs at roughly half engine-speed in top gear."

"In view of the shaft breakage that certain Continental manufacturers sometimes encountered before the war when they produced shaft-driven machines, how do you account for the Sunbeam's immunity from this form of trouble?"

"We keep the shaft short enough not to be troubled by whirling effects at high speeds, and it is made of steel—steel strong enough and thick enough to have a considerable safety factor, and which possesses very high resistance to fatigue. In fact, the shaft is capable of standing up to a power output greatly in excess of the highest figure likely to be obtained."

"Anything special about the universal joints?"

"The one at the rear is a metal Hooke's joint made by Hardy Spicer, and the one in front is a Layrub flexible-rubber-type coupling. These provide a convenient combination, since the flexible coupling looks after the deflection due to the working of the rear suspension, while the metal joint looks after any angularity between the shaft and the worm drive and relieves the shaft from all bending stresses."

"Shall we next discuss engine lubrication?" I asked.

"By all means," said Mr. Munro; "but, in order to begin talking about lubrication, it is first necessary for me to point out that the mainshaft plain bearing housing is a separate cast-iron piece fixed to the crankcase wall by six studs ——"

"Why separate?" I interrupted.

"In order to be able to assemble the engine," replied Mr. Munro. He went on: "This housing also forms a body for the gear-type oil-pump, which is driven off a pinion pressed and keyed on to the crankshaft. The same pinion, incidentally, also drives the camshaft pinion. In the housing there is a spring-loaded release valve which allows oil to by-pass into the sump if there should be any obstruction in the system. The oil sump has a capacity of four pints."

"Why a sump and not an external tank?"

"Because the Sunbeam engine is not lubricated on the dry-sump principle; instead, a car-type, wet-sump system is used, whereby oil returns to the sump purely by gravity. Also, it was our policy as I have said before, to evolve a self-contained unit.

"The pump," continued Mr. Munro, "operates at a speed slightly higher than engine speed—is designed to give an adequate flow of oil at that speed, and also to conform with the geometry of the pinion layout that drives it.

"Oil is drawn from the sump through a filter and is taken direct to an annular space surrounding the plain main bearing, which has a hole in it and thus is lubricated. From here the oil goes through a drill-way in the bearing and enters the crankshaft, whence it breaks out under pressure to lubricate both the big-ends and the cylinder walls. Surplus oil drains back into the sump.

"From the annular groove already mentioned, through-passages are drilled in the crankcase and cylinder-walls, and these passages carry oil under pressure to the intermediate camshaft pinion, up to the rear camshaft-bearing, through the camshaft to the front camshaft-bearing, and then up a hollow stud (one of three that hold the rocker assembly) and into the hollow rocker shaft, from which the oil emerges to lubricate the rocker-ends and cams. There is a control at the rear camshaft-bearing, where oil passes through only when two holes coincide during rotation; and there is a control at each rocker, where, similarly, oil can emerge only when two holes coincide during oscillation of the rocker.

"Oil then drains from the cam box by gravity, down through the chain tunnel to the bottom of the timing case and thence, through another filter, back into the sump.

"An advantage of this system is that oil reaches the big-ends at full force, but, with the correct size of orifices, fixed by extensive tests, there is a restricted supply 'upstairs.' If the pressure from the pump falls below a certain figure, then a diaphragm-contact-unit comes into action and lights a green lamp in the head-lamp shell; and this warning light is, of course, visible to the rider. Incidentally, the engine breathes through a disc-type breather-valve situated at the front of the rocker-box cover. The designer has cleverly explored the engine to find a position for this valve where air will emerge without oil."

Kickstarter Mechanism

"That seems to clear up the engine lubrication," I said. . . . "Now, before we discuss the Sunbeam flexible engine-mounting, may I please tie up a few loose ends in my questioning so far?"

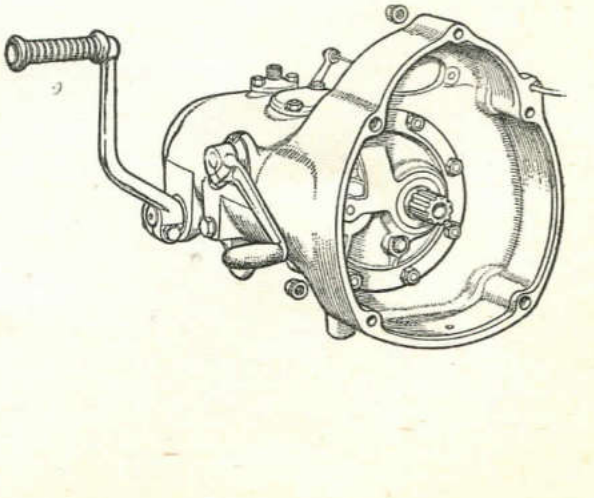
"Certainly," answered Mr. Munro.

"First, then," I asked, "how do you get the kickstarter working in the normal manner and not sideways. With the crankshaft in the fore-and-aft position, one would have thought——"

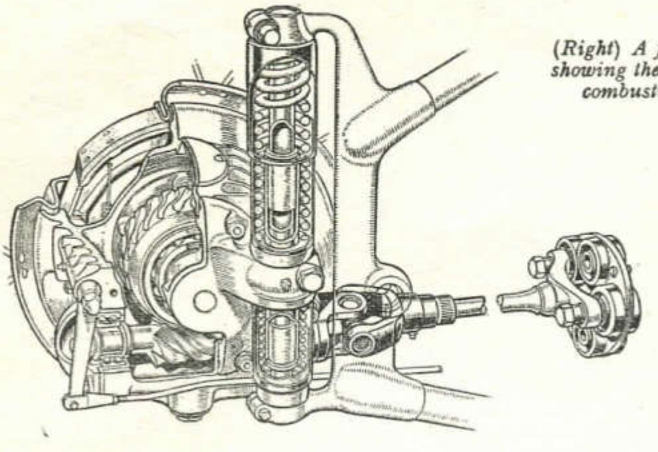
"It is achieved," was Mr. Munro's reply, "by our going to the expense of providing accurately machined phosphor-bronze and steel skew gears."

"What about engine-balance, compared with that of a single of the same capacity?"

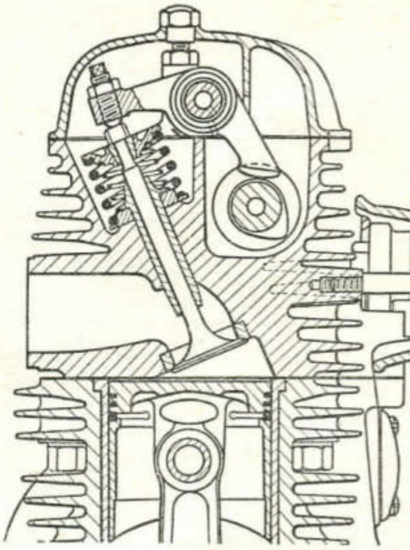
"The crankshaft is dynamically balanced on a special machine. Balance of the engine, with the pistons going, of course, up and down together and firing alternately, is rather better than would be that of a single of the same capacity."



Engine and gear box are in unit. There is a single 7in-diameter clutch friction plate. The kickstarter operates through a skew gear



Detail construction of the shaft-drive and plunger-type rear suspension



(Right) A factory drawing showing the "squish"-type combustion chamber

"Anything special about the ports?"

"No, nothing special. As you see, there are two exhaust ports and one inlet. The single inlet port serves both cylinders, of course."

"I notice you have a short piece of flexible piping set in the exhaust system."

"Yes, that is to allow for engine 'shake' on the rubber mounting during tickover. Incidentally, the silencer is of the ordinary absorption type."

"What is the power output of the Sunbeam engine—assuming that the standard compression ratio of 6.8 to 1 is used?"

"It is 26 b.h.p. at 5,800 r.p.m."

"Good; that, I think, completes my questions about the engine itself. Now, about its mounting in the frame: why is a flexible mounting necessary?"

"Because the crankshaft is in line with the frame, and therefore vibration is felt if the engine is rigidly mounted. I should make it quite clear that this engine is not any more prone to vibration than other engines; but such vibrations as there are can make themselves felt more, since they are occurring in the sideways directions and therefore are not so easily absorbed as they would be were they occurring in the fore-and-aft directions.

"We get over this problem in the following manner:—Low-frequency vibration is absorbed by two, diagonally disposed, bonded-rubber engine mountings. An imaginary line drawn from one to the other would intersect the crankshaft at a point very near the centre of gravity of the power unit. Being placed about this axis, the engine supports have the highest possible absorbing moment. High-frequency vibration, caused mainly by the motion of the con-rods, is dealt with by a spring-loaded friction damper at the top (rear) of the engine—a position that has been found to be the most effective.

"Oscillation is further controlled by small rubber buffers—we call them 'snubbers'—placed at the top (rear) and near the bottom (front) of the engine. These snubbers are particularly helpful in cushioning the engine when it is affected by torque."

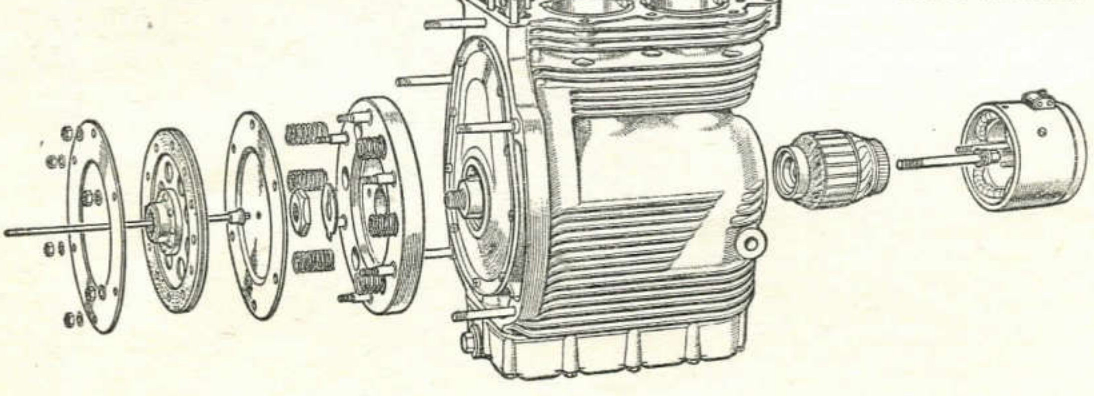
"Are you satisfied with these arrangements?"

"Yes, extremely satisfied. Previous critics are now thoroughly convinced, and are inclined to set this model up as a standard by which other models should be judged."

"Suppose the setting gets out of adjustment?"

"That is not likely to happen, except after very long periods of running; but in any case, it is quite easy to centralize the engine again visually."

"Thank you," I said. "You have explained everything so clearly that I feel I ought to write a large 'Q.E.D.' at the end of the article."



Oil is contained in a detachable sump, the lubrication system operating on the wet-sump principle

497 c.c.

E. A. Sitwell Questions

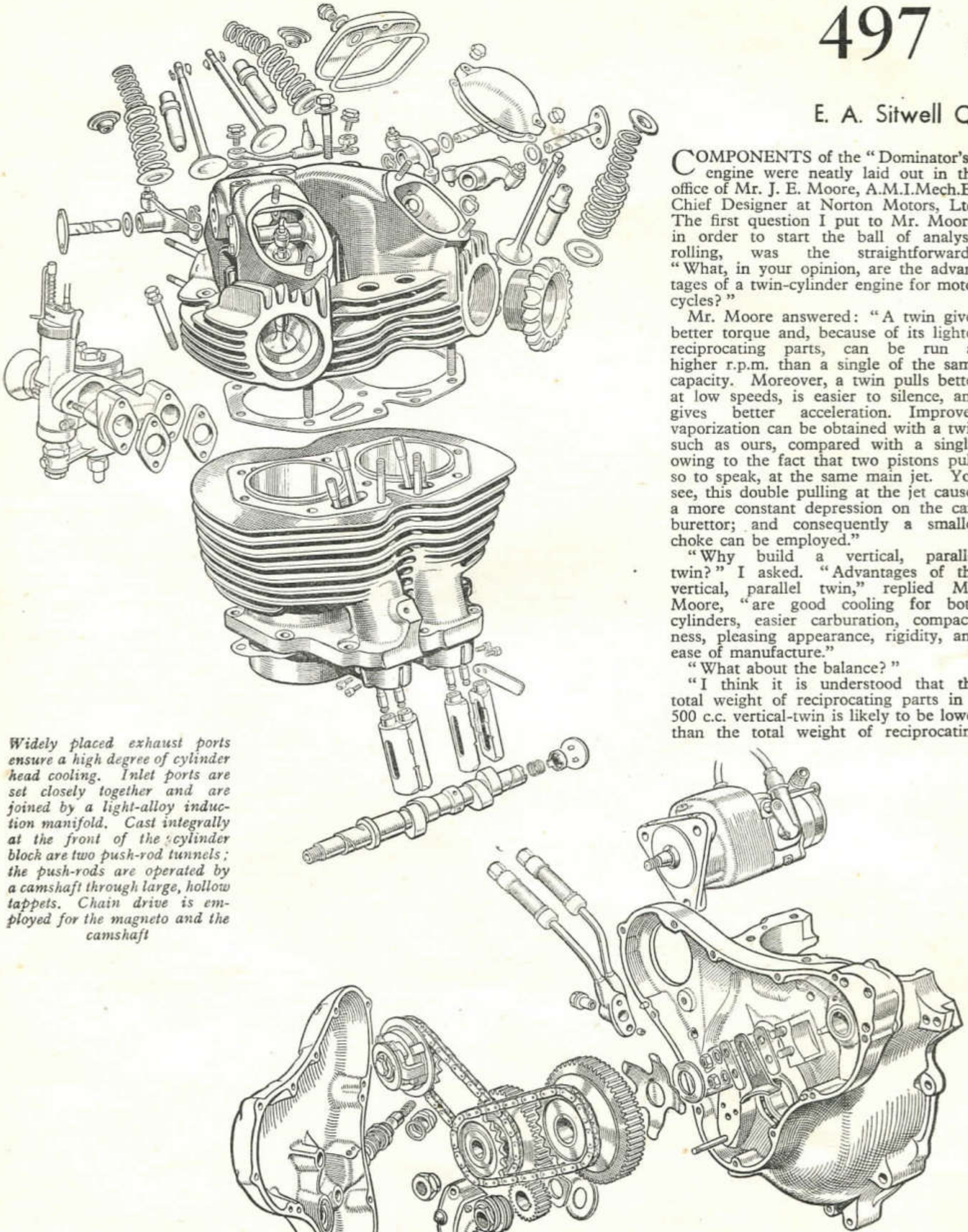
COMPONENTS of the "Dominator's" engine were neatly laid out in the office of Mr. J. E. Moore, A.M.I.Mech.E., Chief Designer at Norton Motors, Ltd. The first question I put to Mr. Moore, in order to start the ball of analysis rolling, was the straightforward: "What, in your opinion, are the advantages of a twin-cylinder engine for motor cycles?"

Mr. Moore answered: "A twin gives better torque and, because of its lighter reciprocating parts, can be run at higher r.p.m. than a single of the same capacity. Moreover, a twin pulls better at low speeds, is easier to silence, and gives better acceleration. Improved vaporization can be obtained with a twin such as ours, compared with a single, owing to the fact that two pistons pull, so to speak, at the same main jet. You see, this double pulling at the jet causes a more constant depression on the carburettor; and consequently a smaller choke can be employed."

"Why build a vertical, parallel twin?" I asked. "Advantages of the vertical, parallel twin," replied Mr. Moore, "are good cooling for both cylinders, easier carburation, compactness, pleasing appearance, rigidity, and ease of manufacture."

"What about the balance?"

"I think it is understood that the total weight of reciprocating parts in a 500 c.c. vertical-twin is likely to be lower than the total weight of reciprocating



Widely placed exhaust ports ensure a high degree of cylinder head cooling. Inlet ports are set closely together and are joined by a light-alloy induction manifold. Cast integrally at the front of the cylinder block are two push-rod tunnels; the push-rods are operated by a camshaft through large, hollow tappets. Chain drive is employed for the magneto and the camshaft

Norton Vertical Twin

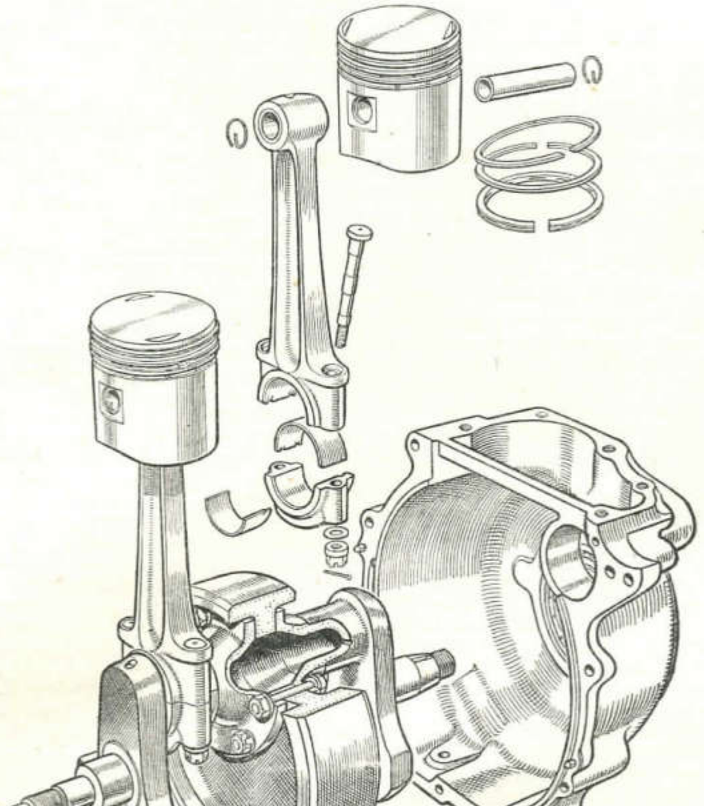
Mr. J. E. Moore, A.M.I.Mech.E., About the Engine Design of the "Dominator"

parts in a single of the same capacity. For instance, a vertical-twin usually has light-alloy con-rods; and a shorter stroke is, of course, employed than in a single. Therefore, although the theoretical balance is identical in practice there are lower inertia forces in the twin for a given r.p.m., with consequent smoother running. In balancing an engine, the aim should be to make the reciprocating and rotating parts as light as possible relative to the flywheel mass, in order to achieve smoothness at high r.p.m. This has been our aim with the Norton twin."

"I see you use a built-up crankshaft and flywheel assembly," I said. Mr. Moore replied: "We favour the bolted-up arrangement on the score of simplicity of manufacture. That statement, however, needs further explanation: we think that, with a really high-efficiency engine, forged crank cheeks are desirable and this dictates the building-up, since it would be impracticable to use a forged one-piece crankshaft and flywheel assembly because of the excessive machining that would be required after forging."

"What material is used for the shaft?"

"The shaft is made of manganese-molybdenum and has toughened journals. We use this material because of its high tensile strength, which is about 65 tons per square inch."



Pistons are made of Lo-Ex aluminium alloy and give a compression ratio of 6.7 to 1. The hollow, fully floating gudgeon pins are located by circlips in the orthodox manner. Connecting rods are forgings in R.R.56 light-alloy and there are steel back shell bearings at the big-ends. The cast-iron flywheel is bolted between the bob-weighted crank cheeks, which are forgings. Large main bearings, roller on the drive-side and ball on the timing-side, carry the crankshaft assembly

"And the flywheel—what is that made of?"

"Cast-iron — an entirely suitable material, and more than strong enough for the job, especially since a flywheel is intrinsically strong in section."

"What are the dimensions of the wheel?"

"They are 7in × 1⅞in."

"Will you please explain the construction of the crankshaft and flywheel assembly?"

"Certainly. As you see, the wheel is sandwiched between the bobweighted crank cheeks, each of which has a flange for fixing purposes. These flanges are specially large in diameter in order to promote rigidity in the whole assembly. Four bolts and two studs pass through the flanges and the flywheel, holding all three together. To ensure accurate alignment, there is a large diameter central dowel."

"How are the nuts on the studs and bolts locked?"

"The end of each bolt is centre-punched over its nut; also, the two locking plates that you can see, one on each side of the flywheel, are turned up against the stud nuts. These plates, incidentally, secure the dowel endwise."

"Have you the dimensions of the crank journals?"

"Yes; 1½in dia. × 1in long."

"Concerning the main bearings, why did you go in for two and not three? In other words, why not a central bearing as well as one at each end of the crankshaft?" Mr. Moore answered, "Our tests have proved that entirely satisfactory results are obtained with two main bearings and a centrally disposed flywheel. With this arrangement there is greater simplicity of construction. Moreover, a central bearing would increase the overall width of the engine."

"What can you tell me about the bearings you employ?"

"For ease of manufacture of both crankcase and mainshaft, the bearings are both the same diameter. Dimensions are 72mm × 30mm × 19mm, which, you will agree, make the bearings particularly robust. On the driving-side we have a roller journal, and on the timing-side there is a ball journal. We prefer to use a roller journal on the driving-side, as it is the higher loaded of the two bearings and has to look after the driving torque."

"I suppose there is an oil seal for the driving-side main bearing?"

"Yes; a synthetic rubber, spring-loaded oil seal."

"As you have already suggested, the con-rods are made of light alloy. . . ."

"Yes; each con-rod and end cap is a forging of R.R.56, a material chosen for its lightness and high tensile strength."

"What can you tell me about con-rod length and piston speed?"

"As you know, bore and stroke of the engine are 66mm and 72.6mm respectively giving a total capacity of 497 c.c. Each con-rod is 6in long, and the ratio of con-rod length to crankshaft throw (i.e. to half the stroke) is 4.19. This we have found through development is the best compromise for keeping the piston speed down (consequently reducing wear) and at the same time keeping con-rod angulation to a minimum."

"Why do you use loose shells for the plain big-end bearings?" "For ease of replacement and servicing."

"What are the shells made of?"

"They are steel-back, Micro-Babbitt shells. The steel gives us rigidity and the Babbitt part a good bearing surface."

"How are the shells located?" "By the little nicks or grooves in the con-rod. Each groove holds a small offset abutment of the shell, of which complete location is thus ensured."

"Anything special about the small-ends?" "No; they each have an orthodox, pressed-in, phosphor-bronze bush. Fully floating gudgeon pins are used. located by circlips."

"I see you employ a pair of flat-top pistons. Will you please give me further information about them?"

"Each piston has a full skirt, is form-turned oval, and is made of Lo-Ex aluminium-alloy, which has an expansion coefficient of 0.0000105 per deg. Centigrade. Clearances when cold are 6 thou at the top of the skirt and 4 thou at the bottom. Compression ratio is 6.7 to 1, which we think is as high as we can go on pool petrol. Both pistons are flat-topped in order to conform with combustion chamber characteristics. Each has one $\frac{5}{32}$in slotted scraper ring and two $\frac{1}{16}$in compression rings."

Pistons Differ

Here Mr. Moore paused to take a breath, and I continued for him: "But there is a right- and left-hand piston. I always remember that one!"

"Correct," Mr. Moore said. "You see, because of the V-section formation of the cylinder head, the valve clearance pockets in the top of each piston are not at right angles to the gudgeon pin; therefore, as you say, there is a right- and a left-hand piston."

"Now we come to the barrel block," I said, "which, as one can see, incorporates push-rod tunnels in front and has air spaces not only between each cylinder barrel, but also transversely between the bores and the push-rod tunnels." Mr. Moore said: "Yes, the aim, of course, has been to provide maximum cooling. The block is a one-piece casting of close-grained cast-iron. It is spigoted into the aluminium-alloy crankcase."

"To what depth?" "One inch."

"How is the block held down?" "By seven $\frac{3}{8}$in diameter and two $\frac{5}{16}$in diameter studs. Incidentally, the joint of the crankcase is slightly offset from the centre line in order to accommodate a central holding-down stud."

"I see the barrel block is very slightly spigoted into the cylinder head. I presume this is for added rigidity?" "Yes; and, of course, for gas tightness." Mr. Moore went on: "The cylinder head is of patented formation designed for maximum cooling, and it is held to the barrel by seven bolts and three head studs. It is made of cast-iron and has an integral rocker box. We use a copper-asbestos gasket between the head and the barrel. To allow a full flow of air at the front of the head, the exhaust valves are widely disposed. I liked your original description in *The Motor Cycle* when you wrote: '. . . the cylinder head as it were opens its arms wide to the incoming flow of air.' As you know, there is a flow of air between the combustion chambers and also transversely between the exhaust and inlet valves. In plan, the port axes converge towards the rear, making a total angle of 50deg. The valves make a total angle with each other of 58deg, which means that they are fairly upright; and it follows that we can use shallow combustion chambers."

"Why is it good to have shallow combustion chambers?" I asked. "Because," Mr. Moore replied, "the surface of the chambers is reduced, and thus they keep cooler and give better combustion."

"What can you tell me about the rockers and their shafts?" I asked. Mr. Moore picked up a flanged rocker shaft and said: "Each shaft is pushed in, and its flange is pulled up to the flat face by two $\frac{1}{4}$in pins. The rockers themselves are hollow and oscillate round the stationary shafts."

Rocker Material

"What are the rockers made of?"

"Three per cent nickel steel, case-hardened in the bore. At the valve end of each rocker is a hardened steel adjuster with a lock nut. At the other end is a fixed, hardened steel ball which seats in the push-rod cup."

"Anything special about the valve springs?" "No; there is, of course, an inner and outer coil spring—wound in opposite directions to prevent trapping."

"Can you give me a load figure for the springs?" "Yes; the initial seat load exerted by a pair of springs is 88 lb."

"I see that each end of the two rocker-box covers on the exhaust side is held down by two $\frac{5}{16}$in studs, and that the single inlet-side rocker box cover is secured by a stud protruding from the inlet cavity. That seems to complete the information about the rocker box. Now the valves—what are they made of and why?

"The valves are made of Silchrome, a material chosen because it withstands heat extremely well."

"What are the valve dimensions?" "Port diameters are $1\frac{7}{32}$in, and stem diameters are $\frac{5}{16}$in. Incidentally, each top spring-cup is taper-cotter retained, and the bottom spring-cup is an inverted cup located by the head of the valve-guide."

"What is the valve-guide material?" "Chilled cast-iron, which provides a good bearing surface. The guides are pressed in."

"Obviously," I said, "there is no need for valve-seat inserts, since the head is made of cast-iron." Mr. Moore answered, "That is correct."

"Why," I asked, "do you now employ two induction ports? I remember there was only one in the original design." Mr. Moore replied: "As you remark, the cylinder head now has two induction ports—one per valve—and there is a short aluminium induction manifold connecting with a single, flange-fitting Amal carburettor of 1in bore. The two induction ports give a higher volumetric efficiency—better cylinder filling—than one, and therefore the general performance of the engine is higher. Obviously, with the present arrangement, the gases have a longer *straight* port in which to gather speed before reaching the valve. The two Tufnol distance pieces between the manifold and the head are put there, of course, for purposes of heat insulation."

I picked up a push-rod. "You tell me," I said, "that the push-rods are made of $\frac{9}{32}$in light-gauge high tensile steel tubing. In order to save reciprocating weight, why not use light-alloy rods?"

"Because it is doubtful," Mr. Moore answered, "if there would be any saving in weight by the time we had increased the section (in the alloy) for strength." He continued, "Each rod has a hardened steel cup at the top to hold oil and to take the ball on the rocker end. There is a hardened steel ball at each lower end. You will notice, of course, that the two pairs of rods are of different lengths."

Unusual Tappets

"What are the main points about these massive, car-type tappets?" "We use this patented type of tappet because it has a large bearing surface with consequent reduced wear. Also, we can do without tappet guides. The tappets are hollow and made of cast-iron. They have chilled rubbing surfaces. Each pair forms a complete circle, of which each half forms a complete tappet and moves independently. Bolted to an extension of each cylinder spigot is a retaining plate sandwiched between the lower ends of each tappet in order to prevent rotation. Incidentally, these plates effectively prevent the tappets from falling out when the cylinder block is lifted. In the top of each tappet there is a small cup which takes the ball end of the push-rod and holds oil. The tappets are particularly robust, but they are also light: you will see that windows are cast in the sides to reduce weight."

"Yes," I said; "and I also notice that the tappets are slightly chamfered fore-and-aft at their lowest ends. Is this also to save weight?"

"Yes."

"Another question: the tappet housings are hollow milled at each lower end, obviously in order to provide sufficient clearance for the rotating cams. Why are the housings not machined straight across? Clearance could surely still be achieved?"

"Because we wanted to provide plenty of fore-and-aft support for each tappet on its initial thrust by the cam."

Discussion reached the camshaft. Mr. Moore said: "The camshaft is carried on two widely spaced, plain, phosphor-bronze bearings. It is made of forged, case-hardened Ubas steel, and, in order to reduce weight, it is machined hollow. Designed for efficiency and quietness, the cams have quietening curves. Neutral diameter of each cam is 1⅝in. Each cam is individually tested for hardness."

I looked at the timing gear, and Mr. Moore went over the main points. He explained: "This pinion on the end of the mainshaft drives an intermediate gear on a fixed shaft at half engine-speed. Integral with this intermediate gear are two chain sprockets, of which one drives the automatic advance-and-retard magneto at the rear, and the other the camshaft in front. Both chains have straight-sided links. The camshaft chain has a slipper-type tensioner, for which the straight-sided links are particularly suitable. Dimensions of the magneto chain are ⅜in pitch × 0.155in width, and of the camshaft chain, ⅜in pitch × 0.225in width."

"Why use chains and not gears?" I asked. "For quietness in operation," Mr. Moore replied. He went on: "A slight adjustment of the magneto chain can be made by moving the instrument. The dynamo, which is in front of the engine, is driven by a spring-loaded fibre wheel which is carried on the camshaft and forms a slipping-clutch drive. Slip occurs only on inertia overloads."

Lubrication System

"Now I think we should come to the lubrication. Would you please enumerate its general characteristics?"

"Certainly. The system is actuated by a double-action gear pump; and pressure that is built up at the big-ends is controlled by a pressure release valve. Oil pressure is linked up with adequate oil volume. A by-pass from the return pipe lifts oil to the rocker box. Prevention of cylinder lubrication bias has been one of the chief aims in the design of the system; and this aim, as you will see in a minute, has been successfully achieved. Total quantity of oil in circulation is 5 pints."

"Thank you. Now let us follow the oil in detail through the system."

"Right. First the oil falls by gravity from the tank to the gear pump, which is driven by a worm off the mainshaft. This pump then forces the oil through a nipple, which is sealed by a taper synthetic rubber washer, into a horizontal drilling in the timing cover. From here the oil passes to a small chamber in the timing cover; and this chamber is fitted with a spring-loaded synthetic rubber oil seal. When the timing cover is in place, the end of the mainshaft fits snugly into this very oil seal."

At this point I interrupted and said: "Won't the synthetic rubber oil seal wear, with the revolutions of the mainshaft?" Mr. Moore answered: "This is an excellent application for a spring-loaded oil seal of this type, (a) because the seal is lubricated, and so there will be very little wear; (b) because pressure created within the chamber assists in closing the seal down to the shaft; and (c) because, if there *is* any wear in the rubber, the spring will take it up."

Having dealt with that point, Mr. Moore continued: "The oil has reached the chamber I have already described. Now it passes into the hollow crankshaft, and through drillings in the crank members, to the big-ends, which it lubricates under pressure. Oil released from the big-ends is thrown centrifugally to lubricate the cylinder walls, and the surplus drains into the sump at the rear of the crankcase, whence it is picked up by the scavenge pump and returned to the tank."

"What is the pressure at the big-ends, and how is it maintained?"

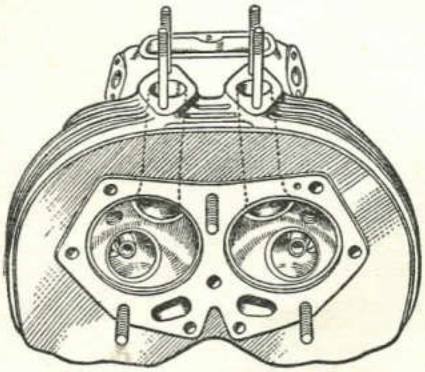
"The pressure is about 80lb per sq in when cold, and it is maintained by a large, spring-loaded, piston-type pressure release valve connected with the horizontal drilling in the timing cover already described. To prevent foreign matter from getting in the valve, there is a gauze filter on its input side. At the pressure mentioned, oil exhausts into the timing chest and lubricates the timing gear. Thence the oil passes through suitable drillways to the middle of the engine at the rear. Thus there is no cylinder lubrication bias, as the oil goes straight down to the sump without running excessively down the timing side crankcase wall, whence it would inevitably be flung up by the crankshaft cheek.

Oil Lifted to Rockers

"A by-pass on the return pipe next to the oil-tank lifts oil up to a T-piece which distributes the lubricant to two banjo unions, one on each side of the rocker box at the top. Oil is led through drillings directly to each hollow rocker shaft, from which it emerges at an annular ring in the middle and feeds the shaft via a scroll. The oil then drains from the lowest points of the rocker box to the crankcase, via the push-rod tunnels on the exhaust side (lubricating the tappets, etc.), and down a drilling in the head and barrel on the inlet side."

"How do you control the amount of oil in the rocker box, to prevent too much oil from getting into the inlet valve guides?"

"It must be remembered that the oil in the rocker box is not there under pressure. It is only *lifted* there from the return side of the system; and it is present in the rocker box in a quantity sufficient for lubricating the rockers. The valve-guides are lubricated by oil mist only, and no level of oil is built up in the rocker box. Thus, there is no possibility of oil draining down the guides."



Separate induction ports are employed. Combustion chambers are unusually shallow

"Where is the oil filter?"

"In the oil-tank. It is a wire gauze, removable type of filter."

"How do you prevent oil from draining into the crankcase when the machine is not being used?"

"We do not find it necessary to employ a ball-valve. Oil just does not leak past the gears in the Norton pump."

"Good," I said. "That seems to deal with the lubrication system. Now would you please describe how the crankcase breathes?"

Power Output

Mr. Moore said: "The engine breather is incorporated in the camshaft. Centre of the camshaft, as you see, is increased in diameter, so that heavy particles of oil will be flung off, and the air immediately surrounding this centre portion will be as free as possible from oil. The raised portion is drilled radially with four holes, which are the pick-up points, so to speak, for the air to be breathed, and lead to the main drilling in the camshaft. Keyed to the end of the camshaft nearer to the driving side of the engine is a spring-loaded valve containing small ports which, as the camshaft revolves, coincide with a stationary ported plate in the crankcase. The stationary ports are connected by a drilling in the rear of the crankcase, and by a pipe, to the open air. With its mechanical arrangement, the breather exhausts at all engine speeds on the downstroke of the pistons, and the ports are closed on the up-stroke. Air, some oil mist, and probably a little moisture are breathed out by the engine. We do not, incidentally, utilize the breathings to lubricate the rear chain, and the exit pipe points merely to the ground."

"That seems to have cleared up most things," I said. "Now, what is the power output of the engine?"

"The output is 29 b.h.p. at 6,000 r.p.m."

"And a pretty good figure," I said. "Another question that occurs to me is to ask why there is no engine-shaft shock-absorber." "Because," Mr. Moore answered, "we have in the clutch a rubber vane type of shock-absorber which has been a feature of Nortons for many years."

Instruction Book Data

"Fine. I think those are all the questions I have to ask, except for a few on such instruction book details as magneto and valve timing, etc."

I took down the following information, dictated by Mr. Moore:—

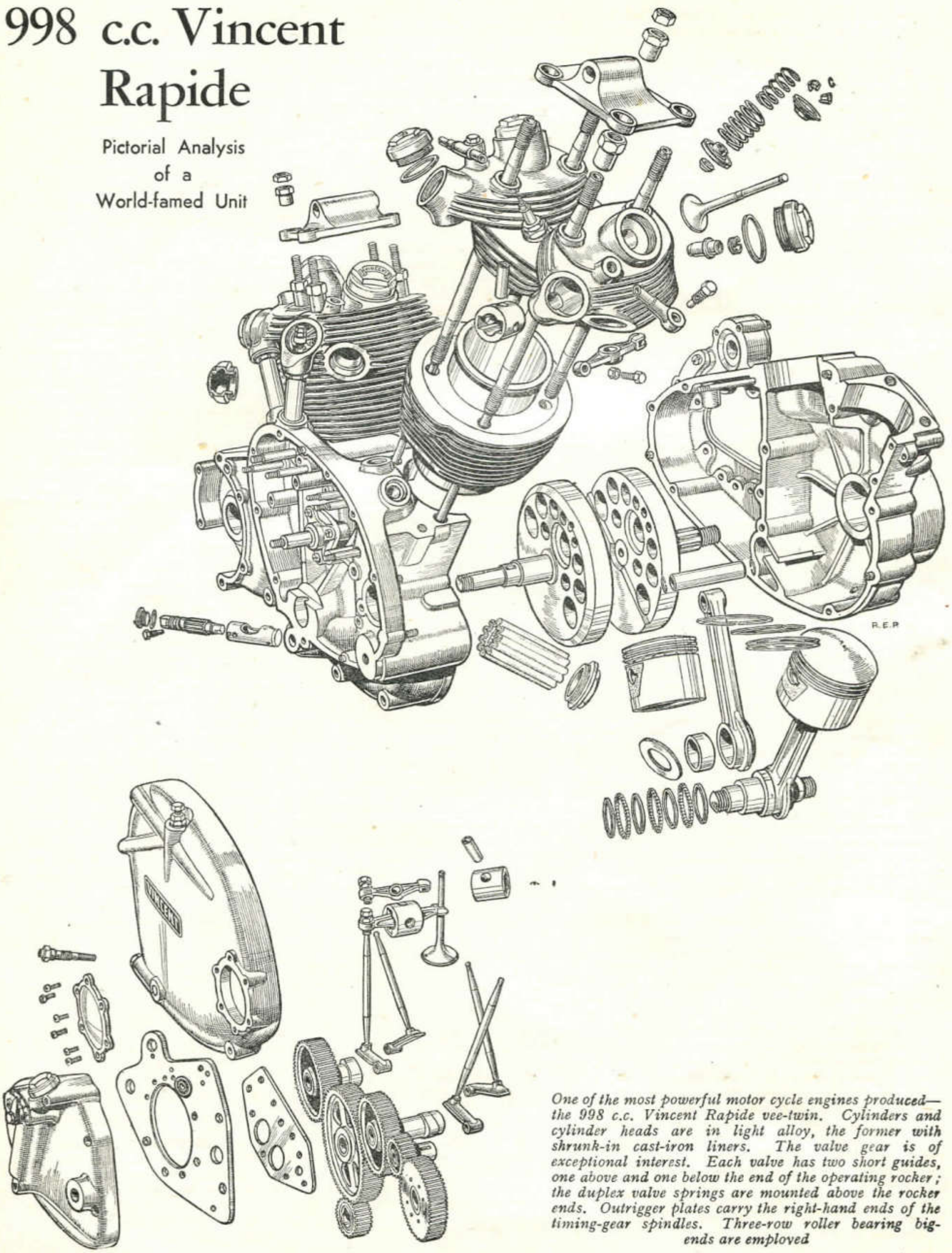
Magneto timing:—Set, in the fully advanced position, at 31 deg before t.d.c.

Valve timing:—Exhaust opens 57.5 deg before b.d.c. and closes 22 deg after t.d.c. Inlet opens 22 deg before t.d.c. and closes 57.5 deg after b.d.c.

It is necessary for the valves to be timed with the tappet clearance set at 10 thou (*not* the working clearance) when cold, because of the quietening curve ramps on the cams. Final working tappet clearances when cold are 3 thou for the inlet and 5 thou for the exhaust.

998 c.c. Vincent Rapide

Pictorial Analysis of a World-famed Unit



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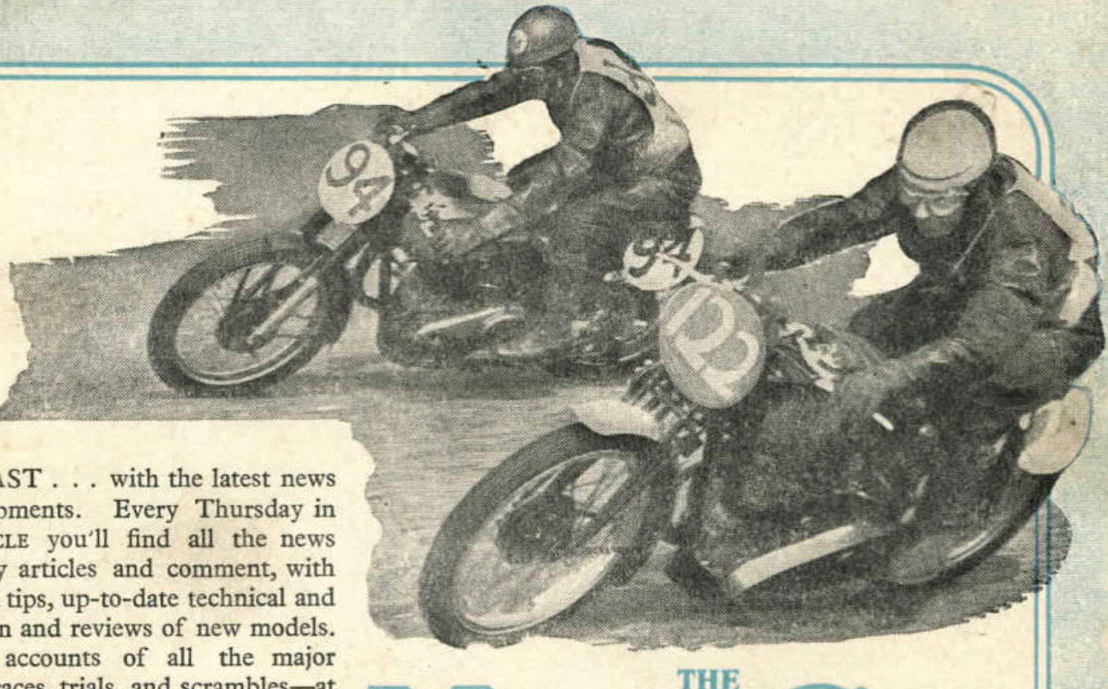

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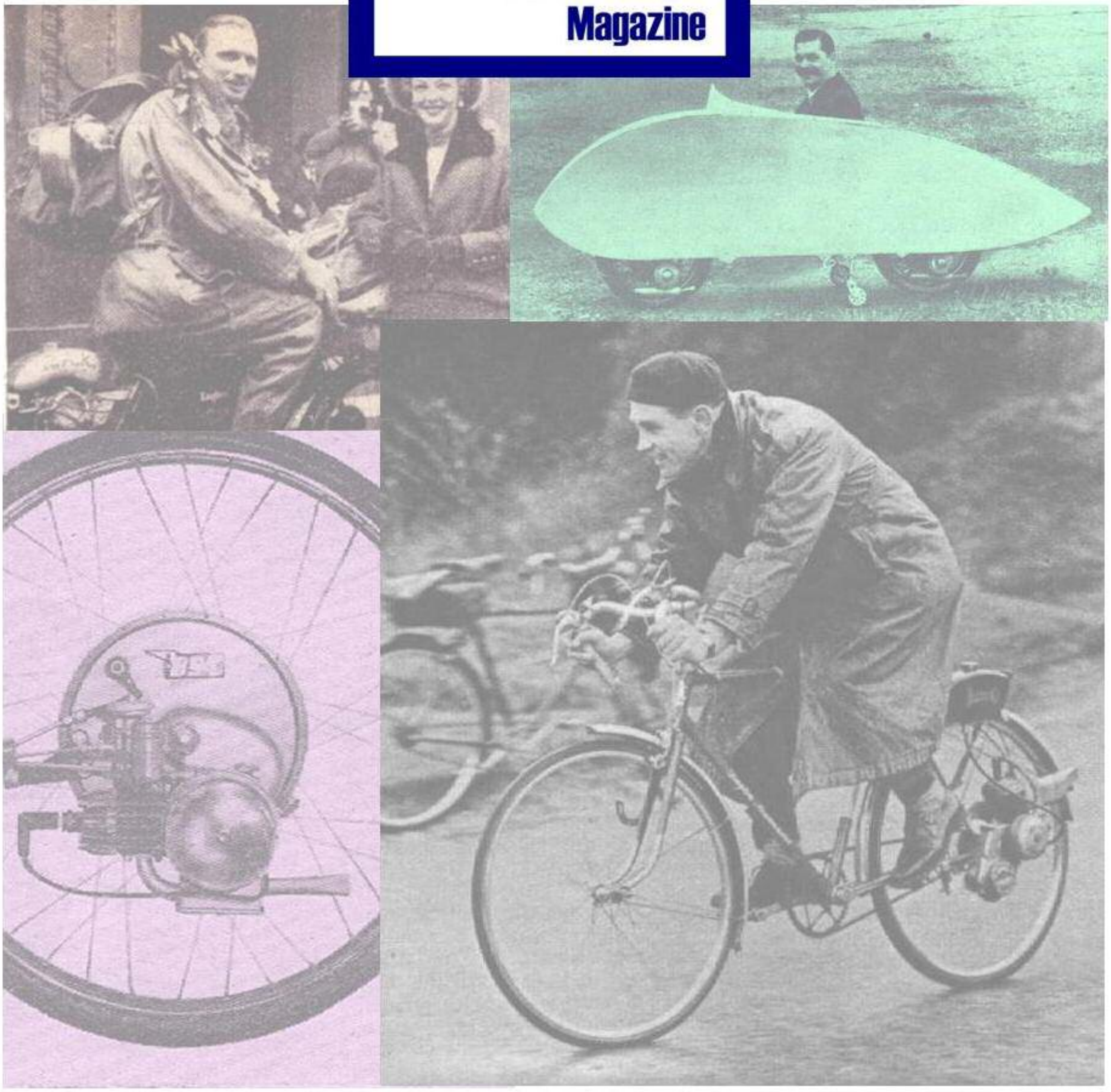

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