MODERN ENGINES

The 149 c.c. Triumph

EDWARD TURNER, Triumph's Managing Director and Chief Designer, and ALAN BAKER, Dissect a Lively Overhead-valve Power Unit of Sma

EARLY in November 1952 came one of the bigger surprises of post-war motor cycling: Triumphs announced an entirely new o.h.v. lightweight to be known as the Terrier. Since the resumption of civilian production, the new Meriden factory had confined its activities to the very popular, medium-capacity vertical twins, and so radical a change of policy was unexpected but most welcome. The Earls Court Show that year had barely opened when it became evident that, in the Terrier, Edward Turner had achieved another outstanding success, worthy of taking its place alongside his Triumph Speed Twin.

The Speed Twin set a new standard for five-hundreds and started one of the major design trends of recent years—that of two cylinders instead of one. Without in any way decrying the Speed Twin, I think it is easier to design a world-beating big machine than an equally successful lightweight. In the larger sizes one has so many cubic centimetres to play with that almost any characteristic can be achieved. A restricted engine capacity, on the other hand, brings other restrictions in its train.

It is not unduly difficult to extract plenty of power from a small engine, but to attain real flexibility without making the machine depressingly slow is a very different matter.

Performance Compromise

Although a lightweight should be capable of undertaking serious road work, it may be regarded primarily as a short-distance machine. Particularly in this country, that means that much of its running must be done in traffic of at least moderate density. Under such conditions it is clearly undesirable to have high performance at the expense of tractability; an excessively "soft" performance, however, is almost as bad.

In the first case the rider is being constantly frustrated by other vehicles, while in the other he is unable to take full advantage of his machine's mobility. To possess a wide appeal nowadays, a lightweight must combine docility and performance, and the most successful designer is he who best resolves the compromises involved.

The Terrier undoubtedly has wide appeal, so it seemed apposite to open my discussion with Mr. Turner by asking how he set about his task and why the Terrier engine is what it is.

Question: "Why did you decide on an overhead-valve one-fifty engine for the Terrier?"

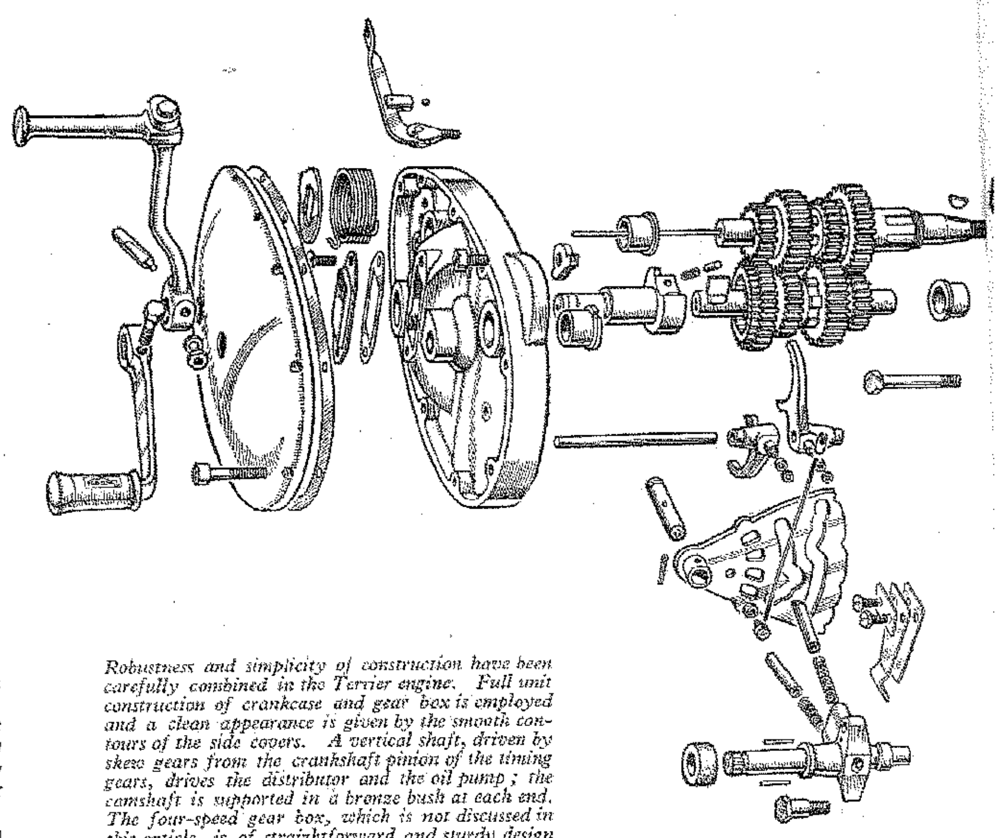
Answer: "Before the war Triumphs produced a 250 c.c. o.h.v. model weighing about 240 lb. As it was desired to go back into the lightweight business, we knew that a modern o.h.v. 150 c.c. engine in a still lighter frame was capable of giving about the same performance with even better economy and lower first cost. Since motor cycles are rather expensive in these days, in common with every other post-war engineering commodity, the new machine was to be a study of how simple, light and efficient a little motor cycle could be and still give a man-sized road performance.

"Overhead-valves were chosen because the two-stroke field is well covered both in this country and abroad, and it is my opinion that an o.h.v. four-stroke costs so little more (expressed as a percentage of the cost of the whole machine) as to be well worth the extra, in view of the very much superior rev range and general performance. In any case, the slight extra cost is more than saved, by lower petrol consumption, in the first year of the average machine's life. While it is true that two-strokes perform remarkably on petroil, I still prefer bearings to be lubricated by green oil instead of slightly coloured petrol.

"The side-valve principle did not appeal to me for this particular application on the score of its inferior breathing at high revs and its unsymmetrical cylinder section which, on a small engine working at full throttle, might result in distortion; also, to give the same performance as an o.h.v. unit, a side-valve engine would have to be larger, which was contrary to the fundamental principle of a light, efficient machine."

Question: "The bore and stroke are nearly square at 57mm and 58.5mm respectively. The proportions, therefore, differ considerably from the 500 c.c. Speed Twin (63 × 80mm) and the 650 c.c. Thunderbird (71 × 82mm). What is the reason for the difference?"

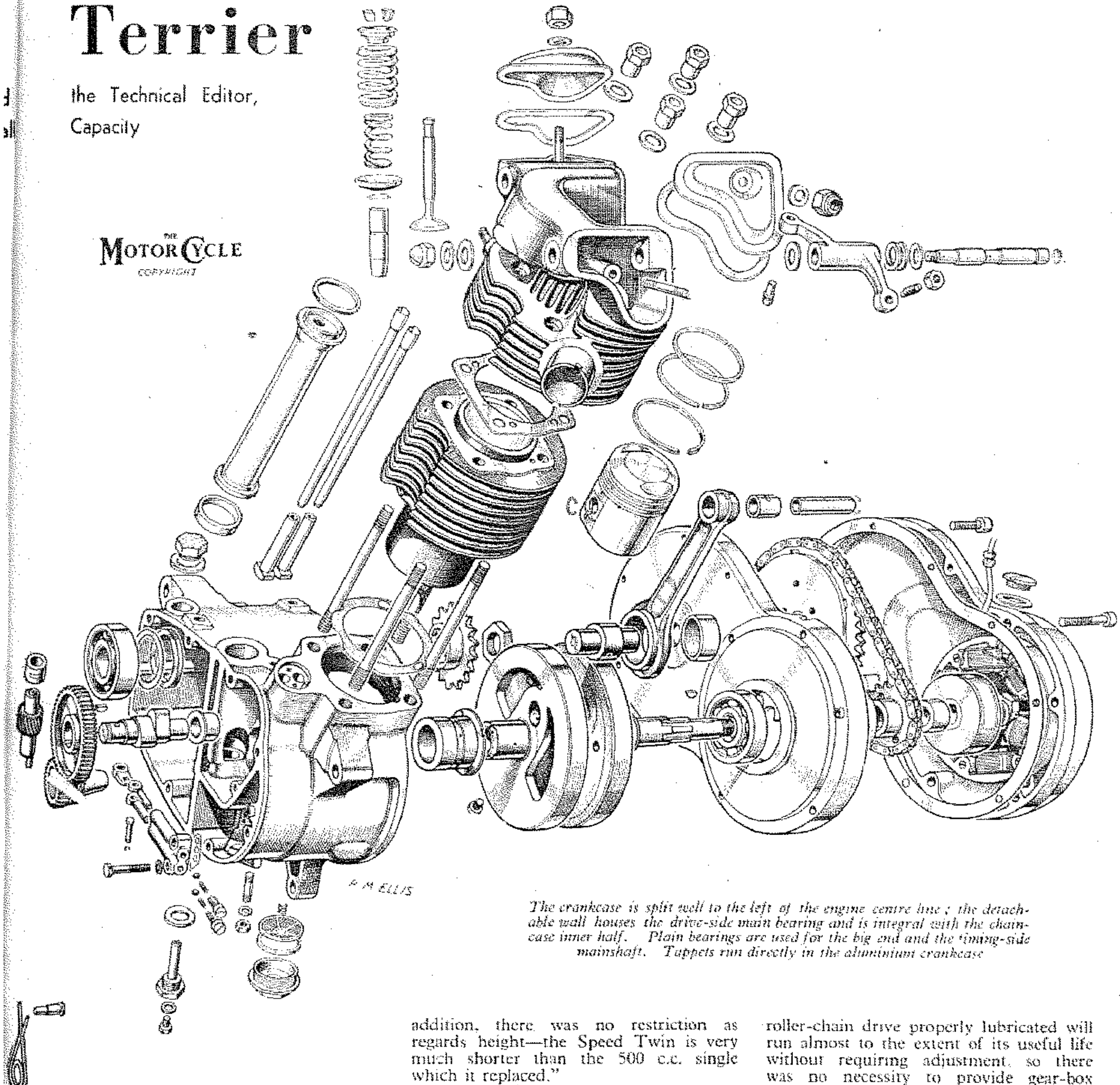
Answer: "I chose a nearly square bore



Robustness and simplicity of construction have been carefully combined in the Terrier engine. Full unit construction of crankcase and gear box is employed and a clean appearance is given by the smooth contours of the side covers. A vertical shaft, driven by skew gears from the crankshaft pinion of the timing gears, drives the distributor and the oil pump; the camshaft is supported in a bronze bush at each end. The four-speed gear box, which is not discussed in this article, is of straightforward and sturdy design but the selector mechanism is unusual: the cam plate is actuated directly by spring-loaded plungers housed in a boss on the gear-pedal shaft

Terrier

the Technical Editor,
Capacity



The crankcase is split well to the left of the engine centre line; the detachable wall houses the drive-side main bearing and is integral with the chaincase inner half. Plain bearings are used for the big end and the timing-side mainshaft. Tappets run directly in the aluminium crankcase

and stroke because such proportioning makes for the smallest and lightest engine for a given power, and because, for a four-stroke, there is a minimum size of piston which, with commercial tolerances, results in a satisfactory job. The Speed Twin bore and stroke, 63 × 80mm, were dictated by an entirely different set of conditions. There my problem was maximum crankshaft stiffness and minimum width between the main bearings; in addition, there was no restriction as regards height—the Speed Twin is very much shorter than the 500 c.c. single which it replaced."

Question: "Though it is in line with current Continental designs, your layout is unusual for this country in that the gear box is in full unit construction with the engine. Why did you decide against a separate or bolted-on gear box?"

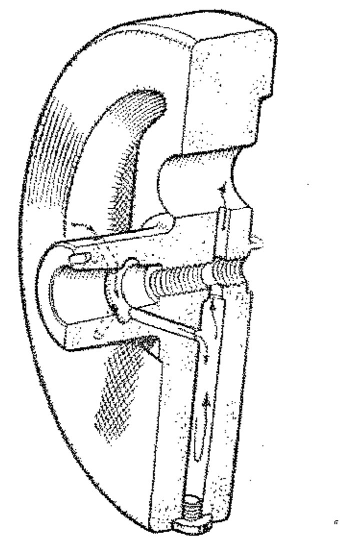
Answer: "Unit construction, i.e., engine and gear box in one casting, was chosen because of the opportunity it afforded to make the minimum amount of metal perform the maximum duty. Unit construction is lighter and is, of course, stiffer, and greater exterior smoothness with fewer cavities makes for ease of cleaning and generally symmetrical appearance.

"It has been found that a short-centre roller-chain drive properly lubricated will run almost to the extent of its useful life without requiring adjustment, so there was no necessity to provide gear-box adjustment. Another advantage of unit construction is that the whole of the light-alloy structure is in direct thermal contact with the hotter zones of the unit, thereby assisting in overall cooling.

"Summing up, unit construction, where it is possible to apply it, is lighter, stiffer, cheaper and cleaner. It also obviates disturbing the tension of the rear chain for primary chain adjustment."

Although the transmission is, strictly speaking, outside the scope of this article, the engine and gear box were designed as one, so I inquired the reason for the decision to adopt four ratios. The reply was that, although the Terrier was to be

Triumph Terrier Engine . . . . continued



The big end is fed with oil from the timing-side main bearing, and there is a centrifugal sludge trap in the flywheel

a light, inexpensive motor cycle, there was no intention of compromising on the specification. The normal four-stroke power-curve characteristics demanded four speeds if full advantage were to be taken of the engine performance under all road and traffic conditions likely to be encountered.

When we turned our attention to the components of the engine, it was obvious that the crankcase and crankshaft layout was unconventional in several important respects.

One-piece Crankcase

Question: "The construction of your main crankcase-gear box unit is unusual in that it is not split along the longitudinal centre line; the division occurs more or less in the plane of the drive-side main bearing. What are the advantages of this layout?"

Answer: "By arranging for the crankcase to be in one piece, with the flywheel assembly covered by a side-plate which is part of the chain oil-bath, great economy of casting is attained and a much more rigid and accurate crankcase assembly results.

"This is not practicable on the larger engines, but where it can be done it is an obvious advantage to have fewer parts and sections, thus achieving maximum stiffness. The arrangement also enables the drive-side main bearing to be replaced without complete dismantling of the engine; furthermore, the engine can be dismantled in its entirety without disturbing the gear box."

Question: "The shouldered crankpin, of En.36 nickel-chrome case-hardening steel, is a parallel interference fit in the flywheels, which are of high-grade, high-elongation cast iron. On the timing side, the mainshaft is integral with the wheel, but the En.36 drive-side shaft is a parallel pressed-in fit and is prevented from rotating by a serrated flange. Why is there this difference in the mainshafts?"

Answer: "On the more lightly loaded timing side, the shaft is relatively short and runs in a steel-backed, white-metal-lined bush. A cast-iron shaft, which has excellent wearing properties, is quite strong enough for the duty. To deal with the heavier drive-side loading I decided to use a ball main bearing; the overhung loading is such that cast iron would not be strong enough, so a separate shaft was necessary."

Of 80-ton tensile strength, the toughened, nickel-chrome steel connecting rod has a pressed-in big-end bush which, like the timing-side main bearing, is white metal on a steel backing. Earlier engines embodied a roller-bearing big end, but the change to a plain bearing was made to give longer life and rather quieter running. Triumphs' experience with plain big ends on the twins has been very satisfactory in those respects.

TECHNICAL DATA

CAPACITY: 149 c.c.

BORE: 57mm.

STROKE: 58.5mm.

COMPRESSION RATIO: 7 to 1.

PISTON RING END GAP: Compression and scraper rings, 0.006 to 0.011in.

PISTON RING SIDE CLEARANCE: Compression rings, 0.001 to 0.003in; scraper ring, 0.0013 to 0.0033in.

VALVE CLEARANCE: Engine cold—0.010in inlet and exhaust.

VALVE TIMING: With 0.015in valve clearance—inlet valve opens 30 degrees before top dead centre and closes 50 degrees after bottom dead centre; exhaust valve opens 55 degrees before bottom dead centre and closes 25 degrees after top dead centre.

IGNITION TIMING: On full retard, contact-breaker points begin to open 8 degrees ($\frac{1}{32}$in) before top dead centre.

ENGINE DIMENSIONS: Crankshaft drive-side ball bearing, 20mm bore x 52mm outside diameter x 15mm wide; crankshaft timing-side plain bearing, 1$\frac{1}{8}$in bore x $\frac{13}{16}$in long; big-end plain bearing, 1$\frac{1}{8}$in bore x $\frac{7}{8}$in long; small-end bush $\frac{7}{16}$in bore x $\frac{3}{4}$in long; connecting-rod length, big-end to small-end centres, 4$\frac{5}{8}$in. Valve diameters, inlet and exhaust: head, 1$\frac{1}{8}$in; throat, 1$\frac{1}{16}$in; stem, $\frac{5}{16}$in. Valve-seat angle, 45 degrees. Valve lift, 0.280in.

CARBURETTOR: Amal, type 332/2; choke diameter, $\frac{11}{16}$in; 25 degrees of downdraught. 90 main jet. No. 4 throttle valve. Needle clip fitted in third groove from top.

Having a one-piece crankshaft, the twins must be fitted with split big-end bearings, but splitting is unnecessary on the Terrier with its built-up shaft. A solid bearing is, of course, lighter and more robust as well as cheaper than a bearing of the split type.

Question: "The timing pinion is integral with the skew gear which drives the distributor and oil pump. The two gears have a tapered shaft which engages with a female taper in the mainshaft. A long bolt screwing into the flywheel secures the gears and there is a positioning dowel for valve-timing purposes. What is the reason for this rather unorthodox attachment method?"

Answer: "Since cast iron has a low tensile strength, it would not have been good practice to mount these gears on a relatively slender shaft. The method adopted, though unconventional in the motor-cycle industry, is sound engineering practice."

Question: "You employ a double-plunger oil pump, as on the larger models, but it is driven by a small connecting rod from an eccentric on the end of the driving shaft, instead of directly from the eccentric. Why do you prefer plunger to gear pumps and why did you adopt this different driving system on the Terrier?"

Vertical-shaft Drive

Answer: "Although the gear-type pump is capable of high outputs, it is more sensitive to oil viscosity than the plunger pump, and so its delivery is smaller when the oil is cold and thick. Also, since it is unable to prime itself, it has to run immersed and is critical to air leaks. I therefore consider the plunger pump to be more reliable for normal purposes.

"To be incorporated in the Terrier layout, the oil pump had to be mounted in a plane different from that on the twins. Since we already had a vertical shaft to drive the distributor, it was common sense to use that shaft also for the pump. The connecting-rod drive then presented itself as the obvious method."

The lubrication system of the Terrier is orthodox. Oil is delivered by the feed pump to the timing-side main bearing, whence it enters the mainshaft through drillways which lead it to the big-end bearing. A centrifugal sludge trap, the outer end of which is closed by a plug, removable for cleaning, is incorporated in the timing-side flywheel.

In normal Triumph fashion, the overhead rocker gear is lubricated from the scavenge side of the system. Some of the oil drains down the pushrod cover tube to lubricate the cams, tappets and timing gear, while that which collects in the valve pockets drains back to the crankcase through drillways in the cylinder head and barrel.

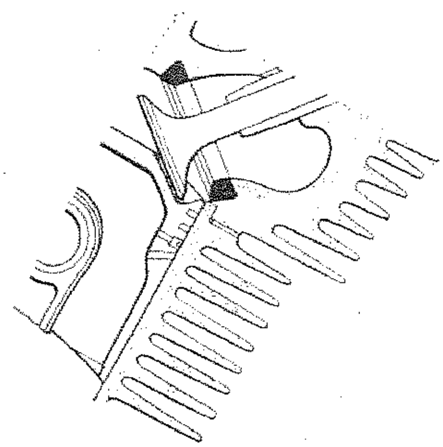
Camshaft Material

The timing gear is extremely simple and comprises only two pinions. The cams are integral with their shaft, on to which the cam pinion is pressed and keyed. The camshaft is supported in a bronze bush at each end.

Question: "What material do you employ for the camshaft, and why?"

Answer: "Case-hardened mild steel is used because it gives an extremely hard and therefore durable case. Since the shaft is short, stiff and well supported, there is no disadvantage in using a material which has a relatively low strength of core."

Hardened-steel tappets operate directly in the aluminium of the crankcase. Since this is a rather unusual practice I inquired of Mr. Turner why renewable guide bushes were not fitted. He replied that the bearing area provided was so great in relation to the loading that to fit separate bushes would be an unjustifiable complication. Indeed, the tappet-guide sur-



Dovetailing of the valve-seat inserts ensures their complete security in the light-alloy cylinder head

faces on the Terrier were larger than those on the Speed Twin and, from their experience, should outlast the engine before wear became excessive.

Question: "Another interesting feature of the valve gear is that the pushrods have hardened-steel end caps only at the top. Why do you not fit end caps also at the bottom of the rods?"

Answer: "The angular movement of the lower ends of the pushrods relative to the tappet cups is so small during valve operation that the amount of rubbing which occurs is negligible. Since the mating surfaces are well lubricated by oil draining down the pushrod-cover tube, the rate of wear is minute and it is quite unnecessary to fit hardened ends. Also, to do so would increase the reciprocating weight of the valve gear."

Integral Rocker Boxes

The cylinder head is die-cast in a high-grade, copper-containing light alloy, and has integral rocker boxes with pressed-steel covers over the valves; each cover is secured by a single stud and nut. I inquired why it was decided to employ integral construction instead of separate rocker boxes such as are used on the twins.

Answer: "The twins, except for the Tiger 100, have cast-iron cylinder heads; separate aluminium rocker boxes are used because their detachability simplifies work on the top half of the engine. Because of its smaller size, the Terrier is more accessible, and I decided initially to use a light-alloy head in order to make a moderately high compression ratio practicable. Integral rocker boxes were logical for this engine because they cost less, are very rigid, and provide an excellent heat path to aid cooling of the cylinder head."

Question: The rockers, I know, are steel forgings, hardened and ground in the bore, and run directly on hardened-steel spindles. Did technical or economic considerations influence your decision against the employment of bronze-bushed rockers?"

Answer: "We have always run hardened-steel rockers on steel pins with every success. It is unnecessary to bush the rockers because the character of the load is reciprocating with unilateral bearing pressures."

An interesting feature of the cylinder head is the herringbone layout of the top fins; the object is to give the best possible cooling. The exhaust rocker box effectively diverts direct air flow from the middle of the head; thus transverse or longitudinal finning would be of little benefit. Cool air is deflected inward from each side of the head by the herringbone fins, and the gap between the two sets of fins enables the heated air to get away, an essential factor if effective cooling is to be achieved.

Valve-gear Details

Inlet and exhaust valves are of the same size and run in normal cast-iron guides at an included angle of 75 degrees. The combustion chamber form is part-spherical. The valve included angle is relatively small, and I ascertained that its adoption was governed primarily by the desire to use a single pushrod cover tube, in the interests of neat appearance and minimum weight; a wider angle would have meant increased rocker-arm length. The angle chosen is also near-ideal for the bore, stroke and compression ratio of the Terrier engine.

Valve-seat inserts are of a special cast iron which has a high coefficient of expansion to match that of the cylinder head. The inserts are cast in and an unusual method of securing them is employed; they have a tapered periphery which gives a dovetailed effect. The inserts are heated before the aluminium alloy is poured.

Question: "Although you have a light-alloy cylinder head, the barrel is of cast iron. Why did you not adopt light alloy for the barrel also, and why do you paint the barrel aluminium, a finish which does not promote effective cooling?"

Answer: "The cast-iron barrel used on the Terrier is almost completely symmetrical in cross-section and, therefore, can be made very thin with close-pitch fins which give adequate cooling. A light-alloy barrel would introduce unnecessary complications. A fairly substantial cast-iron liner would be necessary, and a certain minimum section is required for a light-alloy barrel to retain contact with the liner; the bi-metal arrangement would result in greater cost, less rigidity and equal weight, to no advantage.

Crankcase Breather

"The Terrier barrel is painted aluminium to avoid breaking up the colour pattern of the whole engine; although the ideal finish would be black, the barrel has ample cooling capacity for the aluminium finish to be practicable."

Question: "I see that you employ a ported crankcase breather in the outer camshaft bush. In view of this controlled breathing, I should have thought the oil seal outboard of the drive-side main bearing was unnecessary. Why do you fit the seal?"

Answer: "The breathing arrangements are so effective that there is a pressure differential between the chainbath and the crankcase, with the attendant danger of losing oil to the main system at the expense of the chain; hence a seal is necessary."

Question: "The Terrier engine was obviously designed from the start with an A.C. generator in view. Such a generator, of course, eliminates the need for two electrical instruments for ignition and lighting purposes, and thereby saves weight, cost and power loss. Do you find the extra overhung weight of the rotor on the mainshaft has any adverse effect on main-bearing life?"

Answer: "There is no disadvantage in the overhung rotor, or appreciable extra load on the main bearing which has to support the weight of the rotor also. As a matter of fact, the moment of inertia of the rotor has the beneficial effect of cancelling out certain loads on the main bearing."

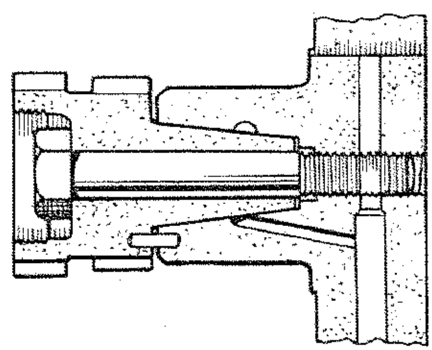
Distributor Accessibility

Question: "The distributor location, on top of the crankcase, provides first-class accessibility but has been criticized, not without some justification, as marring the appearance of an otherwise shapely power unit. Why did you not drive the distributor from the end of the camshaft and enclose it within the timing-side cover, with an inspection plate provided in the cover for contact-breaker accessibility?"

Answer: "I disagree with the criticism of the position of the distributor. Actually, we went to considerable trouble and expense in order to provide that position; the first requirement was that the distributor should be accessible. Furthermore, with a vertical distributor there is clearly less tendency for oil to seep into the contacts. Driving the distributor from the end of the camshaft would have increased considerably the overall width and weight of the unit."

To round off the discussion, I asked Mr. Turner my usual question about power and torque figures, for the benefit of the more technically inclined. I was told that the average engine, with silencer and air cleaner fitted, develops 8.3 b.h.p. at its peak speed of 6,500 r.p.m.

The torque peak occurs slightly below 5,000 r.p.m. and the maximum value is 185 lb in. Although the peak occurs at a fairly high engine speed, the curve is comparatively flat and the torque at 2,750 r.p.m. is 150 lb in



An unusual taper fixing is employed to attach the timing-gear pinion to the mainshaft stub of the cast-iron flywheel