A PETROL ENGINE with power and flexibility

A new design for a 30 C.C. overhead valve four-cylinder engine of the Seal class

By Edgar T. Westbury

It is now over ten years since I introduced what I believe to be the first really small four-cylinder engine specially designed for amateur construction, and in which the particular problems of machining with limited equipment had been fully considered. For a time the prospects of such a design ever becoming really popular were dubious, due to its greater complication than previous designs, and competition with ready-made engines which were becoming available in increasing numbers.

Gradually, however, it became apparent that there was a definite field for the multi-cylinder engine, not only as a realistic and controllable power plant for model boats and other purposes, but as a worth while model in its own right.

The success of the Seal 15 C.C. engine, in the hands of expert constructors and also, in some cases, of those who had not built an engine before, soon " sealed " its popularity. Today it is in greater demand than ever.

Readers who built one of these engines and afterwards wished to dispose of it, found it to be a readily neeotiable asset: and 1 have received many urgent requests from those unable to build engines themselves, to " find me a Seal regardless of cost."

The performance of the Seal engine (which has never been claimed to be a high-efficiency engine), has often been compared adversely with that of some single-cylinder engines. Nevertheless, in proportion to its capacity, it has been ample for the purposes visualised in its design, such as the propulsion of boats 36 in. to 48 in. long. There have, however, been many demands for a more powerful engine of the same general type, and to some extent this need has been met bv the introduction of the Seal Major 30 C.C. engine, which conforms to the design of the original engine in all respects except that of dimensions.

Enterprising constructors have wished to improve the efficiency of the engine without increasing its size, and this of course, is quite a feasible proposition. Apart from increasing the bore of the cylinders to a limited extent, which was allowed for in the design (and carried out in several cases), the most promising line of development lies in increasing the compression ratio and making the combustion head more compact. This, obviously, can only be done by adopting overhead valves, and as readers mav have gathered from discussions in' ME, severa1 constructors have considered converting the Seal in this way.

It may be of interest to review my reasons for using side valves for this engine in the first place. They were decided on only after all possibilities had been fully examined. First, I considered that they had advantges in respect of reliability. This is more important than ultimate performance in engines other than those designed for racing.

I do not mean to imply that overhead valves are necessarily more prone to breakdown than side valves; but their operation involves more mechanical complication than side valves, and greater difficulty in maintaining exact adjustment at all points. It is a generally accepted fact that even in full size, side valve engines hold their " tune " longer than o.h.v. engines without attention.

Secondly, and almost as important, is constructional simplicitv. There are fewer oarts in a side valve engine than in the o.h.v. type, and in-an engine designed to obtain the ultimate straightforwardness in construction, this is important. Even more so is its effect on design problems in a small engine; consider the difficulty of getting no less than eight valves, four sparking plugs, ten or more holding-down studs, and adequate cooling jacket space, into a cylinder head less than 4 in. long ! It can be done; but when assessed in conjunction with casting problems and the difficulties of the amateur in working to fine location-limits, it becomes rather formidable.

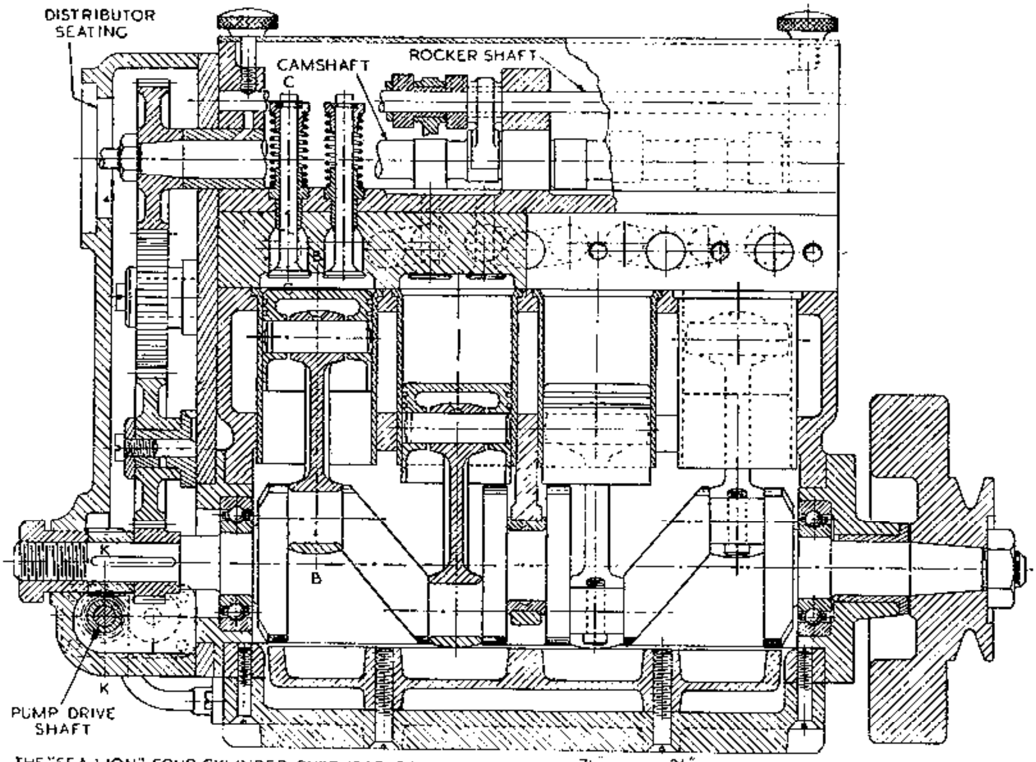
Some readers who attempted to convert the Seal engine to o.h.v. came up against these problems well and truly. I know of one who practically finished the job before he realised that there was -nowhere to put the sparking plugs, and has been trying ever since to get the engine to work on compression-ignition !

More often, it is the water-jacketing problem which proves most difficult and if not properly tackled, it may lead to local hot spots which impair both efficiency and reliability. These snags probably account largely for the fact that many promising efforts are never successfully completed.

In the course of experiments which led to the develoument of the Seal engine, I designed two four-cylinder engines, a 15 C.C. water-cooled and a 10 C.C. air-cooled engine, with push-rod operated overhead valves. In both cases some constructional difficulties were involved and I did not feel sufficiently confident in the designs to recommend them.

After some deliberation, I concluded that for a first venture in o.h.v. multi-cylinder engines it would not be desirable to go below 30 C.C. capacity, though I may do so after further experience. Although the simplest way to produce the design would be hv modification of onlv the cylinder and head design of the Seal, l decided for various reasons to go still further and use an overhead camshaft. Though this adds to the mechanical complication it is, generally speaking, more likelv to keeu in proper adiustment over- a period of-ruining ihan when the valves are operated through push rods.

The overhead camshaft, however, is not as simple to apply successfully as it may appear. Many years ago I worked on the development of one of the first o.h.c. motor-cycle engines, and became well acquainted with the problems-most of them by no means obvious-in this method of operation. Of course, a single-cylinder engine offers the greatest difficulty in this



THE "SEA LION" FOUR-CYLINDER OVERHEAD-CAMSHAFT ENGINE 7/8 BORE x 3/4 STROKE (30cc) SIDE ELEVATION

respect, owing to the intermittent load on the entire operating gear. But even in four-cylinder o.h.c. engines, the use of brakes on the camshaft to eliminate noise and " snatch " has been known, and some of these engines have been fitted with supplementary spring-loaded cams for the same purpose.

The position of the camshaft, and transmission of motion to the valves, calls for careful consideration. In all o.h.v. engines, height must necessarily be greater than in side-valve engines, and the addition of an o.h. camshaft adds to this still further-which may be a serious objection when an engine is required to tit into limited headroom.

Some designers consider that the ideal position for the camshaft is immediately over the centre of the valves, which are thus operated directly without intermediate rockers or tappets. This requires some way of taking side thrust other than on the slender valve guides, and it may also complicate the adjustment of valve clearance. Steeply inclined valves, either operated through rockers from a central camshaft, or directly from two separate camshafts, may make for a more compact arrangement, but they complicate constructional problems and make it more difficult to obtain high compression. The would-be designer will do well to avoid following " advanced " full size practice blindly, because many features do not work so well when scaled down, or are too difficult to make them really worth while. There is much to be said in favour of a flat combustion head with vertical valves, operated through short rockers from an offset camshaft.

Transmission of power to a camshaft situated more or less remotely from the main engine shaft also has its problems. In designing the Sealion engine, all the known alternative methods of driving the camshaft were considered. The use of a vertical intermediate shaft was attractive, as it could be used to drive the oil pump at the bottom and the distributor at the top. However, the difficulty of obtaining suitable skew or bevel gears deterred me from adopting this arrangement.

Chain drive, using the smallest available size of roller chain and sprockets (Renold 8 mm. Chainette), was practicable, but too bulky to enable a really compact timing case to be used, apart from possible tension adjustment problems. Some o.h.c engines have an ingenious camshaft drive through double or triple eccentrics, but the friction in this arrangement must be pretty considerable, even if it is made to the highest precrsion limits possible.

In settling for a train of spur gears, the fact that these are already known to be available to model engineers was an important consideration. The distributor is intended to be fitted horizontally and driven from the end of the camshaft, though it may be geared to operate vertically if desired. Oil and water pumps, of the gear-wheel type, are optional fittings, requiring a small worm-geared cross shaft at the bottom of the timing case.

So far as other parts of the engine are concerned, the design mainly follows exactly the same pattern as the Seal engines, though with one or two important modifications, such as the fitting of a centre main bearing to the crankshaft. Many readers considered that the Seal engine should have a centre bearing, but it would have increased the length of the engine block, and introduced a line-boring operation which might have worried constructors. In the present design the bearing is kept short so that it does not affect overall length, but large in diameter to simplify boring. One of its functions is to act as an oil distributor, in cases where a drilled crankshaft is considered worth while.

Whether the engine is fitted for forced lubrication or otherwise, the fitting of troughs under the big-end bearings and a central oil feed is worthwhile, even if the latter is only used in emergency. Full size engines nowadays generally have a deep and capacious sump, to hold an ample reserve of oil for long periods of running.

While this is desirable. it cornpliates the already difficult problem 01 keeping the height of the engine within reasonable limits, and even more, of keeping down the shaft angle when the engine is installed in a boat. As it should not be necessary to run a long time without replenishing the oil, the matter of sump capacity is not highly important.

The policy of using " oversquare " cylinders-that is, having the bore greater than the stroke-is popular nowadays, in contrast to the long stroke and small bore which were once favoured. This is generally conducive to higher rotational speeds, but incidentally it also makes the entire engine more compact, especially in respect of height, and can also help to effect some economy in weight.

One of the greatest problems in the production of a small multi-cylinder engine, namely the forming and accurate location of a number of cams, was effectively dealt with in the Seal engine, by methods which considerably simplified machining processes and reduced risk of error.

The same methods are recommended for the Sealion camshaft, though some slight modification of timing, to suit the different valve arrangement, has been introduced. As I have had many requests for repetition of the article on making the Seal camshaft, which appeared in ME for 15 May 1947, I propose to describe the necessary operations (applicable to all multi-cylinder engines) in detail.

The entire camshaft and valve gear are enclosed within a sheet metal cover, readily removable for access to all parts, and if desired, arrangements for positive lubrication can be made, though I do not consider this necessary for relatively short runs.

Questions often arise as to how difficult is the construction of a multi-cylinder engine. I do not pretend that it is easy to build any kind of petrol engine, and neither the Seal nor the Sealion is recommended as an exercise for beginners-though some of them have successfully tackled the Seal. But " difficulty," insofar as it can be assessed, is related more to cylinder dimensions than anything else.

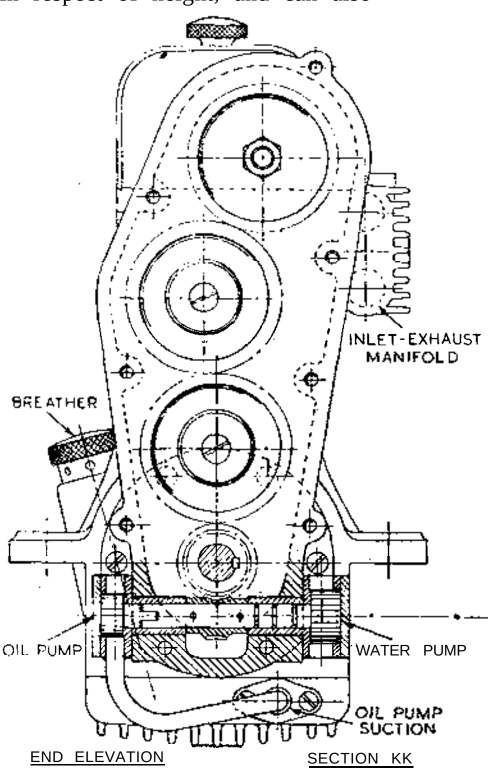
A " multi " has a larger number of parts, and therefore demands more patience, not necessarily more skill, than a " single." Some of the operations on the Seal and Sealion are, in fact, simpler and more straightforward than those in engines which look much easier to build.

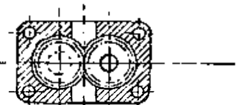
Regarding the performance of the Sealion, I do not propose to make any statements, or even guesses, at the present time. Experience with previous engines has shown that different constructors get widely varying results from the same set of blueprints and castings.

Any engine can only be as good as you make it, and the only claim that the designer can make is that the design is sound. I am, however, quite confident that if built to competent model engineering standards, the engine will supply ample power for propelling the largest and heaviest model prototype boats normally seen on ponds, or a 5 in. gauge passenger hauling locomotive.

Castings and parts for the construction of this engine will in due course be marketed by Craftsmanship Models Ltd, who are already the authorised suppliers of castings for the Seal, Seagull, Cherub and other popular engines of my design.

* ***To be continued on January 22***





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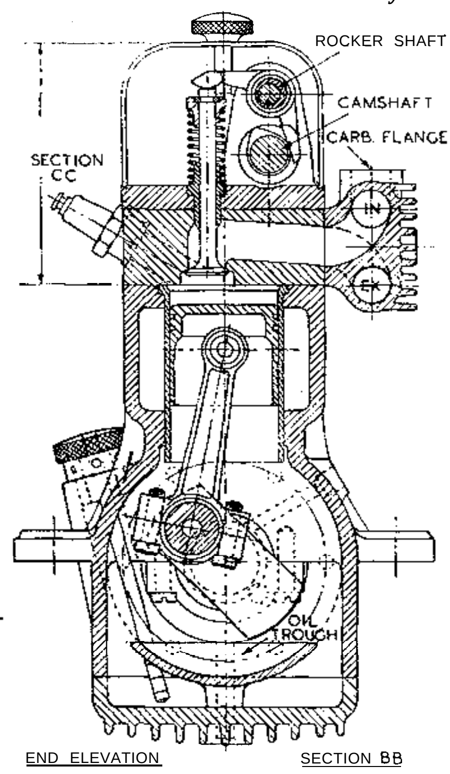

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A PETROL ENGINE with power and flexibility

Continued from January 8, pages **40 to 42**

IN planning this engine, every care has been taken to ensure that all operations are as simple and straightforward as possible. All the machining problems have been foreseen and dealt with, and there is no operation which cannot be carried out with the type of equipment normally found in the model engineer's workshop. Experience with the Seal and other engines, in the hands of many constructors whose ability and facilities vary widely, has been applied wherever possible to further these ends.

In this instalment EDGAR T. WESTBURY deals with the body casting and sump casting of Sealion, a new 30 C.C. overhead valve four-cylinder engine of the Seal class

The largest casting in the engine, the main body, is of monobloc form, comprising the crankcase and water jacket, with seatings for, the main bearing housings and the inserted "wet" cylinder liners. Apart from the absence of side valve seatings, it differs from the Seal body castmg also in having a central main bearing housing, which-must be split to enable a crankshaft of orthodox design to be fitted.

This feature, which has been considered highly desirable by many prospective constructors, called for some hard thinking to enable it to be carried out in a practical and effective manner. The possibility of providing a solid diaphragm, bored out to the crank web diameter to take either a large journal or a ring ball race which could be threaded over the crank webs was fully considered, but eventually it was decided that a more conventional capped bearing would be simpler to fit.

Marking-out of the casting is reduced to a minimum, as all the machining centres are on one line, and parallel or square with each other. I am not a great believer in elaborate marking-out operations. They often defeat their own object, since they necessarily involve the transfer of measurements from a rule or height gauge and working to a marked line, involving the possibility of error at every stage. Small and light parts need to be clamped to the marking-off table to avoid the risk of shifting under scribing pressure; and the plugging of cored holes to enable the centres to be located, is not as easy as it sounds. I prefer where possible to work from fixed reference points, as few in number as possible, on the principle normally employed in jig work.

The first operation on this casting should be to face off the underside, which may be done by holding it in the four-jaw chuck or mounting it on the faceplate with the aid of clamps or straps over the bearer lugs. In the latter case it will be necessary first to ensure that the top surface is reasonably flat to bed firmly against the faceplate. The sides of the crankcase should be square, and the under faces of the bearer lugs all the same distance from the chuck or faceplate in either case.

It is not normally necessary to machine the bearer faces, but any obvious irregularities must be removed so that they will rest truly on parallel mounting surfaces. Making them coincide with the level of the shaft centre line simplifies lining up when the engine is direct-coupled to a propeller shaft or other machinery. After facing the bottom surface of the casting, the centre projection should also be faced off to the level of the crankshaft centre line, at the same setting, to form a seating for the bearing cap.

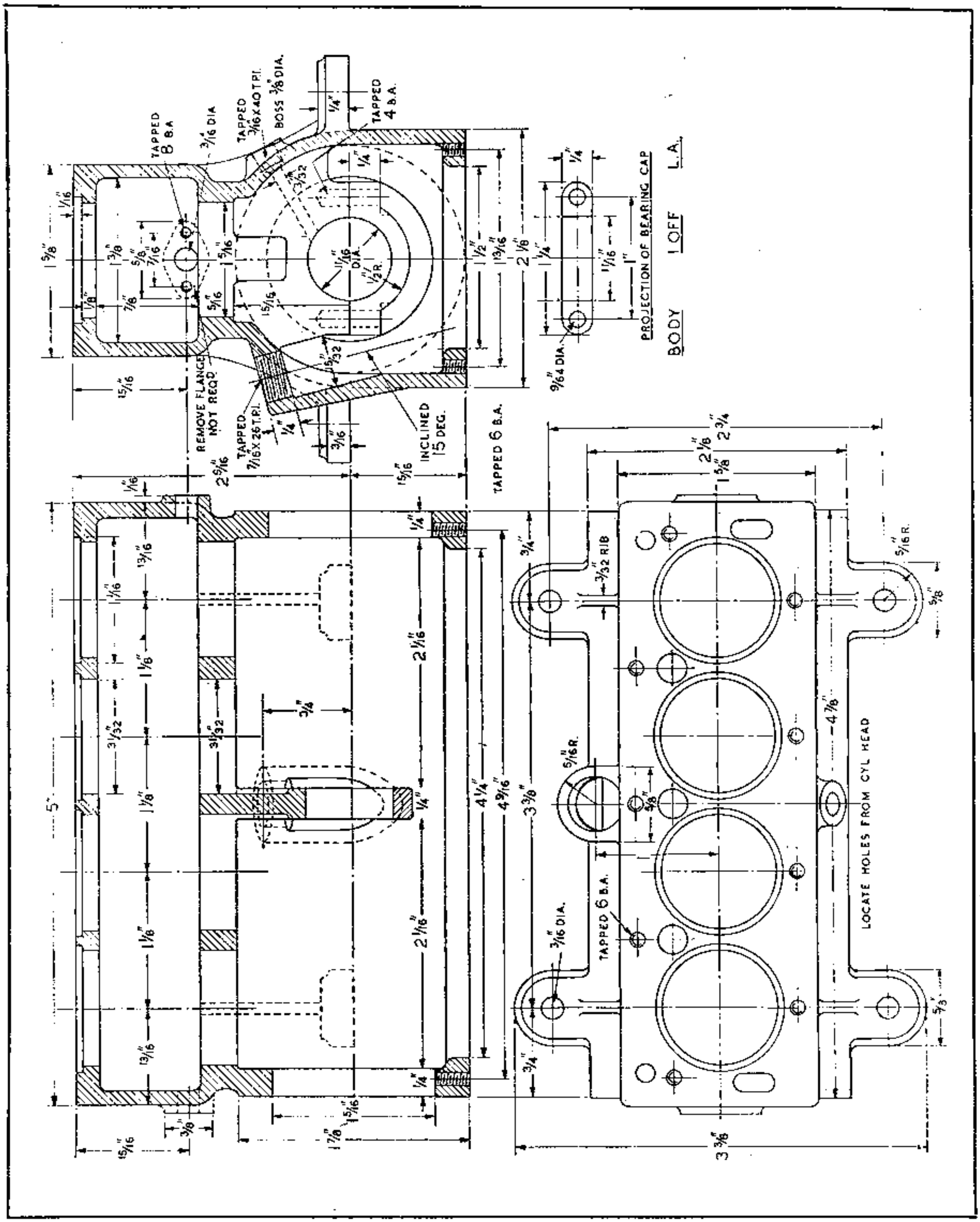
Before proceeding further with machining the body, the "horns" of the bearing cap should be faced, and holes drilled in both this and the seating, the latter being tapped 4 BA, so-that it can be secured in position for the boring operation. The top face of the casting can then be machined, though not necessarily to its finished level, by mounting it on the faceplate in the reverse position; if preferred, however, this may be deferred until the Job is set up for boring the liner seatings.

In order to bore and face the main bearing seatings, it is advisable, unless a large lathe is available, to mount the casting on the cross slide and machine it with a rotating cutter bar held in the chuck at one end, and supported on the tail centre at the other. This is better than using both centres, as it provides greater rigidity. For the same reason it is desirable to use a bar as large and as stiff as possible-up to 5/8 in. dia., and to avoid unnecessary length or traversing distance, three tool positions should be provided, with tapped cross-holes for grubscrews to hold the cutter bits.

It will, of course, be necessary to pack the casting to exactly the correct height for the boring operation, and this should be checked with a scribing block at both ends. Hardwood packing is permissible, provided allowance is made for the fact that it may be compressed slightly when the clamps or straps are fully tightened. Metal packing eliminates this risk but may be more difficult to adjust to critical accuracy. With the Myford ML7 lathe, in which the height from the cross slide to the centres is 2 1/16in., the thickness of the packing required is 1 1/8in.

When the position has been properly adjusted both vertically and horizontally, and the work finally secured to the cross slide, the gibs of the latter should be tightened to prevent the possibility of inadvertent movement. It is also desirable to check the adjustment of the saddle slide to make certain 'there is no slackness here, though it should not be so stiff as to impair normal traversing movement.

The bearing seatings may then be


BODY 1 OFF L.A.
PROJECTION OF BEARING CAP
LOCATE HOLES FROM CYL HEAD
REMOVE FLANGE NOT REQD
INCLINED 15 DEG.
TAPPED 6 B.A.
TAPPED 8 B.A.
TAPPED 4 B.A.

bored to size; critical accuracy is not essential in the diameters, as the ball race housings can be individually fitted afterwards, but the nearer they are to size the better. Note that the crankshaft has to be threaded through these apertures, so that they must at least be a little greater in diameter than the outer edges of the webs. Before a bar of adequate size can be passed through the centre bearing, it may be necessary to open it out with a drill or a single-point overhung cutter. The latter is preferable, as a drill may run out of truth if not carefully watched, which is difficult with an entirely enclosed job of this nature. The final boring of all three bores should in any case be done with a cutter bar supported at both ends.

Facing of the outer surfaces, and both sides of the centre bearing, can be done with right and left-handed side tools fitted to the bar in place of the boring cutter. These may tend to chatter owing to the width of the cut. An alternative method of facing is to mount the casting on a spigot mandrel and work from each end in turn, after boring is completed. If this is done, the mandrel should be stepped to fit the diameters of both the end and centre seatings.

The casting is next mounted on the faceplate for boring the liner seatings. To simplify setting and ensure that all cylinders are in line, I recommend the use of locating strips bolted to the faceplate on one or both sides of the casting. One strip is sufficient, if the casting is kept in close contact with it, but the use of a strip on both sides is a safeguard against error. The surface of the casting near the lower edge must be reasonably straight and parallel with the crankshaft centre, which may call for a little filing. After setting up the casting to centre one liner seating, and this has been bored and recessed, it is only necessary to loosen the casting, slide it along a measured distance, and reclamp for dealing with the next seating in line.

It is desirable that the bores of the seating should be uniform in diameter, and as smooth as possible; the bore in the lower diaphragm of the jacket space may be made slightly smaller in diameter than that of the upper part so that the liners may be eased at the bottom end for easy insertion. The recess for the rim of the liner should also be as accurate and smooth as possible, with a sharp internal comer.

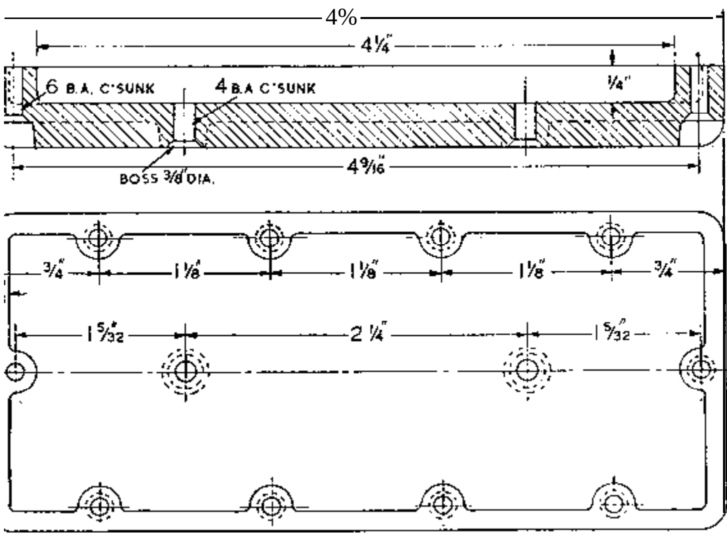
The tapped hole for the breather and oil filler cap should preferably be machined by setting the casting on the faceplate, with a wood or metal packing block having faces at 15 deg. An alternative method is to mount the casting on the vertical slide, with its base swivelled to 15 deg. on the cross slide, and run both the drill and the tap in the lathe chuck. In either case, the top face of the hole should be spot-faced square with its axis.

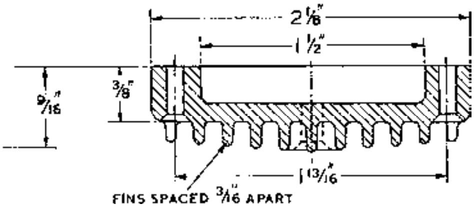
This completes the major operations on the body, the remaining work being mostly the drilling and tapping of holes. located from other machined parts.

The only machining operation on the sump casting, other than drilling holes, is the facing of the top surface to form an oiltight joint when secured on the bottom of the body casting. It can be held across the jaws of the four-jaw chuck, and exact centring is not important. But it should be set as truly as possible on the front face, and it is advisable to clamp the saddle while taking the cut to avoid error in flatness of the surface.

Mention has already been made of the space restrictions which make it necessary to use a relatively shallow sump, but where these do not apply, the oil capacity may be increased to any desired extent by making a sump casting of greater depth. The object of providing fins on the underside of the casting is, of course, to keep the oil as cool as possible. This was not necessary in the Seal engine, in which lubrication conditions were relatively easy. But in a much more highly stressed engine, the oil may become heated, and Its temperature may affect the efficiency of the circulating pump

The two holes in the centre of the sump are to hold the oil trough in position under the big-end bearing. The holes around the edge are to take 6 BA screws for securing the sump to the body. All these holes are countersunk, to conserve space as much as possible.





SUMP 1 OFF L.A.

* *To be continued on February 5*

CORRECTION

Our contributor Roland V. Hutchinson has asked us to point out that the equation for ψ given in his article on " Poppet-valve blowing engines " [ME, November 13, page 627], should read :

$$\psi = 2\phi/[1 - \cos(\phi/2)] \text{ approx.}$$

and that for cos θ should read:

$$\cos\theta = 1 - 8(\phi/\psi) + 8(\phi/\psi)^2 \text{ approx.}$$

A PETROL ENGINE with power and flexibility

Continued from January 22, pages 99 to 101

Machining operations on cylinder head and camshaft housing for Sealion

By Edgar T. Westbury

THE cylinder head casting looks rather complicated, and it certainly involves a number of important machining operations. But they are all fairly straightforward., and unlikely to cause difficulties if the recommended methods are adopted.

No cored ports or passages are provided, as I have found from experience that, quite apart from the extra work, they are often more trouble than they are worth. It is easier to machine them from the solid in a casting of this size. The top of the casting is, however, deeply recessed to provide ample space for cooling water circulation, so that a well formed and accurate contour, of uniform thickness around ports and passages, is essential. Those who prefer to make this component by machining from the solid will find that it involves some intricate profile milling work.

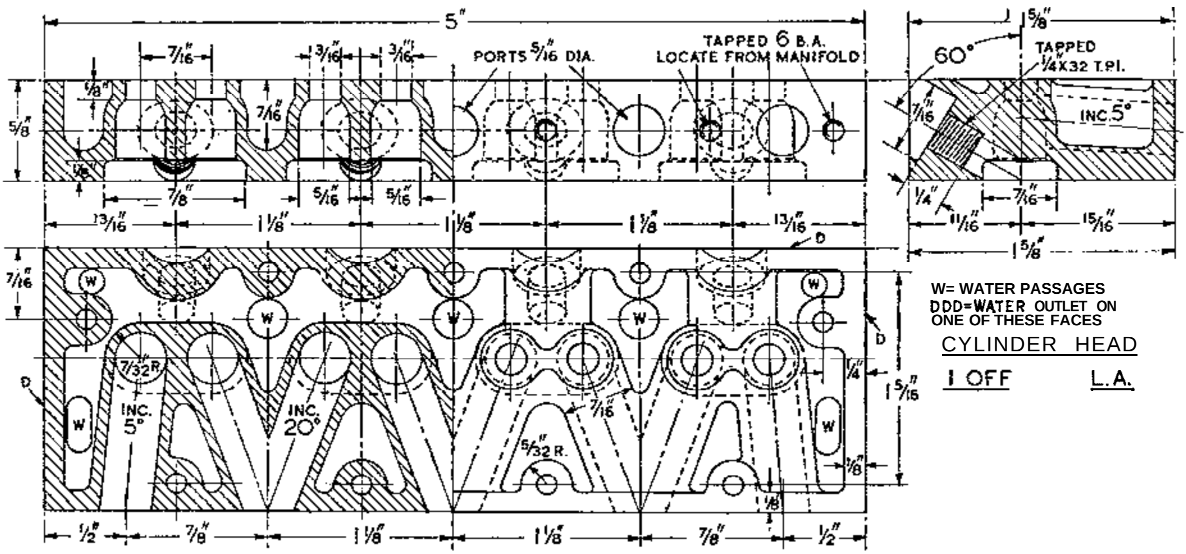
The first operations on the casting are the facing of the top and bottom surfaces, which require to be truly flat, and parallel with each other. This work can, of course, be done by mounting the job across the four-jaw chuck, using two of the jaws reversed, in each case. The sides and ends should next be faced true and square all round, the casting being mounted on an angleplate with clamps or straps. Alternatively, it may be mounted on the lathe cross slide and milled with a single-point fly-cutter or face mill.

The positions of the valve ports should then be marked out on the under-face of the head, in preparation for boring them from the solid. Again, there are two alternative ways of tackling this job; either by setting it up on the faceplate, or mounting it on a vertical slide, or the vertical face of an angleplate on the lathe cross slide, with the centre line of the row of ports set exactly at lathe centre height.

The former method is perhaps the more conducive to accuracy, as the truth of the holes can be closely checked during operations. But it calls for a lathe capacity of not less than 9 in. dia. (this is provided in most 3 1/2 in. gap bed lathes) and careful setting up and balancing, for each individual port. As in the boring of the liner seatings in the body casting, the use of locating strips on one or both sides of the casting will greatly facilitate setting up, from dead measurements if desired.

Mounting on the cross slide will no. doubt be preferred by many constructors, and with reasonable care there should be little risk of errors. Dead measurement may be applied also in this case, using the cross slide feed index. To guard against risk of drilling into the angleplate or vertical slide, the casting should be backed up wjth parallel packing of soft metal, hardwood or plastic material (this is not necessary in faceplate mounting, as the holes will always run out into the hollow of the mandrel socket).

Whether or not this method is applied, I recommend the use of a centre drill for starting the holes,



then a No 15 drill (nearest fractional size, 11/64 in) followed by a 19/64 in. drill to a depth of 3/8in. from the main face, and a 21/64 in. drill to a depth of 1/16in. in both cases reckoned from the lips (full diameter) of the drill, not the point.

Bore alignment

For finishing the ports, I strongly recommend making a D-bit which will cut the three diameters at once, as this will positively preclude the possibility of any misalignment of the guide and seating-one of the most common errors in small four-stroke engine construction, and absolutely fatal to success. I have seen many cylinder heads which have proved unsuccessful, due to their having been machined by rough-and-ready methods, which have only a 50-50 chance of producing properly aligned ports. It is difficult to convince constructors that no amount of grinding-in valves will compensate for errors in this respect. The result is nearly always leaky valves and heavy wear of guides.

The D-bit is simple to make from a piece of 7/16in. dia. silver steel rod, the end of which is turned to 3/16in. dia., then a further length of 3/8in. turned to 5/16in. dia. with a 5/32in radius on the end, and the full bar diameter rounded off to about 1/16in radius. In both cases, the shoulders should be slightly undercut. Do not attempt to form the chamfer of the valve seating, as this can more effectively be done with a hand tool after the valve guides are inserted.

The machined surfaces should be highly finished, after which the cutter is filed away to exactly half its diameter again with a high finish, then hardened and tempered. When in use, great care should be taken to see that it cuts freely and does not clog with chips. In some cases lubrication with thin soluble oil will help to prevent build-up on the cutting edges. It is a good idea to provide some form of depth gauge, such as a brass collar secured to the shank of the cutter, to ensure that all the ports are cut to uniform depth.

It is now necessary to join up the two 7/16in dia. counterbores of each pair of ports, to form the combustion chambers. If the ports have been machined on the cross slide, this can be done at the same setting, by using an endmill in place of the D-bit, and traversing the work as required to produce an elongated slot. Do not use a ready made endmill, which will normally have a square corner; it is easy enough to make a flat cutter, with a radius on the end to conform with that of the counterbore.

For the other essential ports in the head, use packing blocks cut to the appropriate angles for the particular operation. Hardwood is quite suitable, as it is easily planed to shape, and the angles are not critical. In the sparking plug holes, the angle is 60 deg. to the valve axis. This requires the use of packing with included angle of 30deg. if the work is held on an angleplate mounted on the vertical slide. Alternatively, a block with the top face at the appropriate angle may be mounted on the vertical face of an angleplate on the cross slide and adjusted to the correct height. The casting may be held in place by wood screws through two or more of the valve ports.

Watch the break through

A centre drill should again be used for starting the holes, and when followed up by the tapping drill, care should be taken at the point of break-through, to avoid damaging the valve seatings, as the locations are necessarily tight. It is advisable to finish this job from the inside, where operations are fully visible, with the aid of a riffler or rotary file.

To counterbore and machine the joint face of the hole, it is worth while to make a cutter, as the squareness and finish of the face are highly important. Note that the cutter will break into the top surface of the head, cutting out a small crescent, and when the camshaft housing is fitted, some relief at this point may be necessary to clear the body of the plug.

It will be seen that the drilling of the inlet and exhaust passages involves compound angles. This cannot readily be avoided, as a slight upward slope of the passages is necessary to avoid running too close to the valve seatings where they cut into the ports. The angle in this case is 5 deg., and the work may be mounted as for the previous operation. To adjust the angles of the passages in the horizontal plane, the base of the vertical slide (or the angleplate if this is used) is slewed round to 5 deg. from the square-on position (in alternate directions) for each of the end passages and 20 deg. for the siamesed passages which communicate with the remaining six ports.

Avoiding run-out

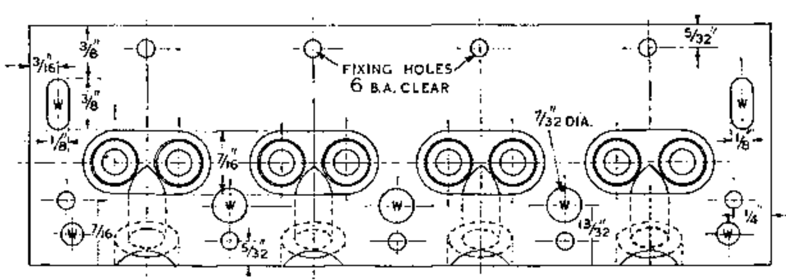
It is desirable to start these ports square-on, using a centre drill first, and then a 9/32in drill entered to a depth of about 1/16 in. full diamter. This will help to ensure that the angular hole (also initially formed by a 9/32in drill) does not tend to wander from its true direction. It is advisable to use a short drill, or one supported as close as possible in the chuck, and if it is properly sharpened and run at high speed, no difficulty should be experienced in putting the passages exactly where they are required.

It remains to drill the holes for holding down the head on the body casting, locating them as accurately as possible and also taking care to ensure that they are drilled exactly square to the main surfaces, through the full thickness of the casting. The corresponding holes in the camshaft housing, and the tapping holes in the body, are spotted or jigged from those in the head. Water communication passages (marked ***W*** in the drawing), also the water outlet (on either of the faces marked ***DDD***) will be dealt with later.

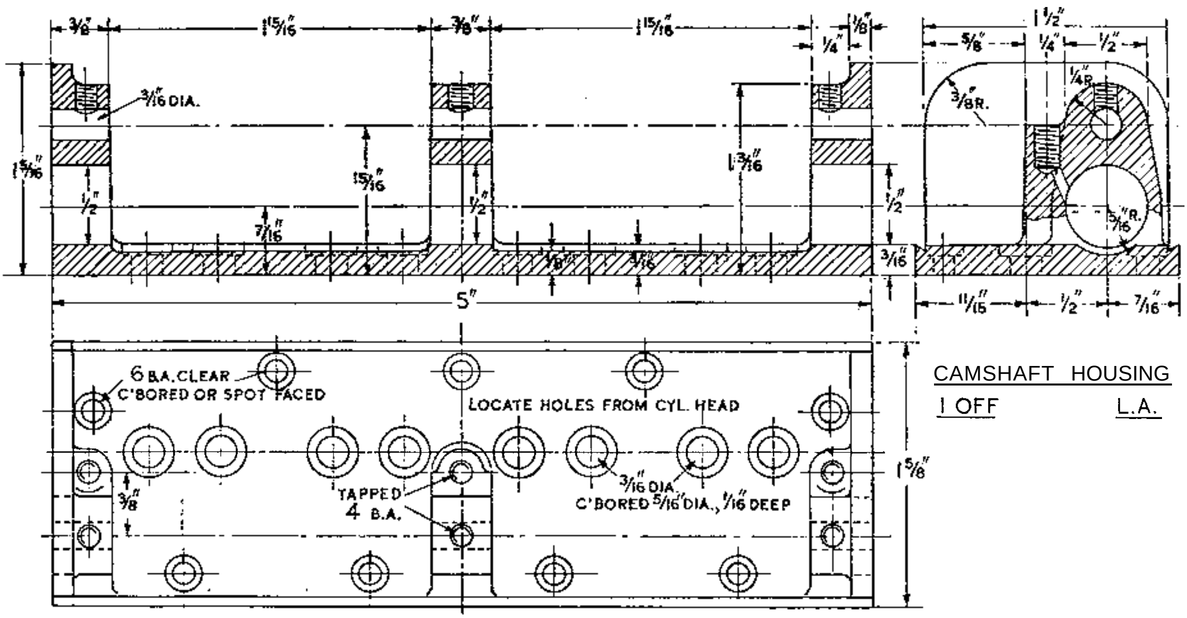
Camshaft housing

The flat plate which forms the base of the camshaft housing serves also as a cover or closure for the water jacket of the cylinder head, forming a watertight joint around its outer edges. The machining of the underside face calls for some care in avoiding the possibility of bowing it by pressure of the chuck jaws on the end flanges. It will, therefore, be found worth while to fit two wood packing blocks between the upright projections, but they should not be *so* tight as to cause an error in the other direction. Packings at the sides of the casting, to enable the jaws of the chuck to take a bearing, may also be found desirable.

After facing, the truth of the face should be checked on a surface plate, in case distortion has taken place in



UNDERSIDE PLAN OF CYLINDER HEAD



spite of these precautions; if so, it may be corrected by scraping or lapping.

The end faces and side edges of the casting should then be machined square all round using similar methods as for the previous component, after which the camshaft and rocker centres are carefully marked out on both ends. In drilling these holes through the three vertical projections, it is, of course, essential that they should all be in correct alignment. But it is hardly practicable to employ the line-boring methods normally used in full size practice, due to the small size of thecasting. The next best thing is to centre drill the end faces deeply, and drill from alternate directions, using undersize drills in each case.

The rocker shaft holes should be drilled with a No 15 drill, through the outer projections only, the remote ends being supported on the back centre of the lathe in each case, and the drill then followed up by a 3/16 in. reamer. A spearpoint drill should then be made from 3/16 in. silver steel rod a close fit for the reamed holes. With it drill the centre projection half-way from each side, using tailstock support as before. With care, the holes will come out dead in line.

Camshaft bearings

Similar methods can be used for the camshaft bearing holes. Accuracy is still more important in this case, but as the diameter is greater, stiffer tools can be used, and it is possible to run a 1/2in. reamer through all three bores to finish them. If, however, there is misalignment when a mandrel is run through them, it is possible to bore out the centre hole to a larger diameter with a cutter bar piloted in the end bores, and fit a bush.

As already mentioned, the fixing holes are located from the head casting. The same applies to the eight holes for the valve guides, but in this case great care must be taken not to damage the guide holes in the valve ports. The use of the spearpoint drill made for the rocker shaft holes will be better than a twist drill for this job. All these holes are spot-faced to provide a true seating for the valve guide collars, as well as the fixing nuts or screw heads. Allen screws, if obtainable in the correct length (1 in.) would be suitable for the latter job; 1/8 in. Whit. may be used instead of 6 BA.

Locating the valve cover

It will be noticed that the side edges of the baseplate have an angular undercut running along their full length. The object of this is to locate and retain the similarly shaped edge of the sheet metal valve cover,. so that it can be held quite securely m place by two (or three) knurled screws. This involves a simple milling operation, using a dovetail-shaped cutter with an inverse included angle of about 60 deg. It may be difficult to obtain ready-made, but is easily made from silver steel rod. I have made dozens of such cutters for various jobs as and, when required, and they take only minutes to produce.

The contour of the end flanges does not need machining, as it calls only for light filing to remove surface roughness. It will be seen that oil holes are drilled from the base of the tapped holes in the projections into the camshaft bearings. These are optional, but they enable oil to be effectively applied when the cover is removed before a run, as an alternative to more positive and continuous methods of oil feed to these bearings.

* *To be continued on February 19.*

READER'S HINT

PINS ON SMOOTH FILE

WHEN putting finishing touches to a piece of work, one is often bothered with the file picking up small pins. The usual file card is generally used to clear them, but I have found it is not as harmless as it might appear.

My remedy is this: Take a small piece of thin-soft sheet iron, or brass, about 1/16 in. thick (a piece about 1 in. x 4 in. will do), then round off one end. File up the other end square and sharp; this will give two sharp edges so that you can plow out any pins that may be bothering your work.

After a few rubs you will find that the sharp edge of the sheet iron cleaner has taken on small teeth that reach down to the bottom of the file teeth, and have the same pitch.

To prevent a file from pinning, just coat it with some lubricating oil. This in itself may sound a bit odd but it works. Just try it.-H. J. REES.

A new design for a 30 c.c. overhead valve four-cylinder engine of the Seal class

Machining the main bearing housings and timing case

By Edgar T. Westbury

THE two housings for the ball races which form the end main bearings for the crankshaft are straightforward jobs. They may be turned from the solid if desired, though the provision of suitable castings will reduce both the amount of machining work and waste of metal.

In both these housings,. it is most essential that the spigot which registers in the bored end of the body, and the recess in which the ball race is fitted, should be exactly concentric with each other. This is easily assured by machining both at the same setting, holding the work, spigot outwards, in either the four-jaw or the three-jaw chuck. The spigot must be a close fit in the body, so that working stresses do not have to be taken in shear by the fixing screws, and the ball race must also be carefully fitted.

The ball races

The races specified are Skefko EE/4 deep-groove single-row type, which have a bore of 1/2 in., outer diameter of 1 1/8 in., and width of 1/4 in., but any other make of similar dimensions and specification may be used. Some latitude is allowable in the housings themselves and also the bore of the body to accommodate modifications. But the diameter of the body must not be less than 1 5/16 in., as it must clear the outside of the crank webs to allow of assembly.

In fitting ball races to light alloy housings, I recommend rather tighter fits than those specified by the makers, for two reasons; first, because expansion of the housings at working temperature may loosen them, and second, because impact loads tend to compress the surface layers of the metal so that properly fitted bearings are often found to be slack after running for a time. A light press fit, equivalent to about 1/2 thou interference, has been found satisfactory in most of my engines, and if the housings are warmed to about " sizzling point," it is easy to insert the races.

Some readers may find difficulty in gauging sizes when boring housings for ball bearings, as it is not easy to use the race itself as a plug gauge-apart from the risk of getting swarf into it in the process. My method is to turn a plug gauge from any odd bit of scrap 'material, preferably with "go" and "not go " dimensions at the ends, to conform with specified limits. If in any doubt,. test the gauge by boring another piece of scrap material before applying it to the actual job; a little waste(?) of time and material may prove to save both in the end.

If there should be any difference in the bore diameters at the two ends of the body casting, take care to fit the bearing housings to their appropriate ends. Note that this engine, in common with the Seal, is designed in. such a way that it can be built either right or left-handed, by changing over the timing and flywheel ends. The only structural component which requires to be modified in such cases is the timing housing.

As shown in the general arrangement drawings [ME, January 81 the flywheel is intended to be fitted on the right, and the timing gear on the left, looking from the manifold side of the engine. Rotation is intended to be clockwise at the flywheel end, and while this can be reversed by inverting the order of cam timing, it makes a slight difference to the valve opening and closing characteristics, which may affect efficiency at high speeds.

AIumlnium alloy bushes

The flywheel end bearing housing has the outer extension bored to provide a steady bearing and also an oil seal. **A** bronze bush may be fitted here,. though I do not consider it a necessity, as ordinary aluminium allov is a much better bearing metal than most people realise,. and where lubrication is imperfect tt does not tend to cut and score the shaft as hard bronze does. Fitting a bush does, however, allow of easy renewal, if and when wear takes place More elaborate bushes or oil seals may, of course, be fitted at the discretion of the constructor, but whether they confer any practical advantages for this particular purpose is a matter of opinion.

Note that the steady bearing or bush must not be long enough to make contact with the inner race of the ball-bearing, and the face of the recess should also be relieved to about the inside diameter of the outer race, to avoid rubbing contact. On the timing side, this is not necessary owing to the large bore which forms a clearance, and also allows oil mist to pass freely through the race to assist in lubricating the timing gears. This housing has a spigot on the outer side which locates the timing backplate, and to ensure that it is concentric with the bore, it is desirable to use a stub mandrel for mounting the housing when machining the spigot.

Lining-up the thin flange

When this housing is assembled, the face of the thin flange should come exactly flush with the end faces of the cylinder head and camshaft housing. A test may be made with a straightedge, allowing for any packing which may be inserted between the housing flange and the body. Any necessary adjustment may be made by machining the outer face of the flange. Fixing holes should not be drilled in the flange at this stage, as it is best to locate them-from the outer attachments. The holes in the flywheel end housing may be marked out or indexed equidistantly around its flange and drilled, the tapping holes in the body then being spotted from it and drilled and tapped.

The timing backplate is not a casting, as it is most easily made from a flat piece of 1/8 in. sheet duralumm or other metal. Its exact contour is not specified on'the drawing, as it can easily be scribed off from the timing case when the latter is offered up for temporary assembly. A true flat surface on both sides of the plate is essential. This should be checked on the surface plate, any necessary correction being made as required. It is not advisable to rely on pulling the plate into truth by means of its tixing screws. The hole to fit closely over the housing spigot should be bored or trepanned by clamping the nlate on the lathe facenlate.

The plate should then be assembled temporarily on the end of the engine, fixing it by means of the five countersunk 6 BA screws around the housing flange, and two in the end face of the camshaft housing. Do not drill the tapping holes marked X at this stage.

It is now possible to find the true location of the bore for the camshaft bush. This may, if desired, be drilled ***in situ*** by using the camshaft bearing housings as a jig-taking care not to score or otherwise damage them-or marking out, drilling undersize, and finishing with a reamer in position.

If exact gear dimensions can be guaranteed, the stub axles for the timing gears may be located by dead measurement, but otherwise it is best to wait until the crankshaft, camshaft and gears themselves are ready for temporary fitting. They may, however, be machined at this stage, so long as due regard is taken of the need to make them a good running fit for the idler gears. It will save time and material if the two axles are made in one piece by the back-to-back method. This will allow them to be turned between centres after drilling right through and countersinking the ends at 60 deg. ; it will also permit shaping the outside of the flanges, before parting off in the middle. Allowance must, of course, be made for the width of the parting tool, plus cleaning up of the flange faces.

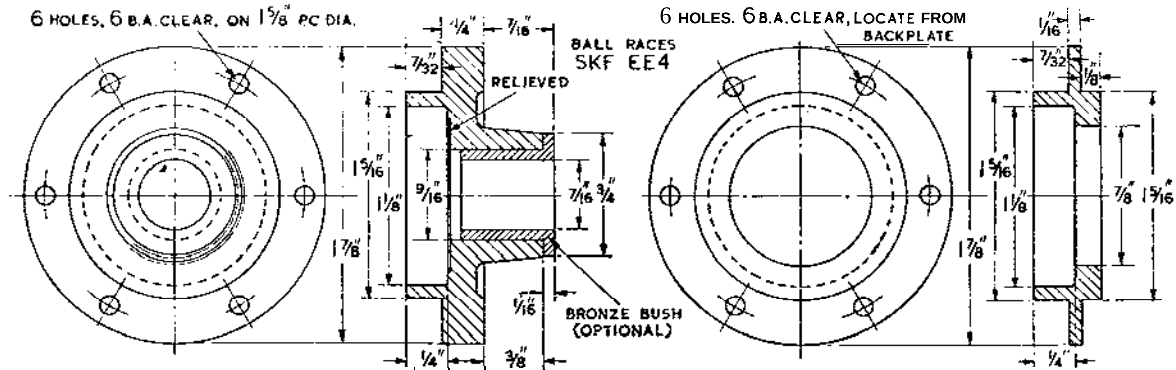
Either round bar, to clean up to 11/16in. dia., or rectangular bar 11/16 in. x 9/16 in. may be used for these items. It will be seen that provision is made for lubricating the axles, by forming a passage at the back of the flange to collect oil which precipitates on the backplate, and lead it by way of the centre hole, to a radial hole on the underside. By the way, the lubrication of parts which run on " dead " axles often proves somewhat difficult. The provision of the usual radial oil hole in the running member only defeats its own object, as oil will not run into it, but on the contrary, is promptly thrown out by centrifugal force. The only effective way to lubricate such a bearing is to feed oil from the ***inside*** and avoid providing an easy way for it to escape from the running member.

To form the oilway in the flange, a round file may be used. A much neater method is to clamp the two axles together back to back in the machine vice, or put a bolt through the centre,and run a 1/8 in. drill radially down on the contact line, followed by an ample countersink. When finished, the bearing surfaces of the axles should be case-hardened and polished.

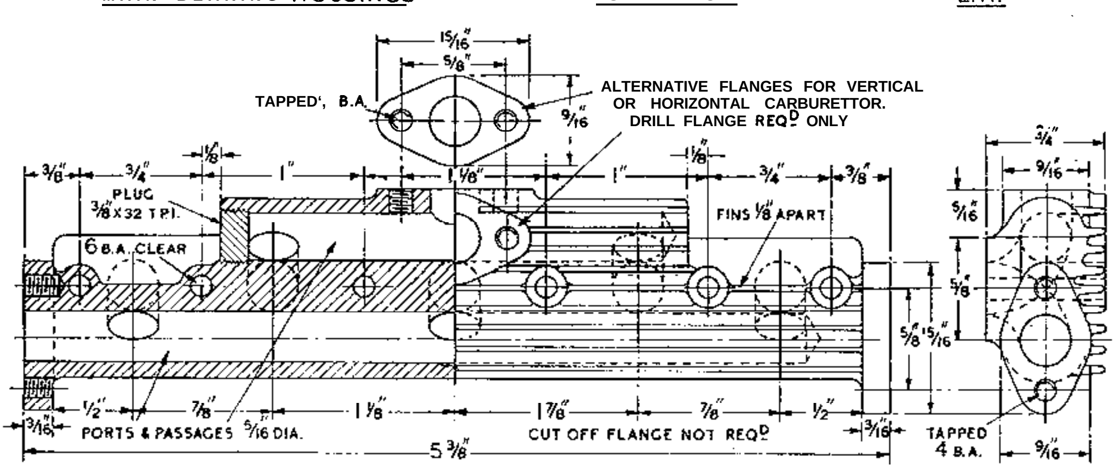
The timing case requires first to be machined on the joint face, which can be done by holding it in the four-jaw chuck, with two of the jaws reversed. After checking the flatness of the face and its true bedding down on the backplate, the fixing holes marked Y in the drawing may be drilled and countersunk on the outside.

The most important dimension on this casting is the distance between the two bores to line up with the crankshaft and camshaft respectively, and before attempting to fix it to the backplate, these bores must be properly located. After checking up by measurement on the casting, and splitting any differences which may exist in the position of the bosses, the hole at the crankshaft end may be bored and faced. This should be done by setting the casting up with its machined face in contact with the faceplate, and then clamping it to the engine assembly, and lining it up by a straight piece of 1/2 in. dia. steel bar through the main ball races.

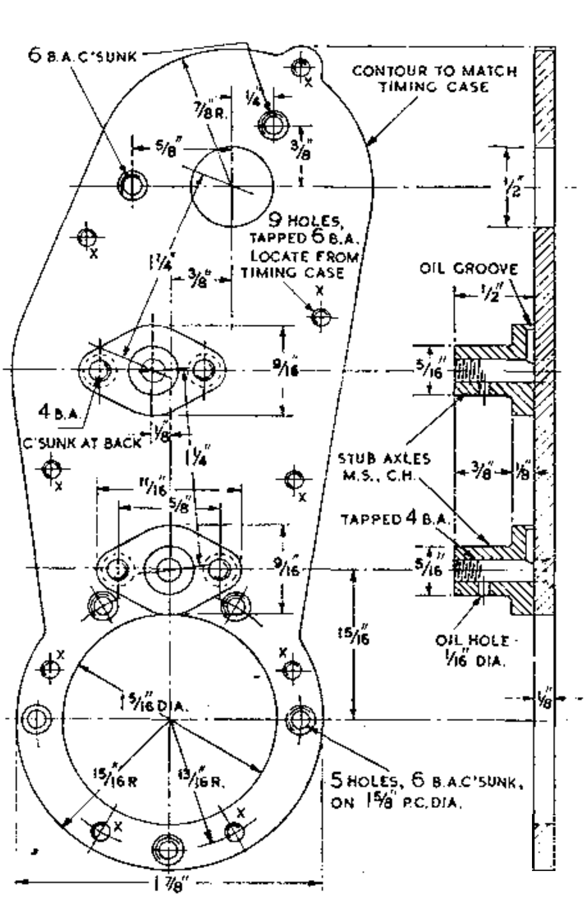
A similar piece of 1/2 in. bar may then be passed through the camshaft



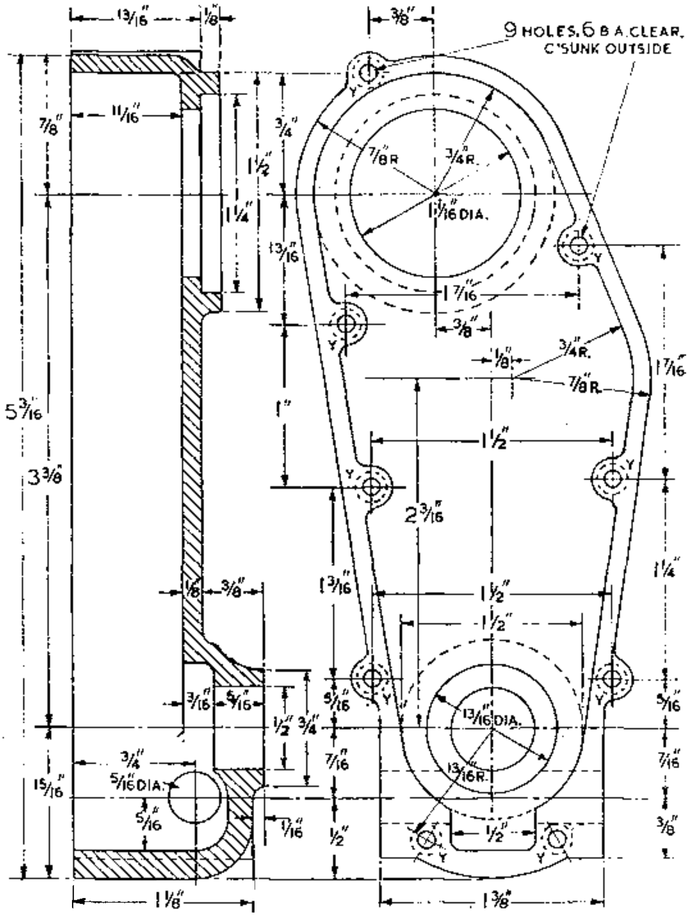
MAIN BEARING HOUSINGS 1 OFF EACH L.A.



INLET-EXHAUST MANIFOLD 1 OFF L.A.



TIMING BACKPLATE 1 OFF DURAL



TIMING CASE 1 OFF L.A.

bearing housings, to locate the centre of the bored seating in the timing case. When proper location has been found, the tapping holes *X* in the backplate should be spotted off from those at *Y*, drilled and tapped. The timing case may then be fixed temporarily in position.

Although a slight error in the alignment of the contact-breaker seating with the camshaft centre could be tolerated, it is quite simple to line it up positively and exactly. The best way to do this is to use the aligning mandrel as a boring bar by equipping it with a cutter, which can be adjusted to bore out the two diameters and the front face. By centre drilling one or both ends of the bar, it may be run in the lathe, the engine body being held by hand, and feed controlled by keeping it in contact with an angle-plate or other fixture mounted on the cross-slide.

Alternatively, the seating may be machined on the lathe faceplate, by removing the timing case and backplate from the engine, fixing them together, and locating the camshaft centre position by means of a 1/2 in. dia. plug in the mandrel socket. Either method will ensure accuracy if properly carried out. Exact dimensions of the seating bores is much less important than their correct alignment, and squareness of faces.

The inlet-exhaust manifold is rather simpler than that of the Seal engine, though the object of its particular design is much the same; namely, to provide just sufficient exhaust heating of the incoming mixture to eliminate refrigerating effect, and prevent the deposition of fuel particles. This often has an adverse effect on proper distribution of mixture in multi-cylinder engines. Hot-spot manifolds, as they were called, are not so popular in full size engines as they were in the days when fuels were of dubious quality. But it is usual to provide some means of taking the chill off the induction pipe, either by heating the incoming air, or by some application of exhaust or water-jacket heat.

From the point of view of engine efficiency, it is not desirable to heat the mixture to any great extent, as air expands roughly 1/273 of its volume for every degree (F) of heat applied. Thus the actual weight of mixture in relation to volume is correspondingly reduced. But a well-designed hot-spot manifold does not *raise* the inlet temperature appreciably, except at idling or low speed, when this is an advantage rather than otherwise. What it does is to prevent *lowering* of temperature caused by rarefication of air and partial evaporation of volatile liquid.

It may be possible to obtain a manifold casting with the passages cored, which will save a good deal of time in its production, but this is rather doubtful, as moulders are not at all keen on small cored castings nowadays. To be on the safe side, I have designed the passages *so* that they can be machined from the solid, and the machining methods are based on this assumption.

★ *To be continued on March 5*

Continued from 19 February 1959, pages 223 to 225

Machining the crankshaft, connecting-rods, pistons

A new design for a 30 C.C. overhead valve four-cylinder engine of the Seal class.

By Edgar T. Westbury

THE casting of the manifold is machined on the joint face, by setting it across the four-jaw chuck, with two of the jaws inverted. The same method of setting is used for facing the intake flange. It will be seen that alternative faces are provided for fitting the carburettor in either of three positions, namely horizontal, vertical downdraught, or updraught. In the latter case the casting needs to be inverted, so that the inlet passage is below that of the exhaust.

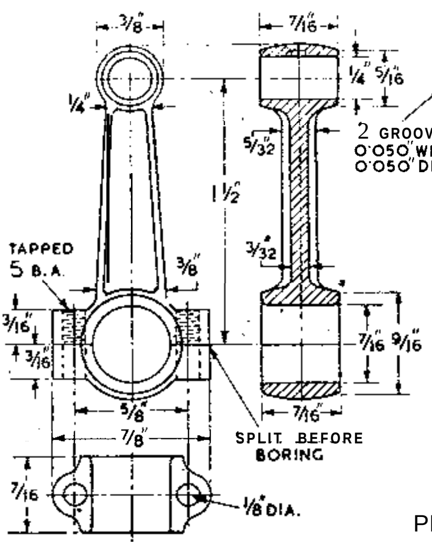
Incidentally, I do not consider that there is anythmg to choose, from the functional aspect, between the various positions; it is mainly a matter of convenience in installing the engine in whatever space may be available for it. A down-draught carburettor may take up more headroom than can be spared, and a horizontal one will increase overall engine width. The vertical updraught position, as specified for the Seal engine, not only favours compactness, but also enables the fuel tank to be placed lower when gravity feed is used.

It is now necessary to decide at which end of the manifold the exhaust is to be led out, and this again will depend on convenience in installation. Flanges are provided on both ends of the casting, and the one not required may be cut off, or alternatively blanked off, just m case it may be desirable to use it some time in the future. Some readers may consider that all these alternative arrangements may tend to confuse the constructor, but experience has taught me that their requirements are many and varied, and that rigidity of design greatly restricts the scope of application.

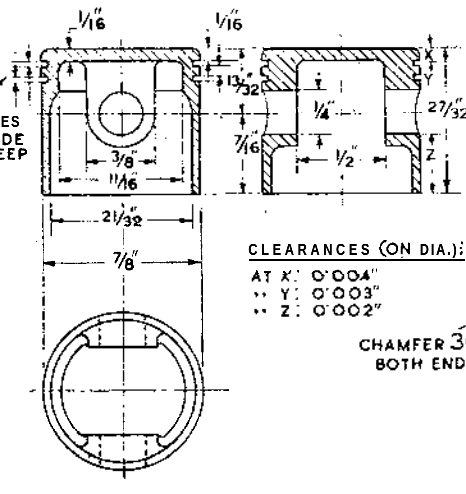
The casting may be set up on an angleplate mounted on the faceplate, for facing the exhaust flange and drilling the longitudinal passage. After this it may be set over to centre the induction passage, which is drilled in the same way, then tapped with a fine thread at the end. A plug is made to fit this thread tightly and, after all other work on the casting is completed, this is coated with joint varnish, screwed in and cut off flush with the casting surface.

Before drilling the ports in the joint face, care should be taken to ensure that they will line up correctly with those in the cylinder head, as bad alignment interferes with smooth gas flow and impairs efficiency. It is worth while to make a template to ensure coincidence, and afterwards, when spotting the tapping holes in the head from the clearing holes in the manifold, short dowels should be inserted in the end ports to ensure true location.

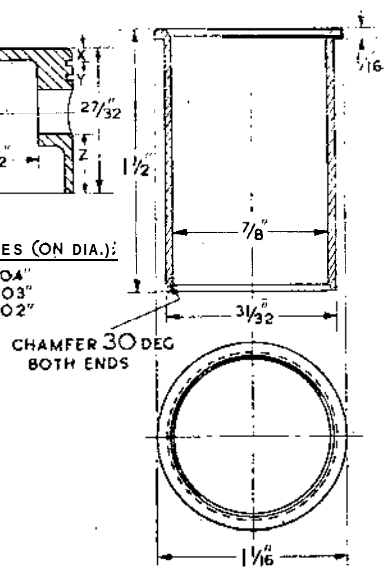
The ports may then be deeply centre drilled, followed by a 5/16 in.



CONNECTING ROD 4 OFF DURAL



PISTON 4 OFF L.A.



CYLINDER LINER 4 OFF C.I.

drill just deep enough to cut to its full diameter, and an acute-angled drill, or better still, a D-bit with a convex point of 1/2in radius, entered to a depth of 3/8in. It is now possible, using a drill about 5/32in dia., at about 30 deg. inclination, to join up the hole with its appropriate passage Beware of ·· taking the wrong turning when doing this. Remember that the ports at both ends and that in the centre, lead to exhaust, and the other two to the induction passage

A little wangling with a riffler, spherical burr, or rotary file will enable the ports to be enlarged and given an easy curved sweep. In the absence of a flexible shaft, the tool can be held in the lathe or drilling machine and the 'casting manipulated by hand.

The crankshaft

The production of a four-throw crankshaft of any kind constitutes a good exercise in lathe work. When machined either from a forging or from solid stock material, the established methods of setting out and turning between centres are difficult to improve upon, except where special machines or fixtures are available. In the present case, therefore, I propose to adhere to these well tried methods, which have already been applied successfully by most constructors of the Seal engines.

The material specified for the crankshaft is high tensile steel. This term covers a wide range of steels, mostly alloy steels containing nickel and chromium with high tensile strength and resistance to fatigue. High carbon steels are not usually favoured for this particular duty, as they tend to brittleness if subjected to heavy intermittent loading, though their properties are satisfactory in other respects. Unfortunately all special steels are difficult to obtain in small quantities and, therefore, it is not possible to specify definitely which kind should be used. Mild steel is not ruled out, as its tensile strength and resilience is satisfactory for the required duty; its surface hardness, however, is lower than is desirable, though this could be remedied by case-hardening or chrome deposition.

Whatever steel is employed, it is desirable to normalise it before machining by heating to dull red and allowing it to cool slowly to release internal stresses which might cause it to go out of truth afterwards. Rectangular bar of 5/8in. x 1 3/8in. section may be used as it is not necessary to machine the sides of the webs if they are reasonably clean. Note that circular crank webs cannot be used in this engine as it would be impossible to assemble the shaft in the body casting. Some constructors seem keen on machining crankshafts out of circular bar, though it involves considerable machining work and produces no advantages except a little more flywheel momentum.

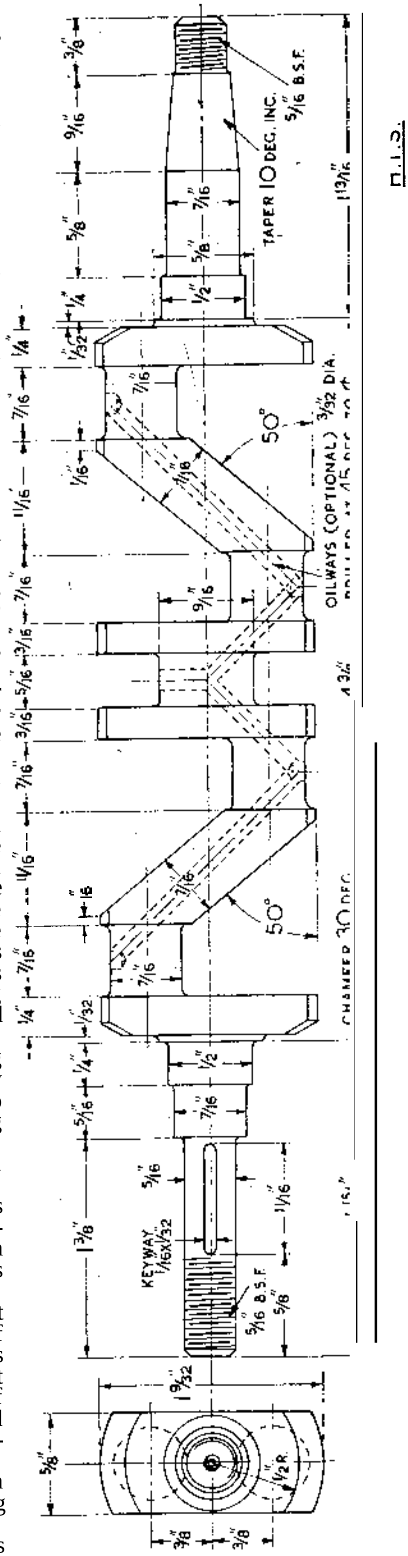
The bar should first be marked out for the main and throw centres with the aid of a scribing block on the surface plate, in order to ensure that the centres are in correct alignment at the two ends. First bed the bar down flat on a parallel packing piece, using a clamp to hold it firm if it shows any tendency to rock, and mark out the centre line at each end; then turn it at right angles and mark out first the main journal centre and then the throw centres, 3/8in above and below it respectively. These marks should be continued along the full length of the bar on one or both sides and the general outline of the shaft can then be marked out as a guide to machining.

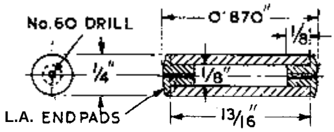
As much as possible of the unwanted material may be cut away from the crankpins and webs by drilling and hacksawing, care being taken to leave enough material to ensure that it will clean up properly. Do not, however, cut away the surplus from the end journals at this stage, or at least leave lugs on the ends for the throw centres. **I** am in favour of leaving as much metal as possible here until the crankpins have machined as it helps to provide much needed support during these operations.

The marked centres of the main journals and crankpins should be accurately centre-punched, and then centre drilled deeply enough to give an adequate bearing on the lathe centres. Turning operations are straight forward' enough, but it is advisable to make haste slowly as a long crankshaft is inherently lacking in rigidity and cannot be steadied while working on the throw centres. The oblique webs simplify turning operations on the crankpins, as they enable a more rigid turning tool to be used than is possible when working between narrow parallel webs. If desired, these webs can be machined on the edges by setting the topslide over to 50 deg. The rounded surfaces thus produced are pleasing in appearance and do not reduce the strength unduly, as compared to square edges produced by filing or milling.

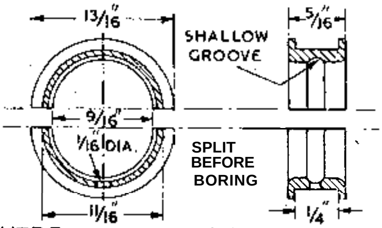
Do not forget to leave a small fillet or internal radius at the corner of each journal. Dead square corners reduce the strength to a great extent and also form a focus for cracks if subsequent heat treatment is found desirable. The surfaces of the crankpins should be finished as highly as possible by using a keen tool with plenty of top rake and lubricating with soluble oil.

The shaft may then be set on its

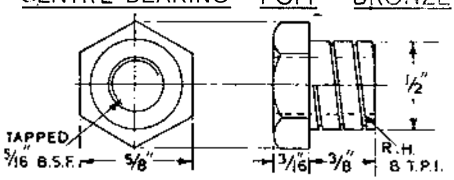




GUDGEON PIN 4 OFF M.S.C.H.



CENTRE BEARING 1 OFF BRONZE



CRANKSHAFT NUT 1 OFF M.S..C.H.

main centres and the middle journal machined, the same care being observed to get a high finish as for the crankpins. In this case it will be necessary to use a fairly narrow tool, like a parting tool with the front corners rounded-off, to produce the fillets. In previous articles I have described a special tool with the front edge grooved or bifurcated to relieve cutting stresses when working on narrow journals; this greatly reduces the risk of digging in or springing of slender work.

After removing surplus metal around the end journals with a hacksaw, the shaft is again set on its main centres and the turning operations completed. The ball race seatings should be finished to a neat wringing fit in the races, and it is desirable to check up on the length to ensure that when the housings are assembled there is neither excessive end play nor binding of the races.

Drilling of the crankshaft for oilways is optional. Some constructors may shy off it, considering it too difficult in view of the great depth of the holes and the propensity of small drills to depart from the " straight and narrow path." It is, however, an advantage, whether full forced lubrication is fitted or not, as it enables oil to be fed positively to the heavily loaded big-end bearings. The method recommended for drilling these passages is as follows: first spot their position on each of the five journals by entering the drill square-on; the middle main journal is drilled to a depth of half its diameter, but in the other journals the depth should be only just sufficient to ensure correct location.

If a drilling machine is available, the shaft may be clamped to the vertical side of an angle plate on the drill table, with its axis at 45 deg., for drilling the oblique passages. I prefer to use the lathe for this operation, with the shaft packed up exactly to centre height on the cross-slide or on an angleplate on the vertical slide, as the positive location obtainable by the lathe feed movements is an aid to accuracy. In either case, a good sharp drill running at the highest speed, and frequently backed out to clear chips, will help in putting the passages where they are wanted.

The keyway in the timing end of the shaft may be cut by whatever method is available. I have shown a closed keyway for a " feather " key, but an open keyway from the screwed end of the shaft is permissible, and may even be useful if some form of keep for the end nut is found to be desirable. A Woodruffe type of cutter is useful for this job, but do not cut the deep " half-moon " keyway for which this type of cutter is specially designed, as it would weaken the shaft too much. The duty of the key is not exacting, and its position on the shaft does not matter as the timing can be adjusted at the other end of the gear train.

Connecting rods

In the Seal engine, cast bronze connecting rods were used and on the whole gave fairly satisfactory results. It is difficult to obtain accurate castings in such a small size and many constructors preferred to to machine them from the solid, in duralumin or similar light alloy, which is more suitable material for the job. The same procedure may be adopted for this engine, but arrangements are being made to produce die castings in a tough alloy which has given complete satisfaction for connecting rods in other engines.

Machining operations on cast or otherwise pre-formed rods are simple, but it is desirable to take some care to obtain accuracy and uniformity. Before separating the caps from the big-end by sawing, using either a hand-saw or a circular slitting saw in the lathe, a hole may be drilled about 3/8 in. dia. to remove most of the unwanted metal, and the screw holes may be drilled, tapped and spot faced. The cut surfaces should then be trued up by machining or filing so that they bed together quite accurately. This is most important as a badly faced joint is a source of weakness. Temporary screws may be used to hold the bearing caps during subsequent operations.

The little-end eyes of all four rods should then be drilled, reamed and faced by holding them in the four-jaw chuck with one jaw reversed and setting the boss to run truly, also setting the shank of the rod exactly parallel with the chuck face. In order to bore and face the big-end bearings and ensure that the length between centres is the same in all cases, I recommend setting them up in the following way. First, remove the reversed jaw from the chuck and make a T-bolt with a head to fit closely in the groove which normally takes the chuck jaw. The shank of the bolt may be screwed 2 BA and provided with a sleeve nut with a fairly broad face to bear against the chuck face, and turned down to 1/4 in. dia. at the outer end to take the little-end eye. If carefully fitted, this should stand square with the chuck face when fitted, but this should be checked to make sure.

The little-end of the rod should be fitted to the projecting sleeve and the big-end bearing set true by means of the three chuck jaws, before tightening the sleeve nut. When properly located and the nut tightened, it is not shifted until the set of rods have been bored. A nut and washer on the end of the T-bolt will secure the little-end of the rod firmly, and the boring of the big-ends to fit the journals may then be carried out with the assurance that they will be uniform and properly aligned.

Oil holes are provided in the little-end bearings, but the big-ends should only be drilled if no oilways are provided in the crankshaft. The use of scoops on the bearing caps, as recommended by Mr Curwen, is helpful in picking up oil from the trough in the latter case. For the securing screws, really good material is essential and I recommend drilling the screw heads so that they can be locked by threading a wire through the two lifter they are tightened up. I believe that it is possible to obtain Allen type cap screws with cross-drilled heads, but if not, screws made from tough steel, such as aircraft bolts, may be used.

j, *To be continued on March* 19

CORRECTION

My apologies are due for an error in the detail drawing of the body casting on page 100 of the January 22 issue. In the sectional end sectional view, the diameter across the lower liner seating is given as l 5/16 in., whereas in the side view it is correctly shown as 31/32in. The former dimension actually refers to the width across the ***outside*** of the casting at the waist, below the water jacket.