WHIPPET for the water

This medium-performance petrol engine can be used in model power boats

By Edgar T. Westbury

THE ENGINES which I have designed and described in ME during more than 30 years have also covered nearly all the duties for which engines are likely to be employed in model engineering. Two-strokes and four-strokes, horizontal and vertical, air-cooled and water-cooled, single and multi-cylinder-all have had their fair share of representation, and their sizes have varied from 2-1/2 to 60 cc.

While I have never claimed that the engines designed for high performance will break all records, several have been notably successful in the hands of various constructors, some of whom have modified or tuned them to conform with their own ideas. The only claims I have made are that the designs are sound and will give reliable and efficient service if they are properly constructed. Furthermore, every new engine has been an exercise in experimental design, in which definite, and-I hope-practical, reasons for their individual features have been given.

Having finished blowing my own trumpet, I will explain why I have produced yet another engine design for general duties and for model power boats in particular. It has often been suggested that for the amateur the petrol engine is a dead duck because ready-made compression-ignition and glow plug engines are obtainable everywhere and cost little, if anything, more than the construction of an engine from castings. The need for electrical ignition equipment, and the added weight which this involves, is often cited against the orthodox petrol engine. Regarded purely as a means to an end, the ready-made engines satisfy many users, and have helped to popularise many power-driven models by bringing them within reach of those who have no ability or facilities for constructing engines themselves.

But though the petrol engine suffered a severe set-back in the years after the war, there are now many model enthusiasts, particularly in the model power boat world, who are not satisfied with ready-made engines which, however efficient they may be, are mostly lacking in flexibility and depressingly monotonous in design. Even if this were not so, there will always be individualists who regard the engine as an end in itself and a means of self-expression.

I have had many discussions during the last year or two with ME readers who want a new engine design for specific purposes, and have given me some more or less specific instructions. While the instructions vary widely, they have some points in common; the engine must be a compact four-stroke, as simple as possible in construction, and not unduly heavy. It should be water-cooled and have a simple lubrication system which would enable it to run for fairly substantial periods without attention.

Few have demanded extremely high speed or power output, but flexible speed control and easy starting are regarded as essential. Some have suggested 5 cc. or even less, but the greater number are in favour of a size which is more " comfortable " to construct, having no very minute or delicate working parts, and which has some power in hand; with this opinion I am in complete agreement.

The design for the ***Whippet*** is not something that has been dashed off in a moment of inspiration; it has been simmering in my mind for quite a long time and also involved a good deal of experiment with features and components, the final choice of which I have arrived at by a process of elimination. At one stage, I built and tested an overhead valve engine. It was a successful and attractive design, but I considered it too " bitty " for the present purpose, though I may possibly describe it at a later date. The side-valve engine allows the number of parts to be reduced, simplifies the valve gear, and facilitates effective water-cooling of the cylinder head. It restricts the compression ratio to some extent, owing to the space occupied by the side pocket in the head, and is not generally conducive to very high performance, but it promotes flexibility and quiet running. Side valves have been very successfully used in several of my early engines, including the ***Kinglet, Seagull, Seamew and Seal.***

The structural parts are further reduced in number by our making the body of the engine, comprising the cylinder jacket and crankcase, in the form of a single integral casting. This is not uncommon in two-stroke engines (I was one of the first to adopt it, in the original ***Atom Minor*** engine) but is not quite so easy to adapt to four-strokes, as it may introduce machining or assembly difficulties. These have been anticipated and dealt with in the present design. The crankcase is roomier than in most small engines, to give ample oil capacity. A broad base flange permits the engine to be mounted directly on the floor of a flat-bottomed hull, or on a plinth in the case of a stationary installation. This is a breakaway from previous designs, which have nearly all provided for their being mounted on bearers at shaft centre level. Constructors of boats often find that unless provision is made in the initial design of the hull, it is not easy when this mounting is used to fit and locate the engine in true alignment with the propeller shaft.

The engine has an overhung crankshaft, carried in two plain bushes in an endplate registered in and bolted to the front end of the crankcase. A follower worked from the crankpin drives the timing gear and can also be used for an external auxiliary drive. This avoids the need for a split big-end bearing, which is often liable to be troublesome in small engines; the employment of a full one-piece crankshaft would involve not only the split big end but also underside access to **it,** by our splitting the crankcase horizontally or bolting on the sump, for the big end bolts to be properly assembled. No ball bearings are employed anywhere, but they could be fitted instead of plain bushes by modification to the housings. I question their advantages for an engine of moderate performance. They nearly always increase overall bulk and weight.

A side camshaft running parallel to the crankshaft operates the two valves through direct-action flat-based tappets. It is driven by spur gearing in a casing attached to the face of the rear endplate. To avoid making this casing disproportionately large, we fit an intermediate idler pinion between the crankshaft and camshaft gears, enabling both of them to be reduced in size. Although this introduces extra parts, it provides some latitude in the relative position of the shafts, as mesh, adjustment can be made in the idler shaft location.

With the short stroke and the absence of any projections above the cylinder head, the height of the engine is kept to the minimum, so that its centre of gravity is low and it can be installed below decks in a shallow-draught boat.

The machining operations on the body casting can nearly all be carried out by locating from two faces at right angles, on the lathe faceplate and angle plate. In both the bolting surface is the base flange, the width and area of which give adequate stability and eliminate the need for packings. You must first true up the side strips of the flange. This can be done by filing, but it is just as easy to chuck the casting by the cylinder head end and take a facing cut across the strips. At the same setting, the hole for the drain plug *in* the centre of the base-an optional fitting, which some constructors may consider unnecessary-may be faced, drilled and tapped; its position in relation to the cylinder centre line is not critical.

You can use two toe-clamps to attach the casting to the faceplate so that it can be set up for facing the top, and machining the cylinder liner and valve housing bores. Note that the bores are continued through into the crankcase, at reduced diameter; although exact concentricity is not absolutely essential, you are advised to observe it as far as possible. These operations could be carried out in a drilling machine, but it is by no means difficult, and is more conducive to accuracy, to centre them in turn by setting the casting *over on* the faceplate, to bore them in the lathe. The bores should be reamed or otherwise finished smooth and parallel.

The casting is next mounted on an angle plate, which in turn is attached to the faceplate, and centred for facing and boring the endplate register. At the same setting, the bush housing in the rear end should be bored and faced. To machine the register and facing for the timing case, it is best to make a spigot mandrel, thereby ensuring exact truth with the front end. As an alternative, the casting can be reversed on the angle plate, bedded firmly against the faceplate, and set truly from the bore by a dial test indicator or other convenient means. The next operation on the angle plate involves our turning the casting at right angles to machine the valve port face; at the same time it is well worth while to centre and drill the horizontal valve ports.

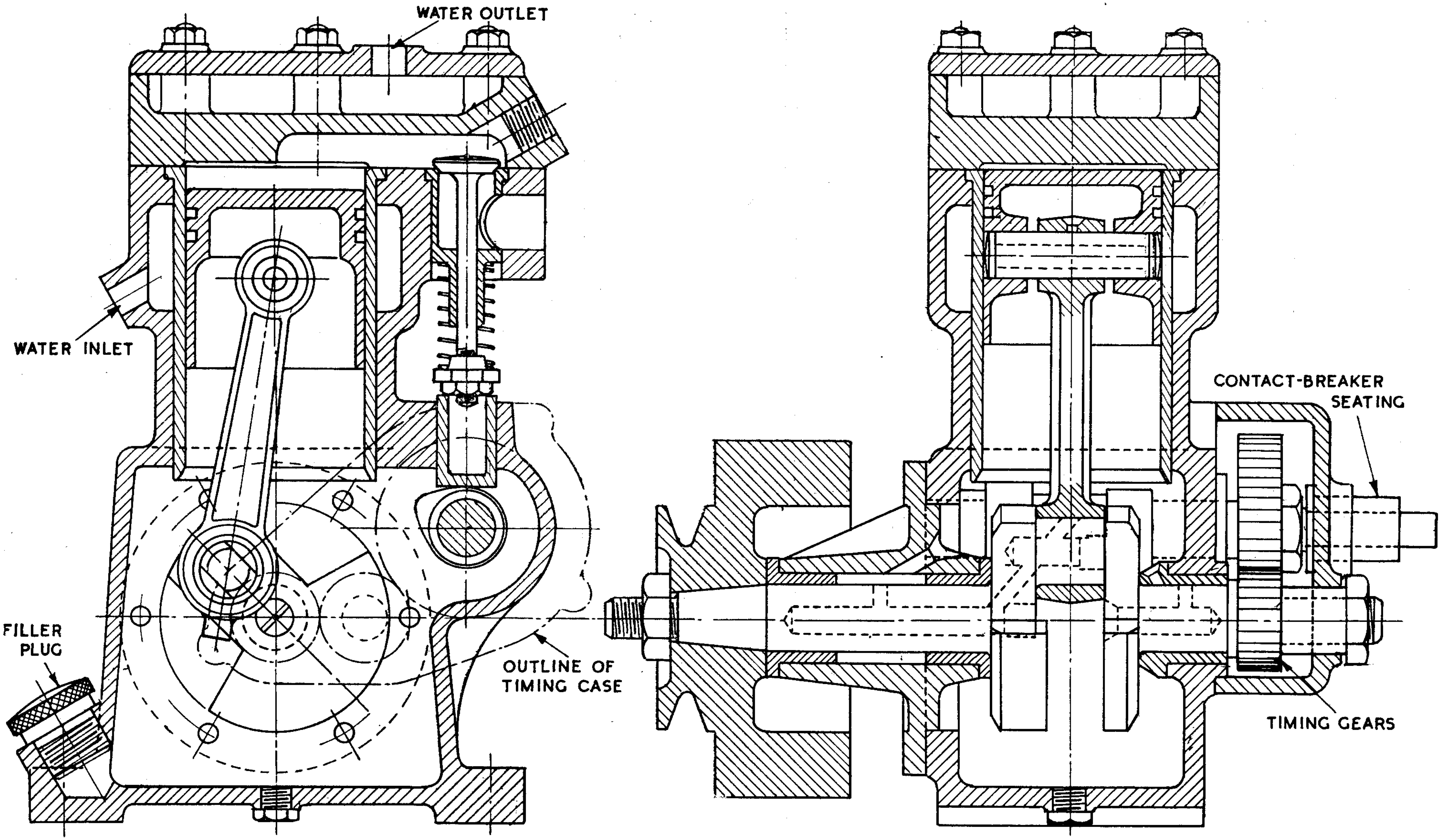
To face, drill and tap the hole for the oil filler cap, bolt the casting on either the front or rear face on the angle plate (protect the machined surfaces by interposing a sheet of paper) and swing it round to the required angle. A single bolt with a truly faced thick washer or disc will hold it securely enough for this light operation. The same procedure may be used for facing and drilling the water inlet flange; some may prefer to tap the hole for a screwed pipe connection. This is simpler, but is not in conformity with full-size practice.

Neither of the two operations calls for critical angular setting. The machining of the casting may seem complicated, but it is just as simple as that of many crankcases of conventional design, and is much more straightforward than some which I have had to tackle.

The main bearing housing, integral with its endplate flange, may be provided with a chucking piece. If it is not, it can be held over the edge of the flange, inner face outwards, for facing and boring. The spigot of the flange should be made a really neat fit in the crankcase register to locate it accurately and avoid shear stress *on* the fixing studs or setscrews. With care in the facing operations, it should be possible to avoid the need for any gaskets or other packing in assembly, but it is permissible to use thin paper or tracing linen (recommended for toughness) for oil joints only. Face off the outer end of the housing truly, preferably by mounting the casting on a mandrel.

Apart from drilling and tapping, the only operations on the cylinder head are the facing of the top and bottom, which can easily be carried out in the four-jaw or three-jaw chuck. It is desirable that these faces should be truly parallel to each other and also dead flat and smooth. The same applies to the cylinder head *cover, only* the underside of which needs facing all over, though it may well be reversed for skimming over the stud bosses and the water outlet flange. When you are drilling the clearance holes in these bosses, allow plenty of clearance so that there is no tendency of the studs to bind. The tapping holes in the body can, of course, be located by clamping the head in position and using it as a jig.

The water communication holes, which are marked Z in the drawing, can be jigged in the same way. Their number and size will give adequate circulation in all circumstances. Some constructors have complained that engines of my design, including the *Kiwi Mark II,* are overcooled. This is quite true if water is forced through them under pressure from a pump or scoop. For natural convection or thermo-syphon cooling, as generally used for stationary work, or closed-circuit marine installations, no restriction in the size of the passages can be tolerated. With forced circulation the communication holes can be reduced in size, but a much more logical and adaptable method is to throttle the flow of water on the *output* side, so that it is discharged at only slightly less than boiling temperature. There is no advantage whatever-rather



WHIPPET S.V. PETROL ENGINE. 10 c.c. capacity, 1 in. bore x $\frac{3}{4}$ in. stroke the opposite-in discharging a full-bore jet of cold water.

Make the internal surfaces of the combustion chamber as smooth as possible and round off any sharp comers, including the edge of the sparking plug hole. It is possible to arrange the inlet and exhaust valves either way round, provided that the camshaft has the cams located to suit. You should therefore decide the position of the sparking plug when you are machining the head, as this should be placed over the inlet valve for efficient ignition. It is worth while to make a metal or hardwood block with a face at 30 deg. so that you can mount the head on the faceplate for boring and facing the sparking plug hole; temporary screws through the water holes may be used to hold it on the block during this operation.

The cylinder liner should preferably be made of close-grained cast iron; this has better wearing properties than any other readily obtainable material. Mild steel, in the unhardened state, is liable to scuff when it is used with aluminium pistons. If it is case-hardened it is liable to distortion unless it is subsequently ground all over, inside and out. In some engines I have successfully used mild steel cylinders with the bore surfaces. either carburised (not quenched) or chrome-deposited.

You had better provide the liner with a chucking piece so that it can be machined all over at one setting, and finally parted off. The bore needs to be parallel and circular within close limits, and it should be lapped or honed after insertion in the body. A tight interference fit is not necessary for the liner, but it must obviously be close enough to make a watertight joint. A coating of jointing varnish, or better still, Loctite, will help here. The rim of the liner should be exactly flush with the top of the body when it is fitted, but if necessary it may be machined or lapped in position.

The crankshaft should be machined from solid steel, though it could be fabricated by brazing; in which instance both the main journal and the crankpin should be shouldered down to 5/16 in. dia. to fit holes in the web, and the rest be left oversize for machining afterwards. If it is made from solid 1-1/4 in. bar, it may be held in the chuck with back centre support for roughing out the main journal, after which most of the unwanted metal at the other end may be sawn away, both on the face and at the sides of the web, to reduce the amount to be removed by machining. The inner end should then be deeply centre-drilled so that the journal can be finished between centres. But before finishing it completely, turn it parallel for its full length so that it may be held in an eccentric fixture for turning the crankpin.

One of the most useful fixtures for this purpose is the Keats V angle plate, obtainable from Buck and Ryan, of Tottenham Court Road, London NWI. Any device which will hold the shaft axially parallel, and can be set over on the faceplate to the required crank throw, can be employed. I have used a large V-block, held by three jaws of the four-jaw chuck while the other gripped the shaft in the V-groove. But care must be taken that the block is bedded firmly against the chuck face so that it cannot get out of line.

The end of the crankpin is drilled, and tapped for a short distance, to be plugged by the driver stud. This hole forms a part of the oil passage and also lightens the crankpin to assist balance. Some may consider the deep drilling of the main journal, and the smaller oil passages, somewhat difficult, but they provide efficient lubrication of the big-end bearing. Alternative methods will be described later.

The taper on the crankshaft must match that of the flywheel seating exactly, and you may defer finishing it until the seating has been bored. Screwcutting methods ensure the truth of the end thread, but careful use of a tailstock die holder will produce a satisfactory result.

The crankshaft main bushes may now be made and fitted to the two ends of the housing. For concentricity, they are best made from gunmetal rod, bored and turned at one setting, and parted off. They should have about I thou interference fit, and you may adjust the length by facing the ends after assembly, so that when the flywheel is secured the shaft turns freely with little or no perceptible end play.

Steel bar of the same size as is used for the crankshaft is suitable for the follower. It can be machined in much the same way so far as the journal is concerned. The slot in the web should fit the sides of the driver stud as closely as possible to avoid play. Another method, which may have some advantages, is to make the stud round at the end and bore the follower to fit. But this calls for high precision, both in the location of the hole and in the alignment of the follower bearing, to prevent binding. The arrangement shown allows some " floating " latitude, and has been found quite satisfactory in practice. A similar bush to that of the main bearing carries the follower, but its flange is bevelled off so that it clears the end of the driver stud.

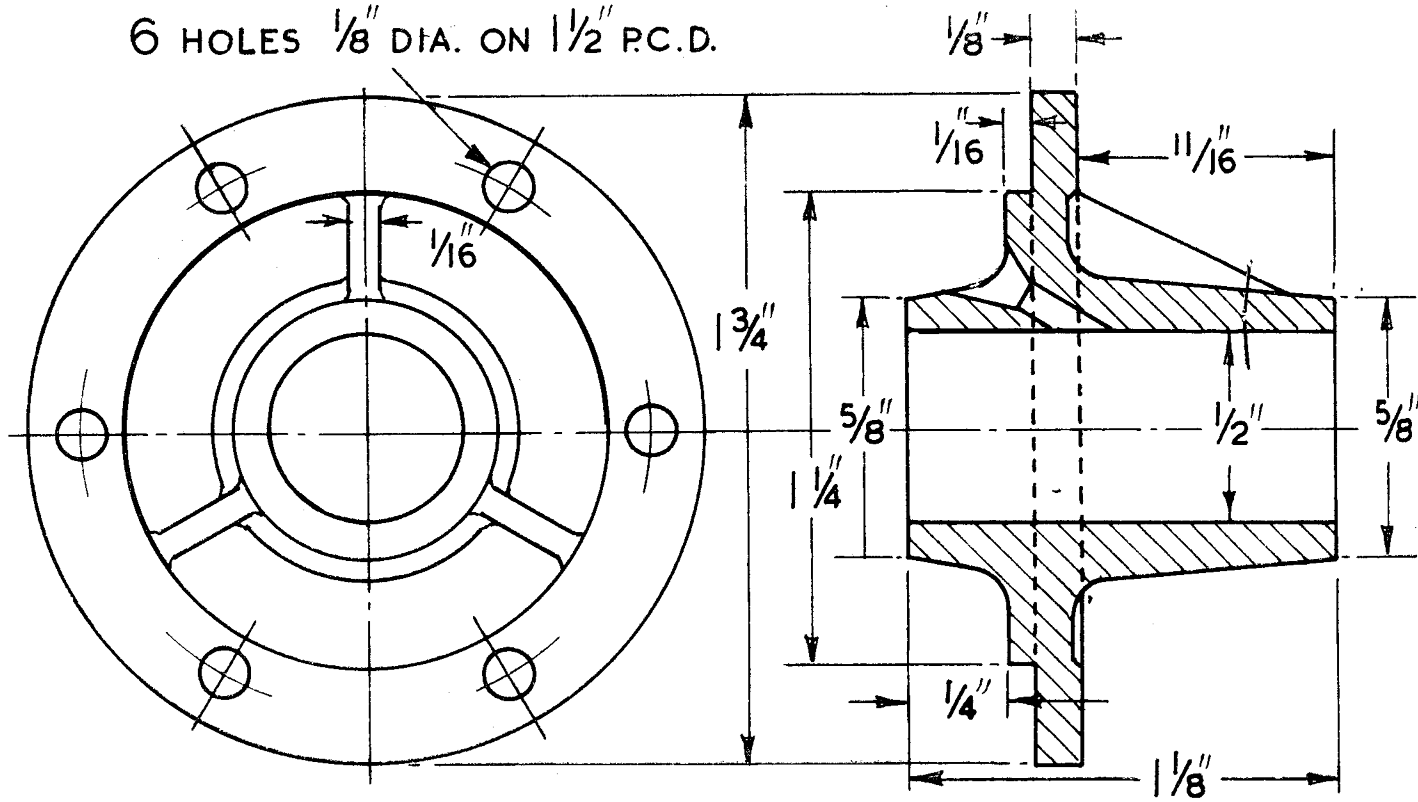
A gunmetal casting is employed for the connecting rod. Although it is somewhat heavy for really high speed, it has been found satisfactory up to about 6,000 r.p.m. If higher speed is anticipated, the alternative is to machine the rod from solid duralumin. The essential point is that the bores of the two eyes must be the right distance apart and exactly parallel with each other. One method is to clamp the casting by its centre part to a flat plate, leaving the bosses clear at each side, and shift the plate on the lathe faceplate to set the eyes centrally, in turn, for drilling and reaming.

The detail drawing shows on the lower end of the rod an extension which dips in the oil and splashes it over the working parts. Its length may call for some adjustment to guard against over-oiling. If the crankshaft is not provided with internal oil passages, the extension piece should be drilled vertically 3/32 in. dia. to admit oil to the bearing at the point of lowest load pressure. In the little-end bearing, this is at the top side, and the hole should be well countersunk.

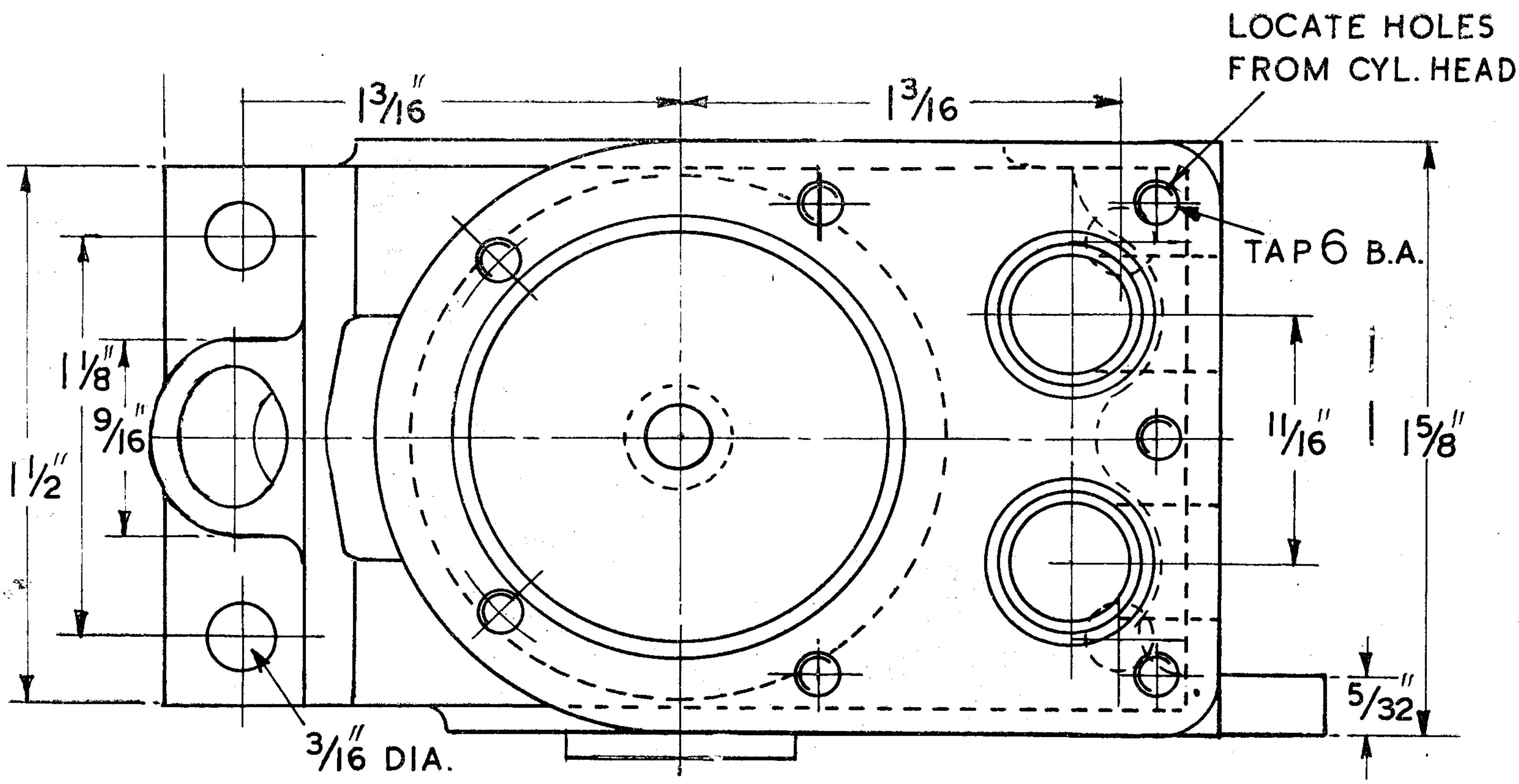
Some of the oil splashed up by the big end drains back through the large countersunk hole in the main housing, into the space between the bushes, and maintains the oil film in both of them. If the crankshaft is drilled, centrifugal force at the crankpin draws oil through the passages and lubricates the big-end bearing.

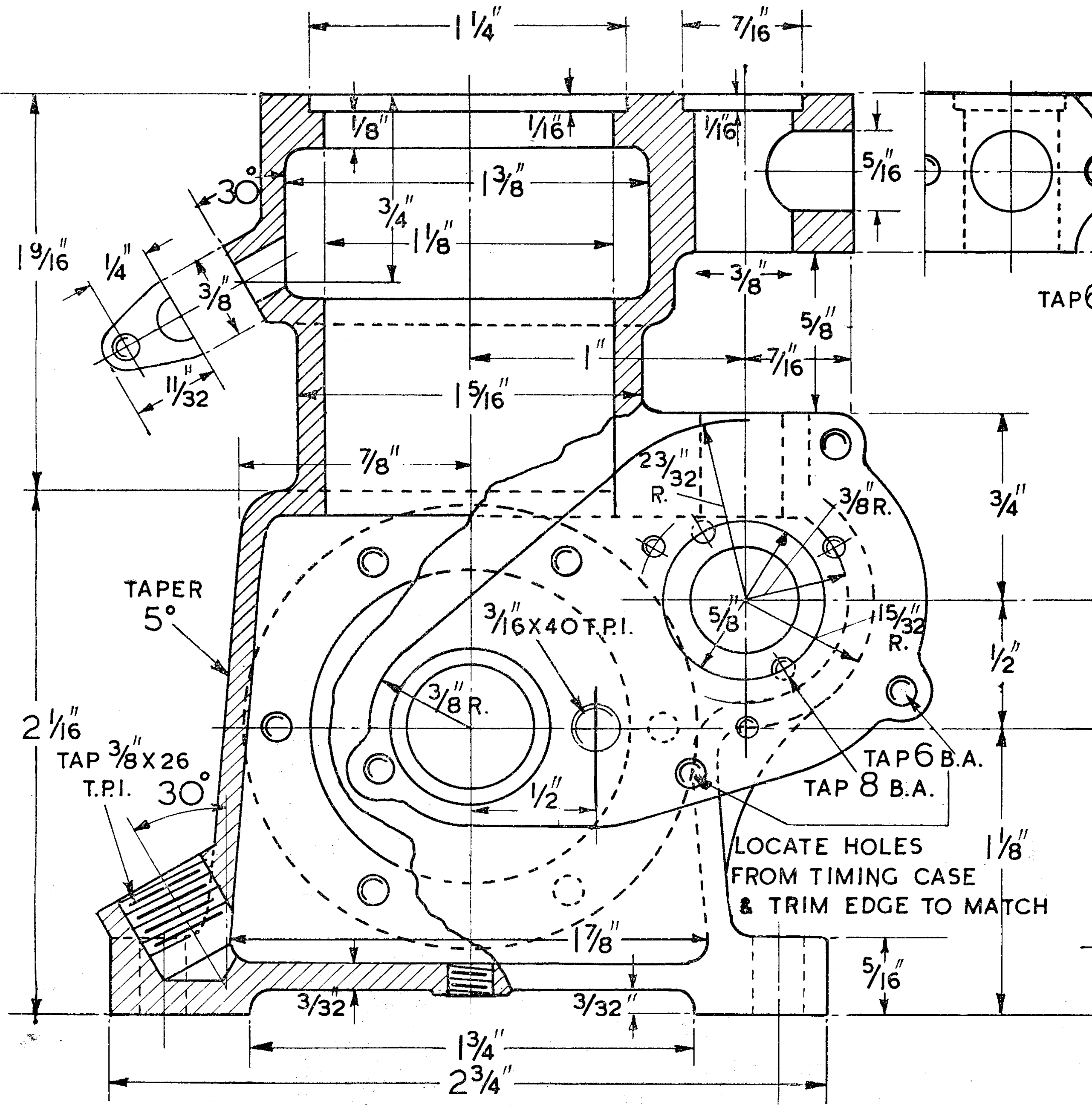
A casting in gunmetal or cast iron is suitable for the flywheel, but it may be machined instead from solid steel bar. I recommend you to chuck it with the starting pulley outwards and to rough-turn all the accessible surfaces, including the V-groove.

* ***To be continued***

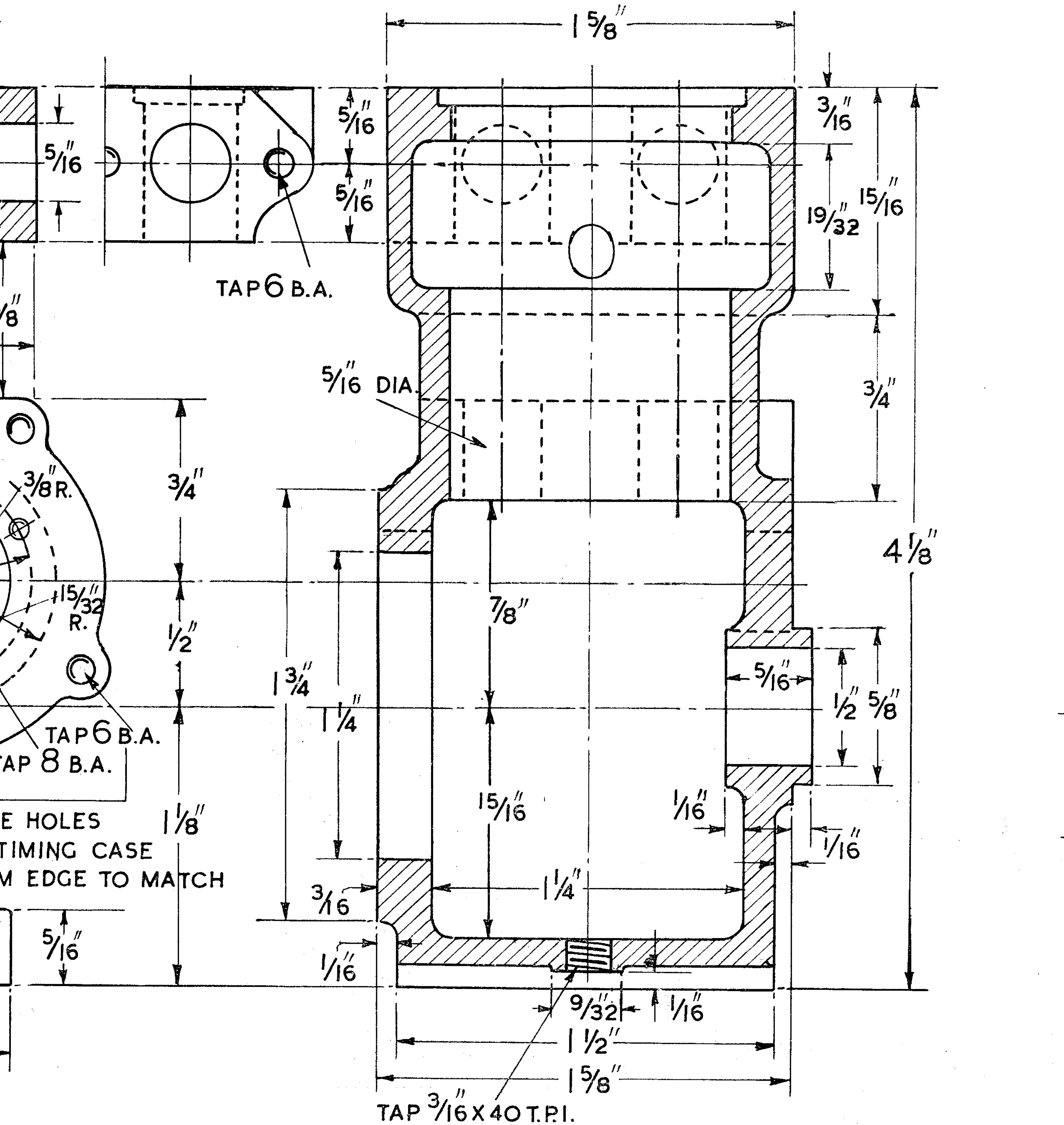


MAIN BEARING HOUSING   1 OFF   L.A.

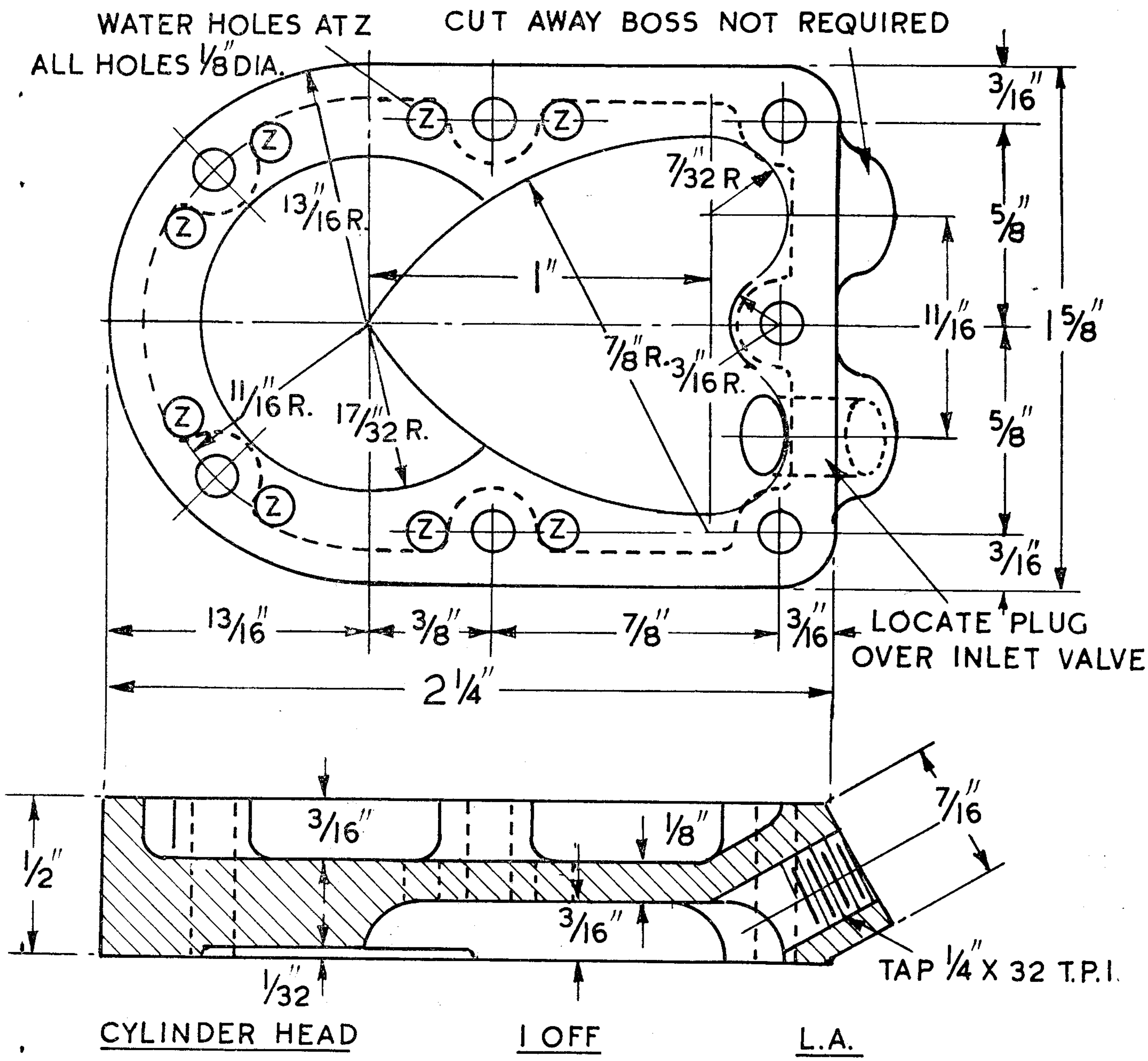




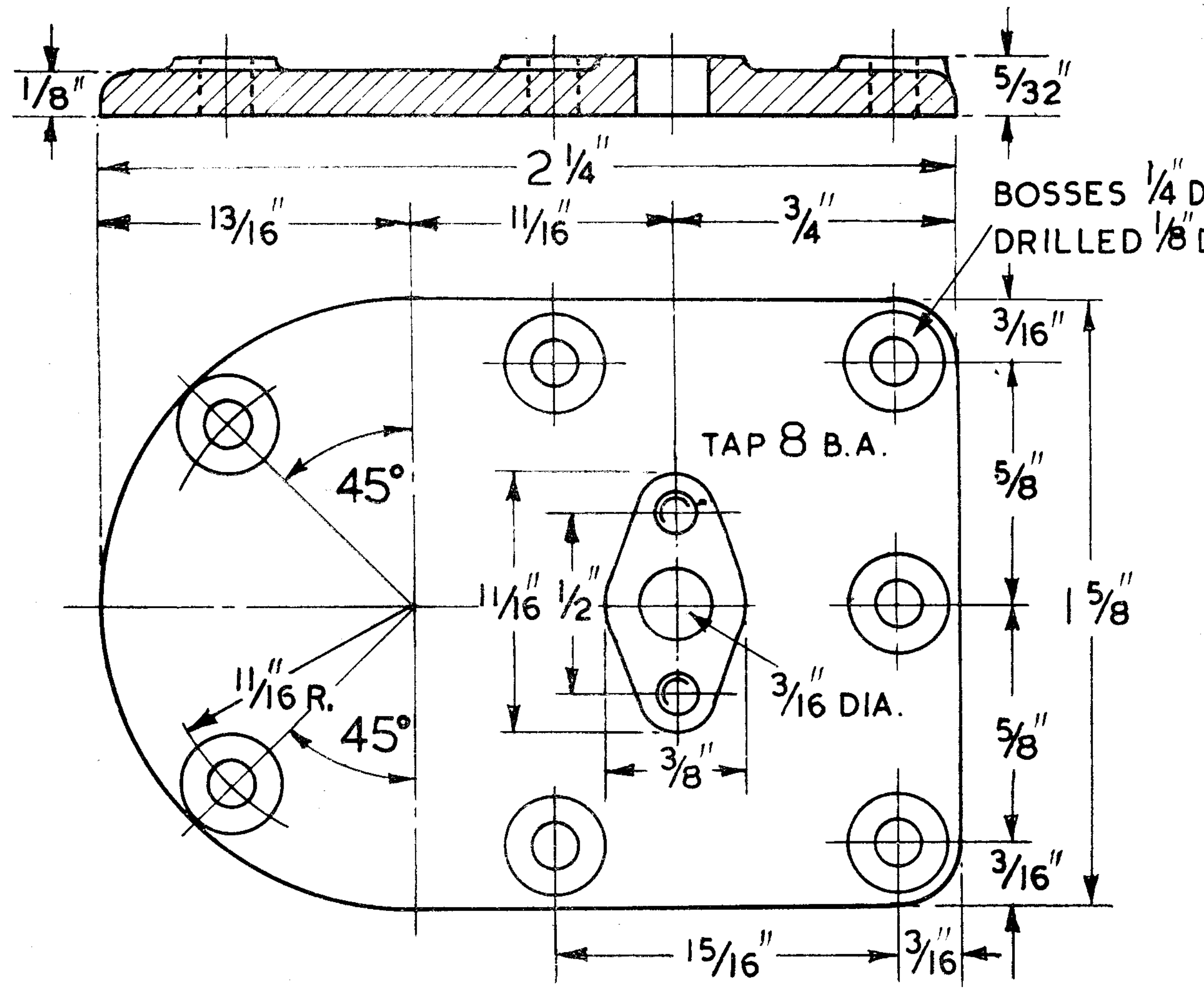
1 1/4"
7/16"
1/8"
1/16"
1/16"
5/16
30°
1 3/8"
3/4"
1 1/8"
1 9/16"
1/4"
3/8"
3/8"
TAP 6
5/8"
1"
7/16"
11/32"
1 5/16"
7/8"
2 3/32" R.
3/8 R.
3/4"
TAPER 5°
3/16" X 40 T.P.I.
5/8"
15/32" R.
1/2"
3/8" R.
2 1/16"
TAP 3/8" X 26 T.P.I.
30°
1/2"
TAP 6 B.A.
TAP 8 B.A.
LOCATE HOLES FROM TIMING CASE & TRIM EDGE TO MATCH
1 1/8"
1 7/8"
5/16"
3/32"
3/32"
1 3/4"
2 3/4"



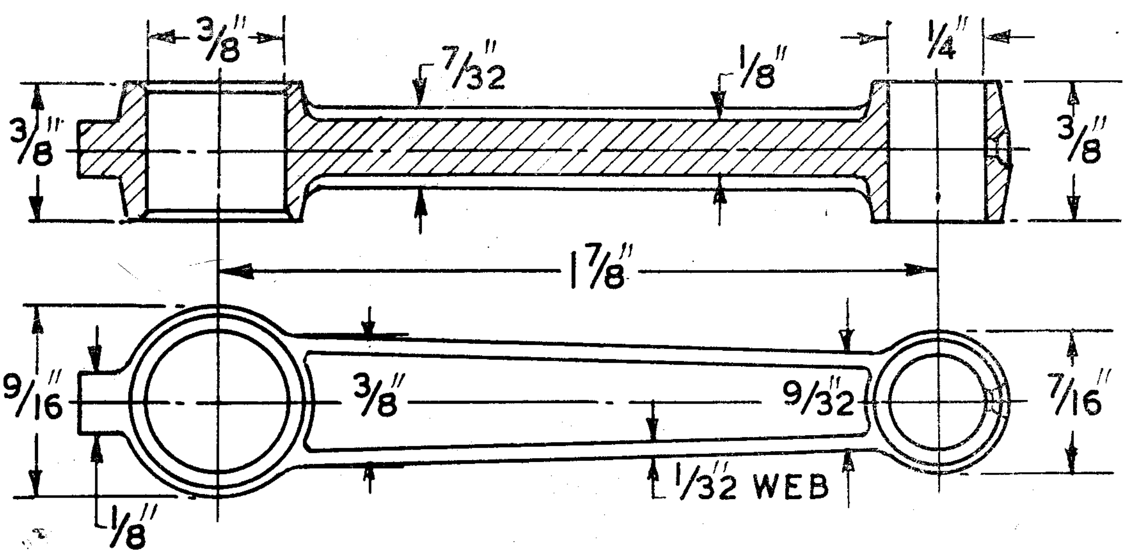
BODY CASTING 1 OFF L.A.



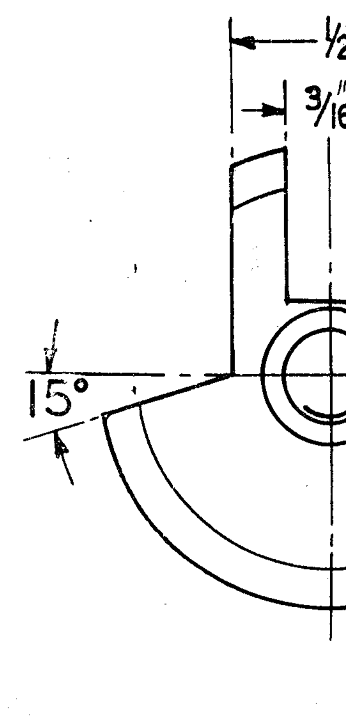
DESIGNED BY EDGAR T. WESTBURY



CYLINDER HEAD COVER 1 OFF L.A.

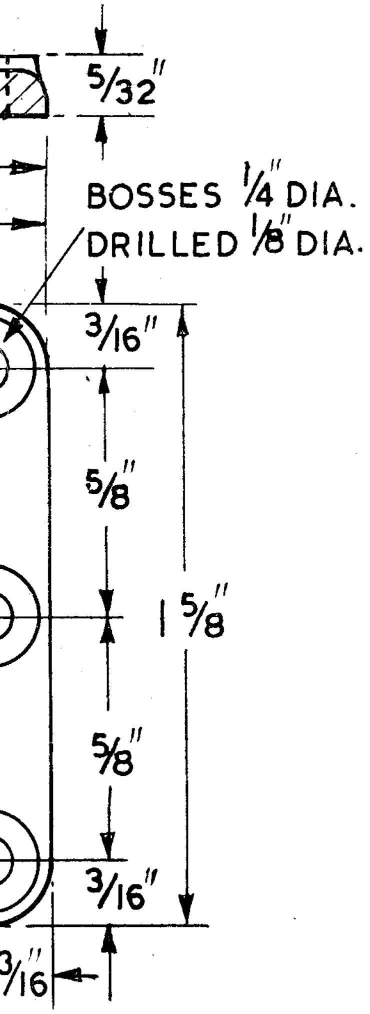


CONNECTING ROD 1 OFF BRONZE

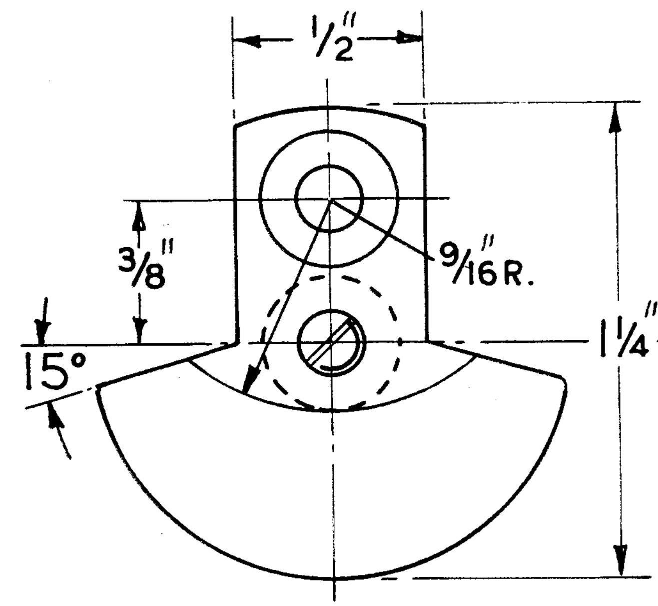


FOLLOWER

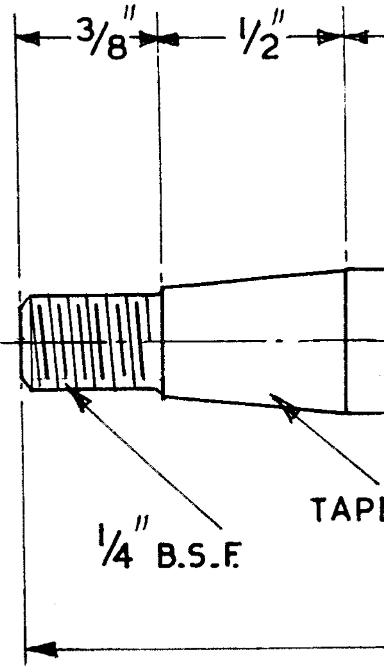
TO OPEN PLAN, FREE THE T



L.A.



CRANKSHAFT



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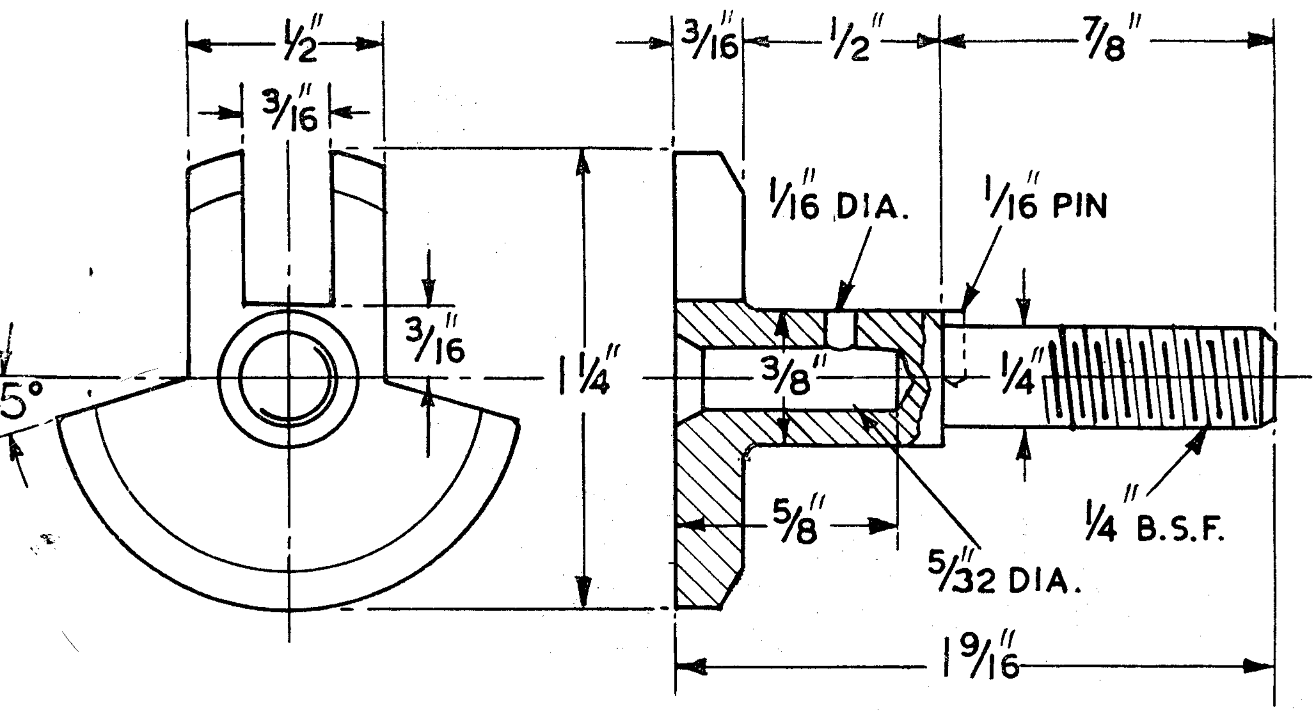

FOLLOWER

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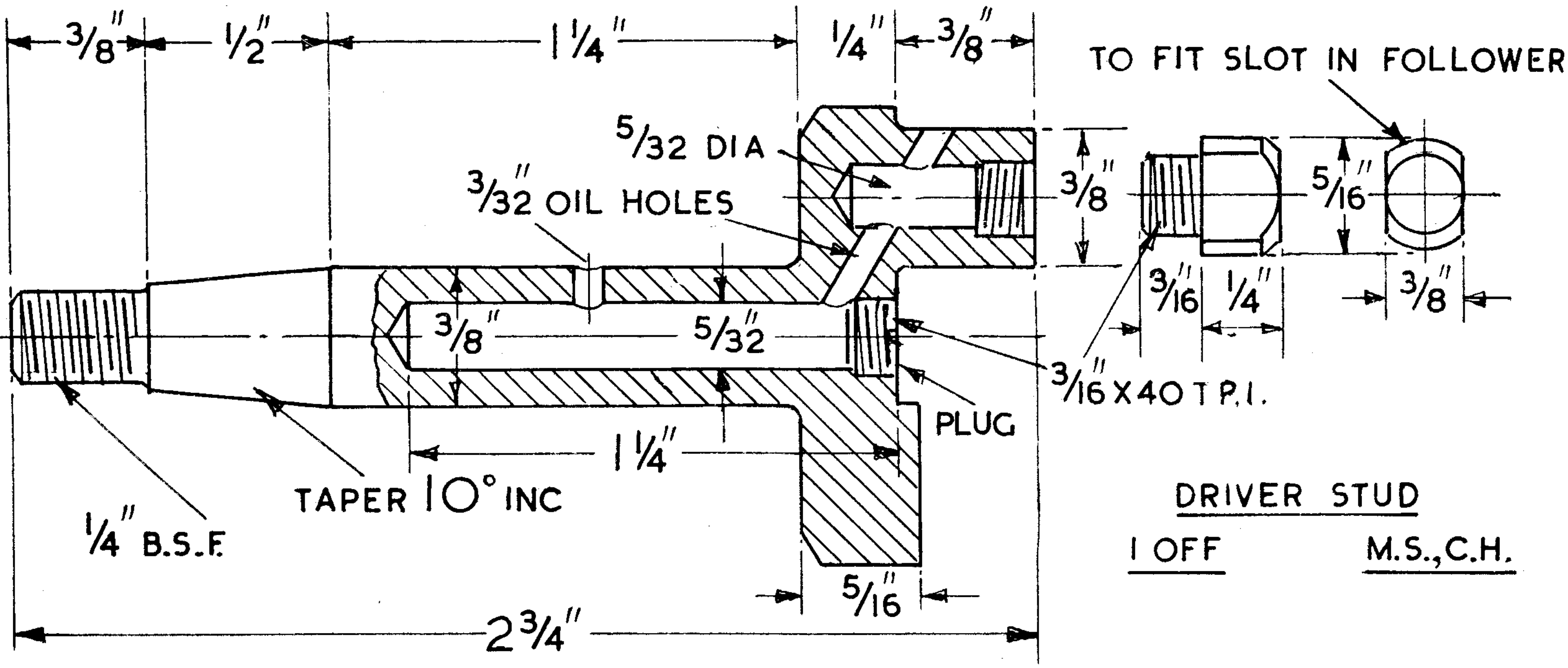
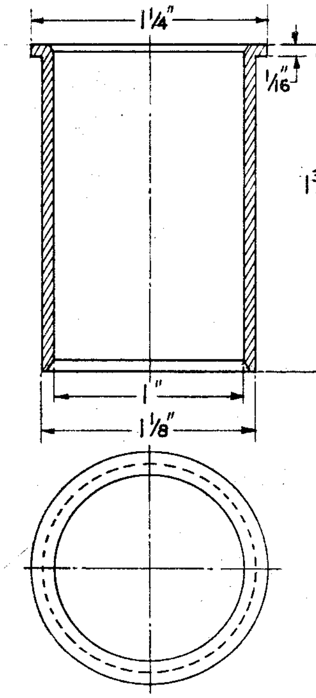
M.S.

AN, FREE THE TOP FOLD

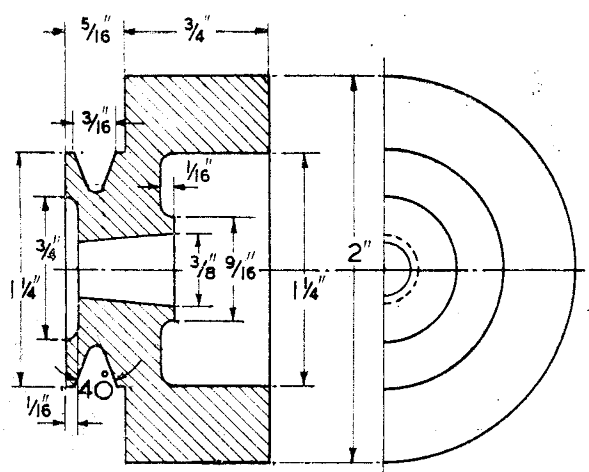


DRIVER STUD   1 OFF   M.S., C.H.

1 OFF   M.S.



CYLINDER LINER   1 OFF   C.I.



FLYWHEEL   1 OFF   C.I. OR G.M.

Continued from June 1, page 93

HOW TO MACHINE THE PARTS

By Edgar T. Westbury

TO COMPLETE the machining of the flywheel casting, it may be reversed in the chuck to turn the remaining surfaces, including the recess, and drill and taper bore. Take care to set the boring tool exactly at centre height and to produce as smooth a tool finish as possible. A reamer of approximately the correct taper will help to produce accuracy, but it should be used only to take out a very light finishing cut. When the flywheel is properly fitted to the shaft, so that it bears evenly over the full length of the taper, you may secure it by the shaft nut and mount the assembly between centres for finish turning.

As the piston casting is provided with a chucking piece, most of the machining of the outside can be carried out at one setting. The advice that I have given several times before, on setting up from the inside surfaces, should be carefully observed. Preliminary truing of the chucking piece, with the piston held in the reverse position,, will help it to be gripped securely in the four-jaw chuck for setting up. Instead of finishing the outside to the specified size, you had better leave it slightly oversize, so that when other operations are complete, it can be held on a spigot by an eyebolt and a dummy gudgeon pin. The mouth of the piston skirt should be bored true, as well as faced, to provide a register to fit the spigot.

While the work is set up for initial turning, the position of the gudgeon pin bosses may be marked out on the outside by a scribing block on the lathe bed (or better still with the small Myford surface plate which is designed to rest on the lathe bed), to ensure that the gudgeon pm will pass through their centres. The lateral position of the bosses can also be marked with a point tool while they are thus set up. To drill and ream the cross holes, mount the piston on an angle plate, setting the axial centre lines to coincide with a line marked squarely across the mounting face, and setting up the assembly to centre the intersection of axial and circumferential lines. After the holes through the bosses have been centre-drilled deeply and drilled undersize, they may be bored or reamed in line.

By finishing the piston after boring the cross holes, you eliminate any risk of distortion or burring. In full-size practice it is usual to oval-turn or otherwise relieve the surface near the ends of the holes; this is not necessary in a small piston. Sometimes the diameter is slightly reduced in the piston centre, but I prefer to retain as much bearing surface as possible, and relieve by filing any high-spots which may develop. The clearances specified for a light alloy piston should be sufficient to avoid the risk of their tightening in the cylinder in prolonged running. Fit the rings so that they just have working side clearance-not more-in the sides of the grooves, but ample depth clearance. Loose rings will often cause oiling up, but if the rings are not free they are useless.

The gudgeon pin is a simple component which may be made from 1/4in. mild steel rod (not silver steel) without external turning, provided that it is a close fit in the piston and the little end of the connecting rod. The brass end pads should be fitted tightly after you have casehardened and polished the pin, and checked the overall length to make sure that it will pass through the cylinder bore.

Before proceeding with the machining of the valve-gear parts, machine and fit the timing case. It can be held in the four-jaw chuck for machining the joint face, after which it is reversed on the faceplate and the lower boss is centred, faced and bored. So that the boss will line up with the main shaft, a register should be bored in the inside of the timing case to fit the spigot on the body. This can best be done by turning a plug mandrel, with a shoulder to give true face alignment, and setting the timing case on it for skimming out the mouth over a sufficient part of the surface to provide true location. The screw holes are then drilled through the bosses of the casing, and it is clamped in position on the body, for spotting the tapping holes for the screws, so that the case can be temporarily fixed for further operations.

The casting for the body is now marked out on the rear flange for the camshaft centre; this position is not critical, but should be as accurate as possible. It is then again mounted on an angle plate, with its front face bedded closely against the faceplate, and is set up to centre the camshaft bearing. After deep centre drilling, it is drilled undersize, through both the back and front of the body, and then bored and reamed to take the bushes. The hole at the front is 7/16in. dia., and the one at the rear must be opened out to 5/8 in. to allow the camshaft to be inserted. As the bushes are flanged and secured by screws, they do not need to be a press fit, but should be neat to provide proper location. While the casting is still set up for these operations, the timing case should be fixed in position and the second boss faced, centre-drilled, drilled undersize and reamed for the outer camshaft bearing.

These bearing bushes are all straightforward, and can be turned and bored at one operation for concentricity. A blind bush at the front end prevents possible oil leakage, but you can bore it right through and fit a blanking flange if you desire. The timing end bush should be a tight fit (about one thou interference) because it forms a seating for the contact breaker, as well as providing a bearing.

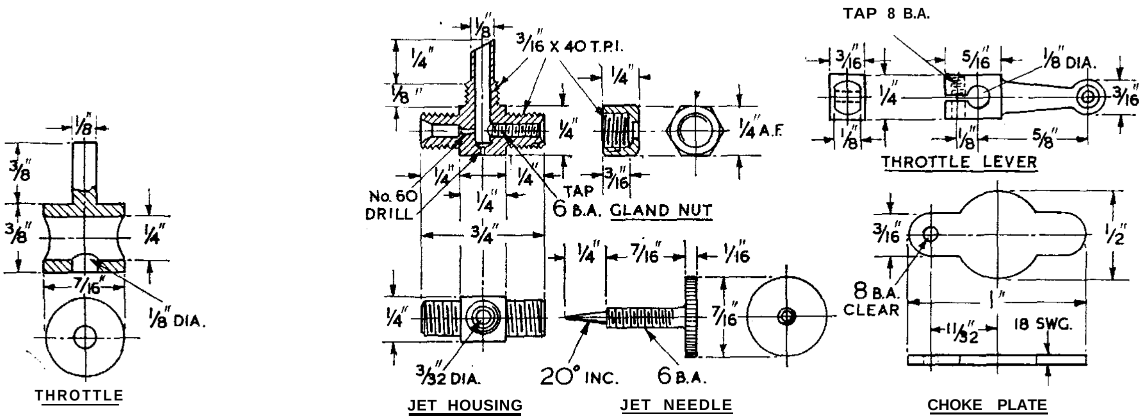
The camshaft blank can be machined all over between centres. The important points to be observed in the turning operations are the accuracy and finish of the journal surfaces which fit the bushes, and the length between the shoulders adjacent to the cams, to provide end location between the bushes for free running without end play when the bushes are fitted. Cam-forming methods follow the principles which have been successfully employed on several earlier engines; these will be described later.

Timing gears are used of the same size and pitch as those for the Kiwi 15 c.c. engine. They vary in detail, and an extra pinion is required for the idler. The large gear requires to be taper-bored to fit the camshaft, an operation which calls for the same methods, and the same care, as the fitting of the flywheel.

To set up the gears for operations on the bore, mount them in recessed bushes and bore them in position to a light press-fit for the outside diameter of the teeth; any subsequent work required may be done by mounting them

gears mesh with the pinion at correct depth. By marking with a scriber inside the button you can locate the centre position approximately. It would be possible to ensure reasonably good meshing simply by drilling the tapping hole for the stud to coincide exactly with the marking; but it is better still to drill first a tapping hole for a 1/8 in. or 5 BA screw to secure the button in position, using a small washer which must not overlap the diameter of the button, under the head of the screw. The running of the gears can then be checked properly. Then remove all three gears, leaving the button in place, so that when the body is again set up on the faceplate, it can be clocked for concentric accuracy, After it has been removed the hole is bored accurately and tapped for the stud.

As shown in the detail drawing, the stud is grooved to take a circlip for endwise location of the pinion, but you can, if you like, tap the outer end and fit a screw and washer (or a large-headed screw) so long as it clears the inside of the timing case. The thread on the stud must be concentric, and must screw right home to the shoulder. I do not recommend undercutting at this point; it is better to counterbore the tapping hole in the body for the depth of the first thread. A centre hole, together with a cross hole in the journal, provides oil mist lubrication.



ALL PARTS I OFF IN BRASS. EXCEPT WHERE OTHERWISE SPECIFIED

on their shafts, or on a true-running mandrel. The timing pinion is located on the follower shaft by cutting a 1/16in. notch in its boss, and sinking a 1/16in. pin into the shaft, flush with the journal face. It needs little securing, as it is clamped endwise by the retainer nut, which should preferably have a spiral groove, as shown, to retard the escape of oil from the timing case. A right-hand spiral is correct for an engine which runs clockwise at the timing end, but if it is intended to drive from this end the rotation of the engine should be reversed and a left-hand spiral cut on the retainer.

The location of the idler stud must be accurate for correct meshing of the gears. You 'had better check it by assembling the idler shaft with its pinion in position, and the camshaft with its spur gear, both in their bearings. To set the position of the stud, use the toolmakers' button method with a piece of 1/4in. rod, 3/8in. long drilled 3/16 in. diameter and faced truly on both ends, as the button. The idler pin is fitted to this, and is located roughly in place on the face of the body so that both

When the stud is screwed in, a strip of copper or aluminium wrapped round it will prevent risk of scoring by the jaws of pliers or other tools, and a touch of Loctite on the thread will prevent loosening.

Other parts of the valve operating gear include the valves and valve housings, and the tappets. Methods of machining valves at one operation have been given in the description of the ***Wyvern*** gas engine last month: the only essential difference is the type of spring retainer, which is preferably of hexagonal form, and larger than the lock nut, which in turn must be oversize, so that it will seat on the top face of the hollow tappet, and enable adjustment for clearance to be made without difficulty. The tappets are simply hollow thimbles; they are drilled to prevent unnecessary inertia. You can make them from bright bar without external machining, but they must be a good working fit in the bores of the body, and dead flat and smooth on the working face, which must be glass-hard.

Gunmetal bar is the preferred material for the valve housings, which may first be drilled and counterbored, with care to keep the bores perfectly concentric, and then mounted on a piloted stub mandrel for turning the outside. They should have about 1/2 thou interference in the bores of the body, and the side ports can be drilled when in position. If the valves and housings have been accurately machined, they should need little or no grinding in; injudiciously applied, this process often does more harm than good in small engines. The seatings should not be more than about 1/32in. wide and they may be trued in position with a piloted cutter, operated by a small hand chuck or tap wrench; but this, again, must never be overdone.

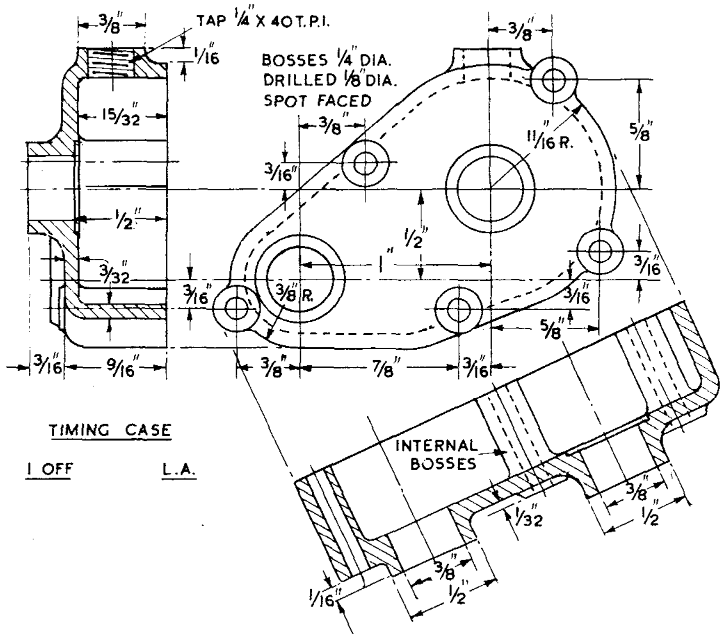
The Whippet has a simple barrel throttle carburettor for working on a suction or gravity feed without the need for a float chamber, though one could be added, and would help to keep feed conditions constant, so long as it was not affected by vibration. Fuel is controlled by a horizontal jet screw, and discharged into the air stream by way of a vertical " pen nib " diffuser, which has an air bleed hole in the base, serving also as an anti-flood drain. The size of this hole, and the shape of the bore through the throttle barrel, can be varied to influence compensation at varying speed. Tuning of small carburettors always calls for a good deal of patience, however well they are designed; and the simpler the carburettor is, the more critical are its adjustments.

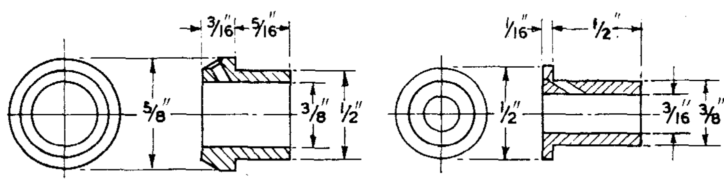
You can chuck the carburettor body by the intake end for facing the discharge end flange, centring, drilling and taper-boring right through; a D-bit is convenient. At the same setting the back face of the flange can be machined with a left-hand tool; a fillet should be left at the shoulder. To machine the intake end, you can use a taper stub mandrel to mount the casting; the flare can best be machined by a hand tool or a bearing scraper.

For boring the throttle housing, it is best to clamp the casting to an angle plate, over the discharge flange; alternatively it may be held crosswise in the four-jaw chuck, if the two ends are protected by soft metal slips, and care is taken to set the axis of the bore square with the lathe centre. After the housing has been set centrally true, the top surface is faced, centre drilled, drilled, tapped and counterbored to produce a smooth and true bearing surface for the barrel. You can chuck the throttle cover over the edge of the flange for facing and turning the spigot to a neat fit in the housing, and for drilling truly through the centre.

As the barrel is not called upon to provide a perfect seal, it need not fit tightly in the housing. But it should be a smooth working fit, including the stem. To bore the cross hole, you may place the barrel in position, and either mark it from both ends of the body, or drill it in position, but if you do, you must take great care to avoid raising burrs, which might prevent the barrel from being removed, or cause scoring of the bore in removing it. Undersize drilling, followed by removal of burrs with a hand scraper, is a more prudent course; the hole can be opened out to size after the barrel is taken out.

The T-piece which forms the fuel inlet, jet tube and diffuser may be held crosswise in the four-jaw chuck for the turning, drilling and screwing of the diffuser. It is then chucked by one of the horizontal ends, for drilling and tapping the hole for the jet screw, and turning and screwing the outside for the gland nut. When the nut is



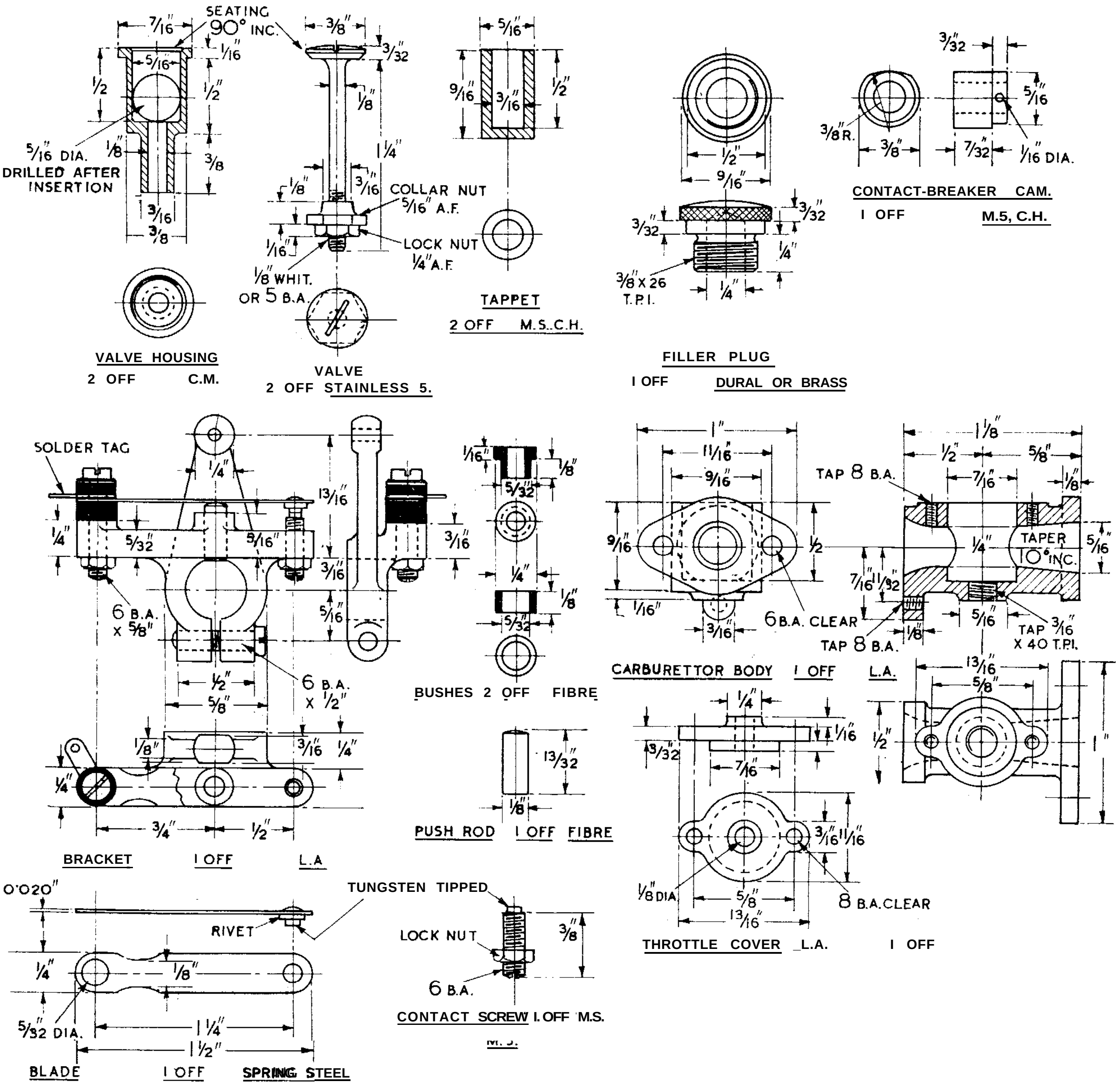


machined you can use it as a screw chuck to hold the T-piece from the other end for drilling the fuel inlet and jet orifice, and for turning it to take a union nut or any other connection which may be preferred; I am a believer in all-metal fuel pipe systems, except where flexibility is really essential.

In all these machining operations, the lathe should be run at top speed, and concentricity of drilling, tapping and external screwing should be strictly observed. The tip of the diffuser should be as close to the height of the main bore centre as possible, and the sloped top should be highest towards the intake end. Packing washers under the throttle housing, to create these conditions, are permissible, but are not needed with careful machining.

Other operations on the carburettor include the making and fitting of the throttle lever, a fairly straightforward task, and the choke plate, cut from brass or alloy sheet and pivoted on an 8 BA screw with a spring friction washer. No provision is made in the design for limiting the movement of the throttle at full-bore and slow-running positions, but stops can be fitted to the cover, or a screw could be set in the side of the body to make contact with the closing edge of the crossbore in the barrel. This allows for individual requirements in the throttle lever position, or direction of opening movement.

Other carburettors, including those designed for the *Kiwi* and *Dolphin* engines, which are already equipped with float feed, can be used on this engine; or their float chambers can be readily adapted so long as the cut-off is



adjusted to maintain the fuel level very slightly below that of the jet orifice-not the diffuser outlet.

For ignition by battery and coil, a contact breaker is fitted to the projecting sleeve of the outer camshaft bearing. As an alternative, the Atomag Minor magneto can be fitted; apart from being equally efficient, it is always ready for use and is immune from any risk of running down or other deterioration. It can be direct-coupled to the engine shaft, and in a boat may be used as an element in the transmission to the propeller shaft. A spark will be produced at each revolution, instead of on alternative revolutions; but this is no disadvantage. Complete sets of parts for this magneto, including the laminations, the ready wound coil, and the super-efficiency magnet, are now obtainable. The magneto is quite straightforward to construct.

A contact-breaker made of standard automobile components, as on several of my engines, could be used if desired. This saves trouble in construction, but is liable to be rather out of proportion. The blade type shown is less obtrusive and gives excellent results but it calls for the fitting of a contact rivet to the spring blade, and some constructors appear to find this difficult. Spring steel is difficult to drill, and there is some risk of cracking the tungsten tip in riveting. You can use a dental burr if you have one of approximately the right size, and solder in the rivet to avoid the need of hammering it; but the joint must be sound, mechanically and electrically.

The bracket casting may be held in the four-jaw chuck for the drilling and facing of the centre, which should fit closely on the extension of the camshaft bearing in the timing case. Drilling and tapping for the clamp screw should be carried out before the lug is split. The

** To be continnued*

Continued from June 15, page 137

These are the CAMS

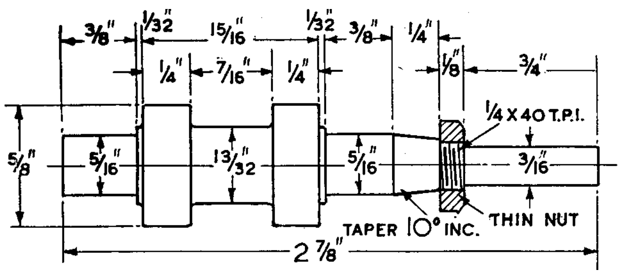
By Edgar T. Westbury

CONTINUING with the contact-breaker, we drill, tap and spot-face the holes in the cross piece; the one in the centre should be reamed to fit the fibre push rod easily. You may have to adjust the length of the push rod so that the spring blade is as near as possible horizontal when the contacts are closed. The contact rivet should line up exactly with the screw; you can make some adjustment by drilling the anchorage hole undersize at first. After fitting it to the screw without the insulators, to determine location, open out the hole by filing, in such a way as to draw it over whichever way is necessary for correction: The need for fitting a solder tag in contact with the blade, to form the Lt. terminal, may be avoided by extending the length of the blade beyond the fixing screw and drilling it to take a terminal screw. Narrowing the blade near its fixed end as shown ensures that it flexes only in this region while the rest remains relatively rigid; it should be bent slightly downwards so that the contacts press firmly together when closed.

Two bushes are made in hard fibre, ebonite or other suitable plastic material, to secure and insulate the blade. The shouldered bush passes through the hole in the blade, through the solder tag, and into the second bush, which should project so that the assembly is held firmly when screwed down, yet with a certain degree of resilience. I have found that a blade held in this way is damped, inhibiting the tendency to bounce at high speed.

Operation of the contact breaker is by a cam which has about 90 degrees of its circumference machined away at about 3/8 in; radius to give a " closed " period of not less than 60 degrees when the open clearance is set at about five thou. It is set on the end of the camshaft, boss outwards, so that with the bracket vertical the contacts are just broken at TDC on the firing stroke; make certain that this takes place in the right direction of engine rotation. If punch marks or a chisel cut are used to mark the cam position, it can be dismantled and drilled for a taper pin, or a close-fitted parallel pin, slightly burred over on the ends.

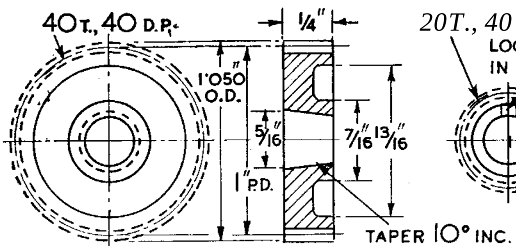
The filler plug may be turned at one setting from dural or brass rod, knurled on the edge, and parted off. It should screw right home against the face of the boss in the body to make an airtight joint; a packing washer is permissible but is best avoided. There is no vent in the plug, but to enable the crankcase to breathe, a hole about 1/4 in. dia. (not shown on the drawings) should be drilled in the timing end flange of the body about midway between the main shaft and camshaft to communicate with the timing case. Air can then escape from the tapped hole at the highest point of the timing case, which may be fitted with a breather pipe or a light non-return valve,



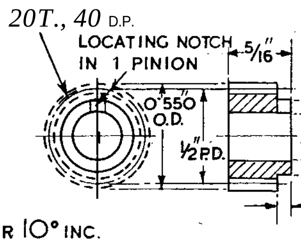
CAMSHAFT BLANK 1 OFF M.S. C.H.

or both. The valve has the advantage that it keeps the mean pressure in the crankcase slightly below atmospheric, and thereby retards the escape of oil from ends of bearings. This helps to keep the engine, and the engine-room generally, neat and clean-in contrast with the conditions found in many model power boats that I have seen.

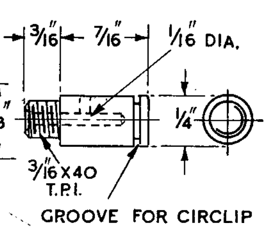
You should have no difficulty in assembling the engine if the parts have been made according to the methods which I have described. Before the camshaft gearwheel is secured tightly on its taper, the engine should be timed in accordance with the diagram. It should rarely, if



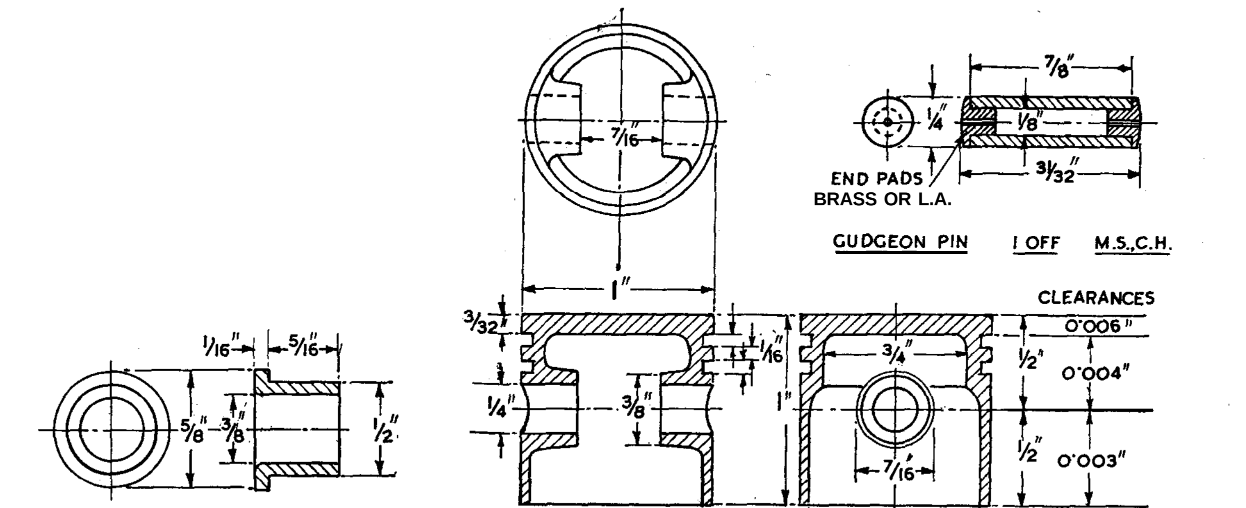
SPUR GEAR 1 OFF M.S. OR BRASS



PINION 2 OFF M.S.

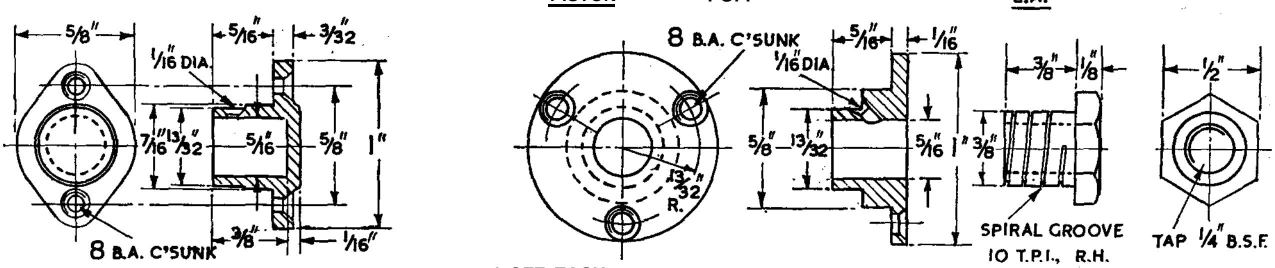


IDLER STUD I OFF M.S., C.H.



MAIN BEARING BUSH 2 OFF G.M.

PISTON I OFF L.A.



CAMSHAFT BUSHES I OFF EACH G.M. RETAINER NUT 1 OFF MS.

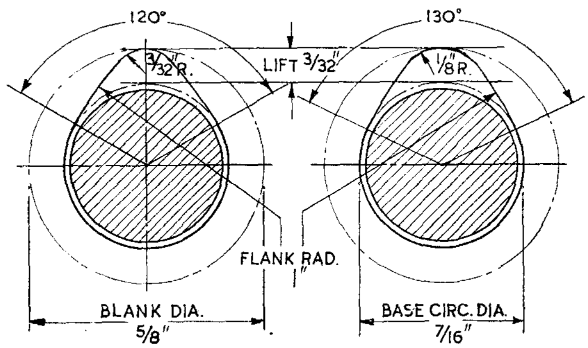
ever, be necessary to shift the wheel once it has been properly adjusted and the positions of the three gears can be defined by centre-dots or other marks to show the juxtaposition of the teeth.

I am confident that the ***Whippet will repay the*** efforts devoted to its construction by setting up new standards in stamina, sprightliness and startability; I will not add " silence ", as this is an absolute term, but the ***Whippet*** will certainly be quieter than most engines of comparable size.

In the progressive design of internal combustion engines, cams have played a very important part. They have been almost universally employed in the operation of valve gear in four-stroke engines **ever since the** intermittently-reciprocating poppet valve was introduced. Even at the present day, cam design is one of the most critical factors in the performance of engines, not only for racing, but also for general purposes, where reliability and long life are more important than sheer power output. It is fairly safe to say that the design and development of cams for operating at high speed has reached a higher degree of perfection in i.c. engines than in any other mechanism.

Small four-stroke engines call for just as much care in the design of their cams as those of larger size, and, indeed for still more accurate work in contour forming to scale limits. In the many designs for these engines which I have described in ME, the problem of producing cams has always been carefully considered, and methods have been worked out by which they can be machined in the simplest and most straightforward ways. Cams can be designed by mathematical methods, provided that all factors in their operation are known and taken into consideration, but it is quite another thing to be ***quite sure*** that they are accurately shaped to produce the desired results, by means generally available to the constructor.

I have dealt with the subject of cam design and construction on several occasions, in the context of particular engines, or in separate articles, but I am constantly being asked for further information on the subject, or to repeat specific instructions which have been given. I propose now to describe the production of the two cams for the 10 c.c. Whippet engine. The principles employed are applicable to many other engines, though they may call for modification of equipment employed, or details of methods.



CAM CONTOUR DETAILS

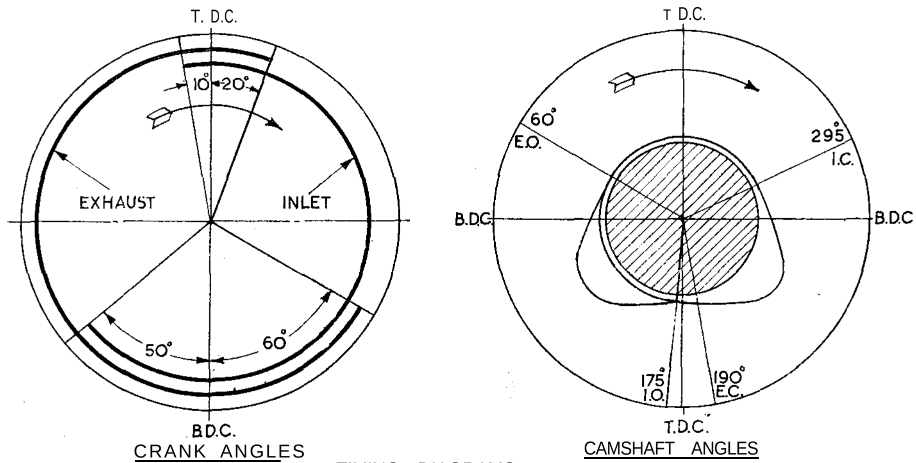
In common with many of my other four-stroke engines, the Whippet employs cams in which the contour is a combination of simple circular arcs. This can be produced in various ways. To obtain consistent accuracy, I have adapted the process, with the aid of a simple jig, in such a manner that both the contour and the timing of a pair of cams-or even a ***number*** of pairs, if necessary -can be positively assured. Cams of this type work with reasonable efficiency in conjunction with flat-based tappets, up to speeds well in excess of those required for all engines, with the possible exception of those super-tuned to attain the utmost speed and performance. Any other cam involves greater complication, in design and production, to give even comparable results; I shall have more to say on this subject at a later date.

All model engineers who construct engines or mechanical devices of any kind, have access to a machine specially designed to generate accurate circular arcs-to wit, a metal turning lathe. Any lathe serviceable for general model engineering work can be employed for cam forming; no special attachments are needed beyond the jig.

The sequence of valve operations for a particular engine is generally set out in assembly and servicing instructions, in the form of a diagram which shows the points at which the valves open and close, in relation to the angular position of the crank of one cylinder unit. Some of my correspondents appear to have found some difficulty in understanding a timing diagram; I cannot think why, but I will try to explain it as simply and lucidly as possible.

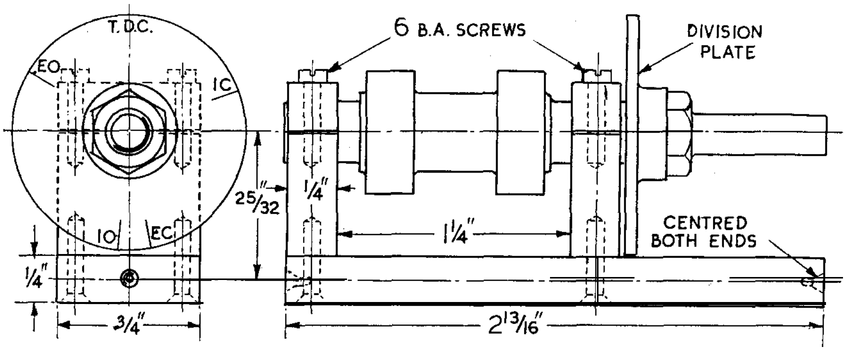
All four-stroke engines, whether gas, petrol or diesel,

Continued on page 166

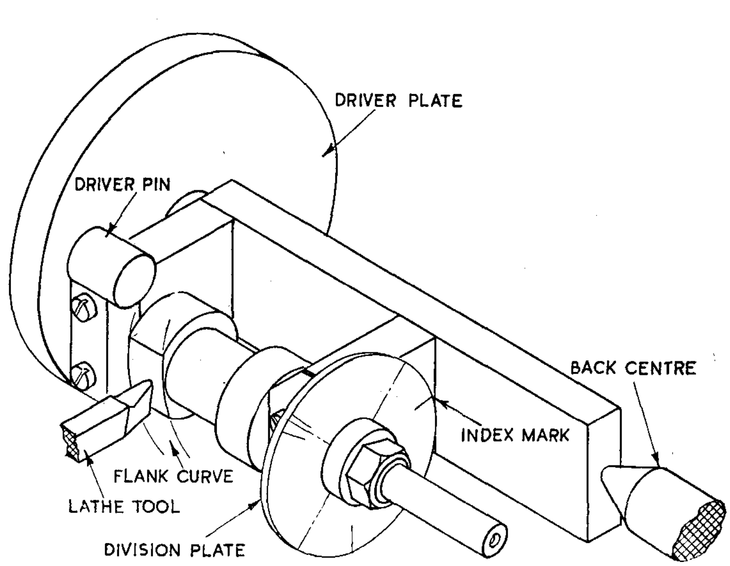


TIMING DIAGRAMS

These are cam contours, enlarged



Camshaft turning jig. It is seen below with the camshaft in place, set up between centres for turning the flanks



THESE ARE THE CAMS

Continued from pag e 158

complete their working cycle in 720 degrees, or two complete revolutions of the crank. To show the sequence of operations in one circular diagram, the opening periods of the two valves are indicated by arcs, or incomplete circles, which must necessarily be of different radii 'so that they are distinct and do not clash with each other. It has been suggested that the diagram should consist of separate circles for the two revolutions but on careful consideration, I do not think that this would simplify the explanation at all.

In the left-hand diagram the arrow indicates that the engine is turning in a clockwise direction-which, in the instance of the Whippet, is correct for normal rotation, viewed from the timing end, though it is subject to modification in certain circumstances. The crank angles are generally checked from the top and bottom dead centres, when the piston is stationary, as these are the easiest positions to verify by removing the cylinder head or inserting a probe or feeler through the sparking plug hole. This is not the most precise method of checking, but it is sufficiently accurate for assembly or servicing.

Starting from t.d.c. on the firing stroke, both valves remain closed until the crank approaches b.d.c., when the effective effort of the burning charge becomes so small that it is not worth while to confine it in the cylinder any longer. A more important matter is to give as much time as possible for getting rid of the exhaust gases, and to clear or " scavenge " the cylinder and so the exhaust valve begins to open well before t.d.c. (60 degrees in the Whippet) as indicated by the outer heavy-line arc. This valve remains open throughout the entire return stroke of the crank, and for 20 degrees after t.d.c., to take advantage of the momentum of the escaping gases.

As shown by the inner arc the inlet valve opens at IO degrees *before* t.d.c. so that it is well open by the time that any effective suction takes place on the next stroke. It remains open as long as the combined effect of suction and momentum can be used-till 50 degrees after b.d.c., in fact. For the rest of the stroke, both valves are closed, and the fresh mixture is compressed, before ignition at or near t.d.c., when the cycle of events is repeated. The period of 30 degrees during which both the valves are open together at " half time " is known as overlap. It can be used in high-speed engines to increase effective charging, but this benefit is limited in side valve engines, and its usefulness here consists mainly in preventing restriction or " wiredrawing " of the gases at the time when the valve opening is very small. There is some latitude in the actual opening period, and points of opening and closure of both valves; generally speaking, the best results for a particular engine are obtained by experiment.

The left-hand timing diagram, useful as it is for its designed purpose, is not much use to the constructor, unless it is translated into terms of camshaft angle, as shown in the right-hand diagram, with the cams superimposed on it in their correct relative position. As the camshaft rotates at half engine speed, the equivalent crank positions, t.d.c. and b.d.c. are each shown twice, at 90 degrees to each other. It is not so convenient to indicate events from all four positions; start from t.d.c. and work round the complete circle, with the angles counted in rotation. At first sight it might be thought that the sequence of events has been reversed, though in the Whippet the camshaft rotates in the same direction as the crank, owing to the interposition of an idler pinion. It depends, however, on whether the engine in the diagram is assumed to be stationary. A pointer mounted on the shaft is convenient to indicate rotation.

Details of the cam contours are shown separately in the next drawing, where it will be seen that the major part of the contour is a circular arc, concentric with the shaft axis, and known as the base circle. The flank curve which joins this arc at a tangent, has a radius of I in., and the angular distance embraced by the roots of

● *Continued on page* 189

ELEMENTS OF PATTERNMAKING

Continued from page 162

likely to be used in such a wheel. An old handbook on engineering design which I once read specified that the wheels should have seven spokes; there may have been some logical reason for this rule but it seems to have been more honoured in the breach than the observance.

One of the commonest spoked wheels which model engineers encounter is the driving wheel of a locomotive; it generally has a large number of spokes, and may also incorporate a crank boss and a balance weight. The section of the spokes may vary. Usually they are oval or almond-shaped. To cast them properly, it would be necessary to form impressions in both halves of the mould, and in a small wheel this would not only be difiicult, but would tend to leave unsightly flashes on the centre line. It is more usual to cast the spokes of model locomotive wheels with a taper from front to back, so that moulding is simplified. As the inside surfaces of the wheels are scarcely visible when the engine is assembled, this departure from scale accuracy is generally tolerated.

The section of spoke shown in the drawing illustrated looks better than a plain truncated cone, and in relation to the width on the front edge is rather stronger. Most wheels have a larger number of spokes than the twelve shown, and it is also usual to taper them slightly from the hub to the rim. A liberal fillet should always be given at their inner and outer junctions. Where it is necessary to vary the position or mass of the balance weights in a given set of wheels, it is possible to make the weights in the form of plates which can be temporarily attached on both sides of the wheel, the space between the spokes being filled with wax or another mouldable material. This avoids the need for the making of separate patterns for each type of wheel.

A pattern of *this* kind may be built up on the faceplate like earlier examples, beginning from the front layer of segments and finishing with those of the back. It would be quite in order to use pre-formed strip for the spokes; and to cut indexed grooves to fit this section, in both the rim and the hub, with a suitably shaped D-bit or router. But I fear that my friend who objects to "machine tool " methods in patternmaking might not approve !

EDGAR T. WESTBURY.

* *To be continued*

THESE ARE THE CAMS

Continued from **page** 166

the two flanks represents the period of inlet and exhaust valve opening. Both cams have a lift of 3/32 in., obtained from the radial distance between the base circle diameter of 7/16 in. and the blank diameter of 5/8 in.

It is with the production of the flank curves, and their position in relation to each other, that the cam forming operation is mainly concerned. As I have already explained, there are several ways in which cams can be produced, and any way which produces the desired results is acceptable.

The jig consists primarily of an eccentric turning fixture to hold the complete camshaft blank parallel to the lathe axis, at a suitable distance for an arc of the required radius to be turned. It may be made in any way which achieves this condition; as shown, it consists of a rectangular bar of steel, brass or hard light alloy, centre-drilled at each end, and with pieces of similar, section firmly clamped to it to form bearings in which the shaft journals can rotate. As the base circle of the cams is 7/16 in. diameter, the eccentric radius at the shaft centre to produce the flank radius of 1 in. is 1 in. - 7/32in. = 25/32in., this measurement should be observed as closely as possible for both bearing centres.

A replica of the camshaft timing diagram should be marked out on a disc which can be securely mounted on the camshaft, so that it will not be liable to move during the entire forming operation. The angles for opening and closing points should be inscribed or otherwise marked clearly and legibly. You can set out the diagram on a large scale with a draughtman's protractor, and attach it to the lathe faceplate as a guide to indexing the small disc with a point tool; care must be taken to set both the diagram and the disc to run true. If desired, the timing gear wheel itself may be marked out to serve as a division plate, though its small diameter makes it necessary that you should observe the setting very carefully, preferably with a lens. A flxed index mark is provided on the base of the jig, or other position close to the marks on the disc.

After mounting the camshaft in the jig, and lining up any one of the marks with the index, clamp the bearings and mount the jig between the lathe centres. It can generally be driven in the usual way, by a pin fitted to the lathe driver plate. As with all operations involving intermittent cuts, it is advisable to tie or wire the jig to the pin to prevent noise and juddering. A keen lathe tool, not too wide on the tip and with plenty of top rake, is used to machine the flank curve. It should be fed up by the cross slide until it just barely makes contact with the blank as it rotates; from that point onwards, the depth of cut to form the flank curve is 0.093 in. If possible, a stop to limit the cross feed movement at this point should be used; otherwise, the index reading on the cross slide index must be relied upon.

I have already explained that the valve positions, and therefore those of the cams, are interchangeable as convenient. It therefore does not matter which of the blanks is used for exhaust or inlet. When one flank curve has been machined, shift the camshaft to bring the second mark ***for the same cam*** in line with the index; re-clamp, and machine the opposite flank. The process is repeated for the other cam. This leaves all round the base circle a good deal of unwanted metal, which can be removed in any convenient way; but I find that the best method is to inch the blank round not more than about 5 degrees at a time, and take a number of cuts at the full depth, as for the flank curves. It is highly important that the base circle should be exactly concentric with the shaft axis for the cams to work properly and with minimum tappet clearance.

Take care that the nose of the cam is not machined away by mistake. This is easier to do than you might think. I usually put a spot of quick-drying paint or marking fluid on the nose as soon as the two flanks have been machined.

The base circle, if made as described, will have a large number of small sub-angular curves left on it-this can be smoothed out by a fine file, provided that they are as close together as possible. For forming the nose radius'of the cams, I have found no better method than careful hand-filing. This curve, of course, is a transitional stage between the rising movement of the cam and its descent on the other side; the essential thing is that it should blend smoothly and easily with the other parts of the contour. The complete surface of the cams should be finished as highly as possible. Casehardening, if it can be done without the risk of distortion, is highly desirable. To avoid the need for heat treatment have a thin layer-about 2 thou or so-of hard chrome electro-deposited on the work by the Fescol or Monochrome process.

Camshafts made by this method can be relied upon to give positively accurate timing of both valves, and need only be set by reference to t.d.c. or another definite point on the crank timing diagram.

* ***To be continued***

CRANBORNE

Continued from page 167

board template that you made for positioning the sides of your deckhouse.

The complete covering for the deck is made up of three pieces of wood, one each for the port and starboard sides, and a joining piece across the after end. The width of this last piece is determined by the position of the rudder post. It does not, as you might think, spread over the whole of the stern; the border edge goes out only as far as the rudder post. It does not surround the hatch to the aft store, or the capstan.

As with the doors, but for a different purpose, we have to do some ink-lining to represent the pitch caulking between each board. My drawing shows exactly how the boards run. They do not follow the contour of the side of the deckhouse but are parallel to the centre line of the ship. Where their ends approach either the curve of the bulwark or deckhouse, they are gradually tapered off to about one half of their width and are set into the edge board, which is stepped out to receive them, making a very neat appearance. The piece of wood for the after part presents no problems as it requires only a series of straight lines. When the parts have been made, put them to one side until you are ready for them again.

* ***To be continued***