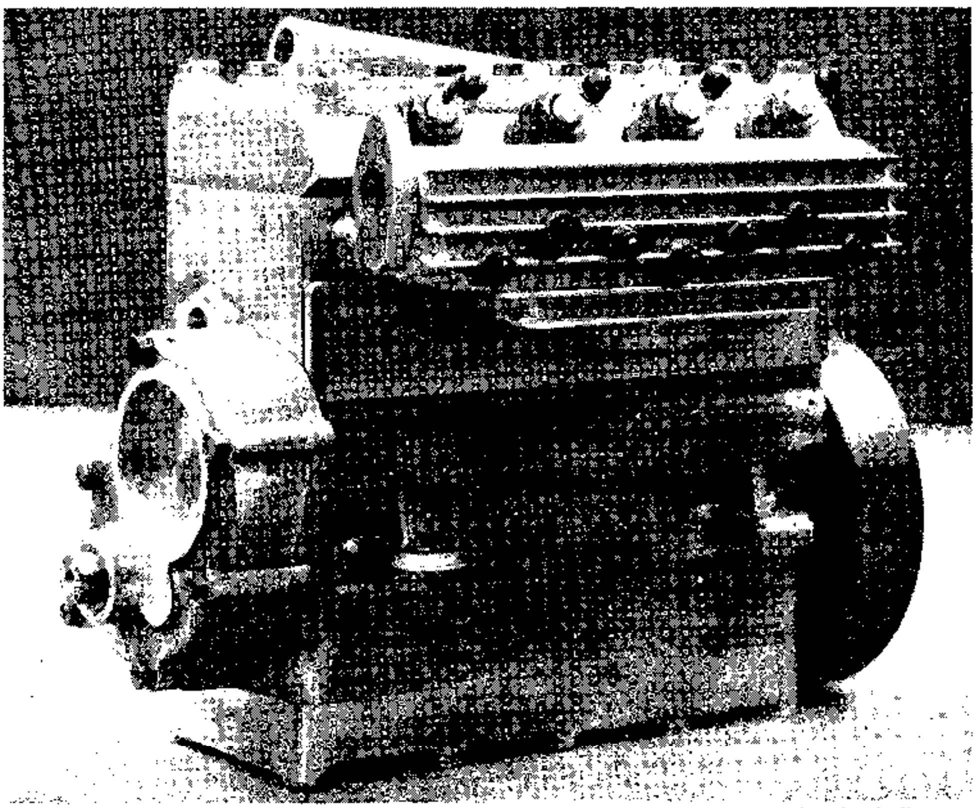
A 15-c.c. FOUR-CYLINDER ENGINE

By Edgar T. Westbury

AS a result of my article on " Multi-cylinder Developments " in the issue of December 12th, I have received many comments from readers on this subject. In a few cases, it is considered a questionable policy to introduce any complication into design, unless it can be shown that this will result in greater utility, or higher performance. Why use a number of cylinders, when one will do the job just as well ?

Here we have an instance of the attitude to which I have already referred in earlier articles, namely, the inability to consider any aspect of the model petrol engine except its function as a power unit, in other words, a mere means to an end. Granting that this aspect is a highly important one, and indeed paramount in many of the applications of the model petrol engine-which, I may add, never have been or will be neglected in *Petrol Engine* Topics, it is certainly by no means the only aspect worth while in model engineering. One might just as well ask why any elaboration or refinement, beyond that required for sheer utility, should be introduced into any kind of model engine. The answer is that the engine is something more than a means to an end, it is a worthy end in itself, and every item in its design or equipment adds to the pleasure of its construction, and the ultimate pride of achievement. For this reason, the development of the multi-cylinder engine is worthy of encouragement, so long as it does not become an obsession which eclipses or side-tracks the equally important considerations of efficiency and compactness, in which the simpler single-cylinder engine is at present supreme.

Objectors to the development of the " multi," however, are very definitely in the minority, and most of my readers have expressed a very emphatic desire for further information on this subject. The mere hint that I am working on the



The " Seal " 15-c.c. engine in course of construction. (Machining by R. C. Marshall)

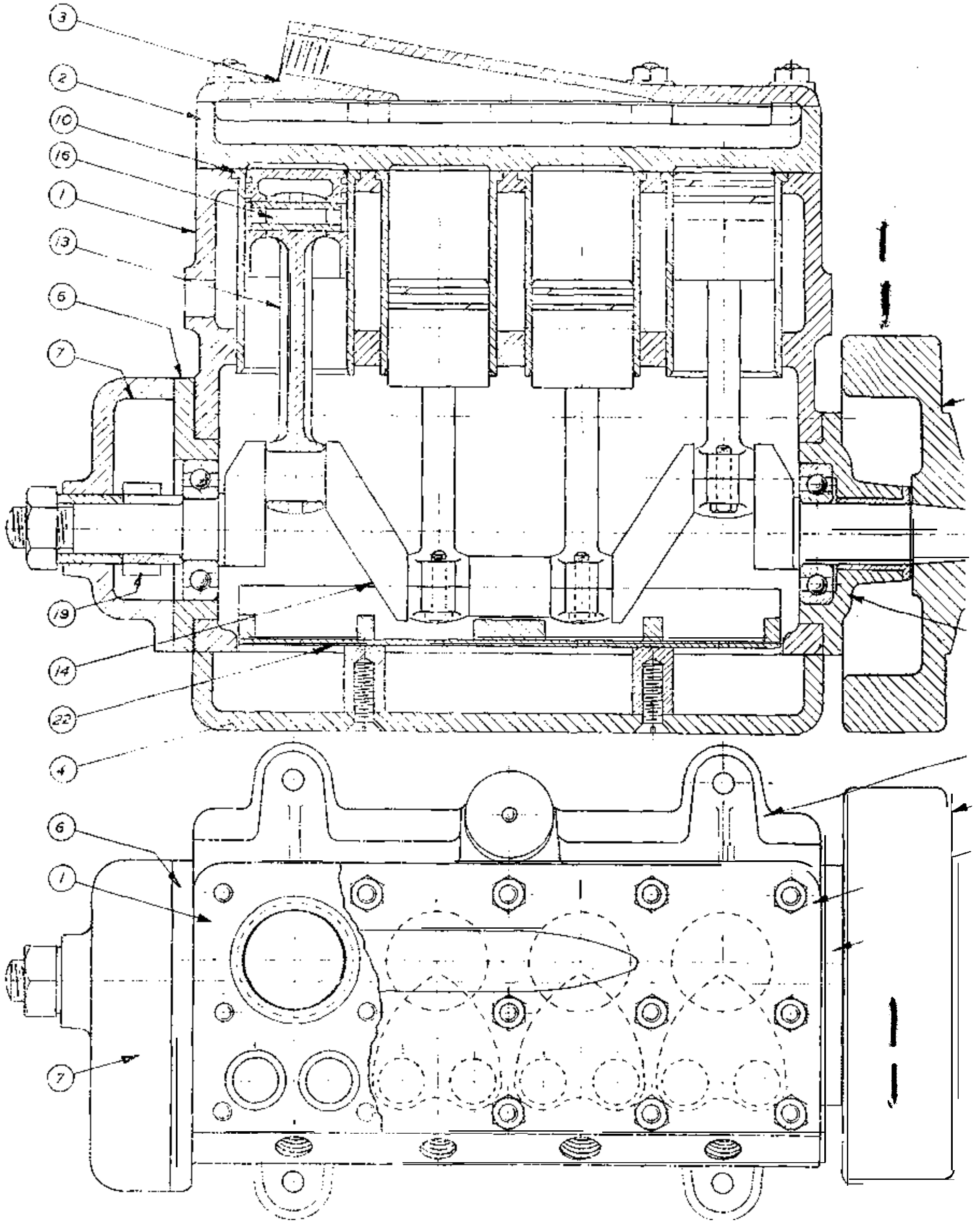
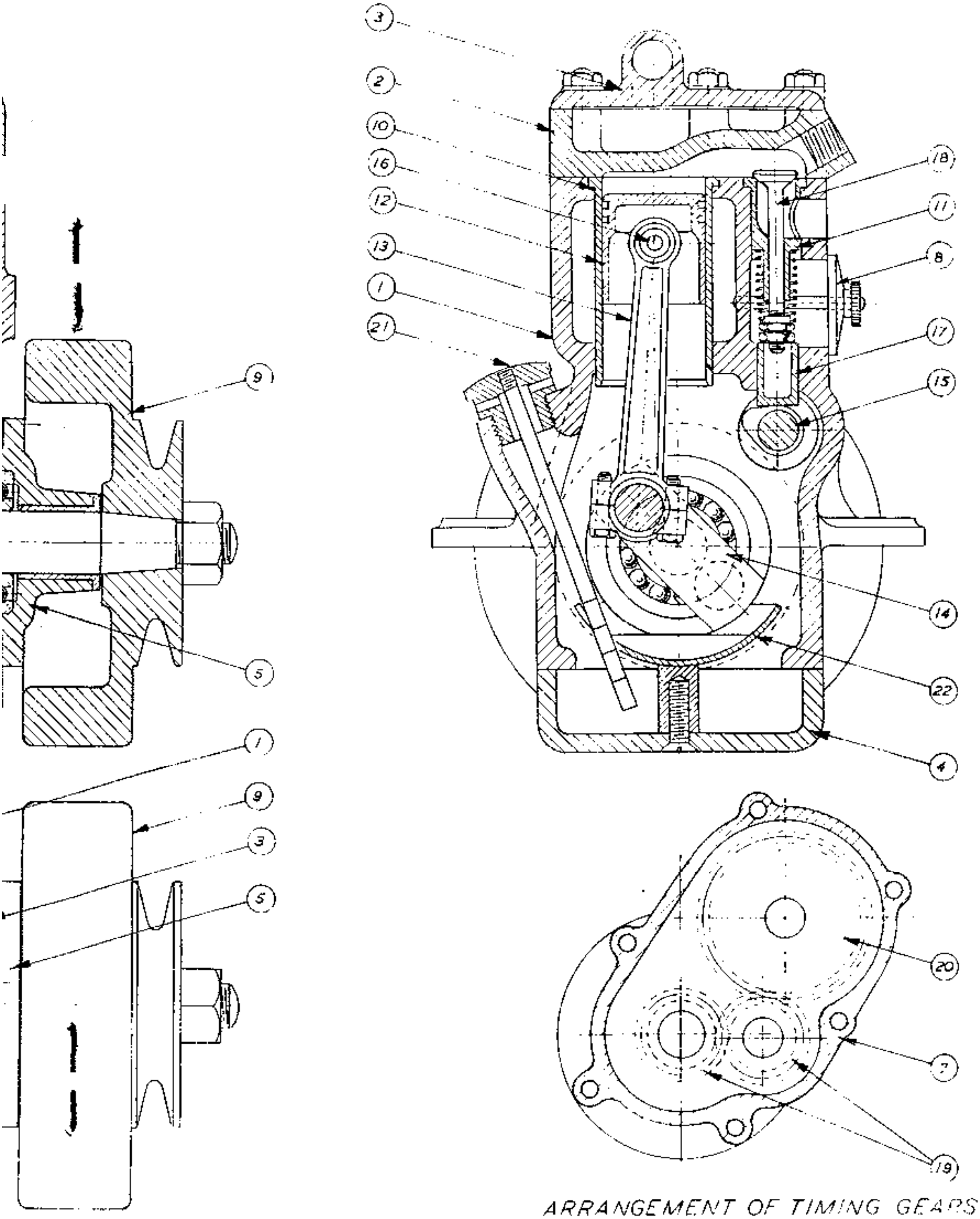


Fig. I. General arrangement of the "

(1) Main cylinder and crankcase block : (2) Cylinder-head :(3) Cylinder jacket cover : (4) Sump : (5) Main bearing Housing : (6) Timing-ge
(13) Connecting-rod : (14) Crankshaft : (15) Camshaft : (16) Gudgean-pin : (17) Tappet guide (18) :



ngement of the "Seal" 15 c.c. engine

Housing : (6) Timing-gear housing : (7) Timing cover : (8) Valve cover ; (9) Flywheel ; (10) Cylinder liner : (11)Valve liner : (12) Piston : Tappet guide :(18) Valve : (19) Timing pinions : (20) Timing spur gear : (21) Breather : (22) Oil trough.

development of a multi-cylinder engine myself has been sufficient to arouse a clamour for the drawings of the engine, and I find that readers are not content to-wait for the indefinite time necessary for me to complete the development work on the design.

The engine in question, general arrangement drawings of which are shown on pages 198 and 199 is a " straight four," water-cooled, side-valve engine of 15 cc., on which I have been working for quite a long time now, and a good deal of practical work has been put into construction and development, with the aid of several friends who are keenly interested in the project. It is my intention to produce designs for engines of both 15 c.c. and 30 c.c., and equipped with either side or overhead valves, but as the smaller size of engine is the more exacting, it has been selected as the one to be tackled first.

There have been quite a few delays and hold-ups in the progress of this work, but to reassure readers who may have any misgivings on this point, I would mention that these have been concerned with ways and means of production rather than design ; questions of the availability of correct materials, machining methods, and delicate problems of patternmaking, of moulding. have caused quite a few headache; These snags have gradually been ironed out, and I hope to be able to show readers alternative methods of construction to cope with such difficulties as they may encounter in these respects. As to the success of the engine, when built correctly to the design, I am in no doubt whatever, as sufficient experience has been obtained in experimental work to ensure that the engine will work according to plan.

The Object of the Design

Although, as already pointed out, one does not really need an excuse to build an interesting type of model engine, I may mention that the design has been produced for a definite purpose ; but its application is by no means confined thereto. It has long been my intention to provide a really suitable power unit for model prototype boats, and in particular, those of the launch or cruiser type, which are deservedly popular in regatta events, such as nomination and steering competitions. Of the many boats of this tvpe in existence, a very large proportion are now equipped with petrol engines ; but while the latter may be quite satisfactory in performance and reliability, few of them are of a really appropri-type, in respect of design and character, for marine installation.

How often does one find, after inspecting the exterior of a model boat on which every loving care has been bestowed to get all details correct and complete, and to preserve the true nautical " atmosphere," that all illusions are shattered on looking down the engine-room hatch ! Without casting any aspersions on the usual commercial type of petrol engine, the sight of it in a ship's engine-room gives one quite a shock, and is often rendered worse when its shortcomings for the particular purpose are imperfectly remedied by the addition of a crudely-made cooling fan, or a tin water-jacket and a yard or two of rubber " plumbing."

This is not an exaggerated picture ; I have seen it in many otherwise excellent model power-boats, both in regattas and exhibitions. It is an object lesson on where the utilitarian creed (" If it does the job, it's O.K.! ") is liable to lead us eventually. I offer no criticism of those who, for want of a more appropriate power unit, have been compelled to use the only available means of motive power, but I do say that it is not good model engineering, and that there is a very strong case for the introduction of engines which are in harmonv with their environment.

It may, perhaps, be objected that the design of the " Seal " engine illustrated here is more in keeping with automobile than marine practice. That is perfectly correct, and the reason is because the former lends itself more readily to simple and straightforward methods of construction ; but it is also true to say that automobile engine design has been used as a basis for some of the most successful light marine engines, and in modern motor craft, conversions or adaptations of automobile engines are becoming increasingly popular. Even for models of the larger types of boats, such as tugs. coasters or even motor liners. the prototypes of which have much more special: ised types of engines, the four-cylinder engine is by no means so blatantly discordant as a single, and moreover, fits in much better with the available space and shape of the engine-room. Should the occasion demand. there is no reason why two, or even more, engines of this type should not be installed.

Most of the multi-cylinder engines so far produced have been too large for installation in hulls of the size popular among model power-boat enthusiasts. Large boats are not only unwieldy and expensive to build, but an even more serious objection is the difficulty of transporting them. I know of one stout fellow who habitually carries around a 6-ft. boat, but he is by no means popular on crowded 'buses and trams with this strange cargo, and even on the railways, it has on more than one occasion been something of a " white elephant." The " Seal " engine is suitable for installation in a metre boat. without being either too heavy? or out of proportion in respect of bulk ; and its power output is ample for the requirements of any craft of this size, other than those intended for racing on the circular course.

This, then? is the primary raison *d'etre* of the " Seal " engme, but it is also quite suitable for other purposes, such as installation in a scale model motor-car (other than a racer), a model locomotive, or even for stationary work such as driving a portable generating set.

Adaptability

It is quite in keeping with the spirit and tradition of model engineering that no two constructors require or prefer quite the same thing ; individuality both in thought and effort is an essential factor in the make-up of the successful model engineer. In all my designs of engines produced in recent years, I have recognised this fact, and have allowed for the possible deviations which constructors may wish to make from the set design. Not only are several of the minor features of the design optional, but the arrangement of the main components can also be modified as required. This ability to " ring the changes " has proved to be one of the most popular attractions in several engine designs, and is by no means lacking in the present example.

Thus the main casting can be turned either way round, so as to bring-the valve gear on either the port or starboard side ; this entails making provision for the attachment of the timing gear to either end of the engine, the castings for the timing case and bearing endplate being "handed" right or left as required. The water circulating system may be arranged so that the water enters or leaves the jacket at either end, this again calling for right- or left-handed castings for the cylinder head cover plate. These optional features may not be of very great importance when only one engine is to be installed, and no serious restrictions of space exist, or exact adherence to a set arrangement has to be complied with ; but they are important when engines have to be used in pairs, to drive contra-rotating propellers.

The auxiliary engine fittings such as manifolds, ignition gear, carburettor, water and oil pumps, are not illustrated in Fig. 1, but it may be observed that these have been fully worked out, and give equal scope for versatility in detail or arrangement. A combined induction and exhaust manifold has been designed, and is shown in position in the photographs. The ignition distributor is fitted on the timing end of the engine, and may be driven directly off the end of the camshaft, as in the " 1831 " engine ; but, for marine work, it is considered preferable to provide a vertical fitting, the shaft being geared to the camshaft, and extended downwards to drive a water circulating pump. Either gravity or forced lubrication is provided for, the former being quite reliable for normal work. A simple form of automatic carburettor, which will give a full range of speed control on the throttle lever only, has been designed for this engine, and although not specified in the standard design, the possibility of equipping the engine with magneto ignition has not been lost sight of, and will be dealt with in an appropriate manner.

It will be clear to most readers that the scheming out of a design to provide such complete equipment, and so many alternative features, has not been a five-minute job, but has taken up several months of spare-time work on the drawing board alone, in the course of which many major and minor parts of the design have been successively evolved and ruthlessly scrapped. An even greater task than that involved in the technical problems of design has been the solution of the machining problems, each one of which has been individually tackled, with due regard to the equipment which the average model engineer will have available to carry it out. The result, I dare venture to assert, is fairly satisfactory from most practical points of view, and although I cannot hope that the design will satisfy all my critics, I have little doubt of its general popularity.

A word of caution to those ambitious constructors who are itching to get going on an advanced design of engine : don't start building this engine until you have weighed up all the difficulties involved, and are quite confident of your ability to carry out all the work to the exacting degree of precision required. Theoretically, it is no more difficult to build a four-cylinder engine than a single of the same bore and stroke, the only difference being the quantity of work involved ; but in practice, the success of a " multi " depends not only on the individual units, but also on their proper co-ordination. I do not underestimate either the ability or the perseverance of my readers, and I know from experience that even raw beginners are capable of overcoming the most formidable difficulties in construction, with totally inadequate equipment, at that ; but it is sometimes difficult to get the beginner to realise just how big a job he is taking on. I have often been criticised for making things seem very difficult, but an ever-increasing number of readers are finding out that my policy of putting them on their guard about the difficulties and pitfalls ahead is better than pretending the latter do not exist. Quite a few people have thought that building small petrol engines was child's play—until they tried it ! There are a few haphazard workers who have enjoyed beginner's luck, but most of us find that the best and most careful work we can do is not too good for this class of model construction. But as in other things in life, difficulties exist not to be dreaded, but to be overcome ; and if there is any reader who is scared away from a job just because he is warned of its difficulty, all I can say is that he would never have made a really successful model engineer in any case.

(To be continued)

PETROL ENGINE TOPICS

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A VERY important factor in the success of an engine of this type is the quality of the castings used in its construction, the accuracy and detail of which need to be of a high order. Both the pattern-making and moulding on these castings have called for great skill; and in the former work, I have been extremely fortunate in obtaining the co-operation of Mr. H. C. W. Frost, who is known to many readers of THE MODEL ENGINEER for his craftsmanship in making small and intricate patterns, some of which have formed the basis of notable exhibition models. The castings have also been produced by a craftsman of no mean ability, and I hope to be able to make an announcement that they will be available to readers in the near future.

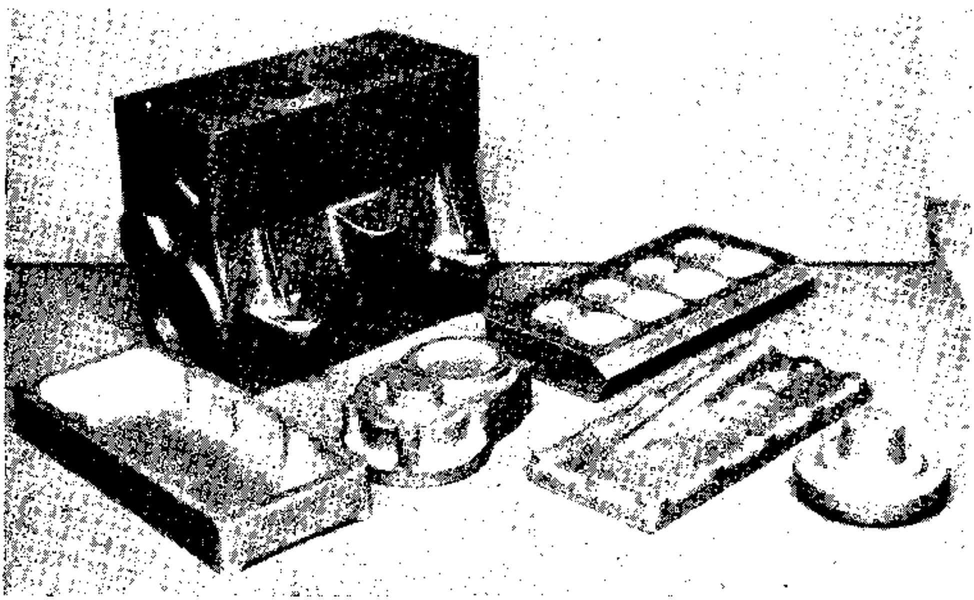
Construction

All the castings of the engine have been designed so that they can be machined by the equipment and methods available to the average model engineer; the largest casting will swing comfortably in a 3-1/2in. lathe, and even with smaller lathes, alternative methods can be devised for handling the essential machining operations. Much of the work on the castings can be done by mounting on a faceplate or angle plate, and odd-angle machining operations have been avoided wherever possible-in fact, they are only introduced in components or surfaces which are not essential to mechanical accuracy, so that small angular errors in these operations do not affect the working of the engine. The small screws and bolts used in the engine are mostly in B.A. sizes, as these are generally the most readily available, and offer the widest choice of sizes ; but there is no objection to the use of the nearest Whitworth sizes, and these offer advantages for threads which are tapped in the light alloy castings. Positions of clearing holes are shown on the drawings, but as the tapping holes, in practically all cases, can be produced by " following through " from these holes, there is no necessity to show these in detail.

***Continued from page 201, " M.E.," February 6, 1947.**

Part No. I.-Main Cylinder and Crankcase Block

This is the largest single component, consisting of a cored casting incorporating seatings for the "wet " cylinder liners, housings for the main bearing end-plates, and surfaces for the attach- attachment of the cylinder head block and sump. It will be noted from Fig. 2 that all the main machined surfaces are at right angles to each other, so that setting-up is simplified, and various alternative machining methods can be employed. The casting should first be set on a surface plate



Main structural castings of the " Seal" 15-c.c. engine

and checked up as to general dimensions ; it is not necessary to attempt complete marking-off, so long as it is ascertained that all essential surfaces will machine up in their correct location and relation, and any possible small errors of dimensions, such as may be caused by slight displacement of cores or misalignment of moulding boxes, are "halved out." Do not forget the invariable rule to take location from surfaces which will not be machined, as the amount of allowance left on machined surfaces may vary slightly, or may be affected in the fettling process.

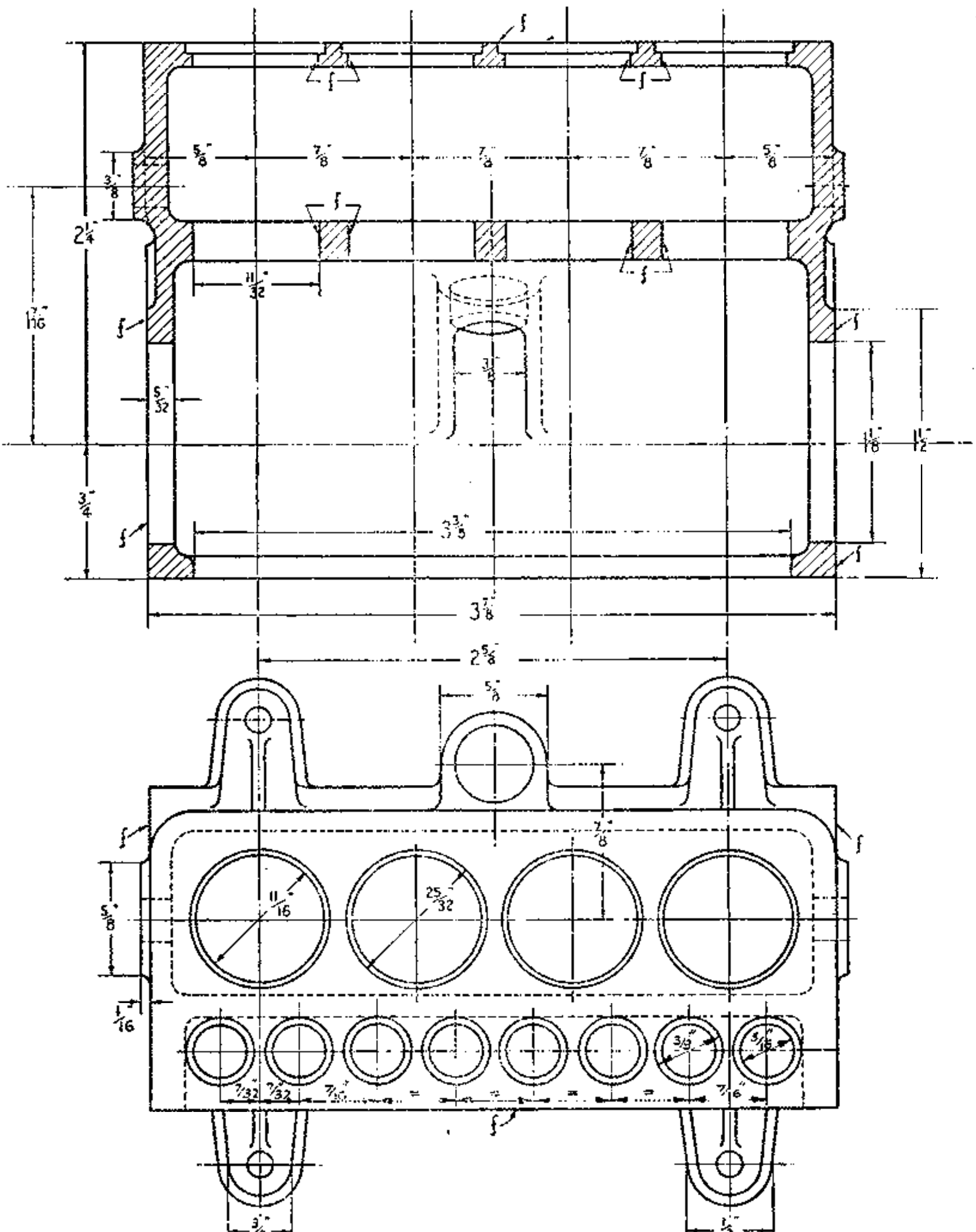


Fig. 2. Sectional side elevation and plan of cylinder and crankcase block

The machined surfaces on this casting are indicated by the customary mark (f). Do not, at this stage, plug the cylinder seating bores for marking the centres, as it is more convenient

squareness, by reference to the preliminary check-up, is preserved, and machining to a distance of 3/4 in. to the shaft centre ***line.*** This dimension ***is*** not a critical one-the really essen-

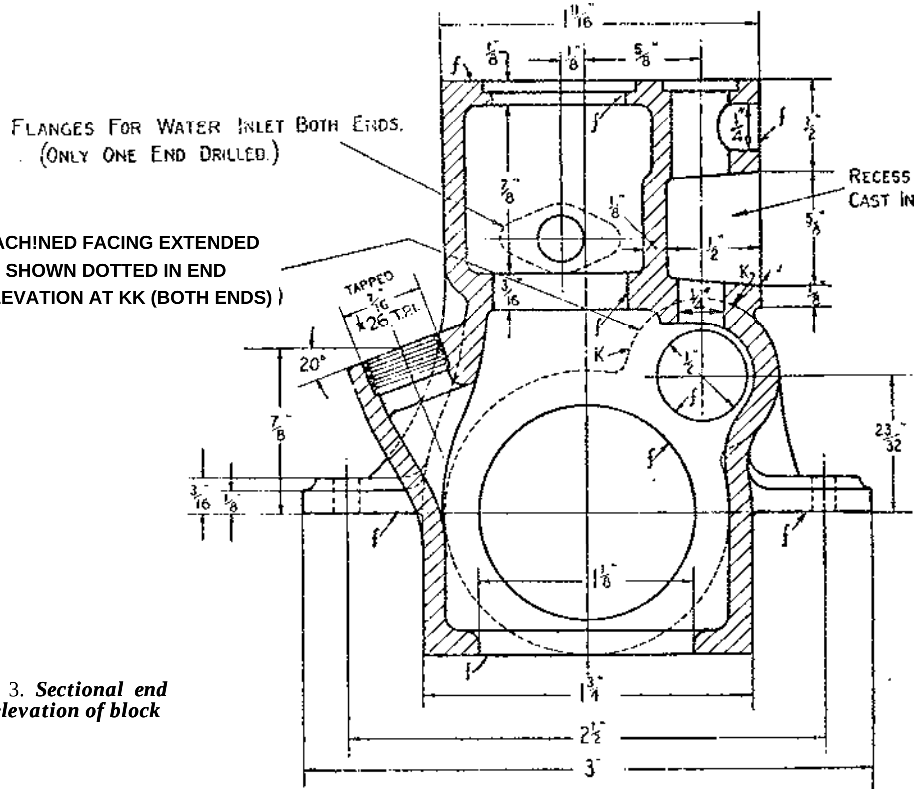


Fig 3. ***Sectional end elevation of block***

to do this at a later stage.

The general checking-up of casting dimensions is one of the first things any constructor should do, as it brings to light any possible errors or discrepancies either in the drawings or castings, and gives one an opportunity to invoke the aid of " the gentle art of cornpromise " in putting them right if it should be necessary. If this rule were universally observed, we should encounter much fewer complaints about castings which won't clean up, or structures which machine up too thin for proper strength. Even in the best regulated designs, and the most carefully made castings, errors are sometimes inevitable, and the common policy of "leaving plenty of metal " on machining surfaces is quite a fallacious one, since it encourages slipshod setting-up, and consequent risk of false relation between machined and unmachined surfaces.

Although there are several quite practical methods of procedure in machining this casting, the recommended method is first to machine off the top and bottom surfaces, and use one or other of these as a reference surface for subsequent operations. The casting may be held in the four-jaw chuck, by the head end, for facing the bottom surface, setting up so that general

tial thing is that the surface should be parallel to the shaft axis, and square with the cylinder bores-but getting it right in the first place will simplify subsequent setting up for other operations. Leave the machined surface as clean and smooth as possible, as it is required to make an oil-tight joint eventually.

For machining the head, it is best to bolt the base to the lathe faceplate, because assuming that the latter runs truly, the parallelism of the top and bottom surfaces will then be beyond dispute. A simple way to hold the casting is to pass a flat bar right through the end-plate housings, with a couple of bolts as near as possible to the ends of the casting, so that they are easy of access and provide maximum security. Incidentally, I have often been criticised for the use of any odd bits of junk for use in bolting work for machining-not at all like the neat straps and clamps so often seen in the text-book illustrations. Well, I am all for using the proper fittings for the job whenever they are available ; and if a great deal of use is made of any kind of fitting, it is worth while to spend any amount of pains to make it not only neat and workmanlike, but also thoroughly well adapted to its job. But the requirements of machining problems in the amateur workshops are so many and varied that one would require a complete arsenal of special fittings to cope with all eventualities. One should not place an undue importance on the fittings themselves-they are purely and simple a means to an end, and may possibly only have to be used once, or at most, very rarely. For this reason, the use of "rag-time " clamping devices is fully justified, providing that they serve their purpose with reasonable efficiency, and do not involve any loss of quality in the work produced.

The truth and smoothness of the finished ton surface is of even greater importance than that of the bottom. but it mav be found a sound policy not to machine it right off to finished dimensions 2-1/4in. from the centre line of shaft or 3 in. from the base surface-but to allow for a finishing cut after the liners are inserted.

Next, the ends of the casting should be faced, and the end-plate housings bored. If a fair-sized angle plate can be swung on the lathe faceplate, the casting may be set on this, securing it by clamps or straps over the feet of the bearers. Check the general squareness of the casting by means of a try-square on each side, then shift the angle plate to centre the housings-do not rely on the cored holes for setting up, but work from essential dimensions, and if any doubt exists as to the correct centre line, plug the bore at one end with a piece of hardwood or metal, and set out the centre on it.

If it is found difficult or impracticable to swing the casting in the lathe, it may be clamped to the cross-slide, packed up to centre height, and bored with a boring.bar. This method has some definite advantages, especially in positive location of the centre line ; if the exact height of the lathe centres, over the cross-slide, is known or ascertained. the reauired thickness of nackinn can also be found, and parallel blocks or strips built up to this thickness. Use the try-square against the lathe faceplate to check the squareness of the casting, and secure it by clamps over the bearers as previously suggested.

The housings are bored to 1-1/8in. diameter, and if it is found difficult to adjust the boring bar to finish exactly to size, it may be noted that this, again, is not a critical dimension? as the external diameter of the bearing housmgs can be adjusted to fit. Facing the end surfaces is best carried out by swinging the castings on a mandrel, for although it is practicable to do this bv means of right- and left-hand facing cutters-in the boring bar, the result often leaves much to be desired. The use of a point facing-tool, in conjunction with traversing movement of the work on the cross-slide, is practicable, if one is quite certain that the cross-slide moves exactly at right angles to the lathe centres-which is by no means to be taken for granted in all cases.

At the same setting as the facing of the ends, a cut can be taken over the flanges on the upper part of the casting. These stand 1/16 in. proud of the end face, but this measurement is not important.

Camshaft Tunnel

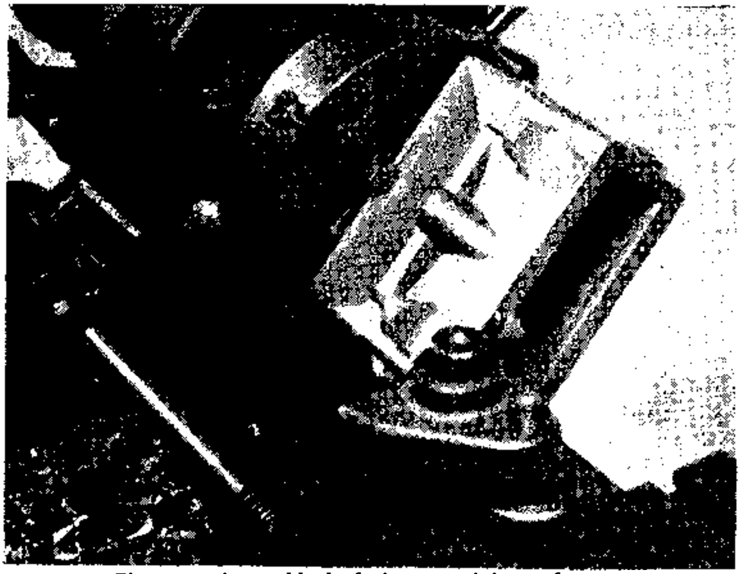
This requires only boring at the two ends, the rest being merely a clearance hole cored integral with the inside of the casting. Whether the end-plate housings are bored on the faceplate or on the cross-slide, the camshaft tunnel is most suitably dealt with by setting the casting over the required amount. It is easy to do this in the former case, simply by swinging the angle plate bodily on the faceplate, and this ensures true parallelism of the two bores. If the boring is done on the cross-slide, however, it must be completely re-set, and the packing under the base reduced bv a thickness eaual to the vertical height of the camshaft above- the main centre, namely, 23/32 in.Care must be taken to ensure that the casting is re-set truly in line with the lathe centres and the use of an alignment bar or mandrel through the bore of the housings would be useful in this respect. The vertical and horizontal offset measurements from the camshaft to the main centre are not highly critical, as the meshing of the gears can be adjusted by the position of the idler gear, but it is best to get them as accurate as possible, on the general principle that good work is easier than bad, because it cuts out the necessity for subsequent "botching" to correct earlier mistakes.

Boring Cylinder Seatings

This is a highly important oneration, as the dimensions, squareness and location of the bores must all be correct. The cored holes should be plugged and the centre line of each very carefully marked, but once the first bore has been located, it is easier and generally more accurate to locate the others by measurement.

If the lathe will swine the casting at maximum eccentricity, that is, when boring either end seating, it may be bolted to the faceplate, using the same means as before, but in this case, some measures are necessary to avoid damaging the finished bores of the housings. A piece of soft wood packing under each end of the strap will serve this purpose. Before mounting the casting, however, one side of the casting, at the base, should be filed straight, and parallel with the centre line, to make contact with an alignment strip for use in locating the bores.

Having lightly attached the casting to the face-plate, set it so that one of the bore-centres runs dead truly, and tighten the bolts holding it in place. Before proceeding further. clamp the alignment strip (any piece of bar or strip material having a dead straight edge) to the faceplate, in contact with the prepared side of the casting. The bore may now be machined to size, using-a stiff boring tool and taking care to ensure parallelism, or rather equal diameter of the upper and lower seatings. At all costs, tapering "the wrong way "larger at the lower seating-must be avoided. If a reamer or sizing cutter is available it may be used to finish the bores to ensure uniformity of size, but it should not take out more than about two or three thousandths of an inch on the diameter. The counterbore at the top end is of course machined at the same setting, and if any metal has been left on the top joint face for final machining, this should be allowed for in assessing the depth of the counter-bore.



First operation on block : facing sump joint surface

uniform in size and exactly parallel ; a second cutter may be mounted in the bar, if desired, to machine the counterbore at the same setting. As it is impossible to run the bar between centres, the overhung cutter may spring to some extent, so it is advisable to take several traverses through each bore, with a slow feed, to eliminate any possible errors from this source. Saddle boring should always be done with the cross-slide locked or very stiffly adjusted, and the saddle gibs set so that they allow no perceptible shake.

After machining one bore, the casting must be shifted exactly the centre distance to the next bore (7/8 in.), keeping it in close contact with the aligning strip. The distance may be measured by any convenient means, such as a depth gauge from the edge of the faceplate, or it may be located by reference to the marked-out centre, but for positive accuracy there is nothing to beat the use of a slip gauge and stop piece. A disc of metal exactly 7/8in. diameter may be used as the gauge, which is placed in contact with the end face of the work (while in its original location) and the stop piece clamped to the faceplate, so that the gauge is just free to move in between the two without shake. The gauge-is then removed, the work loosened, and slid along the alignment strip until it makes contact with the stop piece, then re-bolted for machining the next bore. This procedure is repeated for locating subsequent bores, and will ensure that they are all dead in line, equally spaced, and axially parallel.

For machining the bores on a lathe too small to swing the casting, the latter may be mounted on an angle plate bolted to the cross-slide, due care being taken to set the angle plate dead square with the lathe centres, or parallel with the faceplate, which is the same thing. After locating the first bore, the same methods of relocating for subsequent bores may be employed. If a set boring bar is used, all bores will be

Valve Ports

The setting up and machining of these may be carried out on similar principles to that of the cylinder seatings, with the difference, however, that they are drilled from solid metal. One point which must be carefully watched is the tendency of the drill, after breaking out into the cored recess, to run out of truth when starting to work on the lower part of the hole. This can be avoided by drilling the upper part undersize, and then using a stiff pilot drill, a tight fit in the hole, to start the lower part. The drill may be made from silver-steel, flattened and diamond-pointed at the extreme end only, and it should be lubricated on the shank to avoid risk of seizing in the pilot bore. As there are

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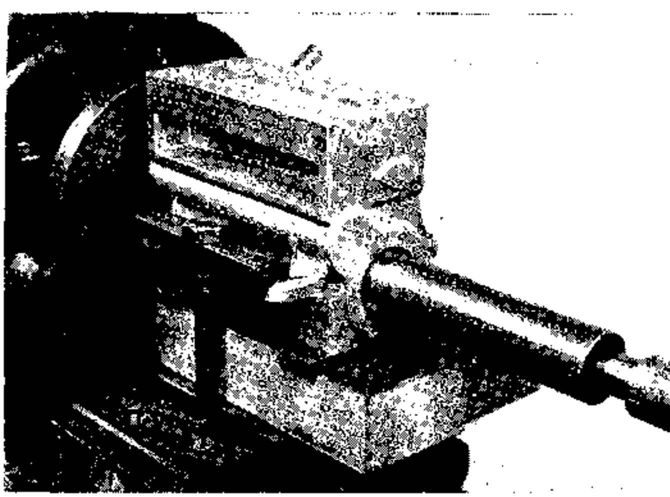

Boring the endplate housings with a boring bar between centres

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eight ports to drill, the making of a simple tool of this kind is worth while. The holes should be opened out and reamered,. the lower part being 1/4 in. diameter, and the upper part 5/16 in., with a counterbore 3/8 in. dia. by 1/16 in. deep.

It is quite practicable to machine these ports in the drilling machine if great care is taken in locating the centres, and keen, true running drills are used. A special sizing and counter-boring cutter may be made for finishing. the bore. But generally speaking, more positive accuracy is obtained by machimng them in the lathe, with proper means of setting up or locating, as already described.

Breather Orifice

It will be seen that the centre line of this is set at an angle of 20 degrees to the vertical, the exact angle not being critical, and the best way to machine it, in the absence of an adjustable angle plate, is to plane up a piece of wood to the required angle, and use this as a packing piece tn mount the canting on the faceplate. The strap and bolts may again be used to secure it, with the wooden pads to avoid marking the housings ; the latter allow of a rocking or " self-aligning " motion, so that a good bearing of the strap is obtained. Centre the boss of the breather as exactly as possible, then face the top surface, drill truly and tap or screwcut to 7/16-in. fine thread.

Other machining operations on this casting are quite simple and obvious. The side face of the valve chamber is best machined by face milling, which may be done by bolting it on the cross-slide and using a fly-cutter in the lathe chuck. Mark out the cross holes for the valve passages exactly in line with the vertical ports ; but it is advisable to defer the drilling of them until the valve liners are inserted.

The undersides of the bearers should be milled if possible, and the best way to do this is by mounting the casting on a vertical slide and using an end mill. The surface should be exactly level with the shaft centre line, to facilitate lining up when the engine is installed.

(To be continued)

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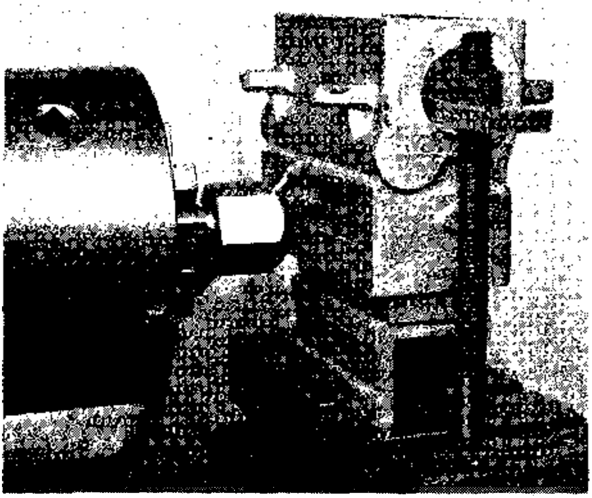
By Edgar T. Westbury

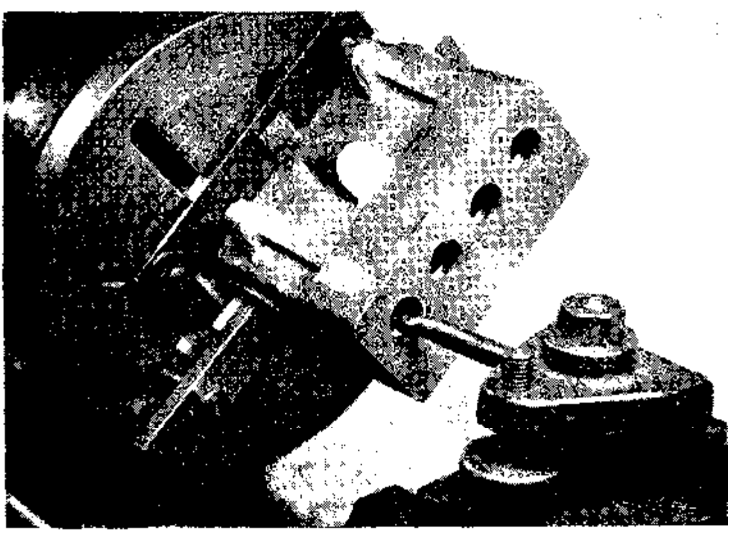
THE flat joint surfaces on the main block and other castings, which form oil, water or gas seals, are intended to be finished eventually by lapping, as this is the simplest way to ensure the smoothness and accuracy necessary to obtain a reliable seal. In machining, however, no pains should be spared to finish these surfaces as smoothly and accurately as possible, to reduce the time and trouble of the lapping operations. Incidentally, one soon finds out faults or inaccuracies in the lathe mandrel or slides as soon as one starts to lap machined surfaces, as the high spots are shown up immediately, and apart from inconsistent errors due to blunt or unsuitable tools, or irregular feed, it indicates the location and nature of the faults in the lathe. One soon finds that there may be, and ***often*** is, a great difference between " finish " and accuracy. The form of tool which I have found most suitable for finishing joint surfaces is either a narrow round-nosed tool or an obtuse vee tool with the angle just slightly rounded ; in either case, the edge should be oilstoned to a high finish. As there is a good deal of surfacing work to do on the castings of this engine, it will pay to make a special tool for the job ; it should be kept in keen condition and only used for a light final cut.



Block set up for face-milling valve cover and manifold joint surface

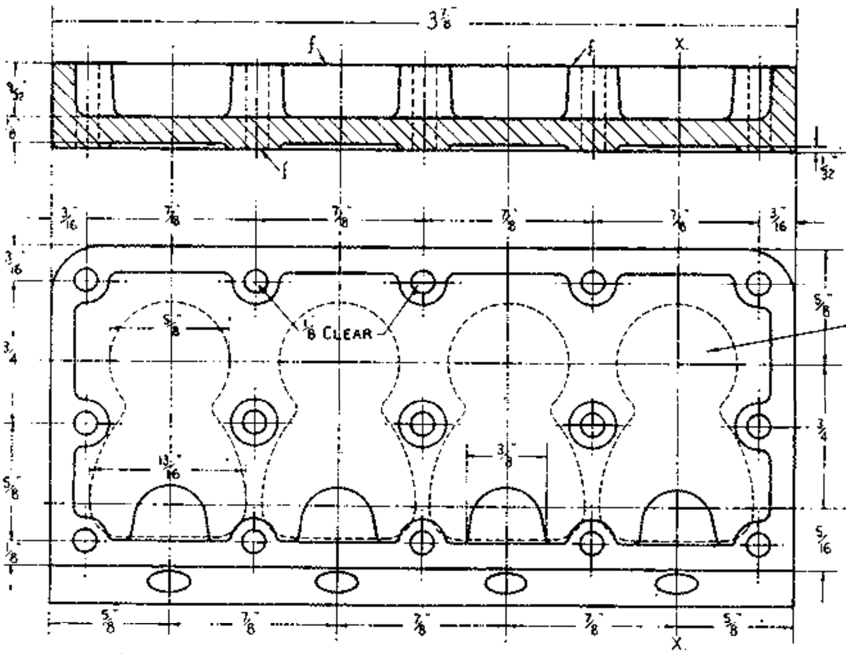
Cylinder-head Block (Fig. 4)

Both the upper and lower surfaces of this casting are joint surfaces, the former being just a low-pressure water joint, while the latter is required to hold cylinder pressure and therefore calls for the most careful fitting. The casting may be held in the four-jaw chuck for machining each surface in turn, care being taken to get them parallel with each other. The inclined side edge in which the sparking plugs are fitted may be machined by clamping the casting to the side of a block of wood planed to an angle of 30 degrees and mounting this on the lathe faceplate. While the head is still attached to the wooden block, the positions of the sparking plugs may be marked off, and each in



Boring the cylinder seatings-note the use of the aligning strip to facilitate re-setting for subsequent bores

****Continued from page 285, " M.E.," March 6, 1947.***



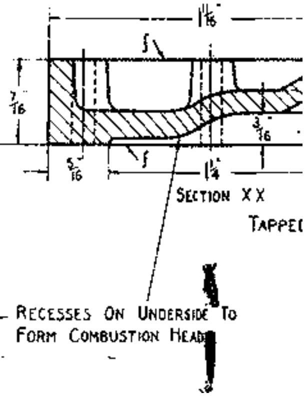
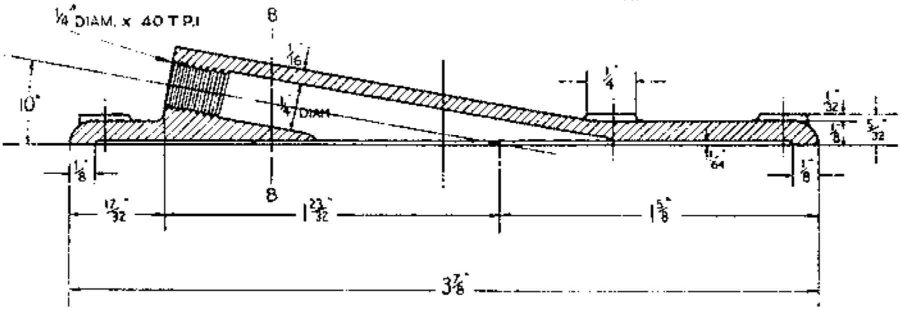


Fig. 4. ***Cylinder-head***



SECTION A.A.

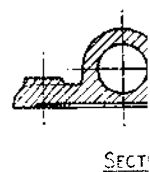


Fig. 5. Cylin
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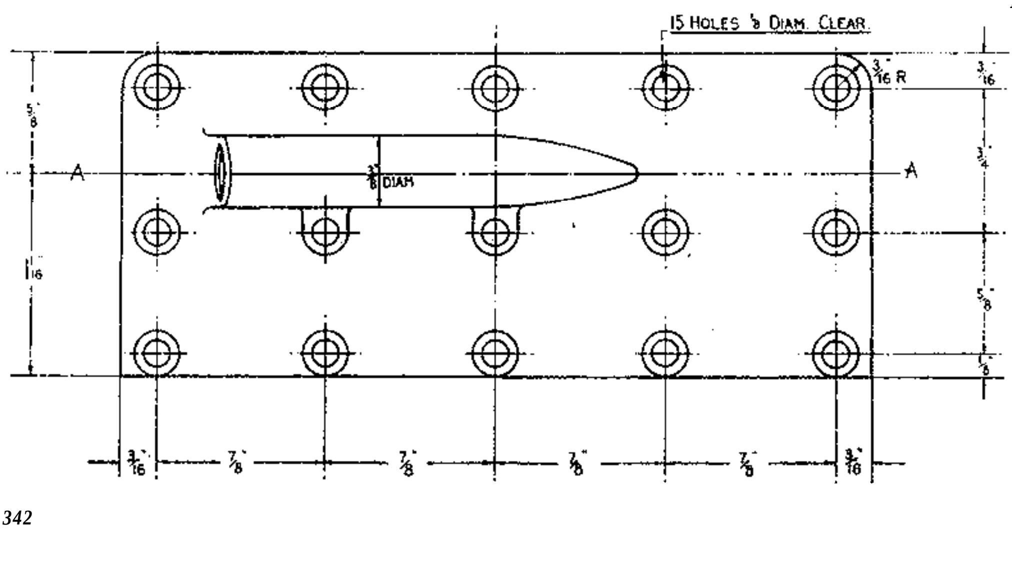

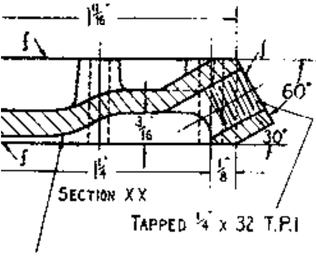

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Cylinder-head block

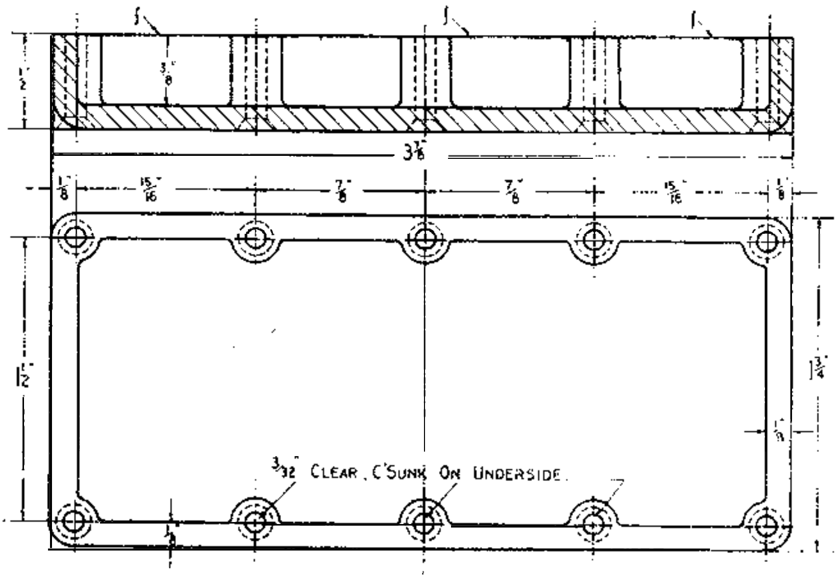


Fig. 6. Sump

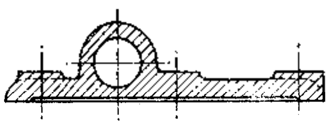


Fig. 5. Cylinder-head cover plate

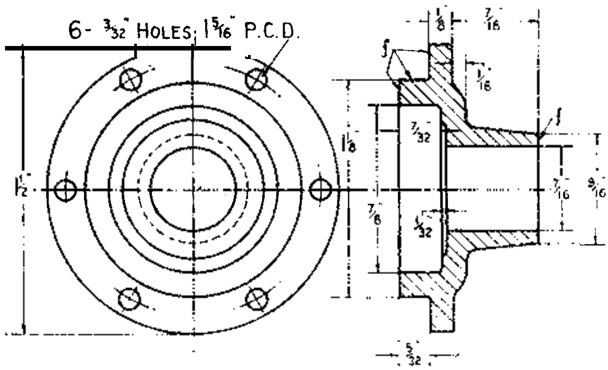


Fig. 8. Main bearing housing

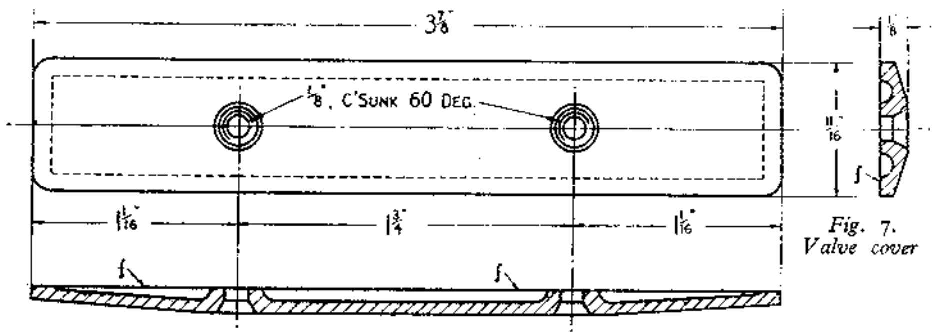


Fig. 7. Valve cover

turn accurately centred on the faceplate for drilling and tapping the holes. This will ensure that the plugs are all at exactly the same angle, and accurately seated when screwed home ; it is a much more reliable method than drilling the holes in a drilling machine and facing them with a pin drill.

Cylinder-head Cover **Plate (Fig. 5)**

This is available with water outlet facing in either direction, to suit engine arrangement, and requires only to be faced on the under surface, which is easily done by holding it in the four-jaw chuck. The hole for the water outlet is drilled at an angle of 10 degrees to this surface (drilling machine methods are quite in order for this) and tapped 1/4 in. fine thread, to take an outlet pipe.

In drilling the stud holes in both the cover-plate and the cylinder-head block, it is of paramount importance to see that their location in the latter casting is correct in relation to the combustion head cavities. It will be seen that on the sparking plug side of the casting, there is very little room to spare for the stud holes, and should one of them break out into the cavity, the casting is ruined. For this reason, it is advisable to mark out the positions of the holes very carefully ; do not rely on simply centring them from the boss positions in either of the castings. It may not look quite so neat to see a stud hole out of centre with the boss, but it is even more important for the engine to work ! However, the castings are sufficiently accurate for both requirements to be fulfilled, so long as the marking-out is done carefully ; but one can imagine what ***might*** happen with castings made carelessly, or from inaccurate patterns.

The best way to mark out the holes is to use a scribing block, resting each casting in turn on a ledge or strip clamped to the side of a heavy vertical block or angle-plate on the surface plate. Mark out the longitudinal lines first, setting the scriber point to the required height, and marking the top side of the cover plate, and ***both*** sides of the cylinder head at one setting. Shift the scriber to the level of the next row of holes, and repeat the procedure. The cross lines are produced in a similar way, with the casting up-ended, and located by a vertical strip on the angle-plate. In this way, the positions of the holes can be exactly' verified, and nothing left to chance. When the main cylinder block is ready for drilling and tapping, the head block may be lightly clamped in place and the holes " spotted " through in position. Either 6-B.A. or 3/32-in. Whit. studs are suitable for securing the cylinder head. Water communication holes are not shown on the detail drawings, but will be dealt with at a later stage in the construction.

Sump (Fig. 6)

Only the upper surface of this is machined, and again, this is a simple chuck operation. The positions of the screw holes may be located from the bosses on the machined face, and after drilling to clearance size for 7-B.A. or 3/32-in. screws, are countersunk on the underside. Use these holes for spotting the positions of the tapping holes in the main block, when the latter are drilled and tapped.

It will be seen from the general arrangement drawing on pages 198 and 199 of the February 6, 1947 issue that an oil trough is fitted inside the sump, being held in place by two countersunk screws through the bottom of the latter. The holes for these screws are not shown in the detail drawing, as it will be found most convenient to mark them out when fitting the trough. A very small machining or filing allowance has been left on the end faces of the sump, as one or other of these will have to be faced to form a seating for either the oil or water circulating pump, if fitted.

Valve **Cover (Fig. 7)**

This is an optional fitting, as some constructors may prefer to leave the valve springs exposed so that their working is visible, but the enclosure of these parts does help to keep them clean and well lubricated, besides reducing mechanical noise. The cover may be made either from a casting or from sheet metal, and requires only to be faced on the inner side. It is attached by means of two studs fitted to tapped holes in the inner wall of the valve cavity, the holes being shown countersunk at an angle of 60 degrees, to fit knurled nuts having the ends bevelled at a similar angle. This helps to provide a friction lock to deter slackening of the nuts, but, if preferred, ordinary hand or spanner nuts, with spring washers, may be fitted.

Main Bearing Housing (Fig. 8)

A casting is normally provided for this component, but it can quite easily be made from a piece of bar material, of a size large enough to clear up to 1-1/2 in. diameter. The machining is quite straightforward, and should be carried out at one setting, so far as the essential locating surfaces are concerned. Note that the end face of the ball race recess is relieved to prevent fouling of the inner ring. The recess is bored to take a Skefko EE2 single-row ball race, in the fitting of which a plug gauge should be used, if available ; but, if not, the race itself may be mounted on the end of a screwed mandrel and used as a gauge. Fit the race so that it will press in lightly, and make certain that it goes right home in the recess ; an undercut at the end of the recess is advisable if there is any doubt about this. The spigot of the housing should be a snug push fit in the bore of the main block ; note that the housing may be fitted at either end, according to the "hand " of the engine and the direction of rotation. If there should be any possible difference in the diameter of the bores at the two ends, be sure and fit the main housing at the right end.

The nose of the housing is bored to take a steady bush, which may be used as an oil packing labyrinth seal in the event of a forced lubrication system being fitted. This bore must, of course, be perfectly concentric with the ball race. Machining of the outside of the housing is optional, but a skim should be taken over the rim, and also the outer flange face, to form a seating for the screws or nuts holding the housing in position. These may be either 7-B.A. or Whit.

Neat fitting of the housing spigots in the bore of the main block is essential, in order to avoid taking the piston thrust stresses on the bolts and screws holding the housings.

(To be continued)

PETROL ENGINE TOPICS

* A 15-c.c FOUR-CYLINDER ENGINE

By Edgar T. Westbury

THE timing endplate, Fig. 9, can be machined to suit either hand, according to which end of the engine it is fitted. Thus the boss on one side is superfluous, and must eventually be machined away, but in the meantime, it serves a useful purpose as a chucking piece for boring the ball-race housing, turning the spigot and facing the inner surface which seats against the machined face of the main block. The fitting of the spigot and the ball-race is much the same as for the main housing, but the bore is in this case taken right through, so that the ball-race has no positive end location either way. After completing these operations, the casting is reversed, and held by the spigot in the three-jaw chuck for facing the other side, and removing the unwanted boss. It is essential that the inner and outer faces should be parallel, and this may be verified by measuring the thickness with a micrometer at various points. Further machining on this part should be deferred for the present, until other parts are ready for fitting.

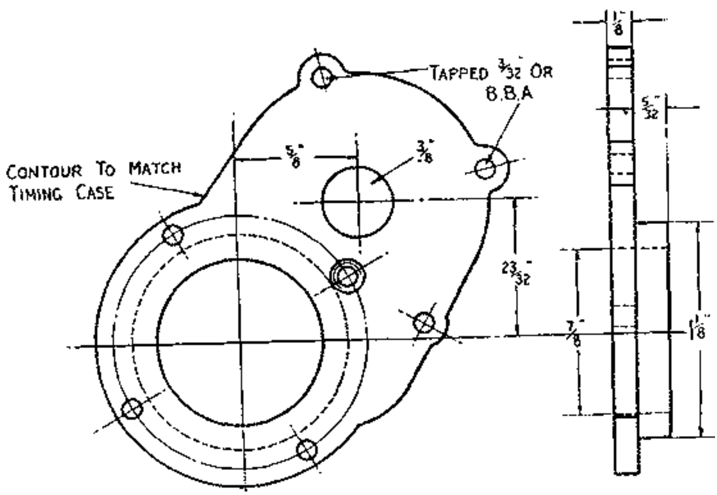


Fig. 9. Timing endplate

Timing Cover (Fig. 10)

In order to enable the timing cover to be fitted at either end of the engine, two separate castings, right- or left-handed respectively, are available, but whichever of these is used, the machining operations are essentially the same. The first operation is the facing of the inside joint face, which may be carried out by holding it in the four-jaw chuck. Then reverse the casting and clamp it to the faceplate, with the main shaft boss set to run truly ; face and centre the boss and bore it to 7/16 in. diameter.

A simple aligning plug is now made, one end of which is turned to 7/8in. diameter, to fit tightly in the bore of the timing endplate, and the other to 7/16 in. diameter, to fit the bore of the cover, This registers the two parts exactly in position for drilling the screw holes

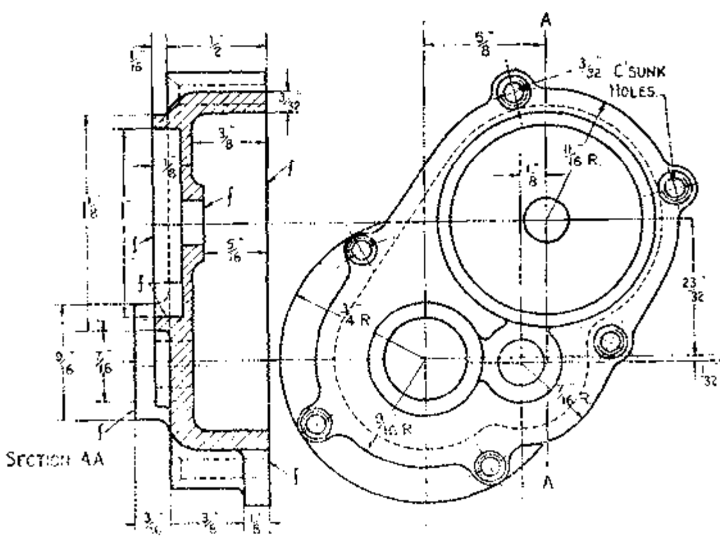


Fig. 10. Timing cover

*Continued from page 344, " M.E.," March 20,

around the edge, to secure them together temporarily or to attach both to the main block for further operations. It may be considered desirable to dowell the parts together to ensure accuracy of register, in which case the dowel holes may be drilled from the back of the endplate, anywhere between the screwholes ; but with carefully fitted countersunk screws, this precaution should not be necessary. The three upper screwholes in the endplate are tapped so that the parts can be held together without the screws projecting at the back ; the rest of the holes are drilled clearance size, and after fitting the endplate in position on the main block, these holes are used to locate the tapping holes in the block, which follow through from the three lower holes in the timing case. A fourth hole is drilled in the timing endplate, to take a countersunk screw, so that there are four equidistant screws securing the endplate to the block ; ***this hole does not come through the timing case.***

It is now necessary to continue the bore of the camshaft housing through the timing endplate and cover, in exact alignment. There are various ways of doing this, and in a large lathe it may be practicable to use a spigot mandrel in the chuck, with the entire assembly mounted on it, so that the centring and boring of both castings could be done in ***situ.*** Failing this, a piloted drill may be made by turning a bar to a close running fit in the camshaft housing, with a hole drilled in the end to take either a centre drill or a short stub drill, which may be secured by a grub screw or soft solder. This is used by running it in the lathe or drilling machine, to start the hole from the inside of the endplate, after which it may be opened out with a larger drill, and finally reamered. The procedure is repeated on the inside face of the timing cover.

It should be noted that the machining of the seating in the timing cover may need to be varied to suit alternative fittings or arrangement of the ignitiondistributor, but, for the present, no harm will be done if it is machined as shown on the detail drawing.

Crankshaft (Fig. 11)

The material specified for the crankshaft is medium alloy steel, about 35 to 50 tons tensile strength, but in view of present supply difficulties, constructors who are unable to obtain this may have to use mild steel, which will be satisfactory as to mechanical strength, but somewhat inferior in respect of wearing properties. It is hardly practicable to case-harden the crankpin journal surfaces because' of liability to distortion. The steel should be normalised before machining, by heating to an even dull red and allowing to cool naturally ; this will release any internal stresses produced in the rolling process, particularly in cold rolling as applied in the manufacture of bright mild steel.

The outside dimensions of the crankshaft are 6-1/2 in. by 1-1/8in. by 7/16 in., but it is desirable to allow a little on both the length and breadth for finishing ; the thickness is not quite so important, though it may be found convenient to use a bar 1/2 in. thick, and machine the sides after other operations are completed. Round bar may be used if desired, the oniy objection to it being the

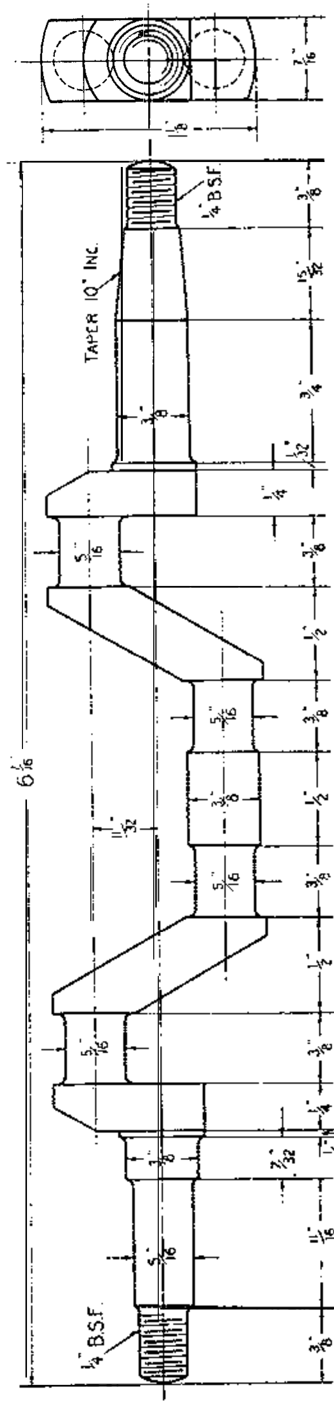


Fig. 11. Crankshaft

amount of material to be removed, and the difficulty of doing this by any other method than eccentric turning, which may be a slow and laborious process on a small lathe. The crank webs may be left circular if round bar is used, but there is no mechanical virtue in this shape, and it serves onlv to add weight to the crankshafttoo close to the centre to have any substantial flywheel effect.

Marking out of the main and crankpin centres is carried out in the usual way, by supporting or clamping the bar parallel to the surface of a flat plate, and using a scribing block to mark a centre line on both ends. If the bar should be distorted so that it does not lie evenly on its supports, it should be packed to eliminate all suspicion of " rock," so as to ensure that the lines marked on the two ends are in exactly the same plane. Next turn the bar up on its edge, that is, at right-angles to its first position ; it may be found desirable to clamp it lightly to the side of an angle plate, with parallel packing blocks underneath. Set the scriber point to the centre height of the bar and mark cross lines on each end, to indicate the position of the main centres. The scriber may now be re-set by measurement to mark the crankpin centres in a similar way, at a distance of 11/32 in. above and below the main centres respectively.

As there is some risk of error in measuring these distances, however, a positive check on their accuracy, or at least their equality (which is the most important thing) may be carried out as follows : Centre-punch the intersection of the main centres at each end as accurately as possible. and make a small but positive *indentation with a drill, either in a machine or a hand brace. Next deepen the centre each end by means of a centre-drill running in the lathe, the work being held by hand, with the indentation at the opposite end resting against the tail centre. The centre-drill should be of small size. with a pilot not more than 1/16 in. diameter. for producing a properly proportioned centre in a shaft of this size. Now run the work between the main centres, and, by means of a point tool presented in turn to each end face, make a light scratch to coincide as closely as possible with the marked radial position of the crankpin centres. Remove the work, and check the distance between these centres with dividers? aided, if necessary, with a lens ; it is fairly obvious that it is possible to work twice as accurately by measuring diameter as compared to *radius*. Should the distance be found correct, the scratches may be deepened with the point tool, so that risk of error in working to the marks, with centre-punch and drill, are reduced. But a slight error in the crankpin throw is of minor importance, providing that all crankpins have the same throw. Drill the crankpin centres in the same way as the main centres.

Should it be desired to modify the crankpin throw in order to alter the engine capacity, this can be done to a limited extent-it is possible to go up to 3/4 in. stroke or down to 5/8 in. stroke-but it should be noted that this affects the length of the connecting-rod, which must be shortened if the stroke is increased, or vice versa, to the same extent as the difference in crankpin radius, in order to bring the piston to the same position in the cylinder at T.D.C.

A good deal of the superfluous metal on the crankshaft may now be removed by drilling and sawing, but do not forget that the ends of the bar must be left intact to preserve the throw centres until the machining of the crankpins is *com*pleted. The oblique centre webs of the crankshaft help to simplify crankpin turning, as they give plenty of tool room and eliminate the need for special long-reach narrow tools, such as are often found necessary for work of this nature. As the shaft is of comparatively robust section, it should be found possible to dispense with " stretchers" or other steadying devices, if due care is exercised and keen, narrow-pointed tools are used ; but should it be found desirable to do so. the gaps may be stiffened by clamping straps across them, to bear firmly on the sides of the bar. The sloping webs may be machined by turning from the crankpin centres, producing-a convex surface, or square across from the side faces by milling, shaping or filing, as desired ; the former method, in my opinion, produces the most shapely result, and the most efficient disposition of material. Finish the crankpins as accurately and smoothly as possible, so that very little finishing by the use of abrasive methods is required.

Having completed the crankpins at both throw settings, the ends of the shaft may now be turned on the main centres. The most important point in this operation is to get the diameter of the ball race seatings correct. It should not be necessary to use undue force in fitting these races, but on the other hand, slackness must at all costs be avoided. The use of a very fine smooth file is permissible for fitting these races, and on the flywheel end, the journal may be very slightly tapered, so that it is not necessary to press the race on all the way. Finishing of the taper may be deferred until the flywheel has been bored, as it is easier to fit the mating tapers by working on the outside surface than the inside. Screwcutting of the threads at each end of the shaft should be done bv eeneratine methods if possible : the use of dies, except possibly for finishing purposes, is liable to result in " drunken " threads, which tend to throw mounted components out of truth and impose distorting strains on the crankshaft.

Why a Two-bearing Crankshaft ?

Some queries and criticisms have been received on this point, many readers considering the two-bearing shaft " cheap and nasty," and expressing preference for at least one additional bearing in the centre , some would go even further, and put a bearmg between each throw, making five main bearings in all. There are, however, excellent reasons why I have adopted the simplest possible bearing arrangement, the first and most important of all being the purely practical one of avoiding difficulty in the lining-up of the bearings. The process of line-boring bearing seatings in a crankcase as small as that on this engine is by no means an easy one, and although there are possible expedients to reduce difficulties in this respect, it is questionable whether they are worth the trouble involved. Any error in bearing alignment would, of course, result in binding, or at least abnormal friction, so that the extra bearings would be worse than useless.

Secondly, the fitting of intermediate bearings would inevitably increase the length of the engine, thereby adding to its bulk and weight, and reducing structural rigidity. Many motor car engine designers have found that an increase in the length of an engine exaggerates many structural problems, increasing the tendency to rocking couples and vibration, and unless the crankshaft is stiffened, it is liable to torsional vibration. Short bearings are prone to rapid wear, as oil films are squashed out at the ends, and in my opinion, bearings in small engines should never be less in length than their diameter. Many well-known motor cars have been fitted with two-bearing crankshafts, and instances have occurred where the addition of a centre bearing has not proved advantageous in the light of practical experience. The way to efficiency does not lie in the fitting of a multiplicity of bearings, but in arranging each bearing to carry its fair share of the load, and in vreventine shaft deflection as much as possible. In this respect, the use of ball races on the main journals, supporting the shaft as close up as possible to the crankpins, has been decided upon, after careful consideration, as the most satisfactory solution of the problem.

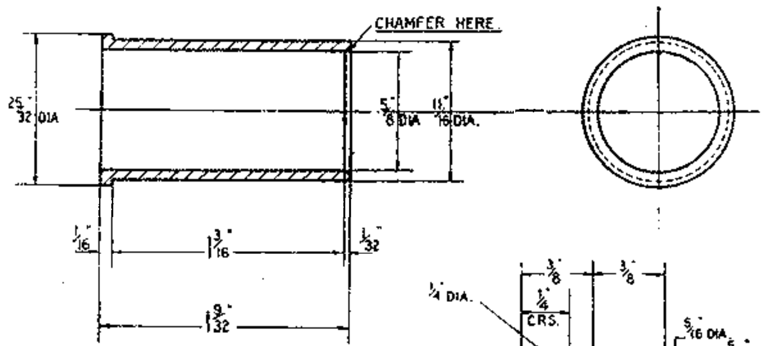


Fig. 12. *Cylinder liner (4 off)*

Cylinder Liners (Fig. 12)

The use of centrifugal or chill cast iron has been specified for these, as being the best material to withstand wear in the normal (un-heat-treated) condition, but steel may be preferred by some constructors, and if judiciously selected for its wearing properties, will be quite satisfactory. I have found that a " straight " carbon steel such as "Pitho" wears well, and almost as good wearing properties may be produced by muffle-carburising mild steel, so as to increase the carbide content of its surface structure, without subsequent hardening by quenching.

The machining of the liners is quite straightforward, and if the boring of the seatings has been carried out as directed, they may all be made *to* exactly the same external and internal dimensions. If the length of the material available allows an ample amount for chucking, they may be turned inside and out at one setting, but failing this, they should first be bored to within about 0.001 in. of finished size, then mounted on a mandrel for turning the outside. The locating rim at the top of the liner does not need to be an exact fit in the recess of the block, but care should be taken to see that it will go in, and a slight allowance should be given on the length of the rim for finishing flush with the top surface of the block after insertion.

On no account should the liners be fitted too tightly to their seatings in the block ; shrink fits or heavy press fits are quite unnecessary, all that is required being to ensure that the liner has a close contact with the seatings at top and bottom and is not liable to turn or otherwise shift after insertion. About 0.0005 in. is the correct amount of interference if one has the means of internal and external measurement to a fine enough limit of accuracy.

The main lapping of the liners may be carried out before insertion, the lap being run in the lathe, and the liner held in the hand with a strip of rag wound round it to increase the grip. In this way good control and " feel " of the lap is obtained, and no distorting force is applied to the liner, such, as might happen if it were held in a chuck. If the liners are inserted before lapping, it is very difficult to get a sensitive " feel " on the block for proper control of lapping, and it is advisable only to carry out a light finishing lapping operation after they are inserted.

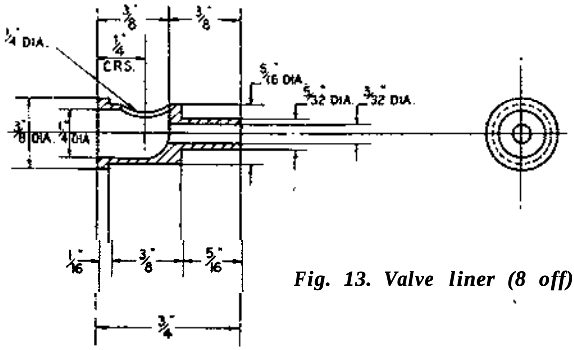


Fig. 13. Valve liner (8 off)

It should be possible to press in the liners by means of the lathe tailstock, using a drill pad in the socket of the barrel, and resting the casting aaainst the facenlate. This will ensure a much better alignment of thrust than is possible by using the vice or an improvised press for the purpose. The outside of each liner should be given a light coating of copal varnish, or even paint, before insertion, as this will serve the dual purpose of a lubricant during insertion, and a sealing medium to prevent creepage of either water or gas later on.

It should be noted that the cylinder block may be bored to take liners up to 11/16 in. bore and 3/4 in. outside diameter, which, in conjunction with slightly increased crank throw, will enable the

(Continued on next page)

Petrol Engine Topics

(Continued from previous page)

engine capacity to be enlarged to 20 c.c., should this be thought desirable.

Either cast-iron or bronze may be used for the valve liners, the former being best for wear resistance, but the latter less liable to loosen through differential expansion. They may be fitted rather tighter than the cylinder liners, as distortion of the bore is less liable to occur and has less serious consequences. The bores of the port end and the guide must be kept perfectly concentric and it will be seen that the end of the port bore is spherical, a special cutter or D-bit being advisable for finishing this. Do not drill the side port or chamfer the valve seating until after the liner is inserted, which may be done in the method recommended for the cylinder liners.

The block may now be mounted on the face-plate and a fine finishing cut taken over the top surface, including the rims of the liners, to vide a dead flush joint face, which is finally lapped until its flatness, as tested on a true surface plate is above suspicion.

(To be continued)

* A 15-c.c. FOUR-CYLINDER ENGINE

By Edgar T. Westbury

THE flywheel should be made from a mild steel blank, if available, but as many constructors may not be able to obtain this, a casting in iron or gunmetal will be suitable. Personally, I favour gunmetal or bronze of fairly good quality for flywheels, as its specific gravity is a little higher than iron or steel, and therefore its momentum is greater for a flywheel of given dimensions. Its appearance, however, may be objected to, though this may be improved by dull plating, if desired. Whatever material is used for the flywheel, it should be machined all over, with due care to keep all parts concentric with each other (Fig. 14).

Recommended procedure for machining the flywheel is as follows : First chuck the blank or casting with the pulley end outwards, and rough turn as much of the outside as is accessible at this setting, including the groove, leaving not more than about 1/32 in. for finishing. If a casting is used, it will be possible to grip it by the inside of the rim, so that the whole of the outer surface can be turned ; but if working from a blank, only a part of this surface is accessible. Next, reverse the work, holding it as truly as possible, to turn the rest of the surface, including the recess and the back face of the rim, which may be finished to size right away, also rough turn any part of the rim not accessible at the previous setting ; then centre, drill and taper bore the central boss, all at the same setting. A reamer may be used to finish the bore, if one is available of approximately the specified taper, but should only be applied after boring to within one or two thousandths of an inch of finished size. As already mentioned, it is advisable to finish the flywheel bore first, and match the taper of the crankshaft to it.

The flywheel is secured to the crankshaft, or on a specially-made tapered mandrel (preferably the latter), which is run between centres for finish-turning the exterior surface. With due care, this method should produce a flywheel which is perfectly true all over. It is surprising how many wobbly flywheels one encounters, but there is no excuse whatever for this state of affairs-even the old, old story that the lathe " won't turn true " isn't good enough in this case!

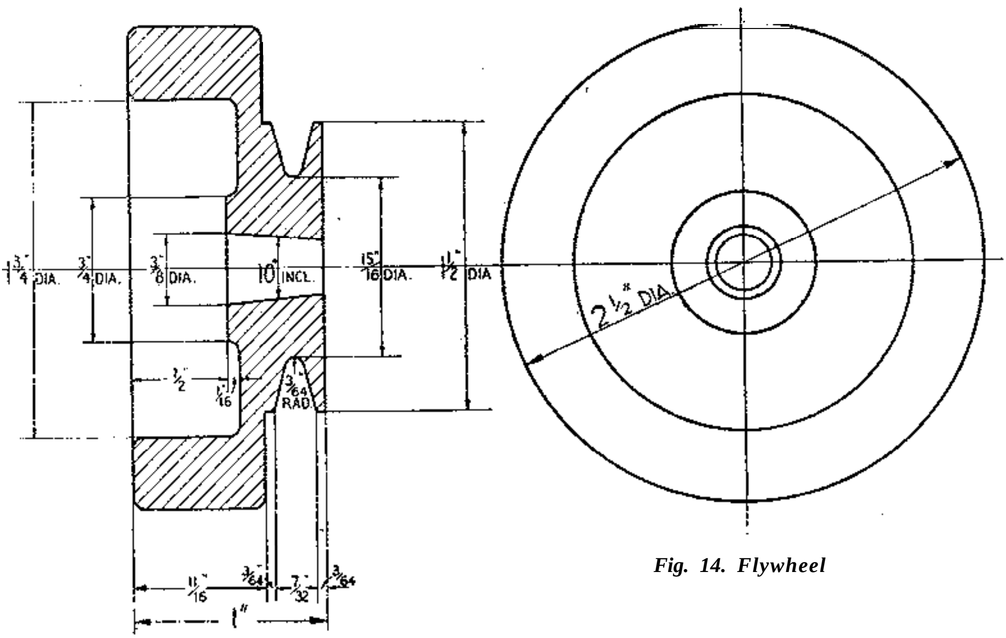


Fig. 14. Flywheel

Balance

When steel or other bar stock material is used, the flywheel should be perfectly balanced when machined all over concentrically, but this does not necessarily apply in the case of a casting, as the material may not be perfectly homogeneous, and may even have concealed blow holes below the surface. It is good policy, in this event, to test the static balance of the flywheel by rolling its mandrel on knife-edges, and if an error is found, correct it by drilling the inner side of the rim on the heavy side, or by running a little soft solder inside the rim on the light side.

***Continued from page 416, " M.E.," April 3, 1947.**

The latter is perhaps the best way, as quite a thin film of solder, not sufficient to affect appearance much, is usually adequate, and it may be scraped away to obtain fine adjustment of balance.

The static balance of the crankshaft itself may be tested out and similarly corrected if necessary, but static balance, in this case, is not sufficient. Owing to the length of the crankshaft, it is possible that serious errors in dynamic balance

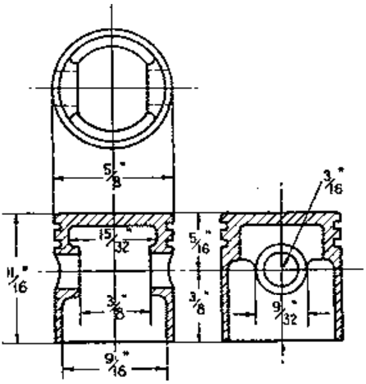


Fig. 15. **Pistons (4 off)**

may exist although static balance is perfect, but this may be avoided to a great extent by ensuring that the distribution of mass is equal at the two ends of the shaft. In other words, any parts which might conceivably be out of balance, such as the end webs, the diagonal centre webs, and the crankpins themselves, should match, end for end, in respect of dimensional uniformity.

Balance is, perhaps, more important on an engine of this type than on the usual single or twin, because it is really capable of something like perfect balance if due care is taken, and the sweet running and absence of vibration of a well-balanced four-cylinder is one of its most impressive characteristics.

For the benefit of those who have not studied balancing problems, it may be mentioned that although the reciprocating weight of a piston may be balanced by that of another piston of equal weight moving in opposite phase-as in a twin cylinder engine with opposed cranks-true dynamic balance can only be obtained when the pistons move in exactly in the same plane-as in the opposed piston engine, or an opposed twin with no " offset." But when the pistons are side by side, their motion produces a " couple," tending to rock the shaft about a point between the crank throws ; and the effect of this can be, and often is, much worse than that produced by the unbalanced reciprocating weight.

In the normal type of four-cylinder engine, the rocking couple is cancelled out by opposing one half of the mechanical system against the other half ; this is known as " mirror " balance, because one half is the counterpart of the ***other*** as seen by reflection in a mirror. Rocking couples are then produced in each half of the crankshaft, but they are equal and opposite, and assuming reasonable structural rigidity in the engine, produce no external effects. This applies not only to four, but also six, eight or more cylinders when arranged side by side in the same plane. If, however, the weights of the opposed reciprocating or rotating pairs at the two ends of the engine are not equal, they do not cancel exactly, and vibration or rough running will result.

Pistons

These are illustrated in Fig. 15, and it will be seen that they are intended to be made from castings in iron or aluminium, and to be fitted with rings. At the moment however, it is not certain whether piston rings of the size required can be obtained, and although it is possible for the amateur to produce rings which will work satisfactorily, this is an extremely delicate job which most constructors will probably wish to avoid if possible. Plain pistons machined from cast iron, and fitted to the finest possible clearance in the cylinders, will give quite good results, and unlike two-stroke engine pistons, the presence of the empty ring grooves will do no harm ; in fact, they are advantageous, as they will help to preserve an oil seal. The procedure for machining pistons from the solid has been described several times, in connection with the construction of two-stroke engines, and need not be repeated here. It is desirable to make the pistons as light as possible, and each should be exactly the same weight.

If there is any variation in the diameter of the cylinder liner bores, selective fitting of the

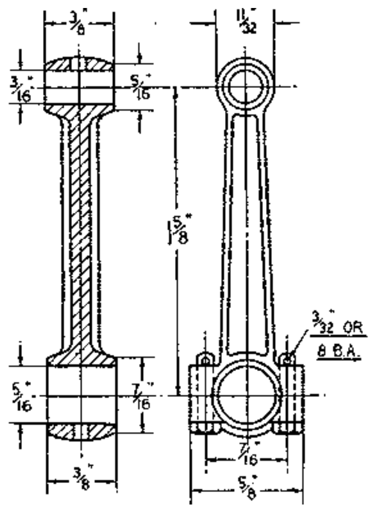


Fig. 16. ***Connecting-rods (4 off)***

pistons is necessary, and each one should be marked to show in which cylinder it belongs. By the way, it is usual to number the cylinders from the timing end, but either way wiil do, so long as it is decided upon definitely, and adhered to. Aluminium pistons will not be entirely satisfactory unless fitted with rings, as they call for greater clearance to allow for expansion, and will therefore fail to produce a good compression seal when starting up from cold. The advantages of reduced weight and improved heat conductivity of aluminium pistons are not likely to make much difference to performance in so small an engine.

Connecting Rods (Fig. 16)

Cast bronze rods are the simplest form of construction, and give quite satisfactory results in small engines for speeds up to 7 or 8 thousand r.p.m. Duralumin *or* steel rods, *machined* from the solid, may be preferred by the more fastidious worker, but show little, if any, advantages in practice, and in the latter case, bronze or anti-friction metal linings would have to be fitted in both big and little ends, which would consequently have to be enlarged in diameter, increasing bulk and weight.

The four rods should be identical in the length between the eye centres, and also uniform in weight when finished. If castings with solid big-end eyes are used, there should be sufficient metal to allow for splitting and cleaning up the faces of the bearing, after rough drilling the eye and also the bolt holes, and marking on the sides of the bottom lugs, to number the rods and show positions for assembly. For splitting the eyes,

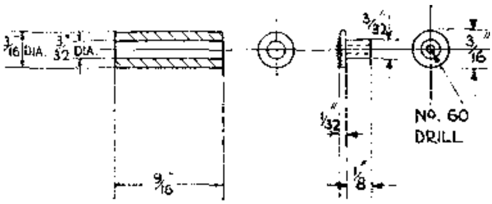


Fig. 17. Gudgeon pins (4 off)

a circular saw running in the lathe is advised, the rods being held in the tool post, with packing above and below, and with the centre line exactly parallel with the lathe axis. This will leave truly finished surfaces, which require hardly any further treatment, beyond a slight rub on a smqoth file to remove burrs. The lower half of the bearing has the holes opened out to clearance size for the fixing. screws, the upper half being tapped, after which temporary screws are fitted. and the rest of the work on the rods is the same as that for the more usual solid-eye type of rod.

It is a good policy to bore the little end of each rod first, holding the rod in the four-jaw chuck, with the boss central, and the centre line of the rod parallel with the chuck face. The end of the boss can be faced at this setting, and it may also be found advisable to skim up the tapered outer surface as far as it can be reached. Similar treatment may be applied to the other end of each boss, by mounting the rod on a stub mandrel. Next make a locating pin to fit the bore of the eye, and mount this squarely on a steel block which can be clamped in the groove of the four-jaw chuck, in place of one of the jaws. By setting the eye of the rod on this pin, at the required distance from the chuck centre, and using the other three *jaws* to *centralise* the big-end, the parallelism of the two eyes is definitely assured. When set for the first rod, the rod is fixed in position for the other three, which will then ensure that the length of the rods between eye centres is exactly the same.

If machined in this way, there should be no question about the correct alignment of the rods when assembled, but in order to check up on any possible errors, the rods should all be assembled on the crankpms, and the crankshaft temporarily assembled in its bearing endplates. The position

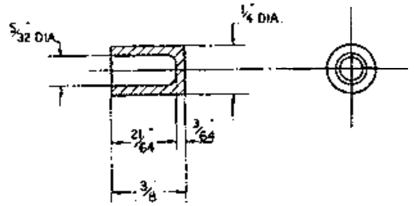


Fig. 18. Valve tappets (8 off)

of the rods can then be seen from the tops of the cylinders, and it will be instantly apparent if they are out of centre ; this should be checked at both ends of the stroke, and correction made, if necessary, not by bending the rods, but by machining away the face of the little end boss. It is better to allow plenty of side play between the little end boss and the piston bosses than to risk binding on either side ; but the dimensions shown on the drawings do not allow for definite end play, because of the desirability of obtaining maximum permissible bearing length in the little ends.

Gudgeon Pins (Fig. 17)

These may be made of mild steel and case-hardened, or of high-tensile steel, without subsequent hardening. They are drilled through the *centre,* and fitted with soft brass or aluminium end pads in the usual way.

Valve Tappets (Fig. 18)

These also are best made of mild steel and

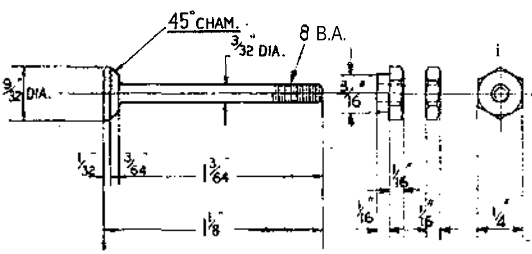


Fig. 19. Valves, with adjusting and locking nuts (8 off)

case-hardened. They consist of light thimbles, eight in number, which should be finished to a smooth sliding fit in their guides. In order to lighten them as much as possible, they are drilled in the centre, and the end of the hole should be finished with a flat-ended drill or D-bit, chamfered or rounded at the corners. The bottom end face should be finished dead smooth and true, and hardening is essential. If desired, two or three fine oil grooves may be turned in the outside of the tappet to distribute oil and check oil creeping.

It has not been thought necessary to bush the tappet guides, as this would call for a somewhat awkward boring operation, the diameter of the bush seating being larger than the entry passage through the valve port. The side thrust on the guides is not heavy, and no great wear and tear at this point is expected ; but bronze bushes may be fitted if the constructor is prepared to go to the extra trouble entailed in doing so.

Valves (Fig. 19)

Although it is not necessary to use special valve steel for making these, something better than ordinary mild steel is desirable. Good results have been obtained with 3 per cent. nickel steel, and also with stainless steel of the " free cutting " grade ; high-tensile stainless and other special steels are generally very difficult to machine, and are best avoided for delicate components which call for accuracy and good finish.

The valves may be turned at one setting and parted off, the use of a running-down tool being helpful for ensuring a smooth, parallel finish on the shank. If only the ordinary tools are available, however, it is advisable first to turn down the extreme end of the shank to finished size, chamfer off the end, and support it with a hollow centre while turning the rest of the shank. A slight radius should be left under the head, and the seating face should be turned by setting over the top slide to 45 degrees-not by the use of a bevel forming tool, which is very liable to leave waves in the finished surface, and thereby prevent the valve from seating properly.

It is important that the shank of the valve should fit the guide closely, so as to avoid the possibility of air leakage, but it must on no account be tight or sticky to cause sluggish or erratic action of the valve under working conditions.

Owing to the small diameter of the valve stem, the problem of retaining the spring is a rather delicate one, as the usual methods were impracticable, and it has been decided to use screwed valve stems, with lock nuts, as this method has proved highly satisfactory on the " Kinglet " and other small engines. This also provides an extremely simple method of tappet adjustment. The upper nut is shouldered to centre the spring, and the lower one is a standard thin lock nut ; both nuts should be case-hardened, and it will be noted that the thrust of the tappet is taken on the face of the nut, not on the end of the valve stem. A slot should be cut across the valve head, so that a screwdriver can be used to hold the valve while adjusting and locking up the nuts.

(To be continued)

*A 15-c.c. FOUR-CYLINDER ENGINE

By Edgar T. Westbury

WE come now to a part of the construction which involves quite a few knotty problems in layout and execution ; namely, the camshaft and timing gear. Many prospective constructors of multi-cylinder engines have been deterred by the apparently formidable task of making and setting the cams ; while others, starting out lightheartedly, but with no very definite idea of procedure, have met their Waterloo when this stage of construction was

In a published design for a multi-cylinder engine, which I once examined, the camshaft details supplied were very vague, and the instructions " File cams as required " struck me as being delightfully optimistic ! While it is no doubt possible to make a camshaft in this way, the chances of it being accurate, either in respect of cam contours or their timing, are very remote ; and it is equally unlikely that an engine fitted with such a camshaft would develop the best possible efficiency. Much of the success of multi-cylinder engines depends upon obtaining equal efficiency from all the cylinders, and the importance of uniformity of valve lift and timing is beyond all question.

However, like many problems in life, the anticipation may be worse than the real thing, and it is possible, by adopting commonsense methods, to make the production of an accurate camshaft not only a fairly straightforward, but also an interesting exercise in machining. In the construction of the twin engine for " I83I," problems of a similar nature were encountered, but the methods evolved for dealing with them proved to be highly effective, as many constructors of the engine can testify. The present engine has twice as many cams, and they are smaller in dimensions, but the same methods are applicable, and I propose to adapt them, with suitable modification of detail, to the job now in hand.

It may be remarked that in the making of a camshaft, one has the choice of making the cams separately, and mounting them on the shaft, or machining the cams in position as an integral part of the shaft ; just as, in steam-engine construction, cranks and eccentrics may be built up or machined in one piece. To many constructors, it may appear that the former method is the simpler, and this is quite correct in certain cases. It would, for instance, very much simplify the production of the cams, and ensure their complete uniformity of shape, if all of one kind were clamped together in a bank, and formed at once. The four inlet cams and the four exhaust cams could thus be dealt with in two operations. Unfortunately, however, with cams made in this way, further problems arise, not only in the secure attachment of the cams to the shaft, but even more so in ensuring their correct relative position to other cams. I do not know of any really simple way of setting separate cams of the size now under consideration, in such a way as to

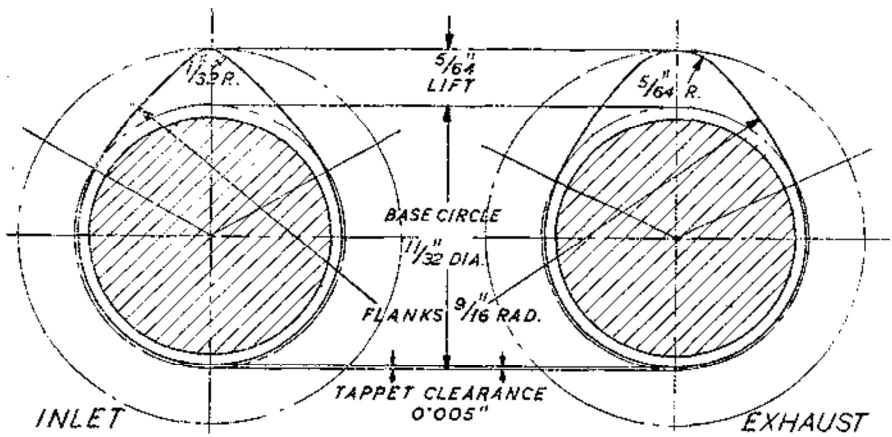


Fig. 20. Contours of inlet and exhaust cams (four times full size)

be quite sure of their correct angular location within a limit of one degree of camshaft angle, which represents two degrees of crankshaft angle.

For this reason, I strongly recommend the use of a solid camshaft with all the cams formed on it. This calls for careful setting out, and it is obviously necessary to eliminate the possiblity of errors, as they cannot afterwards be corrected ; but it enables the cams to be timed to a very close limit of accuracy, and there is no risk of individual cam timing ever becoming altered.

Continued from page 491, " M.E.," April 17, 1947.

Camshaft Blank

Details of this will be given later, and its production is a fairly simple turning operation, which can be carried out between centres. The material recommended is a good case-hardening mild or low alloy steel, and if one is able to exercise any choice in the matter, try to select a make or grade that can be guaranteed to distort very little in quenching. Steels vary enormously in this respect, but if little is known about the steel used, normalising before machining is helpful.

Hardening of a long shaft is always bound to be fraught with some risk, and it would be very nice if we could dispense with it in the case of a component which calls for a good deal of previous machining, such as a camshaft! because it is a serious matter if the part is spoiled by distortion or hardening cracks. However, a soft cam is impracticable, as it would soon lose the accuracy of its profile, even if made of fairly hard-wearing material. The only possible‘ alternative to hardening is the deposition of a hard chrome layer on the steel, which I have not tried out for this particular purpose.

It is practicable to straighten a distorted shaft, though this may be a rather tedious job. To facilitate it, and avoid cracking, the shaft between the cams should be left soft, but there may be some difficulty about this in practice. In production, the usual method of obtaining soft zones in a hardened component is to leave these parts well oversize until after carburising, and then machine away the carburised surface, prior to reheating and quenching. There are other ways of producing local hard and soft zones in machined parts, but generally speaking, they are either more troublesome or less reliable-sometimes both.

All this may sound very complicated, but it will be found much better to consider all eventualities than to blunder in with haphazard methods and finish up, as likely as not, with a spoiled camshaft, after many hours of patient work.

To avoid the risk of hardening cracks developing, small but definite internal radii should be left in all corners of the camshaft. This may appear to be a very small matter, but a " fillet " or radius helps to distribute stress and to prevent the formation of a focal point from which a crack may start and spread. I know of many failures in highly-stressed parts, not only in models, but also in full-sized engines, which have been directly due to stress localisation in sharp corners. Hardened parts are particularly important in this respect, as the sudden change of state in quenching introduces surface stresses in the metal at the corners.

It is advisable, though not absolutely necessary, to defer the finishing of the journals at the ends of the shaft until after the cams are formed, but they should be turned to a definite size to facilitate their fitting to the cam forming jig, which will be described later.

Cam Contours

Before machining the set of cams, their contours should be fully determined and understood. It may be remarked that the contours selected for these particular cams are dictated more by convenience in production than the desire to obtain the utmost ounce of efficiency from the engine, though the latter consideration has not been entirely neglected. In other words, the shape is a compromise between that which gives best results, and that which is easiest to form accurately ; and this is true of most cams used in automobile practice, other than those of specially-made racing engines.

The duty of the cams, at speeds within the range for which this engine is designed to work, is fairly easy, as the inertia of the moving parts of the valve-gear is kept as low as possible ; in this respect, it may be noted that a side-valve engine is at a great advantage over one with overhead valves, especially when the latter is designed for high performance, involving maximum strength and rigidity of valves, rockers and push-rods. Direct operation of the valves through the light thimble tappets relieves the cams of a great deal of inertia load, and conduces to smooth, effortless working.

Fig. **20** shows the contours of the inlet and exhaust cams respectively. It will be seen that both are symmetrical and have convex flanks, the flank radius being the same in each case, but as the opening period, or angle from the base of one flank to that of the other, is greater in the case of the exhaust valve, the nose of the latter is correspondingly broader. For convenience in forming, all curves in the cam contours are built up of true. circular arcs ; and as the flank curves are all the same, the difference in opening period is allowed for by making the radius at the nose different in the two cases.

The relative positions of the inlet and exhaust cams are determined by reference to the timing diagram, which is shown in Fig. **21.** In accordance with normal practice, this is set out in terms of crankshaft angle, and the opening and closing position of each valve is measured from the top and bottom dead-centres respectively. The timing is fairly normal for an engine of this type, with the exception of the fact that as r.p.m. will be higher than most full-sized engines, and lost motion in valve gear relatively.great, the opening periods and " overlap " are slightly on the full side. This policy, it may be mentioned, has been suggested by experience in timing these small engines.

Having decided on the valve timing, it is now necessary to translate the timing diagram in terms of camshaft angle, which, of course, involves halving all the angles ; it is also more convenient to work around the circle from o to 360 deg. instead of working from top and bottom centres of the crankpin or piston. A single stroke of the piston only represents 90 deg. of the camshaft diagram, and there will thus be two top dead centres and two bottom dead centres shown, but the diagram starts from the top centre of the firing stroke, which is the zero point in the diagram on the right of Fig. **21.**

To further clarify this diagram, the cam contours are superimposed on it, so that the juxtaposition of the inlet and exhaust cams for any one cylinder of the engine, and their relation to their respective crank centre, may be clearly seen. It will thus be observed that as the cams rotate, the exhaust cam commences its lift at 60 deg. from zero point, reaches its full lift at

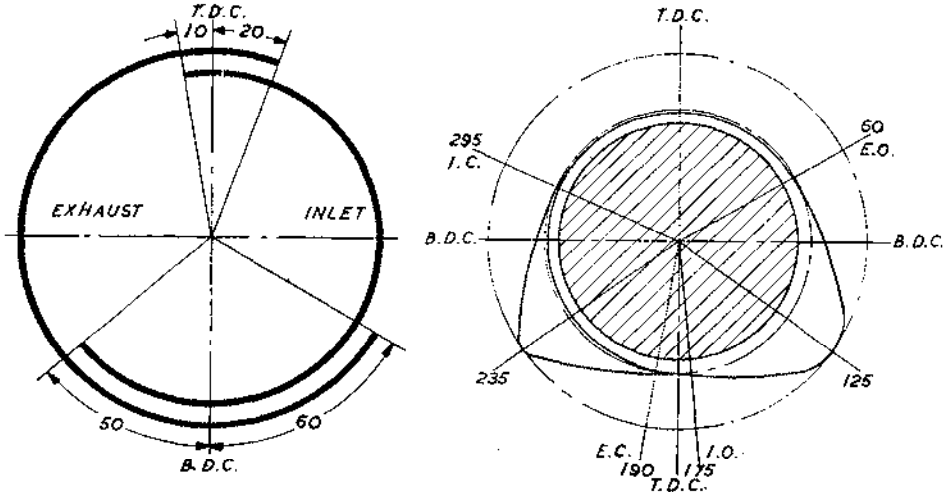


Fig. 21. Timing diagrams, in terms of crankshaft and camshaft angles respectively

125 deg.,and completes its drop at 195 deg. Before the period of this cam is completed, the inlet cam has begun its lift at 175 deg. ; it reaches full lift at 235 deg., and completes its drop at 295 deg., leaving 65 deg. to complete the full circle of rotation.

Arrangement of Eight Cams

1-3-4-2 !!

This gives the positions of the cams for one cylinder only ; *it* is *now necessary to* consider the relative positions of the cams for the other three cylinders. The firing order for this engine is ~~1-2-4-3~~, starting from the timing end, and as the camshaft is geared to the crankshaft with an idler in between, it will rotate in the same direction, which is anti-clockwise at the timing end. Thus the sets of cams for the four cylinders will come into operation in the order given, each set being 90 deg. behind the other in an anti-clockwise direction of rotation.

There are several pitfalls for the unwary in the setting-out of a set of cams, as I can testify, having made quite a few mistakes in my time ! It is very easy to set the cams to give the wrong direction of rotation, or to put the inlets where the exhausts have to be. Correction of these mistakes is practically impossible, so it is advisable to think hard before acting. Note that the sets of cams do not follow in ordered sequence, as regards the endwise position of inlet and exhaust cams ; there *is* first an exhaust cam, then two inlets, two exhausts, two more inlets and finally one more exhaust. These positions have not been selected just to make it more awkward for the constructor, but to simplify manifolding of inlet and exhaust pipes.

The sequence of the cams can be seen clearly by reference to Fig. 22, in which the letters A B C D E F G H refer to the cams in order of their endwise positions on the shaft, and the angular position of each cam is shown, in its relation to the top dead centre of No. 1 cylinder. Note that as No. I and 4 cylinders have their cranks in the same plane, but fire on alternate revolutions, their pairs of cams are in opposite phase. Nos. 2 and 3 cylinders similarly have their pairs of cams in opposite phase to each other, but displaced either 90 or 270 deg. to the corresponding cams of Nos. I and 4 cylinders.

As I have, on many occasions, reminded readers that it is one thing to design components on paper, and quite another to make them exactly *as* designed, I shall proceed in the next instalment of these articles to show how the cams may be produced with simple equipment.

Dead-but Won't Lie Down!

Several times in the past I have had to refer, almost in apologetic terms, to the ancient design of engine known as the " Kestrel," which was introduced to readers in 1937, and might therefore be expected to have earned retirement on a pension. But somehow, the engine-or its constructors-will not accept dismissal, and though " old and rough, and dirty and tough," like Barnacle Bill, it refuses to settle down to a decent and discreet senility. I mentioned some time ago that die-castings for this engine had been produced by Mr. L. D. Johnson, of Birmingham, and it is now brought to my notice that Mr. S. A.

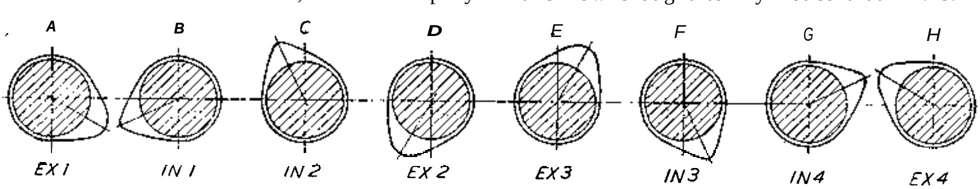
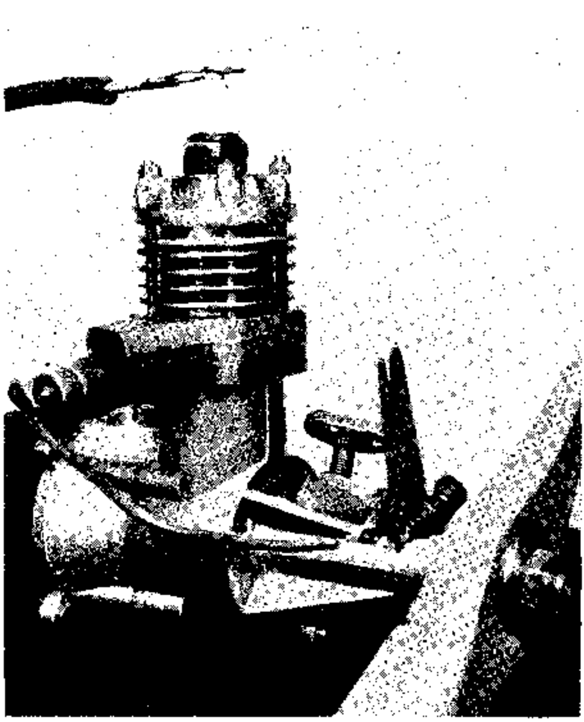


Fig. 22. Relative angular positions of cams, with No. 1 piston at top dead centre

Smith, of Chatham, is using these castings in the production of finished engines? one of which has been submitted to my inspection.

I find that the workmanship is very good indeed, and carried out faithfully to the original design, with the exception of one or two minor details, such as the use of a plain iron piston instead of an aluminium piston with two rings-a modification which is quite in order and in keeping with modern practice. The sample submitted started up readily and ran quite consistently, though being new, and a little on the stiff side, no attempt was made to force the pace or to obtain very high performance. Mr. Smith supplies this engine fitted either for aircraft or racing-car installation, and is prepared to undertake tuning for high efficiency. The appearance of the engine is good, largely due to the quality and accuracy of the die - castings, and those who are looking for a sound, reliable and well-designed engine, might do much worse than try this genuine antique design.



A 5 c.c. Kestrel engine, as produced by Mr. S. A. Smith from die castings supplied by Mr. L. D. Johnson

" Future Plans "

Many thanks to the numerous readers who have responded to my invitation to record their views on this matter. The letters received are all extremely interesting, though hardly any two of them express quite the same opinions, and it would appear that the " Ideal Petrol Engine " is as elusive as the " Ideal Lathe ! " However, there is no doubt that they will be of great value in shaping policy in future articles and designs.

With regard to the judging of these entries, a somewhat dimcult problem arises, in that a few of the letters are from my personal friends, and as I am most anxious to avoid any possible suspicion of favouritism, I have decided to submit the entries to the judgment of independent persons. The result of the competition will be announced as soon as possible and it is likely that in view of their general inerest, it will be found desirable to publish several of the letters, in part or entirely, in THE MODEL ENGINEER.

(To *be continued)*

*A 15-C.C. FOUR-CYLINDER ENGINE

By Edgar T. Westbury

ALTHOUGH the principles and methods employed in forming the cams are generally similar to those which were described in connection with those of the " 1831 " engine, the difference in detail in the two camshafts calls for some modification of the appliances used in the present case. Not only are there twice as many cams, of considerably smaller dimensions, but the method of constructing the jig for the form-machining operation is slightly different.

For the benefit of new readers who have not read previous articles on the design and production of cams, it should be explained that for some years now I have favoured the use of cams in which the contour consists of a blended series of circular arcs. Such cams are reasonably efficient, even for engines of high performance, if the curves are judiciously chosen, and work very smoothly in conjunction with plain flat-ended tappets. But their chief advantage, from the production angle, is that they may be formed, to a close limit of accuracy, by simple methods. The flank contours, which are the most critical both in respect of shape and angular position, can be machined by any method which gives a circular motion-such as by means of a dividing head or rotary table on a milling machine-but even simpler from the amateur's point of view, by plain " common or garden " turning.

The method recommended is to mount the camshaft blank (Fig. 23) in an eccentric turning fixture, so arranged as to present each cam in turn at the correct radius and angle to machine each flank to the required shape. For machining the base circle, a number of similar cuts may be taken at the same radial setting, but with a shift of one or two degrees between each cut ; or as an alternative, a method of circular milling could be employed.

The nose contour of the cams would be much more difficult to machine by this method, and would call for a very elaborate method of setting up, but in this case it is possible to work fairly accurately by hand filing, checked by means of a simple template or radius gauge. As this part of the curve primarily serves the purpose of producing a smooth transition from one flank of the cam to the other, extreme accuracy is of less importance than a smooth blending of the curves.

All this may sound rather complicated to the beginner, but it is not as formidable as it seems, if tackled by sound methods ; and the alternatives are no easier, and much less satisfactory. Apart from haphazard methods of cutting and " trying," which were dismissed in the previous section of these articles, the only other sound methods are (a) copy milling or filing ; (b) tangential milling or filing ; and (c) generating by milling processes.

Copying is a very sound method, and is quite extensively used in production practice, but it obviously calls for something to copy from ; and the production of a master cam, or in this case, a complete set of master cams? all correctly positioned, is no easier than producing the actual cams directly by the methods to be described here. If one had to make a large number of cams, copy milling (or grinding) would be well worth considering ; but as things stand, it does nothing to simplify practical problems.

The use of tangential cams enables forming to be done by filing in the lathe, with the aid of a roller filing rest. I have advocated this method in the past, but one disadvantage of this type of cam is that it cannot be used with a plain tappet, but demands a roller follower, or at least one having a convex working face. A flat tappet used with such a cam would cause the whole surface of the flank to engage the cam at once, with a " slapping " action which would be noisy and mechanically inefficient. It is, of course, quite easy to form a tappet with a cylindrically-curved face, but it must then be prevented from rotating, and this complicates construction in a small engine.

The generation of cam contours, which has been very ably exploited and described by Mr. D. H. Chaddock, is, perhaps, the most accurate method, especially when the cams are designed to give carefully controlled valve motion, but it calls for the working-out of an exact valve lift diagram, and means of controlling both the angular motion of the cam and the feed of the cutter to very fine limits. This method was described in the issues of THE MODEL ENGINEER dated June 9th and 23rd, 1938.

This brief dissertation on means of producing cams should at least convince readers that I have sound practical reasons for adopting the methods to be described-even if they do not agree that these methods are the best which can be devised.

The Cam Turning Jig

The jig used for forming the cams of the " 1831 " engine, as described in THE MODEL ENGINEER, dated September 23rd, 1941, consisted of a round bar, centred at each end, with pillars, or as they may be defined, " headstocks," to form a means of holding the camshaft parallel to the bar, at the correct distance to enable the flanks to be turned to the required radius. It would be practicable to use a somewhat similar method of construction in the present case, but the smaller flank radius limits the permissible size of bar to about 9/32 in. diameter, which is a little on the flimsy side, especially in view of the length and slenderness of the shaft to be supported. It is, therefore, considered better to use a flat or rectangular bar for the " bed " of the jig, the " headstocks " being in the form of split plummer blocks, which may be made from

***Continued from page 556, " M.E.," May 1, 1947.**

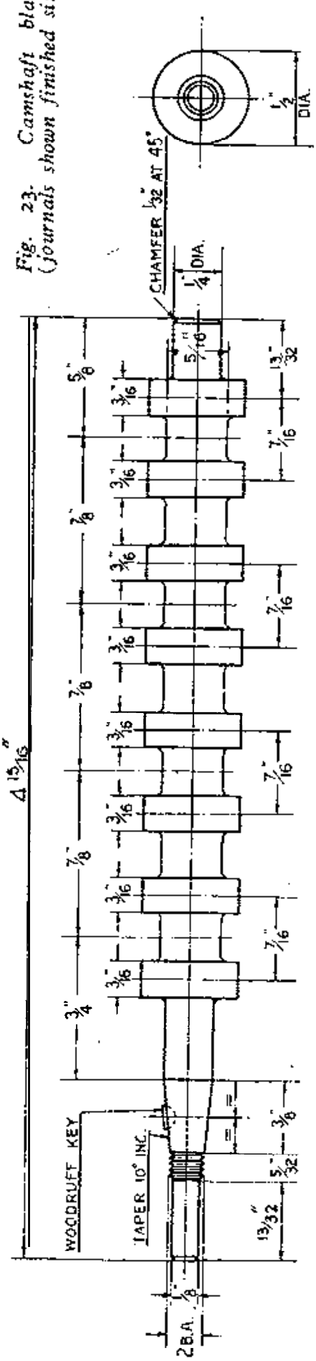


Fig. 23. Camshaft blank (journals shown finished size)

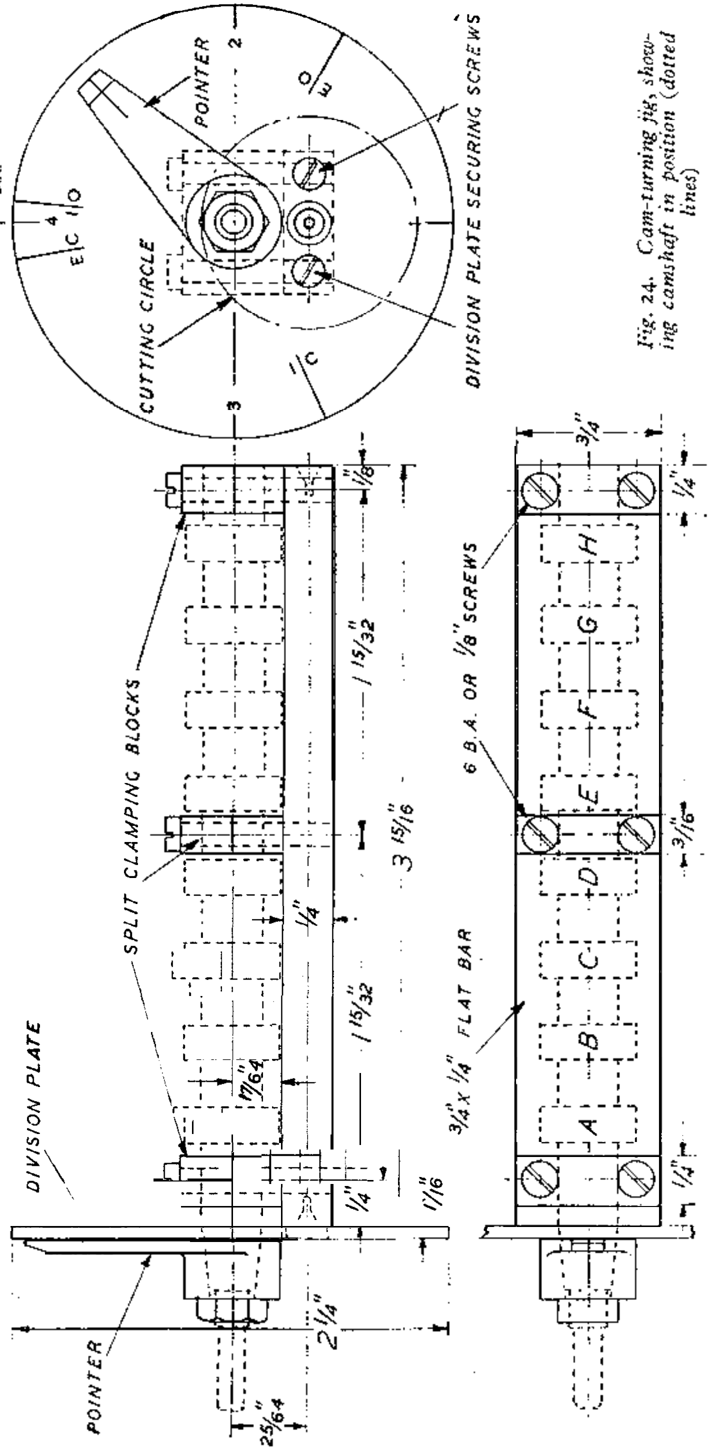


Fig. 24. Cam-turning jig, showing camshaft in position (dotted lines)

a similar section of bar, and each secured to the bed by two screws, as shown in Fig. 24. Three of these split blocks are used, the centre one being by way of a steady bearing to support the middle of the camshaft against spring.

The six pieces of bar which are used to form the three split blocks are all alike, and may be produced by parting off from the rectangular bar. If this is done carefully, very little filing or other truing of the faces will be necessary. One of the blocks may be marked out and drilled for the screw holes, then used as a jig for drilling the others. To drill the cross holes, half in each block of a particular pair, make a vee notch exactly in the centre with a three-cornered file, clamp the pair of blocks together, and drill through the intersection with a small pilot drill ; then open out to slightly under finished size, to allow for reamering on assembly.

The bar to form the bed of the jig should be checked for flatness, as any " wind " will throw the blocks out of truth, after which it is carefully marked out and centre-drilled fairly deeply on each end. Clamp the lower half of each block in position on the bar, using a straight piece of silver-steel rod in each shaft seating as an alignment bar, and " spot " the tapping holes through the holes in the blocks. An identification mark should be made on each half, and also in the appropriate positions on the bed, to show their location and correct way round, when they are dismantled and subsequently reassembled.

After clamping the two end blocks in position, a reamer may be run through both to finally align and size the holes ; if the shaft has been left oversize to allow of final finishing after cutting the cams, this must, of course, be allowed for in the size of the seatings. The centre seating must be finished 5/16 in. diameter, to fit the shaft at this point, so if the ends of the camshaft were left at the same diameter, it would be practicable to line-reamer all three of the seatings together. A paper shim should be placed between the half-blocks to ensure that, after reamering, they may be clamped down to hold the shaft firmly. It is also practicable to use shims under the bases of the blocks, to correct any errors in the height, or radial distance of the shaft from the running centres of the bed.

In order to produce the flank radius of 9/16 in.; the base circle of the cam must be 9/16 in. from the jig centre, and as the diameter of the base circle is 11/32 in., the camshaft centre must be (9/16 in. - 11/64 in.) = 25/64 in. from that of the jig. If a 1-in. bar is used for the bed of the jig, and the running centres are exactly on its centre line, the lower half-blocks must be 17/64 in. thick to bring the shaft in the correct position.

Division Plate

This is attached to one end of the jig, and consists of a plate sufficiently large in diameter to enable the cam timing diagram to be set out on it accurately. As the cams will rotate in an anti-clockwise direction (from the drive end) the marking of the plate will be in reverse, compared to the cam timing diagram shown in Fig. 21. In addition to the zero or dead centre mark on the diagram, which should be marked with the figure I, the plate should have three other marks at 90 degree intervals, marked in order 2, 4, 3, reading in an anti-clockwise direction.

It is most important that all marks on the plate should be clear and definite ; mere scratches or pencil marks are not good enough. If means are available, the plate should be indexed in the lathe and marked with a keen point tool. One need not, however, fear that an error of half a degree or so will prevent the engine from working (it is not guaranteed that the timing is the very best that could be arrived at, anyway) but it is always advisable to work as closely as one possibly can to the specified angles. Mark the valve events clearly to avoid possible risk of error.

The division plate is attached to the end face of the jig by two countersunk screws, tapped into the bar, and extra screws or dowels may also be fitted in the lower half of the split block at this end, if desired, to give further security. Note that a clearance hole for the lathe centre is provided in the plate ; it may be found necessary to use a special extension centre to clear the end of the shaft or the index pointer at this end.

Index Pointer

This is attached to the camshaft, preferably by means of the shift nut, to avoid undue projections, and should be quite firm, yet readily movable when required. The end of the pointer should either be finished to a fine and fairly acute point, or made spade-shaped and provided with a fine radial line ; its length in this case should be a little less than the radius of the plate. When in position the pointer should lie close to the division plate, and its tip should be bevelled off fairly thin to avoid risk of parallax error.

Turning the Cam Flanks

With the camshaft blank in position on the jig, and the index pointer firmly fixed and set to No. I zero point, the jig is set between centres and means provided for engaging it with the driving pin so that it can be rotated. Tighten the screws of the plummer blocks, taking care not to shift the shaft, and then, with the lathe rotating slowly, feed in a sharp turning tool to make a mark on any one of the spaces between the cams. This mark serves as a guide for timing top dead centre on No. I cylinder, and the finer it is the better, so long as it is clearly visible.

Next slacken the shaft clamping screws, and turn the shaft round until the index pointer is exactly at EO on the division plate. It is best to remove the jig from the lathe so that this can be properly seen, using a lens if necessary to make sure that the pointer exactly coincides with the line. Tighten the screws, replace the jig, and all is now set for turning the first flank of the exhaust cam for No. I cylinder, or by reference to Fig. 22, cam A.

It is advisable to use a fairly narrow and well-raked round-nosed tool for turning the cam flanks ; a wide tool is liable to foul the clamping blocks when working on the cams adjacent to them. If possible, select a tool which will keep its edge well throughout the entire operation, as it is most undesirable to have to keep changing tools ; but the actual amount of cutting to be done is quite small, and no difficulty should be encountered with steel that machines reasonably well. Assuming that the blank diameters of the cams are correct within fairly close limits, the depth of cut required to form the flank, down to the base circle, is 0.078 in., which may be measured by means of the index on the cross slide, and if possible, a limit stop should be fixed to ensure that each cam is cut to the same depth. Another way of ensuring that the depth of cut is correct is to temporarily remove the jig and turn a bar between centres to exactly 1-1/8 in. diameter, noting the position of the cross slide index when this size is reached. This, of course, assumes that the radial position of the camshaft on the jig is exactly correct. However, in this case also, dimensional errors are of less importance than errors in uniformity ; and whatever depth of cut is taken in the first place should be adhered to closely throughout the operation.

Having cut the first flank to the required depth, the clamping screws are loosened, and the shaft rotated to bring the pointer opposite EC, when it is again clamped, and the cut repeated on the same cam. Next, shift the shaft to positions IO and IC in turn, and repeat the procedure on cam B. Before going further, it is advisable to take steps to ensure that the points of the cams are readily identifiable, so that in subsequent operations on the base circles there is no risk of cutting them away. The cams at this stage, will look something like the shape shown in Fig. 25, the narrow " land " being destined to become the nose of the cam ; and my favourite method of marking is to apply a dab of quick-drying paint, such as spirit blue? as used for marking-out. If the reason for this is not apparent, it will be later on.

It is now necessary to turn the exhaust and inlet cam flanks for the next cylinder ; but note carefully that these do not follow on in the same order, as C is the inlet and D the exhaust in this case. The timing pointer must be shifted 90 degrees for this pair of cams ; to do this, loosen the clamps, turn the pointer to No. I zero, and re-tighten the clamps. Then loosen the pointer on the shaft, turn it to No. 2 zero, and re-tighten it. In all these moves, care should be taken to work as accurately as possible to the marks.

Operations on the second pair of cams are identical with those on the first pair, and it obviously matters little which of the two cams is dealt with first, so long as they are in their right places. Next, the pointer is again shifted 90 degrees in an anti-clockwise direction, bringing it into position for cams G and H, the inlet and exhaust respectively, for No. 4 cylinder. The final shift, to No. 3 ***zero,*** brings the pointer into position for cams E and F.

It is now necessary to remove the unwanted material from the base circle, and this may be done mainly or entirely by further turning cuts, shifting the cam as required to bring the projecting portions to the top position, exact dividing not being essential in this case. Most of the metal can be removed in about five cuts, leaving the cams as shown in Fig. 25, C and D ; further " nibbling " cuts at small angular intervals, obviously the more the better, will produce almost a true circle, concentric with the camshaft bearings. A mere touch with a smooth file and emery cloth is all that is necessary to complete the job.

Note that the base circle is undercut to provide tappet clearance ; the amount of clearance which I have allowed may seem excessive to some constructors, but the reason is to take care of slight eccentricity which may be caused by distortion of the camshaft in hardening. Whatever amount of clearance is decided upon, however, the tool should be fed in deeper by this amount for machining the base circle, as compared to the cam flanks. To produce the " run-out " where the base circle joins the flanks, the " nibbling " cuts should be taken within about five degrees of the flank positions either way.

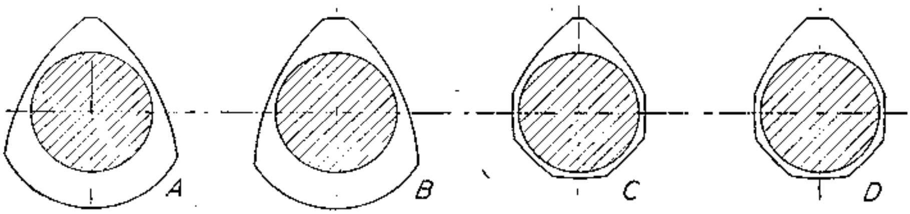


Fig. 25. (A and B). Inlet and exhaust cams after cutting flanks; (C and D). The same cams after " nibbling " base circles in five positiom

It now remains to finish the noses of the cams, and I have not been able to devise a simpler or more. satisfactory method for this than hand filing. Radius gauges may be made by drilling holes of appropriate size in a thin piece of gauge plate (a softened carbon steel hacksaw: blade is suitable) and cutting away all except the required segment of the circle. After taking off the sharp corners. to approximately the required amount, and dealing in the same way with the sub-angles, a dead smooth watch pivot file should be used for finishing, using it with a rolling motion, which assists in producing a smooth, flowing curve to blend exactly with the tip and the two cam flanks. After hardening, the cam surfaces should be polished with fine emery cloth.

If this method of producing a four-cylinder camshaft appears too difficult and tedious for intending constructors, I can only say that it is the one I have found most satisfactory for achieving the desired ends with simple appliances, and as that doughty warrior of the last war but one, " Old Bill," would say-" If you knows of a better 'ole-go to it ! " But don't keep the secret of this superior orifice to yourself-tell us all about it, because I, for one, should be grateful for any information which would simplify or inprove methods of producing this very important component.

(To be continued)

PETROL ENGINE TOPICS

*A 15-c.c. FOUR-CYLINDER ENGINE

By Edgar T. Westbury

HAVING completed the camshaft by turning the journals to size, case-hardening and polishing the cams and journal surfaces, the bushes in which it runs can now be made. These are plain bushes, made from medium hard gun-metal or bronze, and pressed into the ends of the camshaft tunnel. If desired, they may be secured or positively located by grub screws tapped into the walls of the main casting, but with reasonably good fitting, this should not be necessary.

and the gears should not be difficult to cut in the lathe, or have made *to* order. I strongly recommend that model engineers should tackle their own gear-cutting problems wherever possible ; the equipment necessary is by no means elaborate, and sufficient information has been given in THE MODEL ENGINEER articles, including the recent series on " Milling in the Lathe," to enable even the beginner to grasp the essential procedure.

Should it happen that 40 d.p. cutters are not

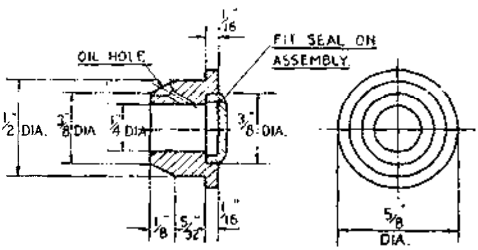


Fig. 26. Flywheel end camshaft bush

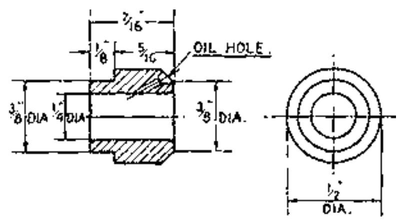


Fig. 27. Timing end camshaft bush

Oil holes should be drilled obliquely from the inner end of each bush, and well countersunk to catch oil splashed up by the cranks, the holes being disposed upwards or slightly inclined towards the cylinders. A blind-ended bearing is desirable on the flywheel end of the camshaft, to avoid oil leakage at this point, but in view of the difficulty of finishing a blind bore accurately, it is suggested that the bush should be drilled and reamered right through, and the seal, if any, fitted afterwards. As there is only 1/8 in. between the end of the camshaft tunnel and the flywheel, however, there is not much room to fit anything projecting beyond the flange of the bush, and the best thing to do will be to make a little recessed cap, to be pressed or sweated into the counterbore at the mouth of the bush. (Fig. 26.)

This fining is only advocated in the interests of keeping the engine externally clean, and in the event of it not being considered necessary, the counterboring of the bush may also be dispensed with.

The inner end camshaft bush (Fig. 27) is turned down to act as a dowel or aligning spigot for the timing endplate. It is, of course, essential that the outside of each bush should be quite concentric with its bore, and the usual precautions should be taken to ensure this.

Timing Gears

The gears specified for this engine are 40 diametral pitch, with **20** and 40 teeth respectively ; both the size and the pitch are very common,

**Continued from page 615 " M.E." May 15, 1947*

available, the pitch of the gears may be modified within fairly wide limits, so long as the correct ratio of gearing is maintained, and pitch diameters approximate. Gears from, say, 30 d.p. to 60 d.p. are permissible, though the finer pitches require to be cut very accurately to run sweetly ; with ordinary gear-cutting facilities, it will generally be found that gears with a small number of teeth work quieter and wear better than those with a large number of teeth. It is quite in order to use metric pitch teeth, despite the slight variation in diameter which these entail, because the use of a " staggered" idler enables the meshing of the gears to be adjusted to compensate discrepancies in this respect.

For best results, the gears should be made of dissimilar materials. I recommend that the large spur wheel should be of bronze, and the two pinions of mild steel, that on the crankshaft being left soft, and the idler case-hardened. In this way, each of the gears will mesh with one of different wearing properties.

The spur wheel (Fig. 28) fits a taper on the camshaft, and in addition, a small Woodruff key is shown to enable positive timing location to be obtained. It is possible to cut this keyway with one of the small rotary cutters of the " dental burr" type, and to plane the internal keyway with a tool in the lathe ; but keying at this point should be regarded as an optional feature, and speaking from personal experience, I regard a well-fitted taper as ample security.

There is, of course, the objection that in the absence of positive location, the camshaft must be re-timed whenever the engine is re-assembled after dismantling, but this is by no means a formidable undertaking, and the friction fitting allows of small adjustments in timing to be made for experimental purposes. Cutting small keyways is a rather finicky job, even with the best care and skill, as it only needs one or two thousandths error in the centring of the cutter to produce a serious angular error in a shaft of this size. This can be corrected by fitting a stepped key, but I imagine few good engineers would condone this expedient.

The crankshaft pinion (Fig. 29B) not being on a taper, is rather different in this respect. My usual practice is to fit a small " snug " key in the boss of the pinion, adjacent to the shoulder of the shaft. This can be located on assembly, after the position of the pinion has been determined. It is only necessary to drill a No. 53 hole through the boss and into the shaft, sufficiently deeply to provide a secure seating for a pin made of 16-gauge steel wire, slightly tapered at the end. The hole in the pinion is then slotted out, as at C, Fig. 29, so that it can be assembled or removed from the shaft, the pin, after driving in, being filed off so that it does not project above the pinion boss.

It should be noted that pre-location of both crankshaft and camshaft keys is hardly practicable, because the three gears in the train are not in a straight line, or even necessarily in exactly determined relative positions, so that it would be a complicated (and in this case, rather unnecessary) matter to set out the positions of the keyways relative to the gear teeth. Incidentally, this difficulty is by no means non-existent, even in production practice ; I have recently encountered an instance where several thousand gears were ordered from a well-known gear-cutting firm, with very explicit instructions regarding the position of the keyways. The instructions were accepted as quite explicit and practical by the gear specialists, but when delivered, all the keyways were found to be at different angles to the gear teeth!

Idler Gear Stud

The idler gear (Fig. 29A) is intended to run on a " dead " shaft in the standard arrangement of the engine, though an optional arrangement, should it be desired to take an external drive from this gear, is to fix it on a " live " shaft running in a bush in the timing cover. One disadvantage of this arrangement, however, is that it is a little more difficult to ensure the meshing up of the gears in their correct timed positions before putting on the timing cover ; and as auxiliary drives can be provided in other ways, it is considered better to use this pinion as its name implies, and nothing more.

On account of the proximity of the idler gear centre to the edge of the ball race housing, it is not practicable to screw the fixed stud into the face of the endplate, unless the rather awkward arrangement of a "joggle " stud with a considerable amount of eccentricity is adopted. The best way, therefore, is to make the stud with a flanged foot, as shown in Fig. 30, and secure it to the endplate by two screws, the outer end of the stud being secured in the timing cover by a nut. This makes the location and fitting of the stud, to give correct gear meshing, quite a simple matter.

The procedure recommended for this operation is as follows : Temporarily assemble the camshaft spur gear and the crankshaft pinion in their running positions, either by assembling the essential components of the engine, or preferably, by fitting dummy shafts to work in concentric bushes in the timing endplate. Assuming the idler stud to be made from g-in. dia. steel, one side of the flange will have to be cut away, but the other may be left on temporarily, to facilitate holding the stud in place on the endplate by means of a small tool-maker's clamp or similar means. Adjust the position of the stud, with the pinion on it, till the gears run quite smoothly and silently with the minimum backlash ; then mark out and drill the holes for the two countersunk fixing screws.

It will be seen that the idler stud is hollow, and cross drilled on the under side to form an oilway. A hole should be drilled through the timing endplate, to line up as closely as possible with the bore of the stud, and thus allow oil mist to pass through from the crankcase to lubricate the bearing. It may be mentioned that " dead" shift bearings are often difficult to lubricate, because the common practice of drilling a radial hole in the boss of the running member only defeats its own object by throwing the oil out by centrifugal force. This trouble is very prevalent in certain engines which have the cams and timing gear mounted on a sleeve which rotates on a fixed stud. The only way to lubricate this type of bearing properly is from the inside of the shaft.

After fitting, and completing the shaping of the base flange, the stud should be case-hardened, leaving the threaded end soft, cr "letting it down " by subsequent re-heating. The heads of the fixing screws must not project above the base flange, or they will foul the gears.

Location in Timing Cover

It is not absolutely necessary to fix the idler pinion stud at the outer end, but it is desirable on the grounds of extra security. This entails drilling a hole in exactly the right position in the boss of the timing case, to take the threaded end of the stud, and some constructors may consider it rather a difficult matter to locate this hole properly.

The method recommended is as follows : First set up the timing endplate in the lathe, with the idler stud fixed in position, and set to run dead truly. A convenient way of setting up is to pack the endplate up with a parallel ring or flat plate having a hole large enough to take the endplate spigot, and clamp it to the faceplate with a single bolt through the camshaft bush seating, leaving the main joint face clear. The stud should be centred with the aid of a test indicator, if available, to the closest possible limit of economic accuracy.

While the endplate is still set up in this position, the screws securing the stud are removed, and the timing cover is assembled in place, securing it by two or three screws. The boss for the stud may now be centred with a centre-drill, then drilled to take the stud, and spot faced, with the assurance that the hole will line up exactly with the stud on assembly.

Poetic Interlude

A few days ago I received the following cryptic message from a reader :

" Just of late, in our dear old " M.E."
Has appeared an engine of 15-c.c.

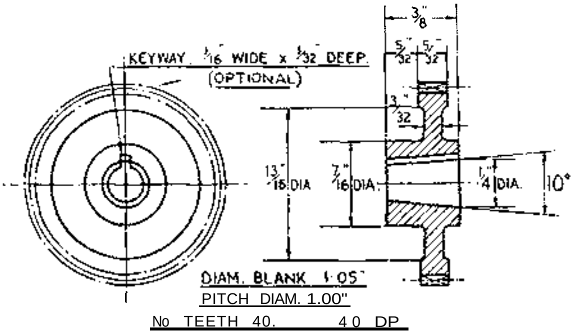


Fig. 28. Camshaft spurgear

With regard to this, your protege,
Your E's, I agree, are quite O.K.,
But although I'm sure you're not a liar,
It's a three, not a two, that you require."

After much exercise of the grey matter, or what is left of it, I came to the conclusion that this constitutes a reference to a slight error in the type number of the ball races used for the main bearings of the Seal engine, which, are 3/8 in. bore by 7/8 in. outside diameter by 7/32 in. wide, and were described as-EE2's, but which I find are actually EE3's.

My reply to this very helpful correspondent was as follows :

Dear friend, I thank you for your mild correction,
I find 'twas my mistake, on close inspection ;
Not only must I mind my P's and Q's,
But also, it would seem, my 3's and 2's !

arranging for supplies. Although one is now deprived of the well-worn ex use so popular, but a couple of years ago-" There's a war on ! " — I should think hardly any reader would need reminding that at the present time there are many factors which are equally effective in holding up and delaying work or the delivery in goods. Castings are particularly difficult at present,

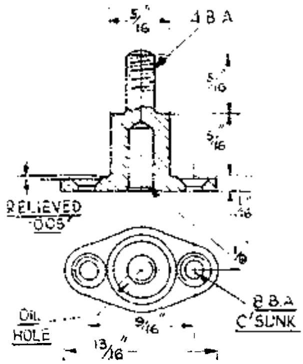


Fig. 30. Idler stud

owing to restrictions in both metal and fuel supplies, and I may mention that the last time I called at the foundry I found the proprietor out-touring the district on his bicycle, in the vain attempt to obtain a bag of coke to run his furnace ! In these days of universal frustration, I beg of readers to spare both themselves and me unprofitable and embarrassing correspondence on this matter, even though most of us may feel that the quality of patience is already strained well beyond the elastic limit.

Miniature Coils and Magnetos

Some time ago I referred to the miniature magnetos which are now produced by the Model Ignition and Accessories Co., of Ewell, Surrey. I have now heard from several readers who are using these magnetos successfully, including Mr. F. G. Buck, of Stoke-on-Trent, who informs

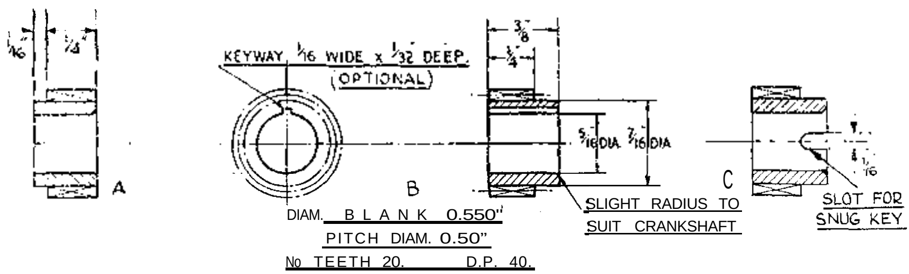


Fig. 29. Pinions : (A) idler, (B) crankshaft pinon ; (C) alternative and simplified method of keying pinon

Castings and Parts for the " Seal " Engine

Despite the assurance that these would be available, as soon as possible, and that an announcement would be made when they were ready, hardly a day passes but enquiries are received on this subject, and I have been rebuked by quite a few readers because of the delay in

me that a magneto of this type is working quite well on his record-breaking model car, and has enabled its performance to be still further improved.

I have recently inspected and tested two of the latest productions of the above firm : the M.I. " Unit" magneto, and the M.I. lowconsumption miniature coil. The former item is intended to simplify the adaptation of magneto ignition either to new or existing engines, be enabling the magneto to be built into the engine structure, instead of being an entirely separaty machine coupled to or otherwise driven from the engine shaft ; a method which I have used in my own engines, and recommended in past articles.

The essential components--coil, stator and rotary magnet-are the same as those of the standard magneto, but the unit is not fitted with bearings or contact-breaker, as it will utilise those already fitted or designed for the engine. No condenser is necessary with these magnetos, though a small one connected across the points will increase their working life. The weight of the unit is 23 oz.

The M.I. " Lightweight " coil is wound on fairly orthodox lines, but achieves unusual economy of current by improved efficiency of the magnetic circuit, which is partially closed, and uses a special high-permeability alloy. It takes only 85 milliamps at 3 volts, and will work off a 2-cell " Penlite " dry battery ; weight of coil, $1\frac{3}{4}$ oz. This coil has been used successfully by Mr. J. Cruickshank in his 10-c.c. model racing car.

There is, perhaps, one comment which should be made *on* the use of any ultra-miniature ignition equipment, to avoid disappointment by users, who are sometimes prone to expect too much from it in the way of electrical output. Although these tiny coils or magnetos are wonderfully efficient for their size, it must be fairly obvious that they deal with very small amounts of electrical energy, and that the spectacular sparking obtained from larger equipment is out of the question.

The ultimate function of any coil or magneto is to provide an effective ignition spark to run an engine at full efficiency ; no matter how long or " fat " the spark may be, it cannot do more than this. I have heard the complaint that the spark obtained from lightweight coils or magnetos is very thin and almost non-luminous ; but it is a fact that this tiny spark, properly applied to the plug, will effect ignition, just as surely as one absorbing half a kilowatt of energy.

(To be continued.)

PETROL ENGINE TOPICS

* A 15-C.C. FOUR-CYLINDER ENGINE

By Edgar T. Westbury

BEFORE leaving the timing gear, one or two comments on the details which have been described may be advisable, to anticipate possible queries. It will be seen that the flange of the idler stud overhangs the bore of the main bearing and that the screws securing this stud have to be kept fairly close to the bearing. If the screws were the only means of securing the stud, this might well be considered an inadequate form of mounting, but in fact it is only necessary for the described, this matter will be referred to later.

The timing pinion on the crankshaft is held in place by the nut on the end of the shaft, acting through a sleeve which is a running **fit** in the bore of the timing cover, and acts as an oil retainer. Details of this sleeve have not yet been given, but will be shown later, and in the event of the engine being coupled to the drive at the timing end, the coupling, sleeve and shaft nut may be made all in one piece ; alternatively,

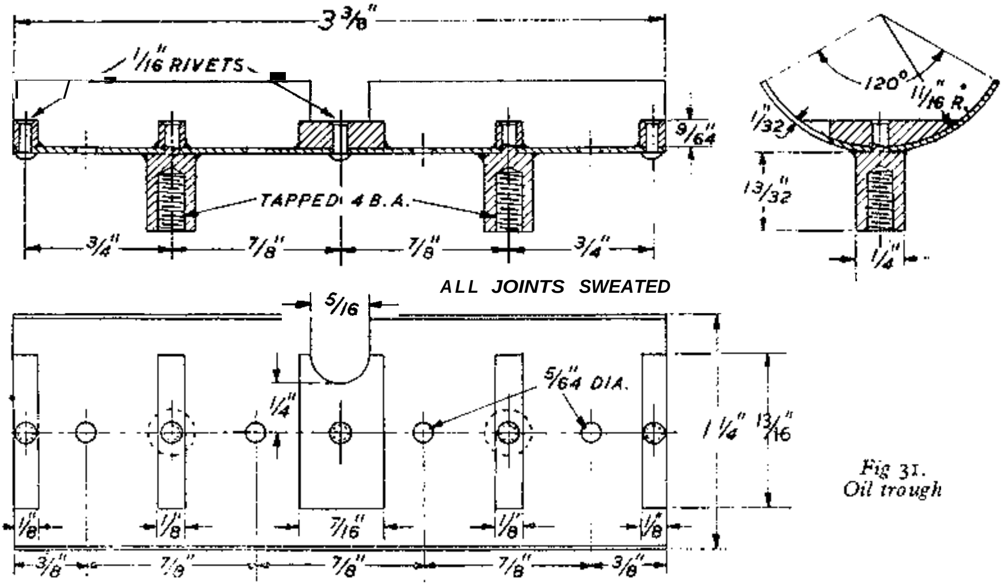


Fig 31. Oil trough

screws to hold the stud in place while timing gears, before the timing covei is assembled, after which the nut on the stud will provide further security.

The flange seating might be improved by leaving an internal lip on the outer end of the bore of the bearing housing, but it is important that this should not bear against the end of the ball race, which should be free to take its own end location .at the timing end.

It may be found necessary to mill or otherwise remove a little material from the inside of the timing cover, to clear the lower foot of the idler stud flange. There is plenty of material in the casting at this point to allow of doing this without impairing the joint surface to any undesirable extent.

The hole in the timing cover for the end of the camshaft will have to be made larger than shown in the detail of this component, for the recommended method of fitting the ignition distributor, but as one or two optional arrangements will be

** Continued from page 666, " M.E.," May 29, 1947.*

a starting dog or similar device may be substituted for the coupling.

Oil Trough

The methods adopted for lubricating small petrol engines have, in general, been rather primitive, and although they have served their purpose more or less satisfactorily for runs of short duration, there is much room for improvement by the adoption of more positive, automatic and reliable means of supplying oil, especially when the engine is intended for long continuous running without attention. Unlike the two-stroke engine, in which oil can be taken in with the fuel, the four-stroke type of engine calls for separate oiling arrangements, though there are many practical advantages in keeping the lubrication apart from the fuel feed in any engine. As the mixture does not pass through the crankcase of a normal four-stroke engine, it is possible to keep fairly large quantities of oil in circulation, and to use the oil as a coolant as well as a lubricant.

I have described several methods of lubricating engines in the past, including automatic forced

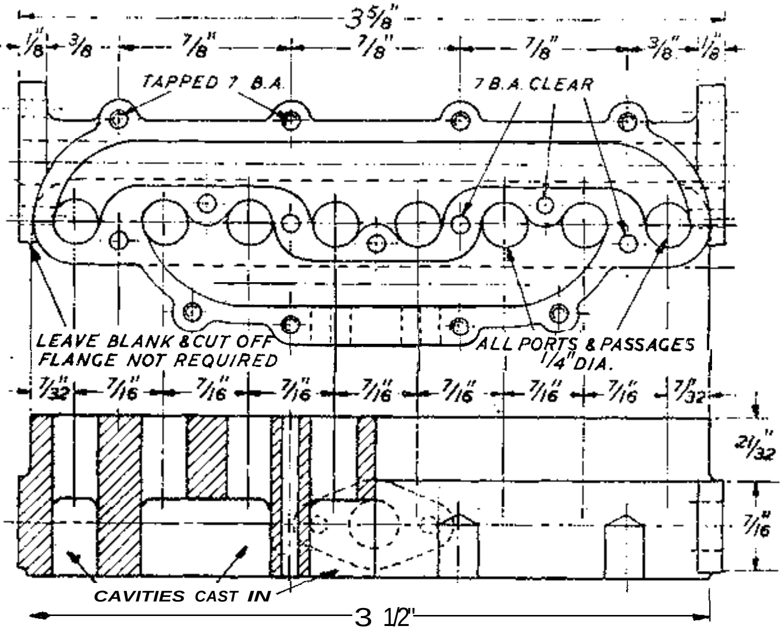


Fig. 33. Inlet and exhaust manifold body casting

lubrication by means of engine-driven pumps of various types. It is quite practicable to fit a pump on this engine, though the restricted space makes this rather difficult, and a positive supply of oil to all the big-end bearings entails drilling oil passages in the crankshaft, which many constructors consider to be a formidable undertaking. On the strength of experience with previous engines, I have decided that a pump may safely be dispensed with, and that adequate lubrication can be obtained by simpler means, to supply all requirements for anything short of a highly-tuned racing engine.

Gravity systems of lubrication-often loosely referred to as " splash " lubrication-can be made to give quite good results, but are not quite

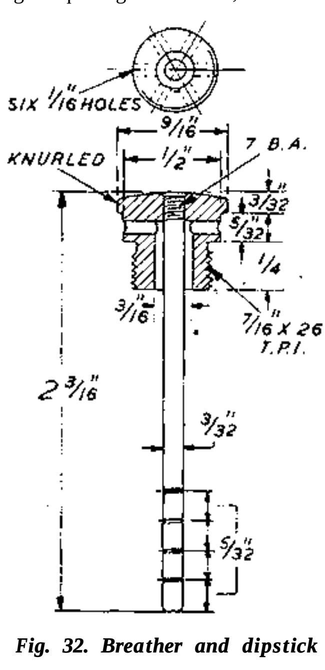


Fig. 32. Breather and dipstick

as simple as they appear ***on*** the surface. The basic form of splash lubrication, in which the base of the crankcase is filled with oil up to a level sufficiently high to allow the big-ends of the connecting-rods to dip in it, and thereby splash oil lavishly all over the working parts, is only practicable in engines which run at comparatively low speed-up to a few hundred r.p.m. At high speeds, the big-ends simply " cut a hole " in the oil, and rotate without picking up any appreciable quantity of it ; thus one may encounter the paradoxical but not unprecedented condition of " starvation in the midst of plenty." Extending the rods to form dippers may make things worse instead of better, especially when scoops or impact ducts are used with the intention of conveying oil directly to the crankpin bearings. A further upsetting factor in an enclosed engine is the agitation of air inside the crankcase, which acts in the same manner as an Atlantic gale, to whip up the oil and destroy all semblance of a definite oil level. I have formed the conclusion that at anything above two or three thousand r.p.m., oil cannot exist in a true liquid form in the main crankcase of a small engine, but is scattered around in small drops and oil mist, with no chance to settle in the bottom for a moment.

It is, however, possible to arrange baffles in the crankcase so that the oil has a chance to settle in the sump without undue disturbance. This does not, however, solve the essential problem of getting oil to the bearings, unless some means is provided for continuously lifting it either to provide direct oil feed or spray. Many engines for motor cars and similar purposes have been fitted with a pump to pick up oil from the sump and fill troughs under each big-end bearing, which although being constantly emptied by the sweep of the moving parts, are

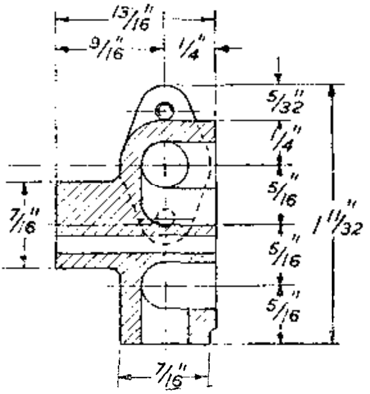


Fig. 34. End section of manifold body

as persistently refilled, so that oil is always present to provide the requirements of the splash lubrication system.

A still simpler version of the same idea consists of using gravity to effect continuous replenishment of oil in the troughs. The latter are made fairly deep and the sump is filled up to a fairly high level-it may even be above the top of the troughs without doing harm. Holes are provided in the bottom of each trough, so that when the engine is running, oil seeps up from below to take the place of that swept away by the movement of the cranks.

This method has been used by me in many small engines, and has been found to give extremely good results in practice, so that I have no hesitation in recommending it in the present case. Once again, it is an optional feature, and may be modified or elaborated as the constructor may desire, but in the form shown, it will satisfy normal requirements, except when the engine is required to run with the crankshaft axis considerably inclined to the horizontal plane.

The oil trough illustrated in Fig. 31, is designed to be fabricated from brass or copper sheet ; a casting might be used, but offers few, if any, advantages, and the trough is so simple to make that it would hardly be worth while. It will be seen that partitions are fitted to the trough, each secured by a single rivet and sweated. The two feet by which the trough is mounted in the sump are extended and reduced in size to act as rivets for two of the partitions. A slot is cut in the centre partition to clear the dipstick, giving ample clearance, so that the latter is not liable to be scraped when it is lifted out to test oil level.

Fitting and Adjusting

The trough should be fitted so that it only just clears the big-ends, and the oil feed holes should be as nearly as possible under the centre of each crankpin. No details are shown in the sump drawing of the holes for the countersunk screws which secure the feet of the trough, but their position will be fairly obvious, and it may be mentioned that spot-facing on the inside of each hole is desirable, to provide a good surface for the feet, and avoid risk of oil leakage at this point. It will be necessary to tilt the sump sideways to get the trough in when assembling, but if any difficulty is experienced, the aperture in the bottom of the main casting may be widened, though it is not desirable to reduce the baffling effect of the rim more than is necessary.

Breather and Dipstick (Fig. 32)

Although no air is actually displaced by the pistons in the crankcase of a four-cylinder engine, ventilation of the crankcase is desirable and possibly necessary. The breather in this engine acts also as the oil filler cap, and also holds the dipstick. It is quite a simple and straightforward machining job, and is made preferably in light alloy, including the dipstick, though any other convenient material may be used. While the breather is set up in the lathe, after drilling, counterboring and tapping the centre, it is advisable to screw in the dipstick as tightly as possible ; any tendency for it to run out of truth may then be detected and corrected. Six holes are drilled crosswise in the edge of the breather to act as air vents.

The marks on the end of the dipstick should be very clearly defined, by turning narrow grooves

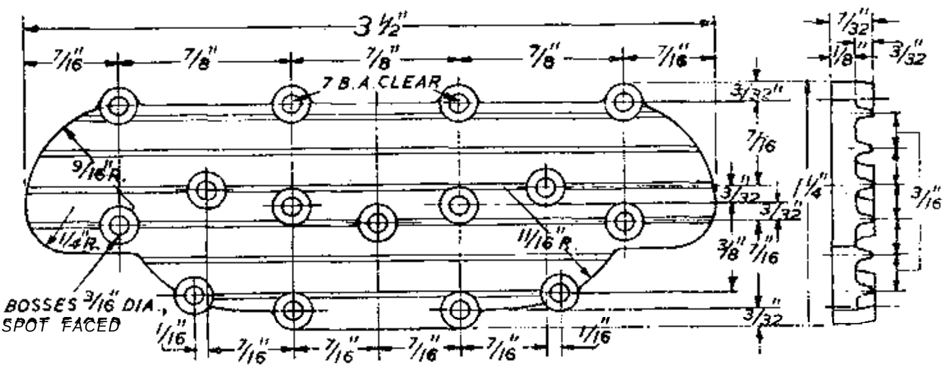


Fig. 35. Manifold cover-plate

with a narrow vee- tool oil-stoned to a slight radius at the tip. These grooves. formed in this way, will hold-oil long enough to'take a reading, but not indefinitely, to show false indications. The positions of the marks are more or less arbitrary, but in the positions shown? it is suggested that the bottom mark is defimtely a low-level danger point ; the next above it is the lowest level permissible in working, the next is normal level, and the top one highest permissible level. Needless to say, oil level readings should only be taken after the engine has been standing for a few minutes. If the breather shows any tendency to throw oil spray, this may be reduced by fitting a conical sleeve on the upper part of the dipstick, point downwards, and fairly close to the breather. Little trouble is, therefore, anticipated in this respect, as a result of experience with earlier engines.

Inlet and Exhaust Manifold

Among the many detail problems in the design of this engine, few have caused more headaches than that of the " plumbing," or manifold system. This has not been so much' a matter of actual design, from the technical standpoint, as of ways and means of producing a satisfactory form of manifolding in a small size. There are, of course. manv practical wavs of fitting inlet and exhaust pipes to a small engine, one of the most obvious being the methods of the coppersmith, in the use of bent and branched pipes, either of copper or other suitable material. Such pipes provide excellent scope for the skill of the craftsman. and look verv nice when properlv executed ; but they are quite a problem if one's particular type of manipulative skill does not run in that direction, and are most decidedly an eyesore if not neatly made. Some experience in this respect has been obtained with the copper exhaust pipe of the " 1831 " engine, which appears to have worried a few constructors. though it is a much larger and less complicated job than a manifold for a 15-c.c. four-cylinder engine.

Not Representative

There were, moreover, other objections to the use of a pipework manifold on this engine ; for one thing, no modern four-cylinder engine of any type that I know of uses such a manifold. and thus it would not be representative of prototype practice. In addition, it would be quite a problem to arrange for the proper attachment of all the inlet and exhaust flanges. with reasonable accessibility of screws or nuts. I also wished to utilise the advantages of combining the inlet and exhaust manifolds, with the object not only of " hot-spotting " to compensate the refrigerating effect in the induction pipe, but also dissipating exhaust heat as well.

It was decided, therefore, to make the manifold in the form of a casting, in which passages were incorporated for both the exhaust and inlet systems. The first type of manifold designed was in a single piece, with an elaborate system of cores to form the two sets of passages ; this was extremely neat and compact, but nearly led to an unofficial strike of patternmakers and moulders when the drawings were produced. Quite apart from the difficulty of making the core boxes, and the cores themselves, the problem arose of ensuring perfectly accurate location of the cores under production conditions. Inaccurate placing of cores would not only result in a high percentage of scrap castings, but might in some cases remain undetected until the engine was finished, when a hitherto unsuspected leak between the exhaust and inlet passages would cause mysterious engine trouble.

Very reluctantly, the one-piece manifold design was scrapped, and the alternadve type shown in detail in Figs. 33, 34 and 35 was produced. This is in two pieces, a main casting and a cover plate, bolted together so as to segregate the two sets of passages, which are cast in as grooves in the main casting, and thus require no core-box. In pursuance of my policy of making the engine design as adaptable as possible, provision is made for attaching the exhaust pipe at either end of the manifold. flanges beine provided at either end. so that the one not required may be sawn away; and the casting faired up by filing to the same shape as the cover plate.

Simple Machining

The machining of these castings is extremelv simple, consisting only of facing-the joint surfaces and drilling the bolt holes ; but some care is necessary in locating the latter properly and ensuring that they pass quite squarely through the casting, as the amount of metal between the passages is necessarily restricted, and careless drilling may spell disaster. It is recommended that the joint faces should finally be lapped flat, and metal-to-metal joints used both between the two parts of the manifold, and between manifold and cylinder block. Fifteen screws or bolts are used in the manifold, those in the centre passing right through into the cylinder block, and those round the edge securing the cover plate to the manifold casting. The size specified is 7-B.A., but 3/32-in. Whitworth is equally suitable, and may be preferred for tapping in light alloy owing to the-coarser thread.

If it is desired to obtain the best air flow efficiency in the passages, they may be cleaned up internallv before attaching the cover plate. using rifflers, rotary Nes or dental burrs. 'Thd fairing off of angles or junctions between the drilled and coredpassages, is the most important in this respect, and care should also be taken to see that the ports in the manifold line up with those in the cylinder block.

Carburettor-Either Way Up

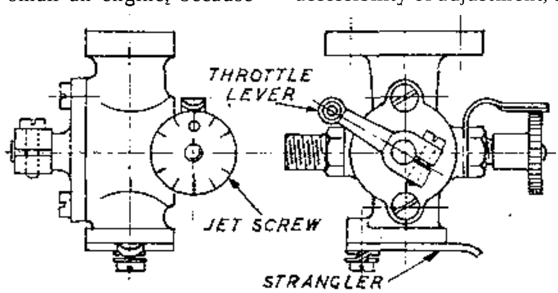
The carburettor flange is on the underside of the manifold, and intended for the fitting of an " up-draught " vertical carburettor. It would, however. be practicable to invert the entire assembly, should the constructor have strong views on the merits of " down-draught " carburettors, as the type of carburettor I have designed for the engine would work either way up. But the elevation of the carburettor above the top of the engine does not strike me as being very desirable, neither do I see any great advantage in sucking air down instead of up.

(To be continued.)

*A 15-c.c. FOUR-CYLINDER ENGINE

By Edgar T. Westbury

A GOOD deal of thought has been devoted to the design of the carburettor, in order to produce a device which is compact, and simple both in construction and adjustment, while at the same time efficient and capable of a wide range of speed control. Simplicity is an essential virtue in a carburettor for so small an engine, because complication not only increases the difficulty of construction, but may also defeat its own purpose by introducing more things to go wrong or out of adjustment. At the same time, however, it is none the less essential to the success of the engine as a whole that the carburettor should do its job without fuss or continual nursing. The space available for the fitting of the carburettor is by no means unlimited, and it is desirable, even if only for appearance sake, to keep it more or less within some semblance of scale proportion.



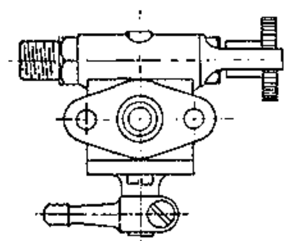


Fig. 36. General arrangement of carburettor

It has not been considered necessary to use float-feed on this carburettor, as small floats, although quite successful if properly made and adjusted, are frequently a source of trouble, and are worse than useless unless they can be relied upon not to flood or stick. Suction feed will give good results if the fuel tank is made fairly shallow and not too far below the jet level ; the low position of the carburettor, when used as normally intended, on the underside of the manifold, favours a convenient arrangement and location of the tank.

The carburettor has a barrel throttle, which is designed to produce mechanical compensation of the mixture, as described in recent articles on carburation. Several successful carburettors of my design, including the " Kiwi " employed on the 15 c.c. engine of the same name, work on this principle, which is quite effective for speed control, though it gives no automatic compensation for varying load. It may be remarked, in passing, that a " Kiwi " carburettor is used on the 60 c.c. four-cylinder engine made by Mr. W. Savage (which has been mentioned and illustrated in THE MODEL ENGINEER in connection with magneto experiments) and has always given satisfactory and consistent results.

The jet is arranged horizontally at the back of the carburettor, this position being convenient for accessibility of adjustment, and also for connecting up the feed pipe. It is of more or less orthodox design, controlled by the usual screwed head and taper needle, but is not situated in the main air passage-a small air passage, little more than an " air bleed," being provided to act as a primary choke, and this communicates with a hole in the centre of the throttle barrel. The main air passage is tapered from thedischarge end, and flared at the intake. to form a venturi tube, the centre part of which is iormed the tarottle barrel, which registers with the main passage when fully open. (See Fig. 36.)

The operation of the carburettor should be quite clear to readers who have followed my articles on this subject, but may be briefly explained as follows : At full throttle? air flows rapidly through the bore of the mam passage, which has a high coefficient of discharge, yet is so proportioned as to produce a suction effect sufficiently strong to induce extra air to flow through the primary choke and also draw fuel from the jet Thus the primary choke discharges a rich air-fuel mixture into the main air stream, in the same manner as an " emulsion jet " used in many full-sized carburettors ; the richness being adjusted by the screw-needle, so that, when diluted by the main air stream, it is of the correct strength for combustion.

When the flow of air is restricted by the partial closing of the throttle, changes in the air pressure and velocity take place which affect the discharge of fuel from the jet. The relative areas of the passage at the intake and discharge edges of the throttle barrel here exert a controlling influence, and must be adjusted to obtain the best results at all positions of throttle opening.

If the throttle were designed to cut off on the

*Continued from page 722, " M.E.," June 12, 1947.

discharge side only, while allowing a free flow at the intake side, it is clear that the suction at the aperture of the primary choke would rapidly diminish with the closing of the throttle, so that the discharge from the jet would fall off so much as to produce a weakening mixture under these conditions. But if closure takes place at the intake end only, the opposite effect is produced ; suction at the primary choke is increased, and the mixture becomes richer as the throttle is closed.

Somewhere between these extremes, a state of affairs can be reached in which just sufficient suction can be diverted to the primary choke to maintain something approaching the correct mixture at all positions of throttle opening. In practice, it is found necessary to close the intake somewhat more rapidly than the discharge, which can be done quite conveniently by tapering the main air passage. But it must be emphasised that some " cutting and trying " is nearly always necessary to obtain the optimum result on any particular engine.

It is intended that the jet adjustment of this carburettor should remain constant when once set, though some slight readjustment may occasionally be found necessary to allow for climatic conditions or variation of fuel quality. But continual knob-twiddling is neither necessary nor desirable. To facilitate starting, a strangler is provided at the main intake, but it is again emphasised that this, also, is not intended to be used as a running control.

Carburettor Body

This is made from a casting, machined to the dimension; shown in Fig. 37. It is advisable first to machine the throttle-barrel housing, holding me casting across the four-jaw chuck for this operation. Do not drill the hole through the jet homing at this setting, as it may throw the drill out of truth when subsequently drilling the hole for the jet-tube ; but it may be started with the pibt end of the centre drill, so that its position may be correctly located afterwards.

Bore the throttle housing parallel, and to a good finish ; one does not aim at air-tightness in a throttle-valve, but the better it is finished, the smoother it will work. Before boring the main air passage, the throttle barrel should be turned and fitted, the cover also being machined, but with the register spigot left proud, so that when screwed down it will bear on the barrel and hold it tight for the boring operation. Assuming these parts are made, the passage can now be bored, holding, the casting from the intake end and first drilling a centre hole right through 5/32 in. diameter and using a taper reamer or D-bit to open up the discharge end. The exact taper is not specified, nor can it be predetermined, to ensure correct operation of the carburettor beforehand ; but an included angle of about 10 deg., as used for fitting shaft tapers, will be somewhere near correct, and in view of the general utility of a D-bit of this angle of taper, it will be worth while to make one. For preference, a long cutting angle, to cover sizes from 1/8in. to 3/8 in diameter, will be found most useful.

Do not, on any account, open up the bore to finished size right away, in view of the fact that adjustment of the bore will almost certainly be necessary, and as everyone knows, it is much easier to remove metal than to put it back afterwards ! It will be sufficient to enter the reamer just far enough to taper out about half the length of the throttle barrel at first. The intake end of the passage may be flared out with a hand-tool, the casting being mounted on a taper plug held in the chuck.

The jet housing may be drilled in a drilling machine, but accuracy in centring the hole is facilitated if the casting is mounted, throttle housing face down, on a small angle-plate attached to the lathe faceplate. Drill the hole 9/64 in. diameter rieht through and face both ends truly. The No. 60 cross-hole may now be drilled from the outside of the casting, and the 3/32 in. hole from the inside of the housing drilled to line up with it.

Jet Tube

This is made from hexagonal brass rod. approximately 7/32 in. across flats, and the plain portion should be turned to a sliding fit in the bore of the jet housing, the end being screwed 4-B.A. for a length of 3/8 in. Take care to centre and drill the hole truly, running the work at the highest possible speed and using a sharp 1/16 in. or No. 52 drill. If desired, the No. 70 hole may also be drilled at this setting, but there are some advantages in drilling it from the other end.

To ensure true running of the work when reversed, it should be chucked by drilling a true hole in a piece of rod held in the lathe chuck, and tapping it 4 B.A., with a 9/64-in. counterbore to a depth of 9/16 in., so that it will screw in up to the shoulder. The screwed and internally-coned end of the jet tube, to provide for a union joint, is optional, but is considered preferable to the more common nipple end for rubber-tube connection. A flexible pipe-joint has its advantages, both in convenience and also as a means of preventing pipe breakage by vibration, but one wonders whether its adoption is not, in many cases, the line of least resistance on the part of the constructor.

The internal cone may be formed by means-of the centre-drill, and a 1/16 in. hole is then drilled to a depth of 7/16 in. from the end, after which a No. 70 drill is used to form the jet orifice. I find it best to apply these tiny drills by hand, holding them in a small pin-chuck, with the lathe running at top speed.

After fitting the jet tube in position and securing it with a 4-B.A. nut at the end, the cross hole may be drilled to line up with the cross holes in the jet housing. It is, of course, essential that the jet tube should always be assembled with these cross holes in line, and it may be found advisable to provide some means of ensuring this, such as by marking the appropriate flats of the hexagon, or fitting a tiny snug key.

Jet Adjusting Screw

This is, strictly speaking, not a screw at all, being an internallv-threaded knurled head, into which the tapered-jet-needle is sweated after assembly. An ordinary dress-pin serves quite well for a jet-needle, though a stainless-steel or German silver needle is stronger and more durable; in either case, a fairly fine taper is desirable to facilitate exact adjustment. The knurled head should be screwed on to the end of the jet tube almost as far as it will go, after which the needle is pushed right home in the jet and sweated in position. Clean off the face of the knurled head, and make one or more radial marks on it to indicate its position.

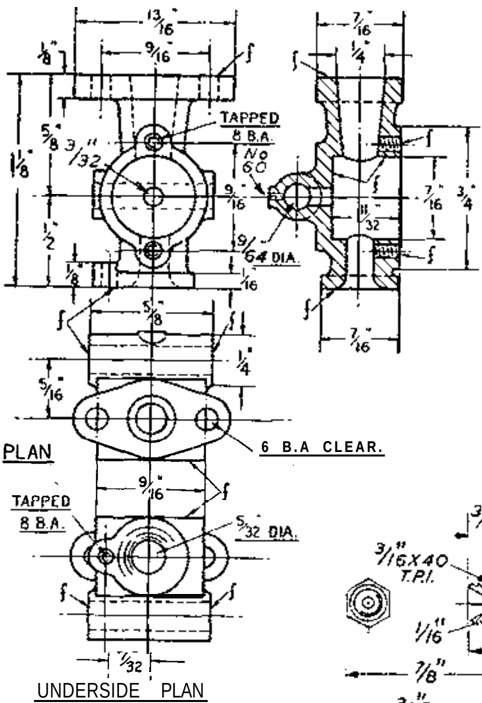


Fig. 37. Carburettor body

The check spring may be filed to shape from any suitable material, such as phosphor-bronze strip or a piece of old clock-spring. The extended end should be formed into a concave channel by hammering it into a vee-block with the pane of the hammer, so that it will bear firmly on the knurling of the head when bent to the shape shown. It is secured under the jet-tube nut as shown in the general arrangement (Fig. 36).

Throttle Barrel and Cover

These are shown in the detail group (Fig. 38), and are quite a straightforward turning job, the barrel and shank being turned from brass rod at one setting. It should turn smoothly in the throttle housing, and as already described, is fitted in place for boring the cross hole. This should be done before drilling the 3/32-in. hole at the back to communicate with the primary choke,

As already stated, the cover is at first made with the register spigot long enough to clamp the barrel in place when the screws are tightened, The surplus length is afterwards faced off to allow the barrel to turn freely, but with little or no end-play, and if desired, the outer part of the face ‘may be relieved slightly to. reduce friction. Alternatively, it may be preferred to introduce friction, if control direct from the throttle lever is desired, and in this case, the centre hole may be counterbored to take a double-turn spring washer.

Throttle Lever

The form of this may be varied to suit the preference or convenience of the constructor. If direct control is used, the lever may be longer than that shown, and some form of quadrant plate attached to the throttle cover will be helpful. The form shown is suitable for use where control rods are fitted to enable the engine to be controlled from some remote point, and a pivot-pin or ball-socket joint may be fitted to the small end of the lever for this purpose.

The bore at the large end of the lever should be a fairly tight fit on the shank of the barrel before splitting, so that the minimum distortion takes place in clamping up. Fit the clamping

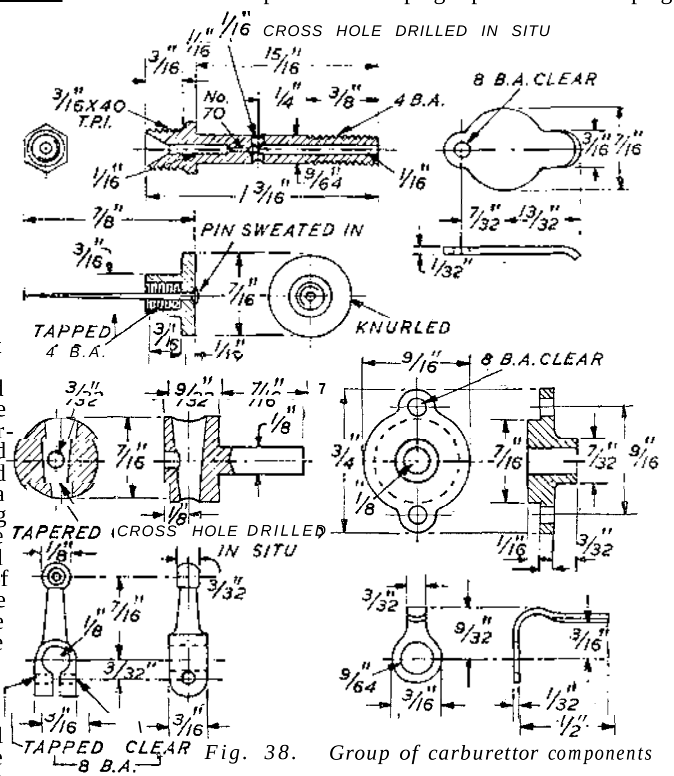


Fig. 38. Group of carburettor components

screw as close as possible to the shank, even to the extent of having to groove the latter to get it in, as this ensures maximum security of grip.

It will be noted that no means of limiting the throttle movement, or fitting a slow-running stop, are provided. The main reason for this is that it is desired to allow for fitting-the lever in any position, for either vertical, horizontal or oblique motion of the control rod. In view of the small dimensions of the parts, a slow-running stop would be a rather finicky fitting, not only to make, but also to handle. If desired, pins may be fitted to the barrel cover in appropriate positions to limit the opening and closing movement of the lever, and one of these might be made eccentric to allow of slow running adjustment. Another method of providing an adjustable stop is to fit a screw horizontally through the side of the passage so that it abuts against the top edge of the barrel aperture, as in the " Kiwi " carburettor.

It should be noted that in the form shown, the throttle will close by turning in either direction ; but should the axis of the barrel not coincide with that of the air passage, or any other deviation from symmetry be introduced, the compensation characteristics will not be the same for both directions, so it is best to legislate for one-way traffic only. A convenient method of operating the throttle, when a full control system is not fitted, is to fit a screwed vertical rod, passing through a hole in a bracket attached to the top of the manifold, and having a knurled adjusting nut and return spring. The slow-running stop could then consist of a couple of lock-nuts, adjusted to the required position on the rod and locked.

The strangler is simply a flat plate of brass or duralumin, filed to the shape shown, and attached by means of an 8-B.A. steel screw with a spring-washer to act as a friction pivot-joint. Tap the screw hole with a taper-tap, in such a way that the screw will fit tightly on the thread without compressing the washer hard up against the plate. A slight bend of the lug on the plate will assist operating it.

When the carburettor is first fitted, it should be adjusted to give the best results with the throttle wide open, and the engine running under load. Next try closing the throttle and note carefully whether the mixture gets weaker or richer. If the former is the case, the area of the discharge end of the throttle barrel should be increased relative to the intake end, by reamering out the bore of the passage with the barrel in position. If, however, the mixture tends to become richer as the throttle is closed, the intake end of the barrel should be opened out, or a vee-notch filed on the closing side ; the latter is usually the best method of getting a fine adjustment of mixture at the lower end of the speed range. Some enrichment of the mixture is absolutely necessary to obtain good idling at low speed, but the engine should never " hunt " or " eight-stroke."

In order to be certain which side the error is on, if one is not certain, the jet-screw may be readjusted, for experimental purposes only, at various throttle positions, when it will easily be found whether it requires to be opened or closed to produce the best running results. It should never be necessary to alter the jet to suit varying throttle positions, once the proper proportions of the air passages have been arrived at. If the carburettor fails to give proper speed control on the throttle lever only, do not blame the design-blame your own lack of skill or patience in arriving at its initial adjustment.

Sometimes it is found difficult to ensure easy starting with fixed jet settings, even when a strangler is used, due to the reluctance of the cold fuel to flow through the jet, especially if the latter is fairly high above the tank level. In such cases, it is permissible to open the jet temporarily for the first few seconds of run, while warming the engine up. An alternative method is the somewhat undignified but highly effective dodge of giving the fuel an initial lift by blowing down the air vent of the tank filler-cap.

(To be continued.)

PETROL ENGINE TOPICS

*A 15-c.c. FOUR-CYLINDER ENGINE

By Edgar T. Westbury

As in the case of the carburettor and manifold system, the design of a suitable ignition system for this engine has presented quite a number of practical problems, due to the desirability- of keeping the size of the components down to something like scale proportions, and at the same time fairly straightforward of the contact-breaker only. It will be seen that both the contact-breaker cam and the distributor rotor are mounted on the extended end of the camshaft, outside the nut which secures the timing gear ; the cam being pinned to the shaft, and the rotor located and driven by a peg fitted to the face of the cam.

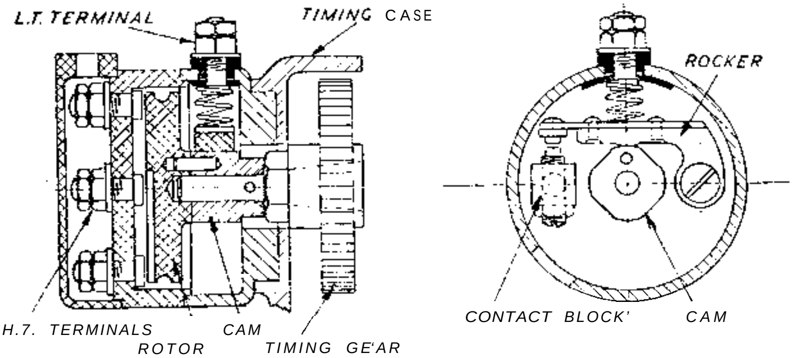


Fig. 39. Section of distributor assembly, showing arrangement of unit on timing case, and face view of contact-breaker

in construction and accessible for adjustment. The arrangement which is almost universally adopted on full-sized engines-namely, a unit comprising the low-tension contact-breaker and high-tension distributor, for operation with a single ignition coil-was decided upon as equally suitable for this small engine, and in a general way, the design presents no difficulties except those imposed by its diminutive size ; but these are by no means insignificant from the practical point of view.

It has been necessary to make some readjustment of the details of these components since the engine was first designed, mainly to meet increasing difficulties and restrictions in the availability of supplies. Plans were made for obtaining a pressure moulding of the distributor casing and rotor, with metal conducting inserts, to make these practically a true scale replica of the components used in full-size practice, but in view of the many delays and set-backs which have occurred with other details, it has been considered better, or at least more judicious, to design these parts, so that they can be machined or fabricated from stock material. This may detract from the neatness and attractive appearance of the ignition fittings, but in no respect does it make them any less efficient or reliable.

The distributor and contact-breaker is shown in Fig. 39, which represents a section on the axial centre line, showing the way the unit is fitted to the timing case of the engine and driven from the end of the camshaft, and a face view

*Continued from page 768, Vol. 96, " M.E.," June 26, 1947.

The contact-breaker housing is of metal, preferably of light alloy, and can be machined from the solid ; plastic material of known insulation efficiency and good machining quality, such as ebonite, vulcanite, or phenol resin (bakelite) having fine-texture fabric or paper pulp base, is used for the distributor block and terminal cover, and these parts also can be machined from the solid. They are registered in alignment by spigot joints, and it is intended that the entire unit assembly should be held in place by a spring clip and stud in the timing case, similar to that used for holding a magneto contact-breaker. Alternative methods may suggest themselves, and may be used at the option of the constructor, but this will be quite satisfactory for most practical purposes, and it is perhaps the simplest, not only in construction, but also for accessibility.

Contact Breaker Casing

A piece of aluminium alloy rod large enough to clean up to 1-1/4 in. diameter is used for this, and may be machined on the outside, end face and spigot, then reversed and bored out from the other side. The spigot should be a close fit in the recess of the timing case, and very slightly shallower in depth, so that it bears on the outer rim when pressed home. It will be seen from the sectional view of the unit that a slight modification has been made to the timing case by boring out the centre of the recess to the same size as the hole through the casing-namely, &-in. diameter. This hole does not form a bearing or register but is simply a clearance for the cam and the timing gear nut, so that neither its diameter nor its concentricity with the recess are of vital importance. It is, however. essential that the recess in the contact-breaker casing should be concentric with the spigot, and that the outer face should be parallel with the back flange, so it is advisable to turn up a simple chucking ring into which the component can be pressed for the second operation.

Two holes are drilled axiallv throueh the back face of the casing, diametrically opposed at a radius of 3/8 in. from the centre. One of these is tapped 4-B.A. and the other drilled 9/64 in., to take the shank of the contact block a close fit. This hole is counterbored with a pin drill or similar cutter to a depth of 3/32 in. from the spigot face so that the nut securing the contact block will sink flush with, or below the surface of, the spigot. Two more holes are drilled in the outer rim of the casing, one being at 90 deg. to the centre line of the axial holes, 5/32 in. diameter. to take the bush of the L.T. terminal, while the other is simply an access hole for the contact-breaker screw, drilled 3/16 in. diameter at an angle of about 45 deg. to the vertical centre-line, so as to come immediately below the contact block.

Distributor Block

This is turned from insulating material, and the most important essential is the fit and concentric alignment of the registering surfaces ; a good method of procedure is to turn the inner face, with its rim, spigot and recess, first, and then turn a metal spigot on which to mount the block for facing and spigoting the outer side.

The five axial holes for the conductor studs should be drilled to a close fit for the shank of a 6-B.A. screw ; if suitable material is available it will be better still to tap these holes, but it will be necessary to counterbore to clearance size from the inside to allow the studs to bed down to the heads if this is done. Ordinary brass 6-B.A. screws, 5/16 in. long, may be used for the conductor studs, and after being secured in place. the heads mav be machined off from the inside to about 1/32 in. thick, that is, 7/32 in. from the front face of the spigot. The two tapped holes in the block are for the purpose of fitting screws to hold the terminal casing in position, but may be dispensed with if the parts are made a good fit, as the spring clip will normally keep the cover in place, and the use of screws is open to certain objections, as there is a slight risk of their picking up H.T. current from the rotor segment and. causing leakage or shocks.

Terminal Cover

The fitting of a cover over the H.T. terminals is at least a highly desirable, if not essential precaution, not only for the sake of neatness but also to avoid leakage of current. Most distributors used in full-size practice employ terminal sockets or insulated terminal nuts, but while these are equally practicable in a small size, they are somewhat difficult to produce unless moulding facilities are available. Taking things by and large, there is nothing to beat an ordinary terminal nut for security and accessibility, and by covering the whole set of terminals, the connections of the leads are projected in the simplest possible way. The cover is made of the same material as the distributor block, and its machining calls for no special comment. If desired, it may be made a plain circular shape and the leads brought out radially at any desired point ; but bringing them out all in a row, through a section of material thick enough to guide and prevent kinking of the leads, has obvious advantages, and enables the leads to be taken neatly and directly to the plugs. It will be seen from Fig. 41 that by inclining the cover at an angle of 22-1/2 deg., the shortest and most direct path is obtained for the leads, and if screws are used to secure the cover, thev should be located as shown to ensure this. The use of P.V.C. insulated leads is recommended. and a suitable size of lead which is a fairly neat fit in the 1/8in. holes in the cover is, I believe, generally available.

Internal Components

Details of these parts are given in Fig. 40, the first being the contact block. which is made from brass or iight alloy, either of square section or flattened on the sides, and turned down and screwed 4-B.A. at one end. The cross hole for the contact screw should be square with the centre line and across the diameter. Small headless 6-B.A. tungsten tipped screws are available, but other sizes of screws, up to a maximum of about 4-B.A. or the Bosch standard of 3.5 m.m. may be’ used. The block is firmly secured in the casing by the flush-fitting nut in the counterbore at the back, which can be tightened with a tubular box spanner ; or a slotted nut, for manipulation with a forked screwdriver; may be used.

In machining the cam, which is made of mild-steel, it is most essential that the four flats should be equally spaced and concentric with the axis. The use of an indexing device on the lathe mandrel, in conjunction with a milling attachment or roller filing rest, will be found very helpful in ensuring this. Another method which might be employed is to make the cam from square section steel bar, setting it up in the four-jaw chuck with the aid of a test indicator, to ensure that the four sides are exactly the same distance from the centre. 5/16 in. diameter square bar could be used, providing that a corresponding modification is made in the rocker dimensions to suit.

The flats should each be about 45 deg., in width, or in other words, the rounded and flat portions of the cam surface should be about the same width. Too wide a flat will waste battery current, while if it is too narrow, the coil will not become; properly saturated at high speed, and ignition efficiency will thereby fall off. But the reallv important thing is that the cam breaks should occur at exactly 90 deg. to each other.

The centre hole of the cam should be chamfered or counterbored at the back so that it can be pressed on to the Shaft to seat against the face of the timing gear nut. It is best secured on the shaft bv means of a small cross pin, but this should not be fitted until the ignition is timed up, and the same applies to the driving peg or dowel for the distributor rotor. Final case-hardening of the cam is recommended.

For making the contact-breaker rocker a really

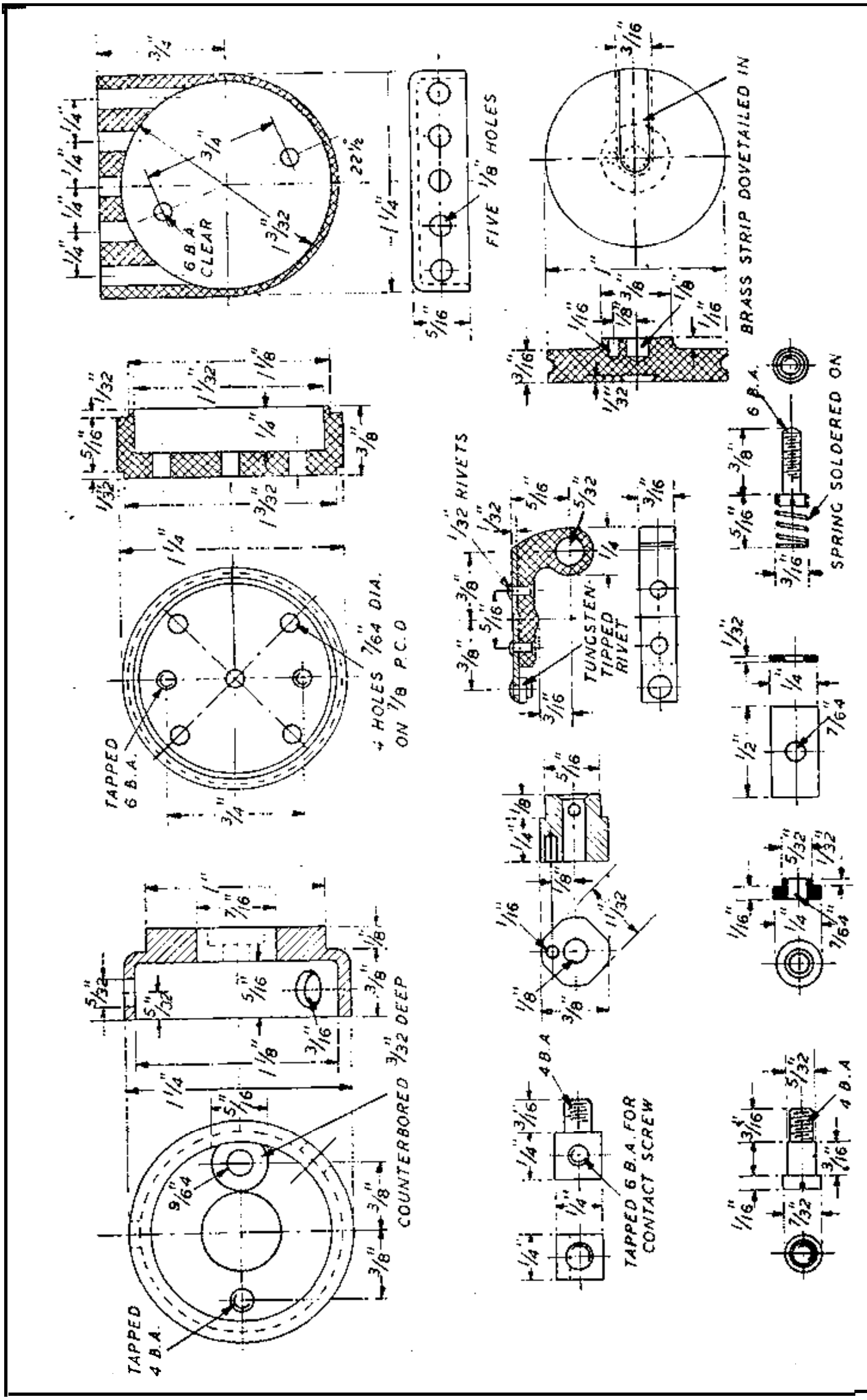


Fig. 40. Details of components for distributor unit

tough plastic material, such as laminated fabric bakelite. is best. Alternativelv. the rocker could be made of metal (preferably-steel), with fibre pivot bush and rubbing pad inserted. It will be clear that this part must be insulated from contact with both the pivot screw and the cam. A strip of 1/32-in. or 20-gauge spring steel plate is used to carry the contact rivet. assuming that the form of construction is as drawn, and this in turn is riveted to the body of the rocker ; two brass pins may be used for rivets, and should have the heads slightly countersunk into the plastic material, and afterwards filed flush so that there is no risk of them touching other metal parts. A slight hump is left between the rivet heads to act as the rubbing pad to rest on the cam surface.

The pivot screw is of mild-steel, and the plain part should be just long enough to allow the. rocker to work without end play when it is screwed tightiy home in the casing. A washer 1/32 in. thick is placed behind the rocker to raise it clear of the inner face of the casing, and care should be taken to see that when the working parts are assembled, the rocker blade cannot touch any metal, other than the top of the contact screw, under working conditions.

A fibre or ebonite insulating washer is made to fit the hole in the casing, over the rocker, and a slip of fibre or leatheroid, of the dimensions shown, is fitted inside the hole. The screw which forms the L.T. terminal is an ordinary 6-B.A. brass screw, 3/8 in. long, the head of which is turned down to fit inside a compression spring of about is in. external diameter, and preferably soldered thereto. This spring forms the electrical connection to the rocker. and should bear firmlv on the centre of the blade, between the rivets, also it should be kept clear of contact with the casing.

The distributor rotor is turned from the same material as that used for the casing and terminal cover, and should have sufficient clearance in the casing to avoid risk of rubbing contact. Its edge is grooved or serrated to provide the maximum length of leakage path around the rotor, and thereby minimise risk of tracking or flashover of the H.T. current. The centre hole at the back of the rotor should not go in deeper than is necessary to locate it properly on the shaft, against the face of the cam.

A brass strip is attached to the front face of the rotor, flush with the surface of the disc, the method recommended being to mill out a radial groove with a 3/16in. undercut or "dovetail" cutter, and shape the strip to press in fairly tightly, but not so as to strain or split the disc. No other securing should be necessary if the fitting is good, but if desired, a small hole may be drilled through strip and rotor at about half the radius and an ivory peg driven through, to prevent shifting of the strip under centrifugal force. The face of the rotor and the strip should be machined or lapped down flush, and when the parts are assembled, this face should run within about 0.005 in. of the faces of the conductor studs in the distributor block.

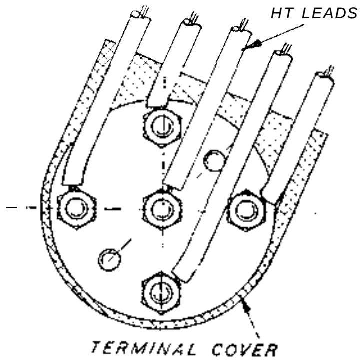


Fig. 41. Section of distributor terminal cover

Assembly

The most important point in assembly is to time both the contact breaker and distributor rotor. It will be noted that the unit is capable of being turned to any position and that no operating lever is shown tor the advance or retard control. It will, of course, be necessary to arrange for such control in most cases, and a suitable lever can be attached at any convenient point on the casing, either by providing it with a concave foot which may be attached with a couple of screws, or making it in the form of a stud which is screwed into the casing radially or nutted on the inside. Alternatively, the L.T. terminal shank could be extended to form a control lever, so long as it is remembered that this terminal is " alive " at battery voltage, and therefore must not be connected in metallic contact with anything on the engine structure.

In timing up the ignition system, it will first of all be necessary to determine the angular position of the breaker casing, and settings are best made from the retarded position. which is approximately top dead centre. The fitting of stops to limit the extent of advance and retard is a sound policy, as it avoids the need for " searching " when starting or adjusting the engine ; but they have not been specified on the drawings, owing to the variations of arrangement which are possible.

The cam should be adjusted so that the points just break as the engine comes up at top dead centre, and pinned in position on the shaft ; either break may be timed for any cylinder, as they should all be alike and equally spaced. The distributor rotor is then located by the driving peg, so that the conducting strip comes opposite one of the stud faces. Here again. either of the four studs will serve, so long as, when the leads are connected, the sequence is arranged so that each plug gets its current as the respective piston comes up on its firing stroke. Timing up an engine is really a very simple business, which only requires a little careful thought, though it is often-regarded as a major mystery.

It is advisable either to mark the relative positions of the contact breaker casing and distributor block, or to locate them positively with a small peg in the register spigot, as it is otherwise possible to get the rotor conductor out of line with the studs. The fit of the parts, and the spring of the retaining clip, should be sufficiently tight to ensure that there is no risk of the assembly shifting under working conditions.

It is not anticipated that any trouble will arise through oil leaking from the timing case into the distributor, as centrifugal force will tend to throw it away from the aperture between them ;

but it is quite an easy matter to fit a felt washer or other sealing device behind the cam if it should be found desirable to do so.

An alternative arrangement for the contact-breaker and distributor, for use in cases where it is desired to fit an oil or water circulating pump will be described later.

Another Correction

Despite the utmost care in the setting-out of the camshaft, I have discovered, thanks to the co-operation of a constructor, that I made a slip-up in the sequence of the valve events. But keep your seats and don't panic-it will not make an atom of difference to results ! It is just another case of "minding my 3's and 2's," as I said the other day. The firing order, which was described as 1-2-4-3, in the issue of May 1st, actually comes Out I-3-4-2 when working to the instructions given. So long as the ignition is timed accordingly, by taking the leads to the plugs in the same order, the working of the engine is unaffected. The error arose due to the apparent paradox (there are quite a few of them in working out these little problems) that shifting the pointer anti-clockwise relative to the camshaft is equivalent to shifting the camshaft clockwise relative to the division plate ; the sequence is thus reversed, though the relation of exhaust to inlet on any one cylinder is the same.

I have also to congratulate the above constructor for making an excellent job of the camshaft which he has submitted for my inspection.

(To be continued)

PETROL ENGINE TOPICS

*A 15-c.c. FOUR-CYLINDER ENGINE

By Edgar T. Westbury

THE direct attachment of the distributor unit to the timing case, and its direct drive from the end of the camshaft, has the merit of mechanical simplicity, and will be found suitable for most engines used for general purposes, but there are instances when a modification of the method of mounting and driving the distributor may be found desirable, or even necessary. For marine work, it is an advantage to have the distributor mounted vertically, providing much better visibility and accessibility when attention to the connections or contact-breaker adjustments are required ; and as such engines often call for some method of forced water circulation through the cooling system, provision must then be made for driving a circulating pump. While the latter may be, and often is, quite an extraneous unit to the engine, and driven by gearing or belt from the propeller shaft or some other convenient rotating part, it is obviously much better, in respect of compactness, efficiency, and reliability, to make it an integral part of the engine unit. This can be done fairly neatly, when gearing is fitted for driving a vertical distributor, by driving the pump from the lower end of the vertical shaft, thereby ensuring the location of the pump in the best possible position, and rendering it accessible, yet unobtrusive.

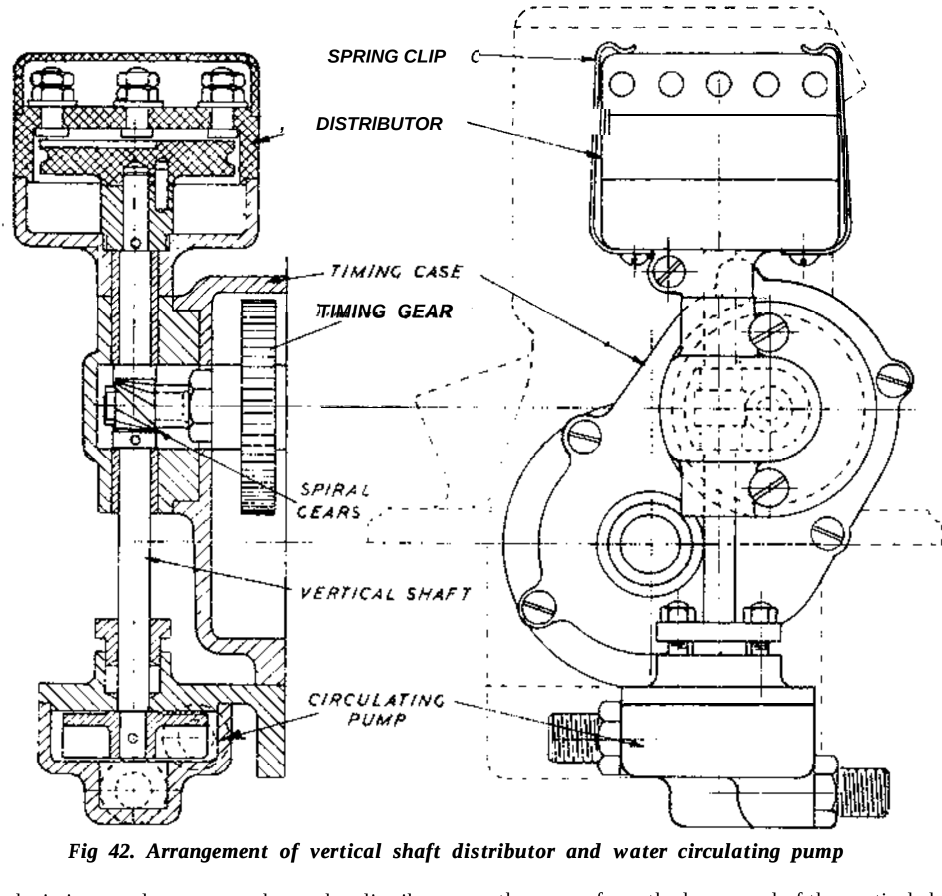


Fig 42. Arrangement of vertical shaft distributor and water circulating pump

Vertical Shaft Drive Gearing (Fig. 42)

In arranging the drive for the vertical shaft which drives the distributor and circulating pump, the choice lies between the use of spiral (or " skew ") and bevel gearing, either of which must be of very small dimensions, owing to the

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**Continued from page 35, "M.E." July 10, 1947.*

very restricted amount of space allowable, or at any rate desirable, for housing them in a neat casing attached to the timing case of the engine. Spiral gears have been selected as being most suitable, and also most likely to be obtainable in the size required. There are, or were, stock spiral gears of a suitable type available, but they are not beyond the resources of the model workshop to produce ; they should be made in mild steel, and case-hardened. The same applies if the constructor decides to use bevel gears. Stock gears of the latter type, in brass, are obtainable in sizes down to 3/8 in. diameter, but appear to be a little on the delicate side for this job, and the layout of the gears, which calls for modification of the shaft position, is not quite so convenient.

In order to simplify construction and economise space, the orthodox arrangement of fitting a coupling to the bottom end of the shaft to drive a separate pump shaft, is dispensed with, the shaft being run right through the pump gland, and having the impeller attached to the end of it. The use of a flanged gland with two studs has been decided upon as preferable to a screw gland in this instance, as the latter, if made of adequate size and depth, would take up more vertical space than can readily be spared, in view of the close proximity of the gland to the main engine shaft. In any case, it has been necessary to reduce the bearing length of the pump to the smallest permissible limit, and it would be quite inadequate if a separate pump shaft were fitted.

Modification of Distributor Unit

The only part of the distributor which requires any alteration for fitting to the vertical shaft is the contact-breaker casing, which must, in this case, be adapted to clamp on the extended bush of the gear housing, instead of being spigoted to fit the recess of the timing case. Details of the modified casing are shown in Fig. 43 ; it may still be machined from the solid without much difficulty, the split lug being left about 3/4 in. diameter when turning, and afterwards milled or filed to the shape shown. The sawcut may be made with a small circular slitting saw in the lathe, as far as permissible without cutting across the other side of the boss, and finished by using an Eclipse " 4s " or Enox hand-slotting saw-or even the crude exuedient of a broken hacksaw blade held in a hand vice.

The contact block is fixed in the casing as before, with a nut on the outside, and the rocker pivot may also with advantage be fitted with a lock nut outside, as the thickness of metal into which it is screwed is hardly sufficient to ensure a really adequate hold. It will be seen that the contact-breaker cam is somewhat shortened, and its boss rests in a recess in the modified casing. If desired, the cam may be pinned through the flats, so long as the pin is secure, and is finished flush with the surface both sides. The lower face of the boss acts as a thrust bearing, to take the end thrust of the driving gears, and it is an advantage to interpose a thin fibre or bakelite washer between the surfaces, though the load they encounter under normal working conditions is not at all heavy.

As will be seen from the assembly drawing (Fig. 42), spring clips are used to hold the distributor to the contact-breaker casing. These are made from 24-gauge spring steel or phosphor-bronze, bent as shown in the detail drawing (Fig. 43), and each secured to the underside of the casing by a 6-B.A. screw.

Skew Gear Housing

This is also shown in the same figure, and may be made either from a casting, or machined from the solid, the internal recess being formed quite easily by end milling, especially when a small milling spindle for use on the cross-slide or vertical slide is available. The most important point in the machining of the housing is the setting out of the centre of the bush seatings, relative to the main centre, to ensure correct gear meshing. It may be found necessary to modify this distance slightly to suit the particular gears available, and in any case it is worth while to make a temporary test jig to verify the correct gear centre distance. It is, of course, possible to allow for gear mesh adjustment by such expedients as eccentric bushes, or even by reducing the spigot diameter of the housing and slotting-out the screw holes so that the housing may be moved sideways on the face of the timing case ; but it is better still, to avoid the necessity for such adjustments if possible. I have described methods of setting up worm and skew gear housings for machining in connection with the construction of previous engines.

Pump Bracket

The two main components of the pump are best made of gunmetal, unless an aluminium alloy of known water-resisting properties is available. As shown in Fig. 44, the top cover of the pump is formed in the shape of an angle-bracket, which is used as the means of mounting the pump on the end face of the engine sump. This part may be made from a casting, fabricated or machined from solid, and the only point about its machining which calls for any comment is that the under face which forms the joint surface may present a slight difficulty, as it cannot be face-turned right across to the corners without cutting the fillet of the vertical flange in the centre. There is, however, no objection to doing this, so long as a liberal fillet is left each side, to provide proper support. Alternatively, an end mill may be used to face the corners on this flange, and slight under-cutting below the circular rim surface will do no harm. The centre hole, spigot and gland counter-bore must, of course, all be true with each other.

The gland should fit the counterbore closely, and its centre hole should be concentric, and a smooth running fit on the vertical shaft. Drilling of the stud holes in the gland and cover may be done in one shot, by clamping the parts together with a bolt through the centre hole.

Pump Body

This also may be constructed in various optional ways, being simply a square box with a lug underneath to take the inlet nipple. Face the top edge and bore the centre to a snap fit on the spigot of the pump cover, also bore the entry port and round off the corner of the hole to reduce the resistance to the water flow. Three of the side corners of the body are rounded off for

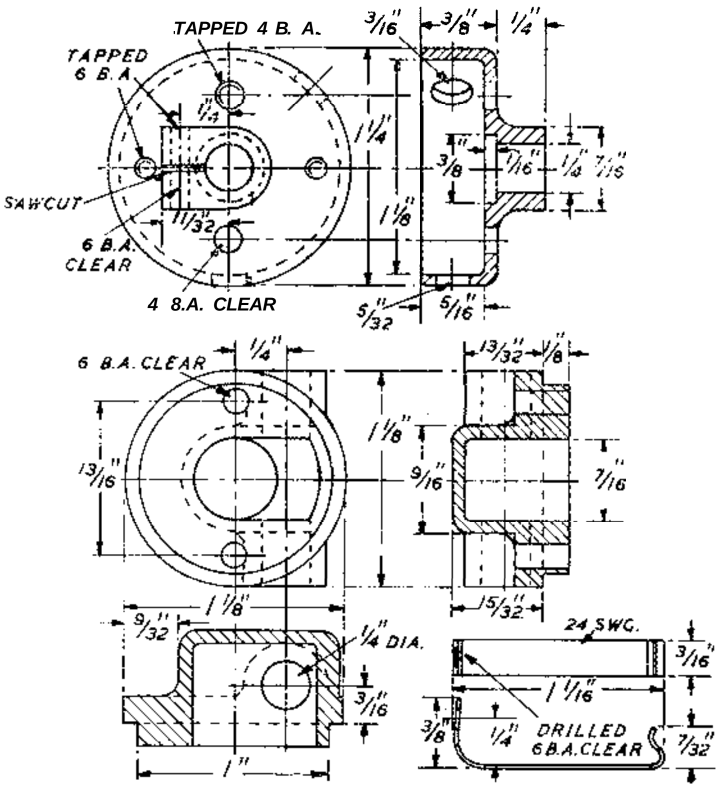


Fig. 43. Spiral gear housing, modified contact-breaker casing, and spring clips for securing distributor

raised boss at this port face. Drill and tap both ports 3/16 in. x 40 t.p.i., and if any doubt exists as to the squareness of the joint surfaces around the ports they should be spot faced.

Vertical Shaft

Stainless steel rod should be used for the shaft, if obtainable, as it is liable to corrosion at the lower end if mild or silver steel is employed. The reduced ends for the seatings of the cam and pump impeller should be quite true with the rest of the shaft, and in the absence of a true-running collet chuck for holding it when turning down the ends may be held in a fixed steady. It is an advantage to centre-drill the ends, so that in the event of any subsequent attention being necessary the shaft may be relied upon to run truly. The dimensions given in Fig. 45 may call for slight modification to suit possible discrepancies in other engine dimensions or variations in arrangement.

neatness, but the fourth, in the vicinity of the delivery port, must not be rounded right off, as this would reduce the bearing surface for the delivery nipple. If a casting is made for this component, it would be desirable to provide a

It will be seen that right-hand spiral 'gears are specified, but it is quite in order to use left-hand gears if other details are modified to suit. The reversed direction of rotation of the vertical shaft will call for reversal of the pump impeller blades,

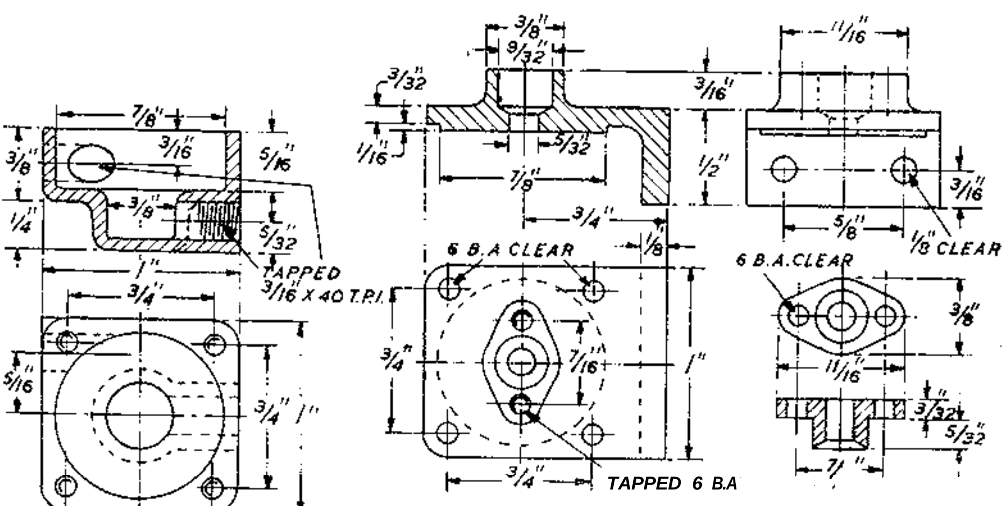


Fig. 44. Water pump bracket, body and gland

and displacement of the pump delivery port to the other side of the body centre line. It is also desirable, though not absolutely essential, to reverse the contact-breaker rocker, so that the pivot is on the left and the contact is on the right, so as to produce the trailing action, and thus reduce mechanical wear and tear.

Impeller

This may be made from brass rod, with sheet-brass blades soldered on. The latter are formed by rolling a strip of 1/32-in. or 20-gauge brass strip around a 7/8in. mandrel and cutting off pieces about 1/2 in. long. To locate them correctly on the rotor flange, one edge may be filed to form small tenons or dowels, to fit holes drilled in the flange and rivet over lightly on the back. If they are carefully fitted in this way, they can be secured quite firmly and need very little further fixing, so that soft-soldering is adequate ; but hard-soldering is much better, and is little more trouble if Easi-flo silver solder is used, in the form of fine gauge wire, which facilitates its application to small work. My method of applying the solder in a job of this kind is to cut short lengths of the wire and lay them along each joint, bury them in flux, and heat up the work until the solder melts. This avoids getting solder where it is not required, or applying too much, so that it calls for a lot of subsequent cleaning up. After allowing the work to cool off, below a red heat, it may be plunged into an acid pickle bath to remove scale and flux, and then washed in water.

Make a small pin mandrel on which to mount the impeller for trimming over the tips of the blades, which should be done with a keen, fine-pointed tool to avoid risk of bending them. The cross hole for pinning the rotor will, of course, have to be drilled in such a position that it dodges the blades, and allows access to the pin from both sides.

The inlet and delivery nipples for the pump are shown in a form suitable to take standard)-in. union joints, which are regarded as the best method of pipe connection for the purpose. If desired, however, the nipples may be adapted to take rubber pipe, windscreen wiper tube being suitable, but I strongly recommend that this should only be used as a flexible connector in a ***metal*** pipe line, and not as a substantial part of the pipe system. Apart from the unsightliness of a lot of rubber pipes sprawling all over an engine installation, it is sure to lead to trouble sooner or later, as the rubber may kink or get pulled off the nipples, and is also exposed to the deleterious effects of petrol and oil. If you must use rubber, use it in the most efficient way, and I also advise the fitting of proper hose-clips wherever possible.

Both upper and lower shaft bushes in the gear housing are in gunmetal, and should be pressed in, and finally reamered in position. If eccentric bushes should be used, ir will, of course, be necessary to provide some means of turning them round for adjusting purposes ; note also that the extended part of the upper bush, which takes the contact-breaker casing, must be concentric with the centre hole. In the event of duralumin being used for the gear housing the bushes could be dispensed with, but it would be necessary to provide an extended spigot on the top end shaft bearing.

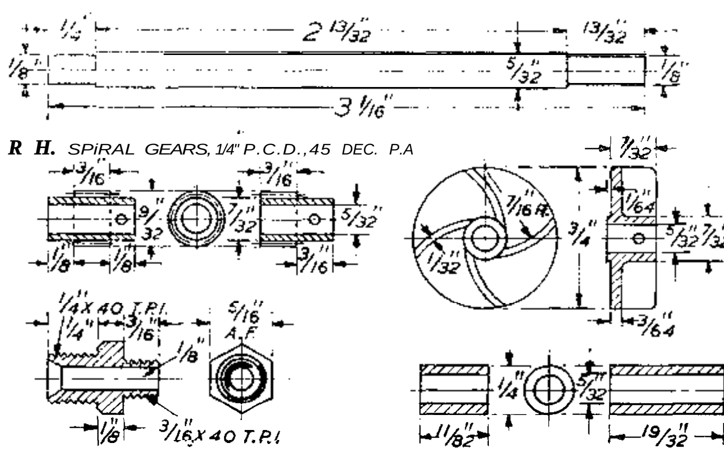


Fig. 45. Vertical shaft, spiral gears and minor components

Assembly of Vertical Shaft

The most important point in assembling this group of components is to ensure proper alignment of the bearings in the gear housing and the pump respectively. Attend first to the proper meshing of the gears, and once they are correct, the housing may be fixed securely by the two screws in its main flange. In order to enable oil mist to enter the housing, the inner flange of the timing case may be cut away to the same shape as the recess in the housing, or a hole of as large a size as practicable drilled opposite the gear position.

A machined or truly-filed surface should be provided on the end of the engine, to take the pump bracket, which is secured by two 1/8in. or 5-B.A. screws in the vertical flange, the back surface of which is also accurately faced. It may be clamped temporarily in position by a long clamp over the ends of the sump, for locating the tapping holes in the latter, in such a position that the shaft runs quite freely when the bracket is secured. It may be necessary to fit shims to pack the bracket out from the sump, or alternately to take a little off the back face, in order to obtain correct alignment in the side plane.

The fitting of the pins to hold the gear, cam and impeller to the vertical shaft, and the gear to the camshaft, calls for some care. It is not necessary to use large pins, or to fit them with a 14-lb. hammer to obtain proper security. I use cabinet-makers' panel pins or printers' block mounting pins, which are just over 0.040 in. diameter and a perfect fit in a No. 60 drilled hole. It is permissible to taper the end of the pin very slightly to assist entry, but unless the hole is definitely broached out taper, and a pin made to exactly the same angle of taper, it is best to rely on a substantially parallel fit. Pins should never be fitted so tightly that they cannot be removed in emergency, but should be tight enough to prevent the risk of inadvertent movement, which at best will mar one's reputation for reliability, and at worst may wreck the entire works.

It may perhaps be objected, by students of good engine design, that the circulating pump for this engine is by no means an efficient one. The answer is that it is not intended to be. Heaving water at the maximum rate or pressure is not the function of a cooling water circulating pump on a tiny engine ; all that is reauired is to keep a small amount of water moving gently through the jacket. It is a positive disadvantage to circulate the water too efficiently, as an overcooled engine never runs hapaily. All that is aimed at in the design is simplicity in construction, and mechanical reliability. I mention this point because I am always receiving letters from readers, pointing out that certain details in my engine designs are not in accordance with the best possible prototype practice, and often suggesting improvements which, while sound in themselves, would complicate design or introduce formidable problems in construction. I once ran foul of a Government department expert-who, incidentally, had never built or designed an engine in his life-over the aerodynamical efficiency of a cooling fan on an engine, though the latter was doing its designed job quite efficiently to all intents and purposes, and not absorbing any measurable amount of power in doing so.

An example of the " Seal " engine camshaft, produced by Mr. N. A. Leach, of Beckenham, Kent

I am definitely not a subscriber to the ultra-utilitarian doctrine that anything which does its job is necessarily good enough, but when the choice is between a very simple device which does its job, and a much more complicated one which may or may not do it one per cent. better-the answer is obvious.

(To be continued)

* A 15-c.c. FOUR-CYLINDER ENGINE

By Edgar T. Westbury

WE come now to the final stages in the construction, including the minor items of fitting and assembly, which should present very little difficulty if the machining has been accurately carried out, but which have a far-reaching effect on the efficiency and reliability of the finished engine.

It has already been stated that practically all the joints between the various components can be made without the use of gaskets or other packing material, the joint surfaces being lapped perfectly flat and a smear of varnish or other liquid jointing preparation being applied before assembly. There is, perhaps, at least one joint surface which cannot be lapped in this way, namely, the flange of the main bearing housing, but as this is a plain circular face with a register spigot, no difficulty should be encountered in machining it true enough, especially as it only has to hold tight against oil creepage.

My method of lapping flat joint surfaces is to use a piece of plate-glass, not less than 1/4 in. thick, smeared with fine carborundum paste, and work the component evenly over its surface, taking care to avoid undue local pressure, by continually shifting one's hold on it. A circular motion of the work produces fairly good results if it is also rotated slowly on its own axis as well, but operators experienced in lapping generally adopt the characteristic " figure of eight " movement, which results in every point on the surface traversing the same linear distance, at the same mean speed. This treatment is continued until the surface of the work shows a perfectly even matt surface, after which it is thoroughly cleaned by washing in petrol or paraffin, particular care being taken to remove the abrasive from tapped holes and other interstices.

It may be remarked that the glass surface will not last indefinitely, as it is gradually worn inaccurate, but it is not expensive to renew, as most glaziers have a few small offcuts of plate-glass which they are only too glad to get rid of. Thin glass is not desirable for this purpose because even if its surface is perfectly true—often it is not—it is capable of distorting to a considerable extent under pressure.

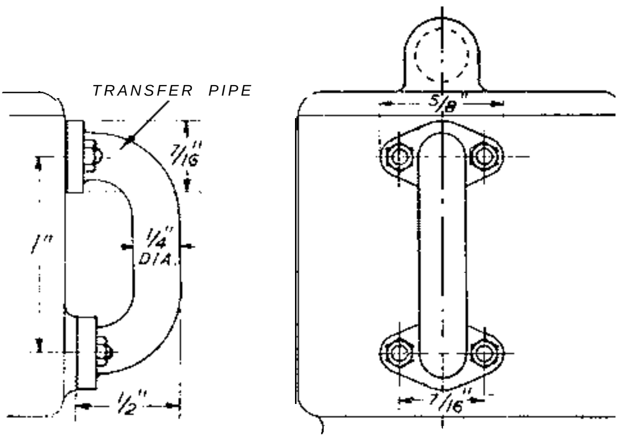


Fig. 46. Showing how a transfer pipe may be fitted to communicate between water jackets in main and cylinder-head blocks

The matt surface produced on the joint faces is better than a highly polished surface, as it holds the varnish film more effectively. Care should be taken to avoid subsequent damage to the surface by scratching or burring ; when small studs are screwed home there is a tendency to throw up a burr around the tapped hole, which should be avoided by lightly countersinking with a small centre-drill. Persistent refusal of the joint to maintain tightness is generally due to " growing " or " seasoning " of the casting by the gradual release of internal stresses, and may call for some patience in getting it finally correct, but aluminium alloys are better than most other metals in settling down quickly.

Water Passages

The communication between the water passages in the body and cylinder-head blocks may be made in two ways ; the first, which is the more common in motor car practice, is to form passages through the horizontal joint surfaces, in such location that they are clear of the combustion spaces and do not interfere with the gas-tightness of the joint. If, however, the constructor has any doubts about using the one joint surface to hold both water and gas pressure, an alternative method is to fit a bent pipe to the flange on the body casting, at the remote end from the water inlet, to carry the water up to a similar flange on the end face of the head. This method is sometimes used in marine engine practice, so it is by no means out of character with the model. No provision has been made on the head casting for fitting a flange joint on the head in this way, but there is sufficient metal on either end face to true up to an accurate

*Continued from page 103, " M.E.," July 24, 1947.

surface, and drill and tap for the securing studs, as shown in Fig. 46.

If holes are drilled to communicate directly through the joint faces, their location should be as indicated in Fig. 47, and in cases where forced circulation is employed, three holes 3/16 in. diameter and two holes 5/32 in. diameter, in the positions shown, will be found sufficient. For thermo-syphon circulation, however, the passages should be of the largest possible area, so as to impede the free convection flow to the minimum extent, and it is thus desirable to open out the communication holes as shown by the dotted lines.

When the supply of circulating water is unlimited, as in the case of a marine installation, it is usuaily convenient to pass it once through the jackets and overboard, or into an exhaust cooler or water-injection silencer. But even in such cases, it may be an advantage to circulate the water in a closed-circuit system, incorporating a radiator or cooling tank, in order to avoid possible clogging of the passages with sand, mud, or weeds. Small radiators are usually of dubious efficiency, but effective re-cooling *of the* circulating water may be assured by running it through a keel pipe or similar form of cooler in contact with the water through which the boat is running.

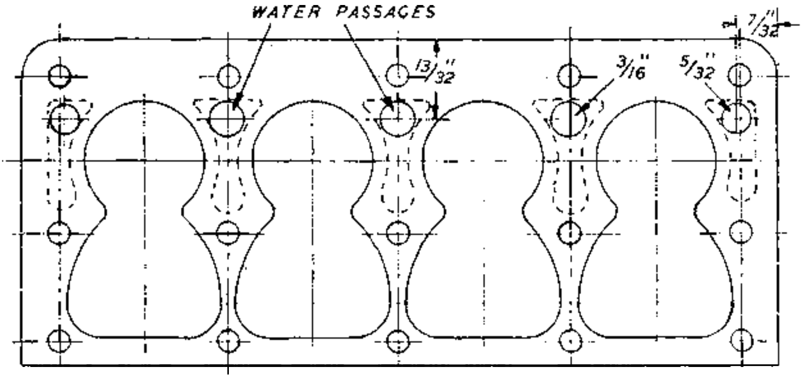


Fig. 47. Plan, of cylinder-head joint surface, showing position of water communication holes. Dotted lines indicate how holes may be enlarged to suit thermo-syphon circulation

Mechanical Assembly

It is most essential that all working parts of the engine should work perfectly smoothly and freely. Particular attention should be paid to the alignment of the pistons and connecting-rods with the crankpins, as mentioned in the April 17th issue, and side binding must at all costs be avoided ; but the big-end bearings should not be given appreciable end clearance, as it is desirable to maintain the maximum bearing area on these bearings. End play, if necessary, should be allowed at the little ends.

In view of the offset of the cylinders, it may be found that the connecting-rods tend to foul on the valve chamber side when at the position of maximum angularity. They must not be wider than shown on the drawing, and may be rounded on the edges to reduce this tendency, but even so, the usual expedient of filing notches in the lower edges of the liners, to give clearance at this point, may be necessary.

The detail drawing of the connecting -rod (Fig. 16, April 17th issue) indicates the use of 3/32-in. set-screws in the big ends, tapped into the upper half of the bearing and cross drilled through the tail ends to take a security wire. In view of the smallness of these screws, and to promote accessibility, I have now found it better to cross drill the screw heads, which may be a good deal deeper than as shown, and need not be hexagonal. Tough material is essential for these screws, commercial screws not being regarded as safe ; I recommend turning them from a piece of motor-cycle spoke, which should be annealed before machining. Do not attempt to screw them up to the bursting point, but secure the heads by passing a steel wire through both of them, and bending round the ends, in such a way as to resist any tendency to unscrew, as shown in Fig. 48.

Accurate Timing

When fitting the camshaft, it is advisable to fix a disc to the flywheel, with the timing diagram marked on it, to suit the proper direction of rotation, and carefully set for top dead centre. This will enable the camshaft to be accurately timed (assuming that it is not positively keyed) and it will be found only necessary to check up on the valve vents for one cylinder, as the others will come right automatically if the cams are correctly machined. Insert the tappets and valves, and adjust them to the specified clearance in the closed position, holding the head with a screwdriver while manipulating and locking up the nuts. Check both the opening and closing points, by noting exactly when the tappet clearance is taken up. It is possible that the opening period may not agree precisely with that shown on the diagram, and if so, the difference should be split, so that the mid-open position is correct ; exact opening and closing angles are of minor importance. When properly timed, tighten up the camshaft nut firmly.

All instructions for timing, so far, have been based on the assumption that the engine is assembled as shown in the drawings, that is, to run anti-clockwise at the timing end. If the body is reversed, for the other direction of running, it is simply necessary to reverse the order and sequence of all timing vents, as if the entire system were viewed in a mirror.

Coupling and Oil Retainer Sleeve

These items have been omitted from previous detail drawings, as they may be open to variation to suit the purpose for which the engine is to be used. It is, in a general way, desirable to take the main drive from the flywheel end, by any kind of coupling which may be considered suitable, such as a pin coupling or flexible disc ; but in many cases, the need for a main or auxiliary drive at the timing end is encountered ;

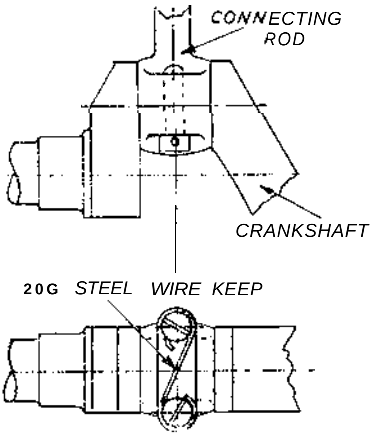


Fig. 48. Use *of steel wire keeps to secure crankpin bearing screws*

or it may be found desirable to fit a starter similar to that designed for " 1831." If no coupling of any kind is required, a plain or castellated 1/4in. B.S.F. nut mav be fitted.

The form of coupling shown in Fig. 49 may be modified as required, to suit a simple " ball and pin," Cardan, or die-block type of universal joint, dog clutch, or face ratchet. It may also be combined with the oil retaining sleeve, if desired, as shown in the alternative detail drawing.

The sleeve acts as a spacer between the shaft nut and the timing pinion, running round with the shaft in the clearance bore of the timing case. A right-hand spiral groove is incised in its outer surface, to retard the escape of oil from the casing, and it should finally be case-hardened and polished ; the coupling, also, may with advantage be hardened when its final form has been decided upon. For an engine of reversed rotation, it will be desirable either to screw the shaft and tap the coupling with a left-hand thread, or to pin it in position ; the oil retaining sleeve must also have a left-hand spiral groove.

Ignition Timing

General instructions on the timing of the contact-breaker and distributor have already been given ; it remains now to connect the individual h.t. leads to their respective plugs. The centre lead, of course, goes to the h.t. terminal of the ignition coil, the others being connected so that the lead from the stud which is adjacent to the distributor segment at the time, goes to the plug of the cylinder which is in the firing position ; that is, at approximately top dead centre with neither valve open nor about to open. Mark the distributor cover with the numbers of the leads, to facilitate subsequent assembly, and fit spring clips or other neat terminals to the lead ends for making connection to the plugs.

A Magneto for the " Seal " Engine

Several readers have asked whether I am going to provide magneto ignition for this engine. The answer is that, like quite a number of other features, it is an optional fitting, and provision for it has been by no means neglected in the scheme of design.

The simplest way to adapt the engine to magneto ignition is to do the same as I have done with the 50 c.c. four-cylinder engine constructed by Mr. Savage, as described some time ago ; namely, to utilise the existing contact-breaker and distributor, in conjunction with a magneto of substantially the same type as that used for a single-cylinder engine. While this does not represent prototype practice, where the orthodox form of multi-cylinder magneto is employed, the latter presents serious difficulties for modelling on a small scale, and from the practical point of view, offers no advantages beyond that of correct appearance.

A self-contained magneto such as the " Atomag " type, or the ready-made " MI." may

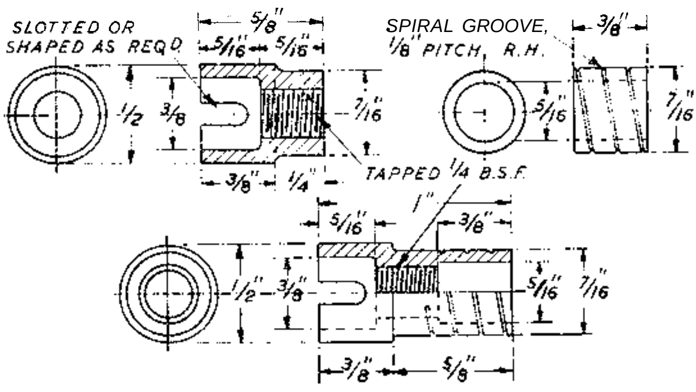
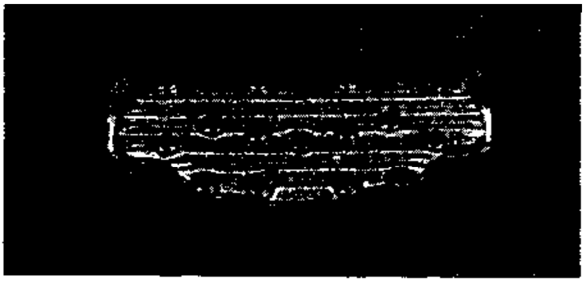


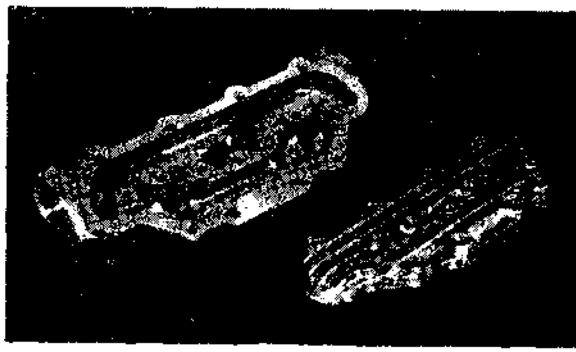
Fig. **49.** ***Coupling and oil retainer sleeve, showing (below) an alternative fitting combining both*** components

be used, fitted with a double-break cam, and direct-coupled to the main engine ***shaft in*** any convenient way. Alternatively, a built-in flywheel magneto of the " Atomax " type may be used, and if adapted in size to conform with the size of the engine, is preferable in respect of compactness and neatness. I have in hand a design for a magneto well suited to this particular application, and hope to be able to arrange for supplies of essential parts for its construction in due course.



Inlet-exhaust manifold for the " Seal " engine.

I must confess to being a little disappointed in the general attitude of readers to the small magneto ; while nearly all petrol engine users are very enthusiastic about it and ready enough to adopt it, few of them seem prepared to tackle the job of making one, though the directions which I have given should be sufficient to enable any model engineer of average ability to carry out this work successfully.



The manifold with cover removed to show exhaust and inlet passages

Final Adjustments

These are not in any essential way different from those of a single-cylinder engine, neither should it be any more difficult to get the engine working, or to maintain it in an efficient running condition. As with any small engine, it is most essential that the compression should be good, and the valves tight, also that jet adjustment and other details should be carefully attended to. The standard form of ignition coil, as used with single-cylinder engines and running at normal voltage, will suit a " multi " fairly well, so long as it is of good quality and capable of a high spark frequency. As the drain on the battery will be greater than that of a single, be sure that the capacity of the battery is ample, or disappointment will be the result. The bad reputation which small petrol engines have acquired in certain quarters is very largely due to ignition trouble caused by cutting the margin of battery capacity and coil efficiency too fine.

Water !

Do not, in the hurry to get the engine running, forget to fit up the water circulating system, or-even more important-to fill it with water ! I have known this happen many times, strange as it may seem. The fuel tank should be placed as near to the carburettor as conveniently possible, and within an inch or two below jet level. Filter all fuel meticulously before putting it in the tank. Oil level should be kept well on the high side during the running-in period ; it is much better to oil a plug than to score a bearing. Never succumb to the temptation to open the engine flat out without load, just to satisfy personal curiosity or show off to admiring friends: remember that there are four split big-ends in the engine, and what ***might*** happen if only one of them failed to stand the strain is better imagined than described.

The " Seal " Steps Out

In this first essay in the design of a small four-cylinder engine, I have attempted to live down, to some extent, the reproach that small petrol engines are not " true models " (whatever that may mean), but at the same time eliminate the major difficulties of near-scale petrol engine modelling, and bring it within the scope of the average model engineer.

The intention to produce four-cylinder engines of similar type, but in other sizes, has been referred to earlier, and I have had many letters asking for both larger and smaller versions. I do not propose to make exact scale copies of the engine in various sizes, though this is quite practicable if readers wish to do it for themselves. I prefer, however, to explore other paths of design, to tackle new problems, and if possible, to attain still further facility of construction and elimination of snags. Supplies of castings and other essential materials of construction are still a problem, but this is gradually being ironed out and I hope to make a definite announcement about it in the near future.

I have already made some progress in the design of a 30-C.C. four-cylinder engine, and a friend is co-operating with me in providing another of 10-c.c.-the smallest size I can contemplate with equanimity at present. But please don't write and ask for advance details of there designs yet-they will be made public when the time is ripe. For the present-Hush ! keep **it** dark-my lips are SEALED