Milling attachment
with three functions

WHILE the slide movements provided on a metal turning lathe for sliding, surfacing and angular work on a horizontal plane are normally sufficient, the scope of the lathe can'be extended to include many kinds of work beyond ordinary turning by the fitting of attachments which provide a vertical movement. Many of these devices, varying in complexity and utility, have been described in ME, and have been put on the market by makers of lathes and their accessory equipment.

The most popular attachment is the vertical slide, which was first used by instrument makers and horologists and was later adapted to larger lathes up to 3 1/2 in. or more in centre height. Many model engineers consider the vertical slide indispensable. One form has a perpendicular slideway, integral with the base or rigidly fixed to it, so that the sliding table can move only in a vertical plane, and the other has a slideway which can be swivelled about a horizontal axis to provide for oblique sliding.

Attachments to carry a milling spindle or a dividing head are often mounted on the vertical slide table, or are made with a self-contained elevating movement. It occurred to me that the three functions of the vertical work table, milling spindle and dividing head could quite easily be combined in one compact unit; this idea is not new, but it has seldom been carried out as neatly or thoroughly as it might be.

One of the most important requirements of any fixture used for milling in the lathe is that it should be as rigid as possible to avoid deflection, which is liable to destroy accuracy, and cause digging-in or chattering of the cutting tool. At the very best, there are limits to the usefulness of a light lathe for milling operations, as its slides are not designed for this work, and it is often necessary to mount the work (or the cutting tool) at some distance from its point of support. Most vertical slides nowadays are of very sturdy design, but this is of little use if the entire fixture is liable to deflection. The number of separate parts or articulated joints must necessarily affect rigidity, and the non-swivelling vertical slide is generally to be preferred. But the weakest feature, indeed the Achilles heel, of the orthodox vertical slide is its attachment by a single bolt to the cross-slide. No matter how broad the base of the slide, or the strength of the fixing bolt, there is a limit to the security which can be obtained by its anchorage to a T-slot in the cross-slide or boring table of the lathe. A practical improvement, though one not easy to carry out without an effect on the adaptability of the fixture, would be to provide the base with a broad foot to take two or more well-separated fixing bolts.

The overhang of the sliding work table from the base of its vertical support is another factor which affects rigidity. Many fixtures, especially those which swivel, do not provide the support to withstand the levering action caused by rotating cutters-generally much greater than the continuous action of a comparable single-point tool.

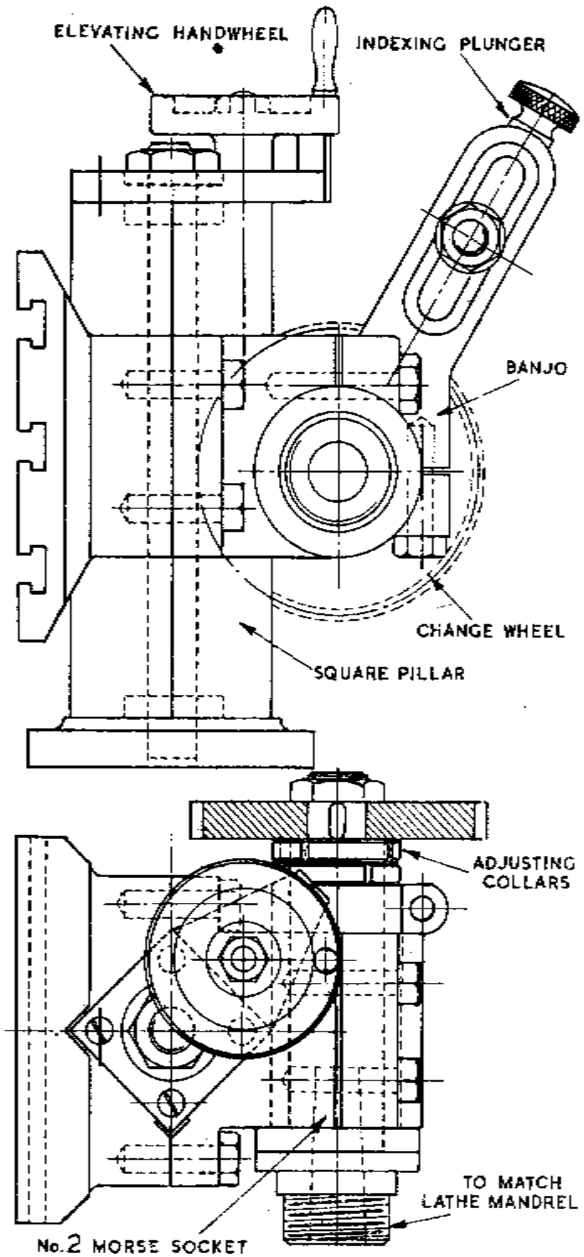
In the appliance shown, the form of vertical support is unusual. It is intended to provide rigidity with the minimum overhang of the work table or milling spindle. Its principle is logical, and by no means without precedent in machine tool design, as the prismatic form of slideway or lathe bed. has been used in some of the best machine tools. But the major reason for the use of a square pillar is ease of production in the home workshop. The pillar itself can be made from stock mild steel bar, which is obtainable in. sufficiently accurate shape to need no more than a little filng and scraping, with the normal checking. Exactness of angle on the four sides is not highly important so long as the sliding parts are fitted to the bar; this also can be done by filing and scraping.

The pillar is mounted on a part-circular baseplate with flats on the sides to bring it within the width of a normal cross-slide-there is no advantage in any overlap-but of an adequate diameter that will provide adequately stable mounting. Slots in the base give a latitude which will accommodate variations in the spacing of the T-slots in the cross-slide, and also the angular position of the base. A 1/2 in. hole is drilled through the centre of the pillar and counterbored at both ends to provide! a register recess. It is secured to the base by a long tension stud, which can be tightened much more securely than is possible with the central anchorage bolt usually fitted on a vertical slide. Alternatively, the pillar could be permanently attached to the base by brazing or welding, but this might restrict the rotation of the pillar for setting the table at angles other than 90 degrees to the lathe axis, unless the baseplate is modified.

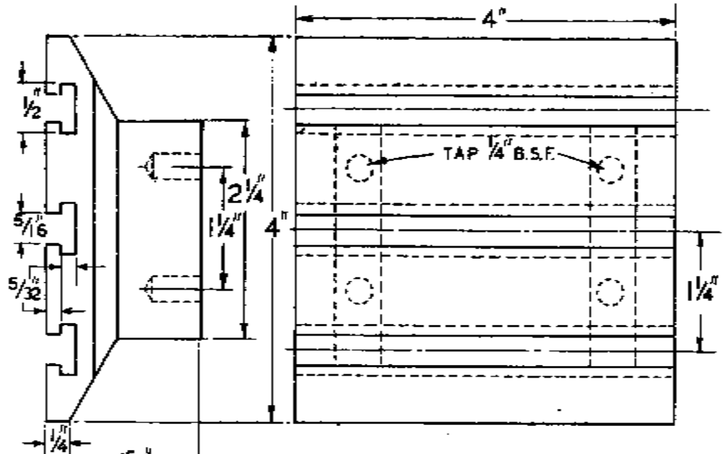
On the side of the pillar opposite to the vertical table, a housing is provided for either a milling spindle or a simple form of dividing head. The bearing for both fittings is of the self-contained quill type; you can remove or replace it without upsetting adjustments. In the general arrangement drawings, the dividing spindle is shown in position; it is designed to take the same nose and socket fittings as the lathe itself, so that work can be transferred from one to the other. The tail end of the spindle takes any of the lathe change wheels, which can be indexed by a spring plunger mounted on a banjo clamped to the quill. This gives a range of divisions which will cope with many-perhaps most-workshop requirements. The range can easily be extended by the addition of a worm gear or other multiple indexing device.

If milling or indexing is never likely to be required, the spindle housing may be replaced by a V-grooved saddle, similarly fitted to slide on the pillar with the vertical table. But the housing takes up so little room, and is so unlikely to get in the way or affect operation of the slide, that it is worth fitting even if its use is not at first envisaged. Only vertical movement of the slide is provided, in the interests of simple construction and rigidity. In my experience, angular movement of the slide is rarely needed; you can generally obtain the essential object by mounting the work obliquely on the table. The spindle housing, in the form shown, is also restricted to the horizontal position. For some kinds of work, provision for swivelling the housing about the horizontal axis, and also for fitting an overarm support bar would be an advantage, but these refinements have already been anticipated in the design and will be incorporated in a modified version.

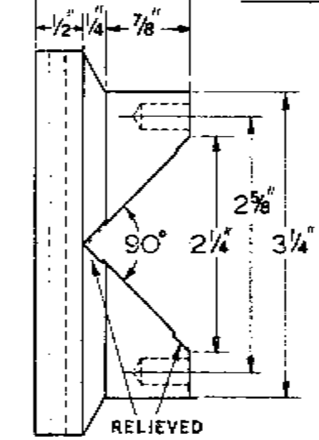
The elevating movement of the slide is provided by a screw, the bearing of which is in an overhanging plate attached to the top of the pillar. It engages a tapped hole in the housing or saddle casting, and is operated by a disc handwheel grad-

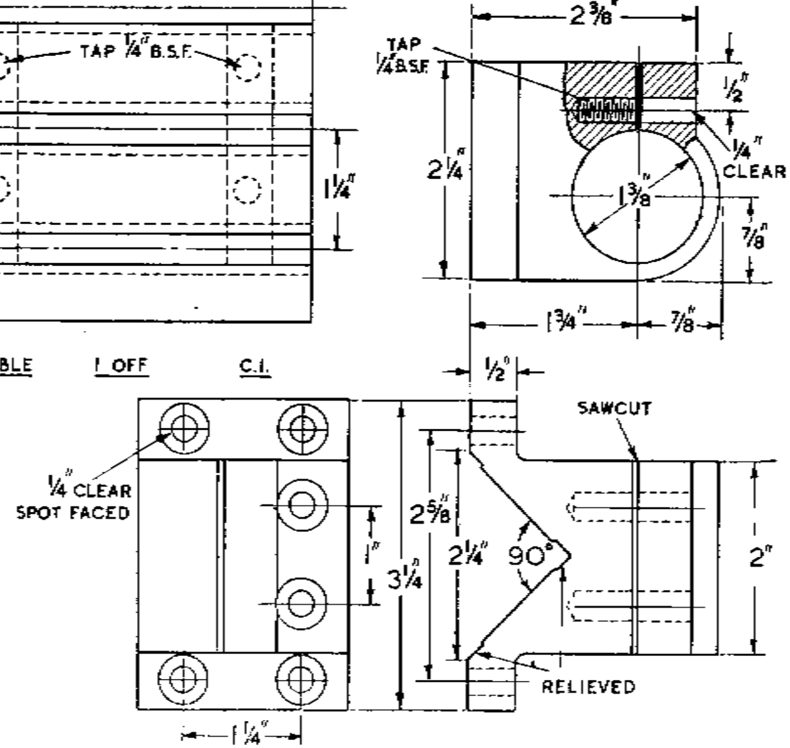


GENERAL ARRANGEMENT OF MILLING FIXTURE

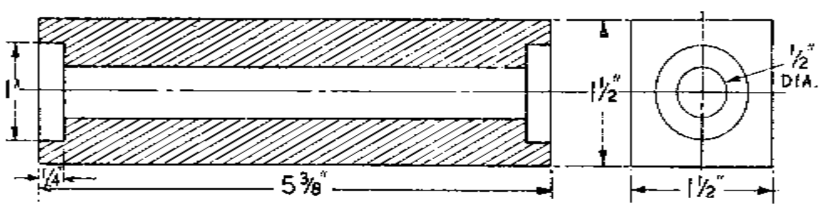


SLIDING TABLE 1 OFF C.I.





QUILL HOUSING 1 OFF C.I.



PILLAR 1 OFF M.S.

TENSION STUD: 6 3/8 LONG x 1/2 DIA. M.S., SCREWED B.S.F. BOTH ENDS uated to serve as an index. This is, in my opinion, much better than the popular ball handle with a separate index disc; it gives a more open spacing of divisions owing to its larger diameter and is therefore easy to read. But this is, of course, an optional fitting, and may be modified to suit your preference. The screw is intended to be 3/8 in. BSF 120 **t.p.i.,** so that if 50 divisions are engraved on the disc, each will represent a vertical movement of 1/1,000 in. Although feed-screws for machine slides generally have square or Acme threads, and are coarser than most standard V forms, the Vs together with their corresponding internal threads, are quite serviceable and provide finer adjustment. They are likely to be at a disadvantage only when frequent and rapid traverse is required.

In making this appliance, you should begin with the square pillar. Having obtained a suitable piece of square steel bar, ***or*** machined it from the solid, you check it for general truth, and mark it out carefully for central drilling. It is then set up in the four-jaw chuck, and its true running is checked over the four flats-not over the corners, which may vary in sharpness. As you cannot steady the projecting end of the bar (except by making a special fitting) the overhang may cause some lack of rigidity, tending to affect the accuracy of drilling. It will therefore be worth while for you to allow an extra 1/2 in. or so of length, which, after the centre-drilling and supporting on the back centre, you can turn circular and run in the three-point steady; this extension will of course have to be parted off afterwards, but it can be retained until you have machined the register recess.

The pillar need not be made to the specified length (though this will give a convenient range of vertical movement for most purposes on lathes of about 3 1/2 in. centres). Neither is it essential that the hole should be exactly central. But it must be at least parallel to the axis, so that when the ends are faced at the same setting as the drilling operation the pillar will stand exactly vertical on a level surface. Take all possible pains to be accurate. Though errors in machining can be corrected in fitting, it is much better if they do not occur in the first place.

Your most suitable tool for forming the recess at each end of the pillar is a counterbore. You can make one by fitting a double-ended high-speed or silver steel bit in a mild steel bar 1/2 in. diameter, to suit the drilled hole. The exact size of the recesses is not critical, as the spigots of the baseplate and cap can be fitted to them.

The baseplate can be made from an iron casting or a piece of steel plate. In the machining, the important points are flatness and parallelism of the underside and pillar seating, and the fit of the spigot. The position of the slots for bolting it to the cross-slide may be modified to suit the spacing of the T-slots in the lathe on which it is to be used. For the tension stud, a suitable length of 1/2 in. mild steel bar is screwed at each end to fit the tapped hole in the baseplate, and to take a standard nut at the top. Screwed rod or studding may be used, but it is not so strong as a properly made double-ended stud.

I recommend simple iron castings for both the sliding table and the quill housing. You can cast in the T-slots in the table by providing a corebox and putting core prints on the pattern, but unless they are cast smooth and accurate they may be more trouble than they are worth. It is quite possible to machine the slots from the solid, or from rudimentary grooves cast directly from the pattern, when the table is fitted to the pillar and mounted on the cross-slide.

The table casting is first machined on the front surface. After it has been mounted in the four-jaw chuck, and reversed for similar treatment on the joint face, you can machine the four edges square by mounting the casting face down on an angle plate. To make sure that these edges are in reasonably true angular relation to the V groove, clamp a round bar in the groove and use it as a location gauge.

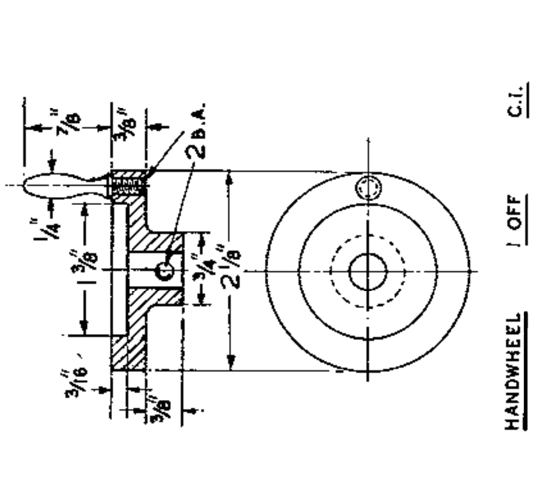
If you do not have a shaping or milling machine you can file and scrape the V surfaces to fit the pillar. Use an accurate flat bar, or a slip of plate glass, to test the individual side surfaces, with the aid of marking colour or " mechanics' blue." You can again use the round bar as a gauge to check both the squareness of the groove with the edges of the table, and its parallel truth with the face. Lay the table on a surface plate with the bar in the groove, and measure its underside distance from the plate at each end with inside calipers, or over the bar with a dial test indicator.

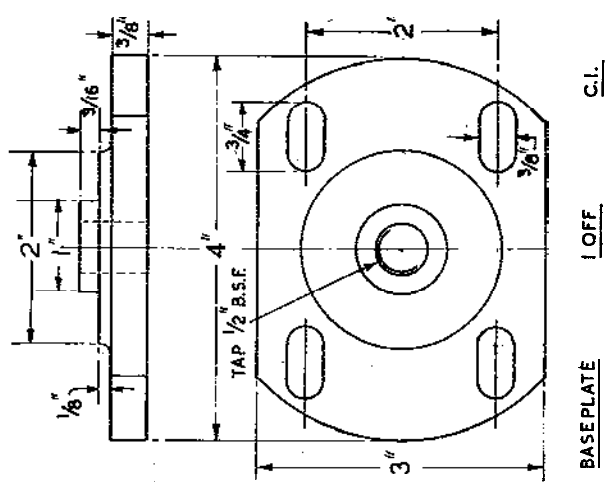
After the quill housing has been machined on the joint face, you can deal with it in the way that you fitted the V groove. When offered up to the pillar, the joint faces may not make contact, and there is a choice between increasing the depth of the grooves or of fitting shims between the faces.

To machine the bore of the quill clamp, the casting may be mounted on an angle plate and squared off carefully from the V groove. The bore should be dead parallel and both ends faced to provide a true seating for the quill when fitted either way round. Before splitting the clamp, the holes for the clamp screws should be drilled, tapped and spot faced.

NED.

To be continued





Continued from **January** I

By Ned

This INDEXING GEAR is accurate and quite easy to construct

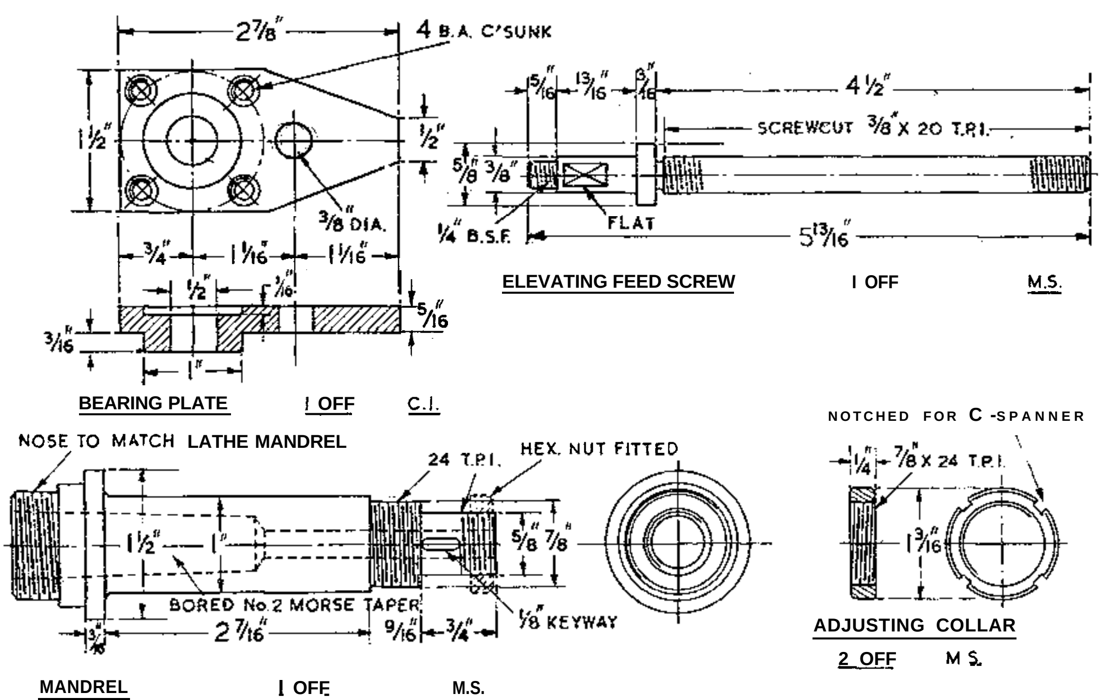
THE bearing plate which fits on the top of the square pillar may be made from a casting or machined from solid material. Both sides should be machined parallel, and the spigot on the underside should fit the recess in the top face of the pillar. A recess in the upper side of the plate, just large enough to clear the comers of the 1/2 in. holding-down nut, allows this nut to be made thick enough for ample strength without undue projection above the plate surface. The four countersunk screws serve only to maintain correct alignment of the feedscrew bearing, and need'be no larger than 4 BA. No details of the tapped holes to take these screws were shown in the drawing of the pillar on December I5, but it will be obvious that they are located from the holes in the plate.

Similarly, the tapped hole in the quill housing, to take the feedscrew, was not shown, as you can more accurately assure its location by spotting through from the hole in the bearing plate, when the parts are assembled on the pillar, than by measurement. It is, of course, essential that the drilling and tapping of this hole should be truly parallel to the vertical face of the pillar. The best way to ensure this, after you have located the hole position, is to set the housing up on an angle plate, with its machined under face bedded firmly against the faceplate. Unless you have a clearanced or through tap, with its shank undercut below the tapping hole diameter, you cannot cut the thread throughout the full 2 1/4 in. depth of the housing; but this will not be necessary, as 3/4 in. depth of thread is ample, and the rest of the length of the hole may be opened out to clearance size.

The elevating fee&crew may be turned between centres from 5/8 in. mild steel bar; this size will provide a substantial thrust collar, though the collar can be brazed on (before the final machining) if you wish to economise in material. The thread should be screwcut, and finished with a chaser; dies often produce an imperfect thread form, and also a pitch error, but a good quality die nut could be used for final sizing of the thread.

To attach the handwheel, several alternative methods are practicable. The arrangement shown is simple and satisfactory. A flat is filed or machined on the shank of the screw, to form a seating for a 2 BA Allen grubscrew in the handwheel hub. This locks it against torque, after the endwise clearance has been adjusted by a 1/4 in. nut on the end of the feedscrew. An indexing pointer may be attached to the small end of the bearing plate, or in any other convenient position.

The indexing mandrel may be varied ***in*** design to suit your convenience; it may be adapted to take standard draw-in collets if you prefer, and the screwed nose may not be needed, in which event it may be shortened to reduce overhang. But there are advantages in the ability to transfer chucks and other fittings from the lathe mandrel to the milling



Details of components for milling and dividing appliance

appliance: the Morse taper socket allows either taper-shank standard arbors and cutters, or the patent Myford collets, to be used. A hole of appropriate size may be drilled right through the mandrel, to take a drawbar which will prevent slacking-off of arbors or cutters.

Whatever internal machining operations are carried out on the mandrel, it is extremely important that their concentric truth with the outer bearing surface should be preserved. Some constructors may prefer to carry out all external machining first, and then set up the mandrel, with the aid of a fixed steady on the outer end, for boring the Morse taper socket or collet seating. Another method is to carry out the boring operations first, and then mount the workpiece on a specially formed mandrel for external machining.

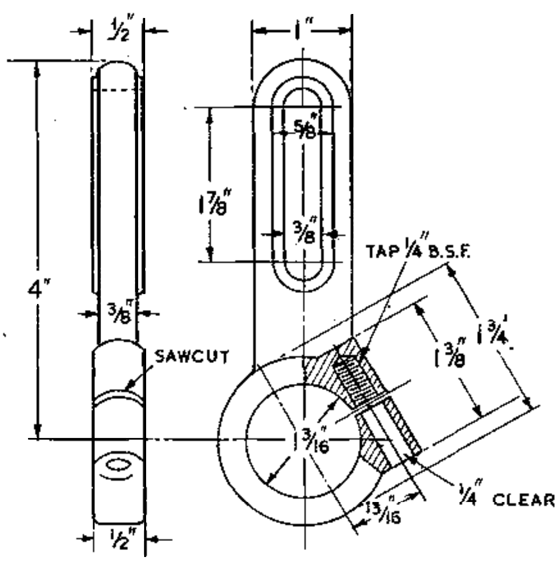
Details of thread and register dimensions for the mandrel nose will, of course, depend on the lathe to which the appliance is fitted. For the Myford ML7 or Super-7, the thread is 1-1/8 in. dia. X 12 t.p.i., and the register is 1-1/4 in. dia. The threads at the outer end of the mandrel, 7/8 in. and 5/8 in. dia., are both specified as 24 t.p.i., as this is a convenient pitch, eliminating any picking-up difficulties. But if you have dies and taps for other fine threads, such as brass pipe standard (26 t.p.i.), you may use them. The bearing surface of the mandrel must be dead smooth and parallel; it may be finished by the use of a ring lap. A key of suitable size for locating the lathe change wheels used for indexing may be fitted to a keyway cut bv end-milling as shown, or by **a** side mill or Woodruffe cutter.

sleeve bearing to be carried out at one setting. The bore should be' finished to a smooth running fit for the mandrel , and the outside to a close fit in the bore of the quill housing. I recommend lapping for final fitting. After parting off, facing the end, and forming a radius or chamfer in the mouth of the bore, to clear the fillet on the shoulder of the mandrel, make a sawcut about halfway along the sleeve from the large end. You can then firmly lock the mandrel against rotation by clamping the sleeve in the quill. Slackening the setscrew of the quill at this end allows the mandrel to be turned, while the sleeve is still firmly held against rotation by the other setscrew.

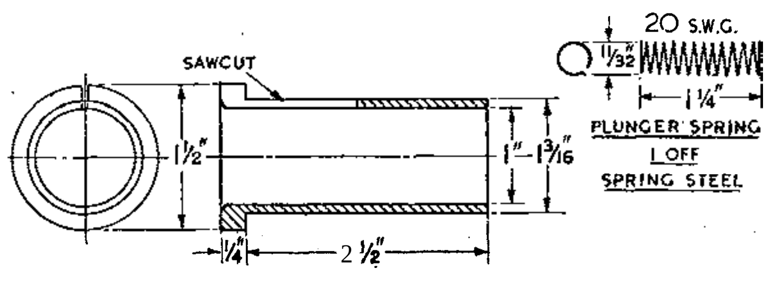
Making the fittings

The banjo casting is set up on the faceplate for boring, and facing the clamp end; this should be a close fit on the tail end of the bearing sleeve. After drilling and tapping the hole for the clamp screw, and spot facing the outer end of the lug, make a radial sawcut. The slot in the arm of the banjo is cast-in but, will call for some trimming, to allow the stud of the plunger housing to slide in it. Facing of the sides to a true parallel surface may be carried out while the casting is set up for boring, or by clamping it on a mandrel afterwards. When the banjo is fitted to the sleeve, only moderate tightening of the clamp screw should -be required to fix it immovably, while loosening it allows it to be adjusted to the most convenient angle for indexing.

A plunger with the end shaped to form a detent, to engage



BANJO I OFF C.I.



SLEEVE BEARING I OFF G.M.

the teeth of any gear wheels employed for indexing, is carried in a housing machined from mild steel or other convenient material. The bore in which the plunger slides must be parallel with the surface which bears against the side of the banjo. It must be dead smooth and parallel. I recommend a D-bit for finishing it. This surface and the surface of the plunger may both be fitted by lapping. While the plunger must slide freely, no slackness can be tolerated if accuracy of indexing is expected. If you are clever enough to fit the plunger so neatly that air is compressed, so much the better-you can easily drill a hole in the housing to release the air !

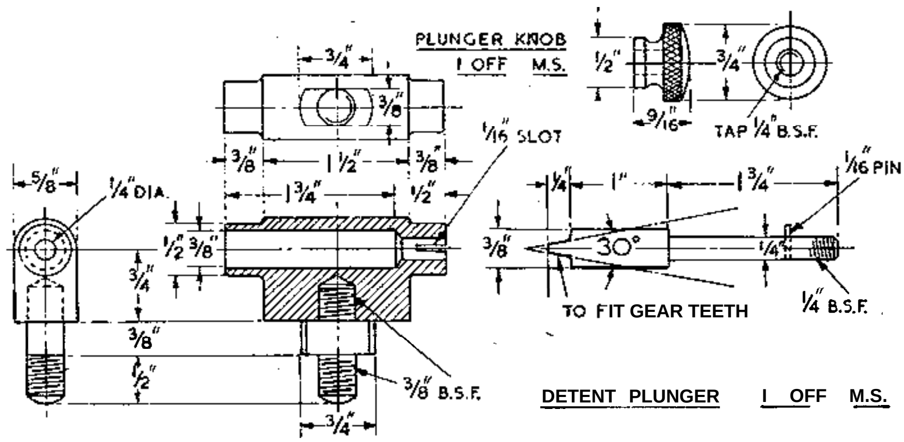
Both ends of the housing are turned concentric with the bore, 1/2 in. diameter for a distance of 3/8 in. At the outer end, a cross slot is cut, 1/16 in. wide, in one side only. The base surface of the housing is drilled and tapped squarely to take a 3/8in. BSF double-ended stud with a central collar 3/4 in. diameter. After this has been tightly screwed in position, the sides are milled or filed away to a width of 3/8 in., to fit the slot in the banjo. If you prefer, you may machine the housing in one piece with an extension to take the place of the separate stud-taking care to face the seating surface truly, so that it beds flat against the banjo.

The collars for end-clearance adjustment of the mandrel may be machined in one piece, including the milling of the notches in the outer edge, and finally parted off. It is important that no burrs should be left to interfere with the true seating of the faces. Instead of notches, holes for a tommy bar or pin-spanner may be used. So that the mandrel and its bearing assembly can be withdrawn from the quill housing without affecting adjustment, the collars cannot be made larger in diameter than the bore of the housing; it is therefore difficult to apply other methods of adjustment, such as a single split-clamped or grubscrewed collar.

A casting with allowance for chucking at the large end will permit both external and internal machining of the

The plunger may be made of 3/8 in. bright steel bar, so long as it is chucked truly for turning down the end to 1/4 in. dia., and threading 1/4 in. BSF, At the other end, it is filed or machined to fit closely between the teeth of the indexing gear wheels. As the exact profile of the tooth spaces varies with the diameter and number of teeth, a universal form-fitting profile cannot be employed. A straight-sided detent at an included angle of 30 degrees will make good line contact with the teeth of wheels of all the sizes likely to be employed; and it has a good wedging action for positive location. The detent may be filed to shape if great care is taken to maintain symmetry and correct angle on the two sides, but you can get more positive accuracy by machining the angular surfaces.

To machine them easily, make the plunger with a small central witness projection on the end, of a diameter equal to that of the bottom of the tooth space. It is fitted in the housing; and held lirmly in position by a nut on the end, and an internal sleeve of such length that the detent projects about 3/8 in. The housing is then mounted on the faceplate, by its fixing stud, in a radial position, with the detent pointing outwards. By swivelling the topslide of the lathe to 15 degrees from the cross centre, you can machine away one side of the detent until the tool just skims the witness projection. The topslide is then swung to the reverse angle, and the process is repeated on the other side of the detent. Only very light cuts should be taken, to avoid heavy intermittent load, but the process is by no means long or tedious.



DETENT PLUNGER I OFF M.S.

PLUNCER HOUSING I OFF M.S.

side milling method

A somewhat quicker method is to mount the plunger in the toolpost, using a split clamp or V packing block which will locate it at approximate centre height. It is set exactly square with the lathe axis, while the swivelling topslide is at zero; then by swinging it 15 degrees each way in turn, you can machine the sides of the detent by a side milling cutter running in the lathe. The witness may be faced off, leaving the end of the detent just wide enough to prevent bottoming in the gear teeth. Symmetry of the wedge surfaces is highly important if the plunger is free to engage either way round; otherwise it is not critical. Some indexing devices have been made with the detent deliberately offset so that they can be used to “split a tooth “-to produce 120 divisions from a 6o-tooth wheel, for instance. They call for meticulous accuracy in the amount of offset, and can be used only with a single size of indexing wheel.

The detent may be case-hardened, but the rest of the plunger should be left soft. A spring of the size shown in the drawing will provide just about sufIicient pressure on the plunger for positive indexing. Where abnormal side torque load is encountered, clamp the mandrel after indexing in each- position. After the indexing gear is assembled, and a gear wheel set up with the detent in proper engagement, a cross hole may be drilled in the shank of the plunger to take a 1/16 in. pin, just clear of the bottom of the slot. The pin may be either a drive fit or screwed in; its duty is light, as it serves only to locate the detent square with the gear tooth. When the plunger is withdrawn and partly turned, the pin will then hold the detent out of engagement and leave the mandrel free. The latitude allowed in the slot of the banjo permits the plunger housing to be adjusted for any lathe change wheel in the range normally supplied, and it may be extended to take larger wheels. It is generally best to use the larger wheels, when you have a choice, as they give greater angular accuracy and torque resistance.

You will find this form of plunger and housing assembly equally useful for indexing the lathe mandrel, if you set it up on the screwcutting gear quadrant or another suitable fitting. Nearly all lathe users have a need for some kind of indexing gear. It is often a crude makeshift, rigged up hastily, and subject to incidental errors. By taking a little time you can construct a sound indexing device which is just as simple to rig up, and far more reliable in accuracy.

The indexing gear is suitable for many operations in normal model practice, such as cutting small spur, worm and ratchet wheels, fluting taps, reamers and milling cutters and cutting squares, hexagons and keyways. In all these operations, the full power of the lathe, and its range of speeds, are used, and no auxiliary drives are required. The indexing spindle is quickly set up in the housing, with the banjo clamped to the bearing and a suitable change wheel mounted on the mandrel. When these things are not required, you need only remove them, and slip the mandrel assembly out of the housing without disturbing its end clearance adjustment. It is equally simple to replace the assembly with a quill-fitted milling or grinding spindle.

For some operations involving indexing or milling appliances, you must swivel the mandrel to various angles other than horizontal. My next instalment will describe an improved swivelling form of quill housing which allows this to be done and also provides for the fitting of an overarm support to steady the end of an arbor.

To be continued

Continued from **January** 15

Here is another form of

HOLDER

for the dividing mandrel

IN THE modified form of the appliance, which provides for angular movement of the dividing mandrel in addition to vertical feed, three new castings are required. They are simple and straightforward to machine. Instead of the solid quill holder fitted directly to the vertical pillar we have a separate saddle piece, on which is mounted a swivelling quill holder. Provision is also made for fitting a steady bar, or overarm; this calls for a steady bracket casting. No alteration whatever need be made in the vertical table or the method of fitting it to the column.

The first operation on the quill holder'is the facing of the rear mounting surface. You can hold the work in the four-jaw chuck, or clamp it to the faceplate, with packing under the smaller of the two bosses, to adjust it so that the axes of both bosses are the same distance from the plate. At this setting, the recess in the back face, to fit the spigot on the saddle piece, should also be bored. The two subsidiary recesses, 9/16 in. dia. X 3/16 in. deep, at I in. centres, provide clearance for the heads of the hook bolts; they can be cast-in if the foundry work is accurate, but it is not safe to rely on this. To use a piloted counterbore to machine these recesses is not practicable, and so your best method is to offset the casting 1/2 in. either way from the centre and bore them out. Exact location and dimensions of the recesses are not important, as they simply have to provide clearance for the bolt heads.

Locking arrangements

The method adopted for locking the swivelling adjustment of the quill holder is unusual. Its object is to provide more positive security than is possible with a central bolt or stud. Resistance to movement is greatly increased, and there is no tendency whatever for the adjustment to shift while it is being finally tightened. Those who are confident that the central fixing with a screw, or a stud 3/8in. dia., is quite adequate may revert to it without any alteration of the castings, but I still recommend the two-bolt arrangement.

Set up the housing on an angle plate to bore the two holes in the bosses exactly parallel with each other in both planes. First clamp the casting to the angle plate, backed up against the faceplate and with its boss centres squared from the mounting face; any further adjustments needed for centring both holes are made by moving the angle plate on the face-plate. Both bores should be smooth and parallel, and a close fit for the quill and the steady bar. For any form of split clamp good fitting is essential. The clamp should never be expected to take up slack before it can be tightened. Particularly in machine-tool components, where true alignment and position are highly important, no pains should be spared in the boring and fitting. A reamer may be used for the final sizing, so long as it takes out a mere scrape-not more than 5 thousand can be guaranteed not to chatter or snatch.

While the housing is set up on the angle plate, you can use it, without altering its setting as a jig to provide true alignment of the steady bracket. Set up the casting in the four-jaw chuck, with one jaw reversed, for boring the larger of. its two bosses, to the same size and standard of accuracy as the corresponding boss of the housing. A short mandrel, turned to a press fit in the bores of both parts, holds the bracket in the exact position for centring and boring the small end boss.. The small end boss of the housing should be bored first, so that when it is shifted to set up the larger boss centre it is in the right position to centre the small end of the bracket.

Splitting the bosses

Both side faces of the quill housing should be machined true and parallel; this too can be done on the angle plate. It remains only to drill and spot-face the holes for clamping bolts, and split the bosses either by a hand or machine saw. A neat and accurate cut with an ordinary hacksaw is not easy to make; a piece of a broken machine saw blade, held in a suitable holder (there are several kinds to choose from these days) will do a cleaner job. With a fairly large slitting saw, on an arbor or mandrel, used in the lathe, the casting may be clamped to the side of an angle plate mounted on the cross-slide. For the steady bracket, a strap with two bolts, and packing under the smaller boss, will be needed for mounting.

If studs or set screws are used instead of through bolts for the split clamps, the clearing holes are drilled in one half only, the other being tapped. The seating faces for nuts or cap screws should always be spot-faced to provide a true surface.

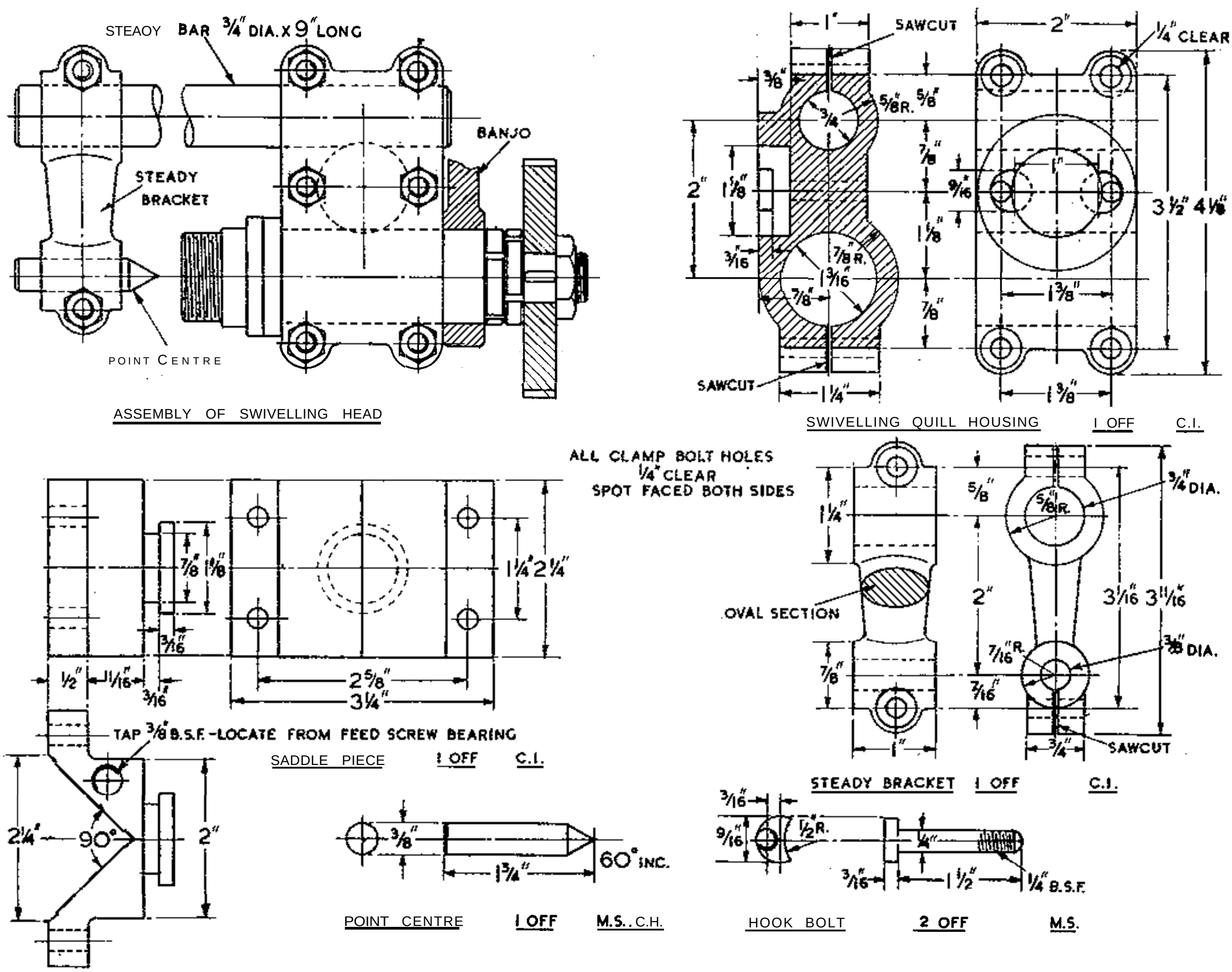
I have found that some readers are not familiar with the term " spot face," and ask what it means and how it is carried out. The meaning is quite literal; it denotes the facing of a "spot" concentric with the hole, and large enough to cover the diameter of the nut, screw head or washer employed. The face can be produced in various ways, such as by a piloted pin drill or a multi-toothed facing cutter; it matters little so long as the desired result is produced.

The bolt holes in these components are located as close to the bores as possible, so that they perform their clamping function efficiently with the minimum risk of distorting or breaking the lugs. To cut into the bosses with the spot-facing tool is better than to space the holes farther out from the boss centres. I have often found it necessary to strain the bosses almost to breaking point before a secure clamping grip is obtained.

You can make the steady bar of mild steel so long as it is straight and is correct in diameter. Silver steel or another high tensile material may be used, but it confers no special advantages in strength. The length of bar stated is the maximum which should be necessary or desirable; where work must be mounted on arbors which require outboard support, the arbors should be kept as short and stiff as possible, and the steady bracket adjusted to suit. I have seen dividing appliances in which the extension of the steady bar is out of all proportion to the support provided by the vertical slide, especially when it relies on a key for torque resistance and is secured to the lathe cross-slide by a single centre bolt.

The saddle piece is fitted- to the vertical column in the same way as the solid quill holder. Its essential dimensions, including the position of fixing holes, and the tapped hole for the vertical feedscrew, are the same. After the major

If you have none, you must first machine the bar to this diameter to form the screw heads. It is then offset, either in the chuck or in an eccentric feature, to about 3/16 in. for turning and screwing the shank of the bolt, so that one side of it runs out about flush with the head. After the parting off, the head is faced to 3/16 in. thick to fit in the groove of the spigot on the saddle piece. The projecting side of the head is then filed or machined concave; when fitted to the groove, the bolt lies snugly against the head of the spigot. Both bolts must be held in this position, on opposite sides, to allow the housing to be assembled and bolted firmly to the saddle piece.



ASSEMBLY OF SWIVELLING HEAD

SWIVELLING QUILL HOUSING 1 OFF C.I.

SADDLE PIECE 1 OFF C.I.

STEADY BRACKET 1 OFF C.I.

POINT CENTRE 1 OFF M.S. C.H.

HOOK BOLT 2 OFF M.S.

machining has been completed and the saddle fitted to slide smoothly on the pillar with the bolts tightened (with or without shims interposed) between the joint faces, the casting is set up on the faceplate for the grooved spigot on the outer face to be turned. The spigot should fit closely in the recess of the quill housing, and its projection should be very slightly less than the depth of the recess, so that the two components make contact on their broad outer faces-not on the end of the spigot.

For the two hook bolts, you can use 9/16 in. mild steel bar.

The only other detail needed for the modified dividing fixture is a point centre, which may be made from mild steel and casehardened, or from silver steel, hardened and tempered on the tip only to a dark straw, the rest of the length being let down to deep blue or purple. I have not thought it necessary to provide any fine adjustment for the centre, as it is usually considered sufficient to slide the bracket on the steady bar so that the point enters the centred end of the arbor; both end-location and radial adjustment are simultaneously obtained, and the bracket simply needs to be tightened on the bar. Some arbors may possibly call for a hollow centre, or a bush of appropriate size, to steady the end of the arbor in the bracket.

Some may have noticed that the dimension given for the bore of the quill housing, in the group of drawings on page 586 of the December 15 issue, does not correspond with that of the sleeve bearing in the next instalment, that the housing, which was originally bored to the stated dimension, seemed a little weak when seen in the flesh, so to speak. (It is not uncommon, when the first casting off has been machined, for the designer to have second thoughts on these details.) So that the casting need not be altered, I reduced the diameter of the bore and made the quill sleeve to fit.

All other parts of the dividing appliance are the same as for the non-swivelling design, including the mandrel in its sleeve-bearing assembly, or'quill, and the banjo to carry the indexing plunger for use with lathe change-wheels. It is possible, with this or the simpler non-swivelling head, to extend the indexing arrangement considerably by the use of worm gearing and orthodox division plates.

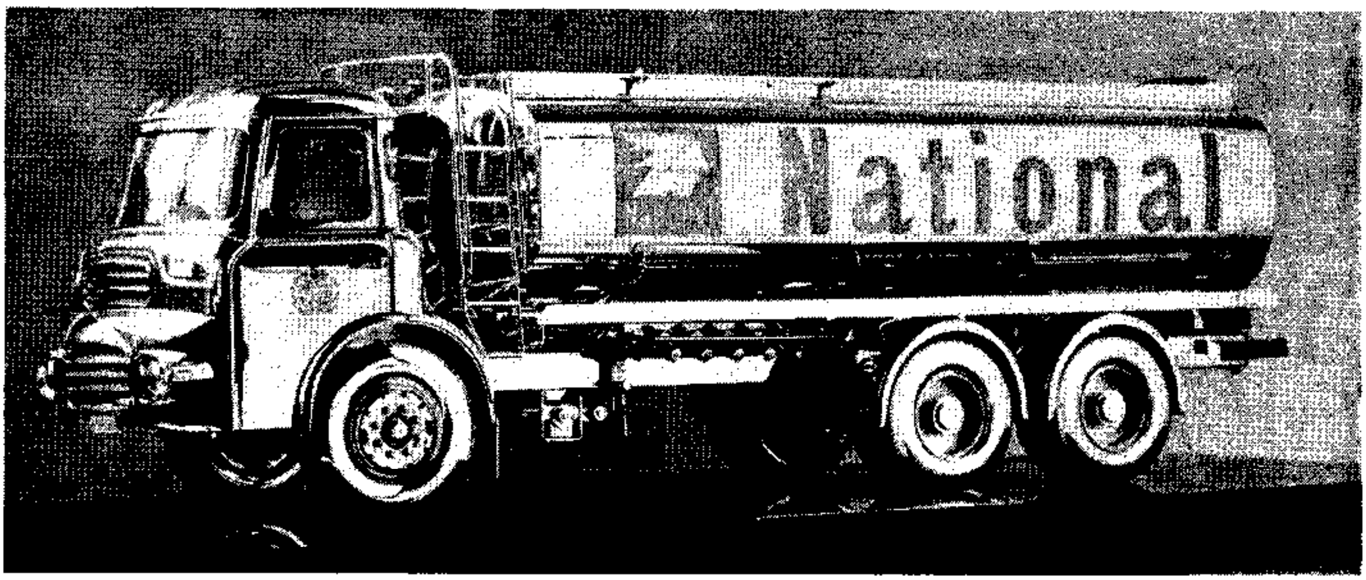
In all these devices, my object has been to provide the fullest possible range of utility and versatility, with the minimum elaboration or difficulty in setting up. But simplicity has not been obtained at the expense of accuracy or rigidity, and 'some of the defects common to appliances of this kind have been eliminated, or at least reduced.

Everyone who has attempted to use milling appliances in the lathe will be aware of the pitfalls which the work involves, especially in critical operations such as gearcutting; yet these operations in themselves are not difficult and should be well within the capacity of any model engineer with a modestly equipped workshop. The trouble is that many of the appliances, from the mere makeshift to the highly elaborate, are not adequate to the working stresses imposed on them. Few appliances are immune from elastic deflection, or spring, which obviously cannot be completely eliminated when the load is imposed at some distance from the point of support. But permanent deflection, often caused by the slipping of articulated joints, is absolutely disastrous. We cannot increase the massiveness of the individual components, or the strength of the joint fixing, beyond a limited amount without making the appliance unwieldy or almost unworkable. But we can do much by studying the basic principles of structure and design; and while I do not claim that this dividing appliance is perfect in either, I believe it to be a step in the right direction.

NED.

To be continued

MODEL AS TANKER TROPHY



A HANDSOME silver-plated model of a National **tanker has** been presented by the Leyland Motor Corporation as the award in a new competition to encourage safe driving and vehicle efficiency among tanker drivers in the National Company. It is to be competed for annually. The 1963 winners are the Midland Division, Birmingham.

The model, which represents an Albion Riever 3,ooo-gallon tanker is 18 in. long overall, giving about 1/18 scale. Mr A. F. Weaver, who is known to many ME readers for his excellent racing car and speed boat models, spent goo hours on building it, mainly-in brass and copper. It includes every detail, down to the design and wording of the Royal Warrant on the cab door.

All the parts had to be capable of being dismantled for plating, but the use of nuts and screws had to be avoided except where they would not be visible from the outside. The top of the tank is divided into five sections with walkways alongside and between. Each section has its inspection covers, cocks and other fittings. The model is mounted on a plinth of black glass which reflects the underside details. ❑

Continued from Februury 1

By Ned

Indirect indexing with worm gears

THE range of divisions which can be obtained by direct indexing, with the set of change wheels provided on a screwcutting lathe, or any other accurate gears, will suffice for the requirements of many. But when a much wider range of divisions is needed, the direct or plain indexing gear may prove inadequate. The most practical device then is one which employs a worm reduction gear in conjunction with primary indexing elements such as division plates.

Nearly everyone is familiar with this form of indexing ***gear.*** It has been established since 'the pioneer days of industry. Briefly, it allows a range of indexing to be obtained from a limited number of primary elements through the ratio of reduction provided by the worm gearing. Thus, with a division plate which has 50 equally spaced holes, and a worm which gives a reduction ratio of 60 to 1, the maximum number of divisions obtainable is 60 X 50 or 3,000. You can get any factor of this number by counting the turns of the primary wormshaft, or the number of holes in the division plate, required to make it up. The same applies to any other combination of primary elements and reduction ratios.

For instance, you may want to engrave an index with graduations each representing one degree-360 degrees to the complete circle. This might be difficult with direct indexing, but is quite simple with worm gearing. If you use a 60 to 1 gear and a 60 division plate (a total combination of 3,600), a movement of the primary shaft equal to 10 holes in the plate will produce 1/360 of a turn on the indexing mandrel. It is often found that the worm gear will deal with indexing problems which are almost impossible by the other means which you are able to employ.

Assuming that the gearing is accurate, the final precision of indexing is at least as high as the precision obtained by any method of direct indexing. It is often higher, because the worm gear gives more positive locking and resistance to displacement. You can set the worm in close engagement with the wheel so that no backlash can occur, or you can springload the shaft bracket to produce the same effect. The accuracy of the primary indexing is much less critical, as any error is divided by the ratio of reduction. A tolerable degree of accuracy can be obtained by the use of hand-divided plates, or anything which provides approximate equality of spacing.

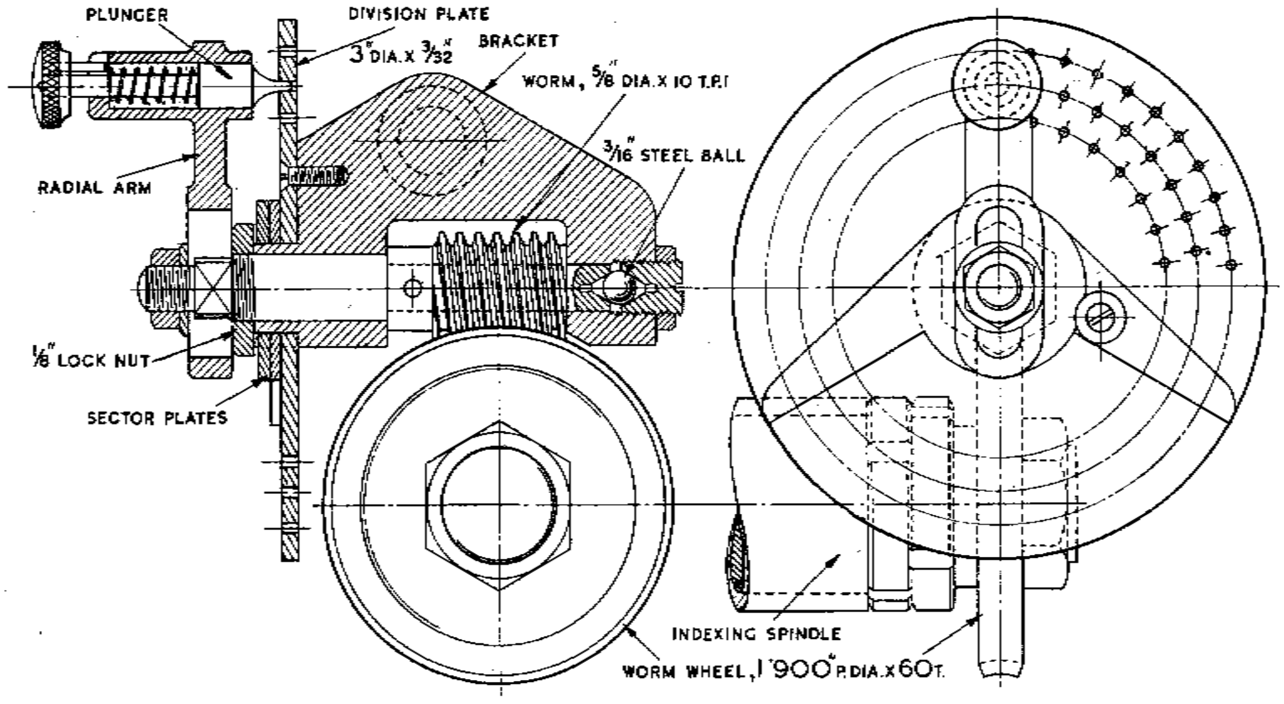
Many years ago George Gentry (a noted exponent of good workshop practice) described a worm indexing device which used cards produced on the drawing board and marked out by trial and error with dividers. I once knew a skilled clockmaker who used a mixed collection of old gear wheels, some of them well worn, in a worm-geared appliance which he used to cut some very fme gears and pinions. **Primary** accuracy is capable of some latitude, but obviously should be observed as closely as practical conditions permit.

Precision in the worm and worm wheel is another matter. Quite apart from pitch accuracy, any error in the concentric mounting of either will have serious results. The thread of the worm must have a constant pitch angle; a drunken thread will produce a periodic error in any work which involves varying angular rotation of the worm. It is not necessary to use a throated worm wheel, or to observe all the fine distinctions of'tooth form which are necessary in worm gears intended for the efficient transmission of power. The contact area between the worm and wheel teeth may be quite small; it is in order to use an accurate spur ***gear*** as a worm wheel if the wormshaft is suitably inclined to match the pitch angle of the thread. A slight error in the pitch of the worm does not atfect the accuracy of indexing, because it will automatically accommodate itself to the pitch line unless it is prevented from doing so by insufhcient tip clearance. So long as the meshing of worm and wheel is fairly good, one complete turn of the worm must necessarily advance the wheel by exactly one tooth, no more or less.

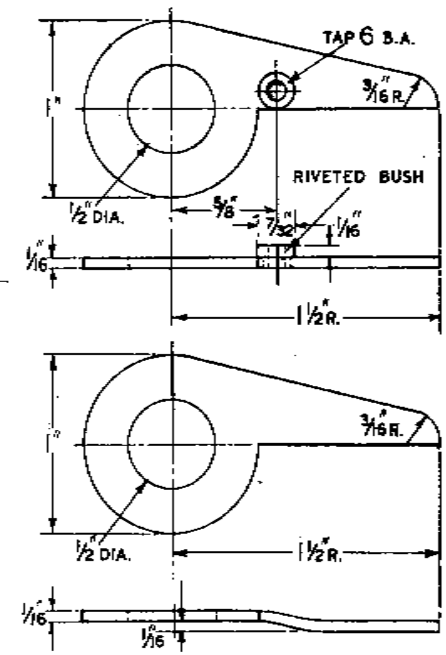
It is not beyond the skill of model engineers to produce both the worm and wheel for themselves. But in view of the importance of these components, most modellers will no doubt prefer to buy them ready-made from a reliable gearcutting specialist. Two well-known ME advertisers, Bond's o' Euston Road, London, and S. H. Muffett of Tunbridge Wells, Kent, produce a range of worm gears; I have examined samples of their products and can recommend them with confidence. The worm and wheel shown in the assembly drawing is taken from Bond's range, and is about the right size for this purpose. It is, as a general rule, advisable to make the worm gearing and division plates of ample size, because the risks of inaccuracy are usually greater when they are very small. But the entire assembly needs to be compact, and in proportion to the rest of the appliance, Remember that it is all supported from the 1 1/2 in. square column; you will gain nothing from making it unduly large or massive.

Division plates, with several rows of holes, are obtainable in the instrument trade, but they are expensive if made to guaranteed accuracy. You will not find it diflicult to drill the plates on the dividing spindle itself, using ***change*** wheels or other components for indexing, and running a centredrill in the chuck. The pilot end of the drill should be about 1/16 in. dia. and it should enter to a uniform depth (a stop for the lathe saddle is helpful), just sufiicient to produce a slight chamfer to each hole. Sheet brass, 3/32 in. thick, is suitable for the plates, and if it is truly flat they need not be machined on the surface. The centre of each plate is bored concentrically to a push fit on the spigot of the bracket, and is secured to it by a single 6 BA countersunk screw. Three rows of holes, to give different indexing ranges, are shown; more can be added if required.

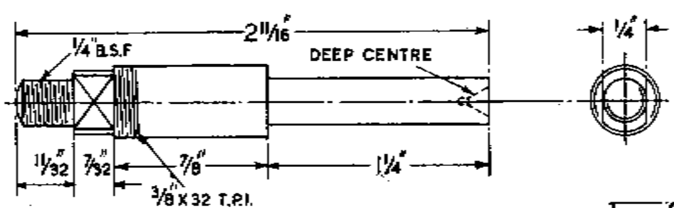
As supplied, the worm gear has a boss 3/4 in. dia., which is hardly large enough to bore out to fit the tail of the indexing mandrel, if this is made to fit the lathe change wheels. A smaller, diameter seating for the gear would be satisfactory, but if it is to be interchangeable with the wheels used for direct indexing you had better make a collar not less than



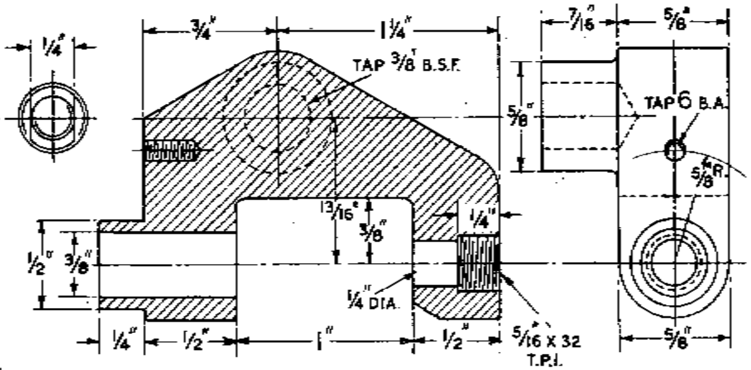
WORM INDEXING GEAR ASSEMBLY



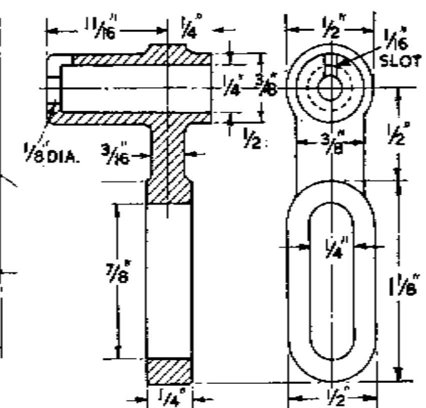
SECTOR PLATES 1 OFF EACH BRASS



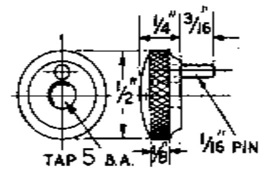
WORMSHAFT 1 OFF M.S.



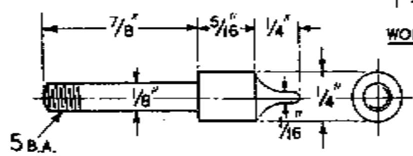
WORMSHAFT BRACKET 1 OFF C.I.



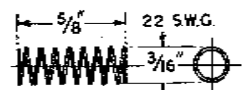
RADIAL ARM 1 OFF C.I.



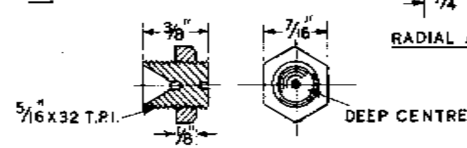
KNOB 1 OFF M.S.



PLUNGER 1 OFF M.S.



SPRING 1 OFF SPRING STEEL



ADJUSTING SCREW 1 OFF M.S.

1 in. in diameter, which can be pressed or sweated over the existing boss to strengthen it and provide a broader face. In boring out the worm gear to fit the seating, great care must be taken to preserve concentric truth. If a collar is fitted over the boss, it can be used as a cup chuck (before it is parted off) to hold the gear during this operation. Make a check over the gear teeth and the machined side face, using a dial test indicator if you have one, to make sure of exact truth before boring. A keyway may' be made in the bore, or any other means of positive location can be employed, so long as it does not tend to force the gear out of truth when fitted. It is clamped endwise by the same nut used for securing the change wheels on the indexing mandrel.

The wormshaft bracket, made from the solid or from a casting, has a boss on the back face, drilled and tapped to take a 3/8 in. stud by which it is secured to the banjo of the indexing gear. Instead the boss may be omitted and a double-ended shouldered bolt used; this will enable the bracket to be fitted either way round, which may sometimes be more convenient. The important thing is that the bracket should have a means of mounting squarely and securely on the banjo. For this reason, you are well advised to mount the bracket on an angle plate for drilling and boring the wormshaft bearing, using the bolt or stud of the boss to secure it for this operation. Take care to drill the bores of the bracket in true alignment; if you have difficulty, finish the large bore first, and then mount the bracket on a stub mandrel for boring, counterboring and tapping The inner face of the front bearing must be machined true. You can best do it with a facing cutter introduced in the gap before it is attached to its arbor, which should be turned to suit both bores and act as a pilot. The spigot on the front bearing should be concentric with the bore, and fit closely in the bore of the division plates.

The wormshaft is a straightforward turning exercise which can be carried out between centres. One end is deeply centre-drilled to take the steel ball for the endwise adjustment, to eliminate play when the worm is secured. This should be a light press fit and firmly cross-pinned or grub-screwed in position. To enable division plates to be removed or replaced without removal of the worm&aft, a thin fine-thread nut is used to provide a seating for the radial arm, which is clamped by the end nut and washer. The part of the shaft immediately in front of the thin nut is turned down to the root diameter of the thread, and has flats milled or filed on the sides for the slot of the radial arm.

Apart from filing or machining the front and back faces of the arm true and parallel, the only operation on this part is the boring of the plunger housing. You should first skim this on the outside by clamping the casting to the lathe faceplate; it can then be held in the chuck for centre-drilling, undersize drilling, and finishing with a D-bit, in the same way as the direct-indexing plunger housing. The plunger is similarly fitted, but the end is turned to fit the holes in the division plates, and may be slightly tapered to assist engagement. A similar method of holding the plunger out of engagement may also be used. To avoid the need for cross-drilling the slender stem of the plunger, you can employ a device consisting as shown of an axial pin pressed or screwed into the inner face of the plunger knob. The pin enters the slot in .the end of the housing to allow the plunger to engage the division plate; at other times the knob can be withdrawn and partly rotated to hold the plunger back. If desired, a shallow slot may be provided in the face of the housing, opposite the deeper slot, to make disengagement more positive.

Only a light spring is required for the plunger, as it does not encounter any stress tending to force it out of engagement. To screw the knob on firmly, you' can hold the tip of the plunger in a pin chuck, and grip the knob in the jaws of a pliers with a strip of thin leather interposed.

The sector plates are made of brass sheet, and are identical in shape, except that one has a tapped bush, flush riveted in position, and the other is bent so that it lies flush with its fellow at the tip. Both are fitted to work freely on the spigot of the bracket and in such a way that they can be locked together by a screw and washer in the tapped bush, the face of which should be slightly lower than the level of the top plate. A more elaborate form of joint and locking device for these plates may be used, but this simple arrangement has proved quite satisfactory. The pair of sector plates serves as a form of caliper to assist the counting of holes in division plates. They are set to span the number of holes requited, plus one, which represents zero or starting point, and locked in position. When the arm is shifted from one position to the next, the sector unit is first turned in the direction of rotation as far as the plunger tip 'will allow, and is held in position on the plate. The plunger pin is then withdrawn and the arm is turned as far as the other sector plate allows and engaged in the nearest hole. This process is repeated for each shift of the arm; besides speeding up operations, it greatly reduces the risk of error, which is always liable to occur when the holes are counted separately for each shift, and is a common cause of disaster in work on which much time has been spent.

When you are setting up the indexing gear, advance the adjustment screw to eliminate end play of the shaft while allowing it to turn freely, and lock it by its nut. The bracket is then secured to the banjo of the indexing spindle, and is adjusted radially so that the worm and wheel engage without backlash, while they are still free to work, before the mounting nut is tightened. With the appropriate division plate in position, the radial arm is adjusted for the plunger to engage freely with the required. ring of holes, and is clamped in position. Turn the arm a few times to verify these adjustments. Make sure that the gears neither bind nor slacken off as they rotate, before work begins.

This indexing gear is capable of a good deal of latitude in dimensions and detail design; it can be fitted to the change wheel quadrant of the lathe for indexing the mandrel, but here I recommend more liberal dimensions all round, as the duty will be a good deal heavier. Similarly it may be applied to the indexing head of a small milling machine. Together with the other units which have been described for the special slide, it vastly extends the range of operations that can be performed, without introducing complicated fittings which take a long time to set up and adjust.

Nearly all kinds of attachments are useful in extending the scope of the lathe, but a multiplicity of them is not conducive to efficiency. We sometimes see lathes so decorated with attachments as to, look like a mechanised Christmas tree, when fewer and simpler devices, if well designed and constructed, would achieve the same purpose. But apart from utility, the practical value of all such appliances depends in a great degree on how easily and quickly they can be set up and brought into action. The multi-purpose attachment described in these articles is designed to give the utmost facility without sacrifice of efficiency, and its construction will, I hope, enable many readers to employ their lathes to the best possible advantage in operations far beyond the range of ordinary turning. El

Milling appliances *Continued from February 15* ***By NED***

ROTARY SPINDLE for the small lathe

ROTARY spindles for driving drills and milling cutters in the lathe vary from the simple fly-cutter arbor, running between centres in a cutter frame, to much more elaborate appliances with specially designed bearings and collet chucks. Each of them is capable of good work within its particular limitations. From experience with most of them, I have attempted to design one which is adaptable and versatile, so that it will cope with the widest possible range of operations on a small lathe. It is intended to be interchangeable with the indexing spindle unit already described, for mounting in either the plain or swivelling quill holder.

I have given much thought to the possibility of adapting a single spindle unit for indexing and driving cutters, but it is difficult to combine the most useful features of the indexing spindle, including the use of standard lathe mandrel fittings, with the free running and precision of a high-speed rotary spindle. While we can use the indexing unit as a milling spindle by fitting a driving pulley in place of the change wheel, the type of bearing is not best suited for running at high speed, and its friction is greater than it should be in view of the limited power.

I consider that high speed is absolutely essential to the success of rotary milling appliances of this sort. While we may have to run some cutters at low speed, and to introduce reduction gearing to the spindle in order to obtain sufficient torque for driving them, most operations can be carried out more accurately, and with better finish, by light rapid cuts. Even with the most primitive cutter spindles, speeds up to 3,000 r.p.m; or more can be used with advantage, but to stand up to such speeds indefinitely an adequate bearing area and good lubrication are essential.

Opposed-cone bearing

The bearing which has long been favoured for high speed and precision, both for light lathes and milling appliances, is the double opposed-cone type, in which radial loads are taken on acute-tapered journals, and end thrust loads on integral obtuse-angled collars. But this is a difficult bearing to machine and fit properly, as the two angular surfaces must register exactly and simultaneously in their bush. If this is done properly, it is one of the best machine tool bearings ever produced; if not, it is one of the worst. Some attempts to use it (not only by amateurs) have been utter failures.

When a tapered journal bearing is used with an independently adjustable thrust surface, construction can be simplified. I have experimented with tapered bearings of varying angle from 5 to 30 degrees included angle, and with different thrust bearings, including axial and angular-contact ball races. Standard races of suitable dimensions for a compact milling spindle are apparently unobtainable, but a plain thrust ring, opposed to a fairly acute-angled journal, has been found to give excellent results for all but the highest loads. This is the bearing which I recommend

The spindle is designed to take standard 8 mm. collets, obtainable ready made for use in watch and instrument lathes; the essential dimensions for fitting them are shown, and the particulars for other sixes of collet can be found in the ME Handbook.

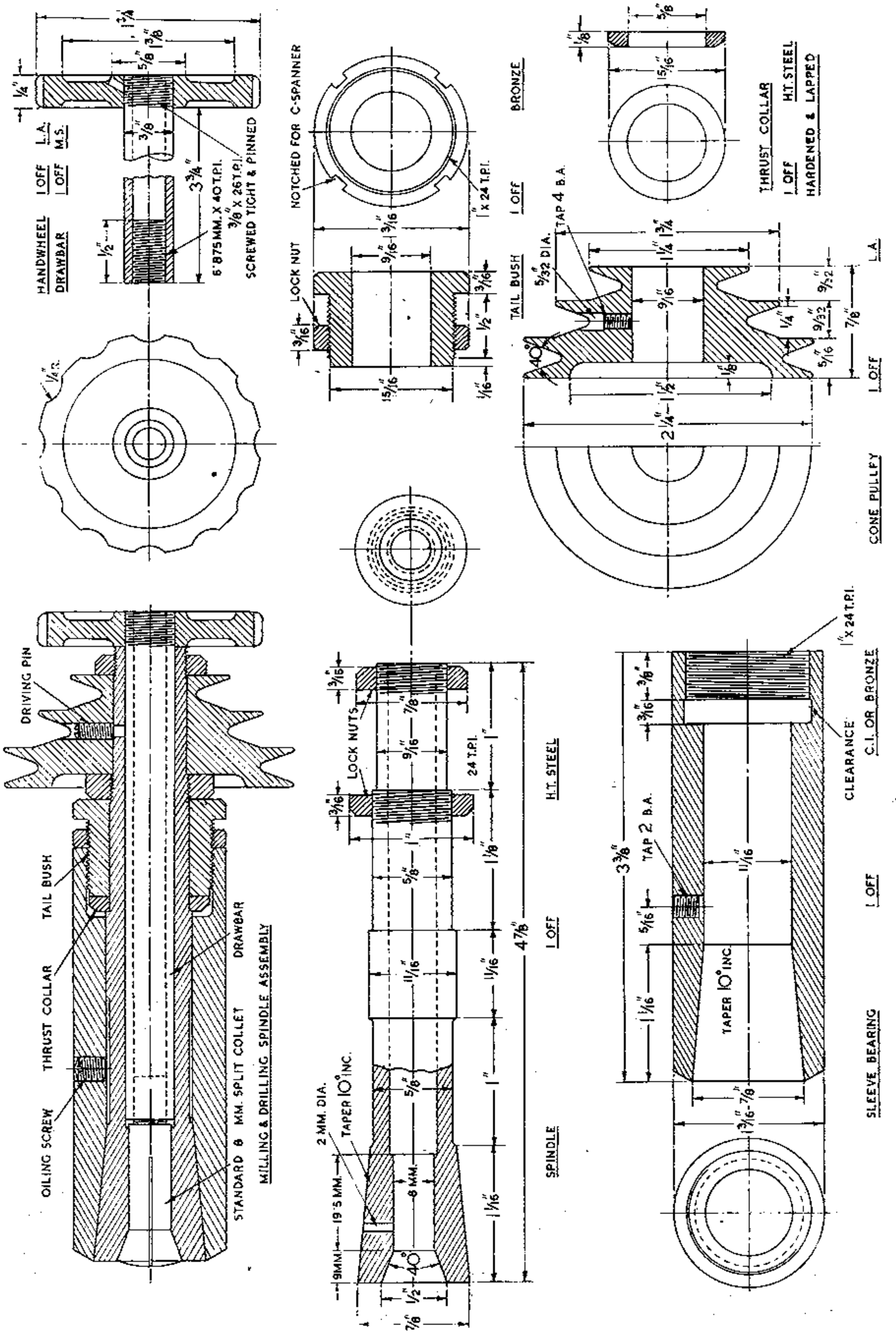
For the sleeve bearing, which is turned externally to the same size as the bearing of the indexing mandrel, cast iron is the best material, but bronze or other good bearing metal is also suitable. If extra length is allowed for chucking, both outside and inside may be machined at one setting. Back centre support can be used for the outside. In the boring of both the parallel and tapered surfaces, a fixed steady on the outer end of the sleeve will be found helpful. It is essential that these surfaces should be as smooth and accurate as possible. After the sleeve has been parted off, it is reversed for counterboring and internal screwcutting.

Getting concentric truth

For concentric truth in the second setting you may use a plug mandrel with a taper to match the bore, and a parallel pilot end may be used, or the sleeve may be held in the chuck and clocked over the outside to the highest possible accuracy. With either method. the fixed steady can again be applied to support the end while you are machining. I recommend 24 t.p.i. thread as for other screwed parts, but other pitches can be used if they are more convenient. Coarse threads should be avoided, as they increase the risk of error in concentricity. A clearance recess provided behind the thread allows the tool to run out into space, and eliminates the danger of digging in.

While the spindle is intended to be made of high tensile steel, a good machining quality mild steel will give reasonable wear. In machine tool practice, spindles are usually hardened and ground, but these processes are not generally for the amateur. Open-hearth casehardening involves the risk of distortion. Chrome deposition to a depth of not more than 1 or 2 thou will provide a hard surface without distortion, but if after-treatment of any kind is to be avoided your best course is to use steel of the highest quality, preferably an alloy or high carbon steel.

Preliminary roughing of the spindle may be carried out between centres, after which the spindle may be chucked at the large end for drilling and boring, with a fixed steady again used on the projecting end, and the chuck end clocked for exact truth. You should drill undersize and finish to size with a D-bit. If you do not have a specially long drill, to reach the depth of nearly four inches, a shorter drill, turned down on the shank, and brazed into a length of tube, will serve still better, as the tube can be used to inject cutting lubricant. Great care is needed in centring and starting the


HANDWHEEL 1 OFF L.A.
DRAWBAR 1 OFF M.S.
6.875 MM. X 40 T.P.I.
3/8" X 26 T.P.I. SCREWED TIGHT & PINNED
LOCK NUT BRONZE
NOTCHED FOR C-SPANNER
1" X 24 T.P.I.
1 OFF
TAIL BUSH
TAP 4 B.A.
5/32" DIA.
THRUST COLLAR 1 OFF H.T. STEEL HARDENED & LAPPED
CONE PULLEY 1 OFF L.A.
DRIVING PIN
TAIL BUSH
THRUST COLLAR
OILING SCREW
STANDARD 8 MM. SPLIT COLLET
DRAWBAR
MILLING & DRILLING SPINDLE ASSEMBLY
LOCK NUTS
24 T.P.I.
2 MM. DIA.
TAPER 10° INC.
19.5 MM.
8 MM.
9 MM.
SPINDLE 1 OFF H.T. STEEL
CLEARANCE
TAP 2 B.A.
TAPER 10° INC.
SLEEVE BEARING 1 OFF C.I. OR BRONZE

drill, as any initial error will worsen as the depth of hole increases. The D-bit, which is easily made from silver steel rod, has a natural tendency to produce a true bore, but it will not correct a badly drilled hole. A chamfer should be provided at the mouth of the hole for centring.

After drilling the deep hole reverse the spindle, with the same precautions to ensure truth at both ends, and drill and bore it to fit the collets The important point to observe is the ***boring*** of the mouth of the hole to the correct size and angle and to perfect smoothness. To mount the spindle for finishing the outside, turn a piece of material in the chuck to form a dummy collet, with the pilot end a press fit in the spindle bore. With the spindle mounted on this, and supported by the back centre at the small end, the concentric truth of the bore is assured.

In the external machining, the fit of the parallel and tapered journals is extremely important. The parallel journals can be finished by lapping, but this process is not satisfactory for the taper bearing, which must be machined to provide a perfect contact over the full length of its mating surface in the sleeve. You can check with marking colour. After getting the most accurate tool finish possible, you may remove the final high spots by a dead-smooth Swiss file. The exact end location of the spindle in the sleeve is less important than a perfect surface fit. Leave the screw-cutting on the tail end of the mandrel, and the fitting of the tail bush and driving pulley, to the last.

Drawbar for collets

For standard pull-in collets, a drawbar and handwheel will be required. They are simple to make, and can be altered according to convenience. The essential details and dimensions are shown in the drawing. As the thread in ihe end of the drawbar must, of course, fit the thread of the collet, you may have to make a special tap unless you can get one of the drawbars used in the clock tool trade and adapt it for length. A hollow drawbar is not generally needed for a milling spindle, but there are occasions when it may be useful.

To ensure concentric truth on the ‘end face and inside and out, turn, screwcut and bore at one setting. It should be a running fit on the spindle, but without any tendency to bind when it is adjusted and locked up; a little extra clearance is better than excessive friction. The flange of the bush, and also the edge of ‘the lock nut, may be notched to take a C-spanner, as for the adjusting collars of the indexing spindle. There is no real need to limit the diameter of these parts, as the spindle assembly is inserted in the quill holder from the reverse end, but it is just as well to maintain some uniformity. The side faces of the lock nut should be machined true with the thread. This applies also to the spindle lock nuts; you can make them hexagonal for convenience in adjusting them with a thin spanner.

For the thrust collar, I suggest an oil-hardening steel, but mild steel; if it can be case-hardened without distortion, is quite suitable. The collar can be machined from bar and parted off at one setting, with the entering end of the hole slightly chamfered, so that it will be sure to go right home against the shoulder on the spindle. At this point it should. be a light press fit, but the rest of the surface may be slightly eased down for convenience in fitting. After being hardened, the collar should be lapped true on both the front and back surfaces, and checked for parallelism with a micrometer. A piece of plate glass, smeared with fine carborundum or emery paste, is suitable for these flat lapping operations.

The driving pulley is another component which is subject to modification; the details and dimensions shown are suitable for general purpose. It will take either 3/16 in. round belting (Whiston’s plastic belting is specially suitable) or endless V-belts of 1/4 in. section. The angle of 40 degrees ‘inclusive, with the bottom of the groove clear of the belt, gives the most efficient belt grip possible. Many pulleys are made with too obtuse a groove angle, allowing the belt to bottom, with excessive slip and loss of efficiency. The pulley is mainly driven by friction between the two lock nuts ‘on the spindle, but a driving pin is also fitted (after end locations are adjusted). It consists of a 4 BA steel screw with the end turned down to fit a 1/8 in. hole in the spindle. You had better drill the tapping hole in the pulley, and counterbore it to 5/32 in. diameter, before the groove is fully turned, or you may find it difficult to start the drill. A hole is also drilled in the taper part of the spindle to take the collet locating pin, which should be a light driving fit, and of such a length that it neither projects above the journal surface, nor fouls the keyway in the collet when fully home. Very little force is required to drive the collet or the spindle itself, and though more elaborate keying arrangements are often used I have not found them necessary.

An oil hole is drilled in the sleeve bearing and tapped to take a short 2 BA grubserew, so that you can close it against the entry of dirt after you have fed in oil. It should not be ,tapped right through; there is then no risk that the screw will foul the spindle. In the assembling of the unit, .the spindle is first inserted in the sleeve and the thrust collar threaded on the small end; it may be pushed truly home by being screwed in the tail bush. Bring the spindle into its taper seating so that it tends to jam, and then adjust the bush so that it is just barely free again, and lock it in position. Put the front locking nut and the pulley on the spindle and adjust the nut to working clearance, when the back nut can be locked against the pulley. The adjustments should be made with the spindle dry, but when the work has been completed oil can be fed in to fill the space around the relieved part. A light low-viscosity spindle oil, such as Shell Vitrea (as recommended by Myford for lathe bearings) is suitable. After the spindle has been run in until the oil no longer comes out black, some slight readjustment, in the same order as before, may be necessary. You will probably find it better to dismantle the parts and examine them for high spots-perhaps more than once.

With the 8 mm. collets, the spindle will take cutter shanks or arbors up to 1/4 in. dia., which is large enough for most operations within its range. You may fit larger arbors, with extension for overarm centre support, by machining the driving end to match the collets, and locking them in with the drawbar. The smaller collets are useful for holding dental burrs and similar cutters, and single-point end mills (virtually D-bits) which can be made in a few minutes from high-speed or silver steel rod. At least one ***arbor*** should be provided with a cross hole to hold fly-cutters for cutting clock wheels and pinions. Grinding wheels can be used to a limited extent, but for really effective grinding with tiny wheels much higher speeds-ro,ooo to 2o,ooo r.p.m.-are necessary, and these are almost impossible to obtain except with specialised -and very expensive-motorised appliances.

Rotary cutter spindles all involve problems in the provision of a suitable drive, especially when they are used in all sorts of odd locations and angles. A good deal of practical information on all kinds of drives can be found in the ME Handbook ***Milling in the Lathe,*** which covers every aspect of appliances and methods.

To be concluded