

# A Dividing Head for the Peatol/Taig Lathe

Tony Jeffree, May 13, 1998

## Introduction

I decided to try my hand at clock-making about 6 years ago, not realizing quite how much time would be involved in acquiring and building a suitable set of tools before I got anywhere near to making any clock parts. Since then, it has seemed to me that the vast majority of the time spent in my engineering activities has involved building tools or jigs of various kinds, in order to build up the set of equipment that I need to achieve the original end - building a clock. Needless to say, 6 years on and I have yet to build my first clock, but on the other hand, as I'm sure others have found in the past, building such tools can be just as satisfying an exercise as using them to complete the original project that necessitated building them in the first place. This article is the result of one such exercise, and one that has resulted in a very useful and versatile piece of equipment.<sup>1</sup>

Previous dabbling had taught me the essentials of cutting and shaping metals using hand tools, but as I had no real experience of machining metal, and in particular, metal turning, the first essential purchase was a small lathe. After much poring over books on clockmaking techniques and equipment, I chose to buy the Peatol Micro Lathe (marketed in the USA as the Taig lathe, in the UK as the Peatol lathe); this is a simple and inexpensive 2¼" centre height, non-screwcutting lathe with a good range of accessories, including steadies, a vertical slide and compound top slide. It comes as a partially assembled kit of parts, so the first exercise for the eager novice metal-turner is to assemble it, and in particular, to work out how to mount the various components on the base plate in a manner that will result in a usable machine...but I digress. The only real drawback with the Peatol/Taig lathe is the absence of screwcutting facilities, which limited my options for some of the aspects of the dividing head design. (Perhaps if there are any Peatol/Taig owners out there who have added screwcutting facilities to their lathe, they might let me know? I am currently working on a design based on adapting some of the parts from the Sherline lathes for this purpose, so would welcome any experience that others can offer in this area.)

From my reading into the subject of clockmaking, I had realised that gear cutting (or wheel cutting, as it is known in the clockmaking literature) capability was likely to be significant if I was to stand any chance of building a clock, so my first problem was to decide on a gearcutting method. A dedicated wheelcutting engine is often used by clockmakers, but I discarded that approach on the grounds that such a device would probably be of little use for any other purpose. The alternative of using a dividing head in conjunction with the lathe had the advantage that it would be useful for many other machining operations as well as for wheelcutting, and I could always add the convenience of a dedicated machine later on. Hence the subject of this article; as there is no dividing head in the Peatol/Taig range and all other designs that I had come across were too large to be conveniently used

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<sup>1</sup>This is an updated and revised version of an article published in the October '97 edition of "Projects in Metal". Visit their website at <http://www.villagepress.com/>

on a lathe of this size, I decided that I would design and build one myself. The usual comments apply, that although the design described was developed for the Peatol/Taig lathe, it could no doubt be adapted for use on other small lathes if so desired. Similarly, in many cases the choice of materials described here reflects what I had to hand at the time I built the prototype; no doubt some readers will choose to adapt the design to suit the stock they have available.

### **Gearcutting set-up**

There are two major options for a gearcutting set-up in the lathe. The first is to use the dividing head, or even just a simple dividing plate, to position the lathe spindle. The spindle in turn holds the wheel blank. A second driven spindle (a milling attachment, perhaps) drives the gear cutter.

The second option is to use the lathe spindle to drive the gear cutter and use the dividing head, mounted on the lathe's vertical slide with its output shaft vertical, to hold the wheel blank. As I was not in possession of a separate spindle to drive a cutter, this design was developed with this second configuration in mind. However, with the use of a suitable adapter plate and split collet to attach the head to the lathe headstock and drive spindle, it should be possible to use the head in either configuration.

### **Design considerations**

The Peatol/Taig lathe has a T-slotted cross slide and vertical slide, both 2" wide by 3 $\frac{3}{4}$ " long, with 2 T-slots running lengthways  $\frac{1}{2}$ " in from each edge. Thus a dividing head that is designed to be mounted on the vertical slide can equally well be mounted on the cross slide. In the latter case, there is an advantage in allowing the dividing head to be mounted with its axis at lathe centre height, as this makes it possible to use the head to drill radial holes in a workpiece. This also requires that the mounting arrangements allow the dividing head to be mounted with its spindle axis at right angles to the lathe spindle.

A major consideration was provision of a chuck for work-holding. At around the time I started thinking about this project, I had taken delivery of a  $\frac{1}{4}$ " Jacobs chuck which came with a "free" 1MT arbor. With no facilities on the Peatol/Taig for the use of 1MT tooling, the arbor was a redundant item, but it led to the idea of using Jacobs chucks as the primary work-holding device for the dividing head. The prototype dividing head was built using this 1MT arbor, somewhat modified as described below, as its output shaft. When set up between centers in the lathe, using a live centre in the tailstock, it was straightforward to turn down the 1MT taper to a more appropriate profile. Needless to say, the arbor was not of the hardened variety!

The construction of the main body of the dividing head needed to be simple, not least because of my as yet limited skills with using the tools of the trade. Castings of any kind were ruled out on grounds of difficulty and expense should the design change as I built it. I had no technical drawing capability at the time, and so I intended to build the prototype without any formal design, largely as an exercise in familiarization with machining tech-

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niques in the lathe, so design changes en route seemed highly likely! (Since then I have acquired a CAD package, AutoSketch for Windows, which I would highly recommend to anyone who has a suitable PC and who doesn't want to learn technical drawing the hard way. The drawings in this article were generated using AutoSketch.) In keeping with the general style of the Peatol/Taig, which makes considerable and ingenious use of aluminium extrusions in its construction, I chose aluminium angle and square sections as the basic constructional material for the frame of the dividing head and its fittings.

There seemed to be a considerable advantage to be gained by following normal practice and employing a worm drive in the design of the head. The reduction ratio of the drive would in itself offer some useful division possibilities, in addition to those available by use of the division plates.

### **Dividing head theory**

A dividing head generally consists of a 40:1 or 60:1 worm drive, with the input shaft driving the worm, and the worm wheel driving the output shaft. The output shaft is fitted with some suitable work-holding device to mount the item to be machined; the input shaft is fitted with an indexing arm, the position of which is measured either against a protractor or against a division plate (a disc with circles of evenly spaced holes drilled in it). Rotating the input shaft by a known number of degrees rotates the output shaft by a smaller amount, in the ratio of the worm drive. For example, if the drive ratio is 40:1, half a turn (180 degrees) of the input shaft rotates the output shaft by  $4\frac{1}{2}$  degrees. Alternatively, rotating the indexing arm by one hole position in a 36-hole circle (i.e. by 10 degrees) rotates the output shaft by exactly  $\frac{1}{4}$  of a degree. A useful consequence of the use of such a reduction drive is that it improves the accuracy with which the output shaft is positioned, in the ratio of the drive. In the above examples an error of one degree in the positioning of the input shaft results in an error in the position of the output shaft of only one fortieth of a degree.

If you wish to divide a circle into a given number of equal divisions, the number of rotations (or fractional rotations) of the input shaft necessary to produce a movement of one division in the output shaft is given by dividing the drive ratio by the number of divisions required. For example, with a 40:1 ratio, if you wish to cut a gear with 50 teeth, the input shaft must be rotated by forty 50ths of a turn between each cut. This is where the numbered circles of holes on the input shaft come into play. The desired result is achieved by moving the indexing arm 40 hole positions on a 50 hole circle between each cut. (The same result can, of course, be achieved by, say, 16 holes in a 20 hole circle, or 4 holes in a 5 hole circle,... etc.)

My apologies to those readers for whom the above has been a lesson in egg-sucking, but the point of all this is that it will be necessary later on to use the partially built dividing head to mark out its own protractor and drill its own division plates. A little thought up front as to how this would work told me that, once I had made an accurate protractor, I could produce reasonably accurate division plates simply by calculating the required rotation of the input shaft in degrees. I concluded that it should be possible to place the input shaft for each division to better than a degree either way, so the error in the output shaft

position would be very small. In use, any error in the drilling of the division plates would again be reduced by the drive ratio, so if the first set of division plates were not accurate enough, I could always cut a second set of plates from the first which would be further improved in accuracy. If necessary, this process could be repeated until no improvement could be gained over the inherent inaccuracies in the dividing head and the drilling setup. In order to follow this constructional route, I therefore needed to choose a drive ratio that would allow me to make a protractor using only the division capabilities provided by the drive ratio itself.

### Choice of Drive Ratio

With a 60:1 worm drive, a 6-hole circle would be all that I would require in order to use the dividing head to mark out a protractor (6 times 60 being 360, so rotating the input shaft by one hole in the 6-hole circle gives one degree rotation of the output shaft). A 6-hole circle would be very easy to derive from a 60:1 ratio on the partially completed dividing head. One would simply mount a suitable blank on the output shaft, mount the dividing head on the cross-slide and use the lathe as a drilling machine; ten full turns of the input shaft after drilling each hole rotates the output shaft by one sixth of a turn.

With a 40:1 ratio, a 9-hole circle would be needed. As there is no simple way of generating this from the 40:1 ratio, this option was rapidly discarded.

A 30:1 drive plus a 12-hole circle would be a suitable, if unconventional, alternative to the 60:1 ratio; cutting the 12-hole circle requires  $2\frac{1}{2}$  turns of the input shaft per division. For the purists amongst us, a two-hole circle could be cut first, to ensure accurate positioning for the half-turns, but this really is unnecessary given the advantage in accuracy that is gained from the worm drive. In practice, I found that judging half-turn positioning by eye, by lining up the indexing arm against a handy vertical, was quite satisfactory for this operation.

30:1 was the final choice of drive ratio, partly as it promised to halve the number of turns of the input shaft when in operation (and hence offer a reduction in operator fatigue) and partly because a browse of the HPC Gears catalogue showed that there was a 30:1 worm drive in their 32DP range that seemed "about right" size wise for the project.

### Main components

Figure 1 shows a side view of the assembled dividing head, Figure 2 shows a rear view. The main components are:

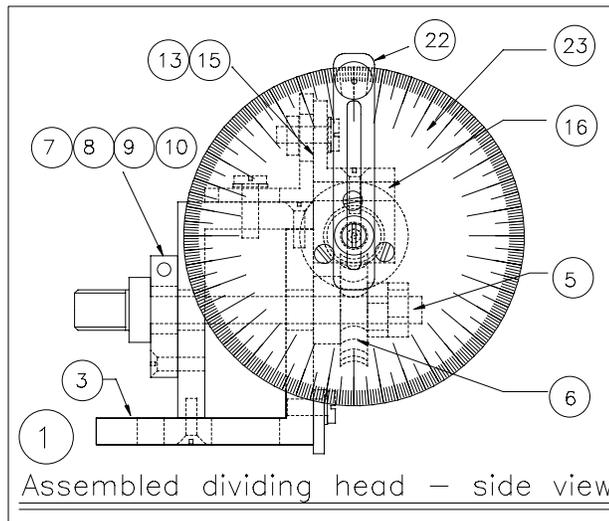
- A main frame, fabricated from Aluminium angle. One piece forms the base-plate (with holes for T-bolts) and the back plate; the other forms the top plate and front plate. The output shaft runs in bearings in the front and back plates.
- The output shaft and wormwheel.
- A brake assembly, to lock the output shaft.
- A worm carrier, fabricated from  $\frac{3}{4}$ " square Aluminium bar, mounted on the main frame

by means of adjustable brackets fabricated from Aluminium angle. This adjustment allows correct positioning of the worm for minimum backlash, but could also be used to accommodate alternative wormwheel sizes if so desired.

- The indexing arm/detent assembly, mounted on the input shaft.
- The protractor/division plate and carrier, mounted on the worm carrier.
- A pair of sector arms, to simplify the otherwise hazardous process of counting holes in division plates.
- An adapter plate, for added height when the dividing head is mounted on the vertical slide for wheelcutting or radial drilling operations.

A suitable construction sequence follows.

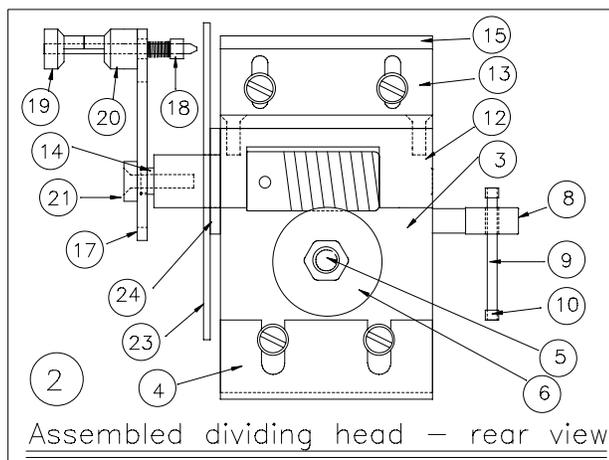
A final section of the article discusses some more major improvements that could be made to the design of the head, which the more adventurous reader may choose to experiment with. These are in the pipeline for a Mark 2 version of the head, which may form the basis of a future article once I have finished working out the constructional details. For Mark 2 I may even try a really radical approach and design it before I start the machining!



Assembled dividing head - side view

## Constructing the main frame and register plate

The frame is constructed from two pieces of 2" X 2" X 1/4" Aluminium angle as, as shown in Figure 3. Cut the lengths slightly oversize; do not finish to their final 2" length yet. Cut off the excess 3/4" strip from the piece that will form the front/top plate; with careful cutting the scrap will be usable for the brake assembly. Mark out, drill 4BA clearance and countersink the top and bottom plates for the six 4BA screws that will hold the two halves of the frame together. The countersinking must be deep enough for the screw heads to be sunk just below the surface. Clamp the two frame halves together in their assembled configuration. Spot through the holes to mark the positions of the holes in the ends of the front and back



Assembled dividing head - rear view

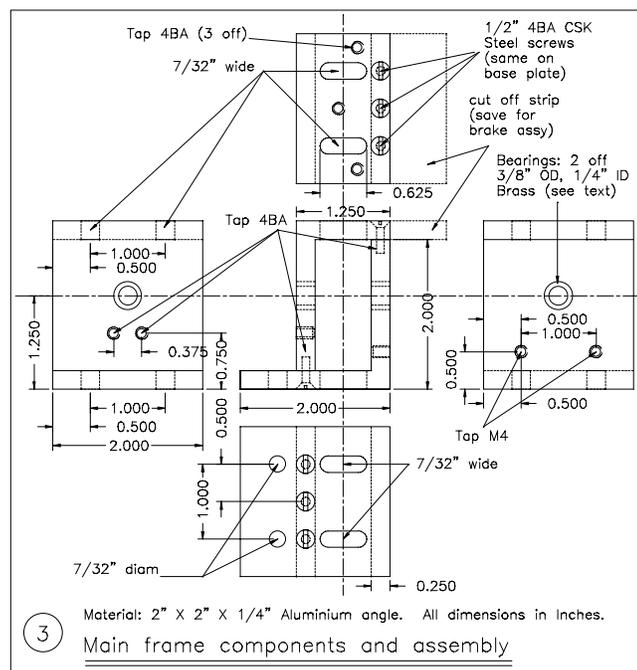
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plates, drill and tap them 4BA. Assemble the frame using 1/2" long countersunk steel screws. Finish the cut end of the top plate so that it is flush with the back plate.

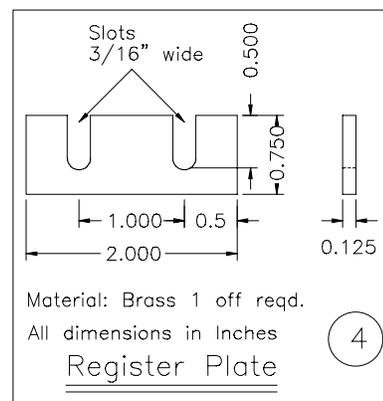
Mount the frame in the four-jaw chuck (or on the faceplate if preferred) and take a light facing cut to true up the sawn ends of the frame components. Mark out the final 2" length of the frame from the trued end, return it to the lathe and finish to length.

Drill the bottom plate for the T-bolt holes and slots, using a 7/32" diameter drill. Finish the slots by filing. This arrangement of mounting holes/slots will allow the head to be mounted on the cross-slide either on the same axis as the lathe spindle or transversely. The two slots allow some adjustment of the bolt positions when the head is mounted transversely. The T-bolts should be

1/2" long, preferably hex socket head bolts, with square nuts to fit the T-slots. The standard T-bolts used on the Peatol/Taig are UNF 10-32, but 3/16 Whitworth is a usable alternative. Drill/file matching slots in the top plate to admit the Allen key.



Cut a 2" length of 3/4" X 1/8" brass strip for the register plate, shown in Figure 4. Form the slots by drilling two 3/16" holes 1/2" in from each end, on the midline of the strip, followed by hacksaw/file to the edge to finish. Drill and tap the two holes in the backplate to take the M4 mounting/adjusting screws and fit the register plate to the frame, with its lower edge projecting about 1/8" below the lower surface of the base plate.



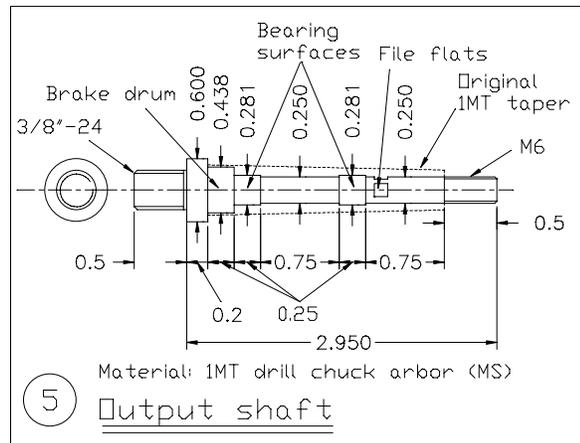
Scribe a vertical midline on the frontplate to act as a guide line for drilling the holes for the bearing inserts. Fit the frame to the cross-slide with the output shaft axis parallel to the lathe bed, sliding it towards the headstock before tightening the T-bolts to ensure that the register plate makes proper contact with the right-hand edge of the cross slide. Fit a drill chuck to the lathe headstock and fit a No.1 centre drill in the chuck. Adjust the cross-slide so that the centre drill will split the scribed line, then lock the cross-slide and centre drill the front plate. Follow this by step-drilling through both front and back plates, to a final diameter of 0.375". Remove the main frame from the cross slide and turn two brass inserts 1/4" thick and nominally 0.375" diameter; these should be a good press-fit

in the front and back plates and will form the output shaft bearings. Clearly, Oilite bushes, bored to 9/32", could be used for this purpose, and in fact on my first attempt I did just that. I was unhappy about the fit of the shaft in these bearings, owing to a little over-enthusiastic turning on its bearing surfaces, so I removed the original bushes and replaced them as described. The result has proved quite satisfactory, and is considerably cheaper, particularly if you haven't destroyed 2 perfectly good Oilite bushes in the process! Fit the inserts to the frame, return the frame to the cross slide and repeat the step-drilling operation, to a final diameter of 9/32".

The front plate is not drilled and tapped for the brake shoe mounting screws until after the output shaft and brake shoe have been constructed.

## Constructing the output shaft

Figure 5 shows the output shaft, and in dotted outline, the original form of the 1MT drill chuck arbor from which it is derived. It is, of course, possible to make this part the hard way, turning it down from suitable stock, say 3/4" mild steel, but the approach adopted here was chosen because it removed the problem of cutting an accurate 3/8"-24 thread, a tricky operation on a lathe that has no screwcutting facilities! Other approaches, for example using a 3/8"-24 die to cut the thread, were considered and rapidly discarded on grounds of the difficulty involved in maintaining any reasonable degree of concentricity between the resultant thread and the remainder of the shaft.

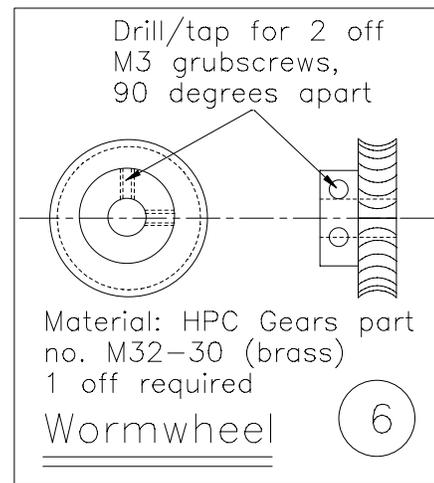


Turning the shaft is a simple matter of mounting it "between centres"; the "free" arbor was ready centre-drilled at both ends, so this was no problem to set up. The turning is otherwise straightforward, as follows:

Turn down the thick end of the MT1 taper to form the brake drum, 7/16" diameter. The length of the brake drum section, nominally 1/4", should be left marginally in excess of the thickness of the "brake shoe" material to avoid the thrust bearing being formed on the front face of the brake shoe. Turn down the remaining length of the taper, nominally to 9/32" diameter; I chose to reduce the shaft diameter slightly between the two bearing surfaces to ease assembly, but this is not essential. Reduce the diameter of the shaft beyond the rear bearing surface to 1/4", to carry the wormwheel. The final 1/2" or so of the shaft is further reduced and threaded 6mm to take the locknuts that will hold the wormwheel in place. The two bearing surfaces and brake drum should be reasonably well finished; a final polish with a burnisher would be ideal. The aim should be to obtain a shake-free running fit in

both bearings; if in doubt, err on the tight side, as the bearings will inevitably bed in to some extent in use.

The wormwheel, shown in Figure 6, is a standard part available from HPC in the UK; no doubt there are similar wormwheels available from US suppliers. The wormwheel is 32 DP, 30 teeth, part number M32-30, in Brass, and takes the corresponding steel single-start worm, HPC part number W32-1. (HPC also manufacture these parts in plastic at a lower cost. As the worm drive in this design is not required to take any significant load, I see no reason why the plastic versions should not be used, but I have no experience of using them.) The worm and wormwheel are already bored for 1/4" shafts; the boss of the wormwheel should be drilled and tapped M3 to take a pair of grub screws, positioned 90 degrees apart. A pair of flats are filed on the output shaft to match the position of the grub screws. The worm comes ready drilled/tapped for an M3 grub screw. HPC appear to be happy to provide small orders for the amateur market; their address is given at the end of the article.



Readers who feel the need for extra rigidity in the output shaft may choose to increase the shaft dimensions accordingly, along with corresponding alterations to the dimensions of the brake shoe/drum and the bearings in the front and back plates. The main limitation here (apart from the dimensions of the MT1 arbor) is that a reasonable shoulder is required between the front bearing and the brake drum, to form a thrust bearing.

### The brake assembly

Figures 7-10 show the components of the brake assembly, and Figure 11 shows the completed assembly fitted in place on the front plate of the main frame.

The brake shoe, Figure 7, is fabricated from 1/4" thick aluminium; if it has been removed with sufficient care, the off-cut from forming the top plate of the main frame will suit very well. Cut and file the off-cut to size, 0.625" X 1.125", to form the brake shoe. Mark the position of the 7/16" hole and step-drill to the final diameter. It is necessary for this hole to be a reasonably snug fit on the brake drum section of the output shaft, so it is worth experimenting on a piece of scrap to determine whether your 7/16" drill will cut accurately enough; if not, make the final cut with a reamer.

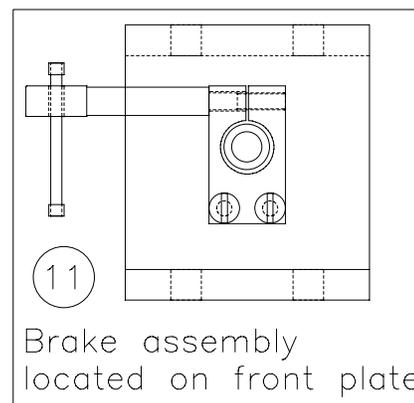
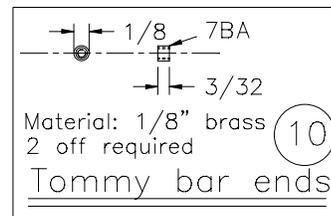
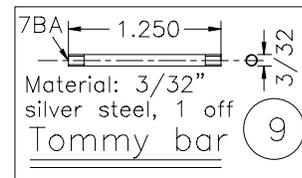
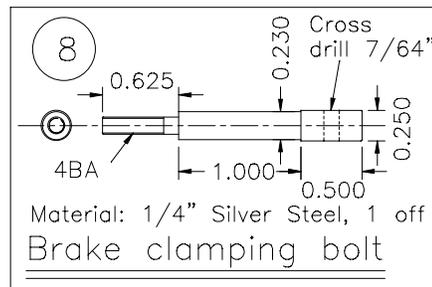
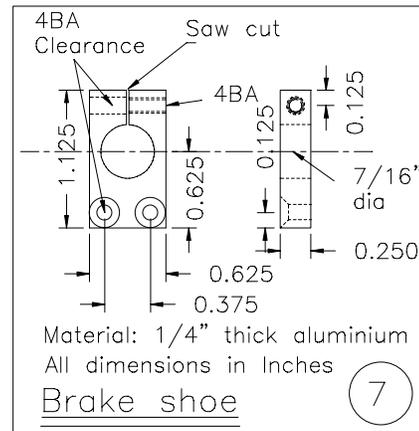
Mark, drill and countersink the two holes to take the 4BA mounting screws. The countersinking should be deep enough to sink the 4BA screw heads flush with the surface. Clamp the brake shoe in position on the front plate, as shown in the assembly diagram, Figure 11, with the output shaft inserted through the shoe and both bearings to ensure accurate posi-

tioning. Spot through the countersunk holes to mark the front plate. Disassemble, drill the two holes in the front plate and tap 4BA.

Cross-drill the brake shoe for the clamping bolt using a 4BA tapping drill, then carefully hacksaw along the mid-line as shown in the drawing, bisecting the hole just drilled. Open out the left-hand hole to 4BA clearance, tap the right-hand hole 4BA. Fit the finished shoe to the front plate with 4BA CSK steel screws.

Re-fit the shaft, fit the worm wheel to the threaded end of the shaft, boss inwards, with a thin steel washer between boss and backplate. Oil the bearings. Screw the wormwheel grub screws in until they just register with the flats on the shaft (but do not tighten them yet), fit a 6mm nut on the end of the shaft and use it to adjust for zero end-float while still allowing the shaft to turn (a little stiffness in the bearings is not a problem), tighten the grub screws and finally lock with a second 6mm nut.

The brake clamping bolt, Figure 8, is fabricated from a length of 1/4" silver steel rod. Reduce the diameter of the last 5/8" to 0.14" diameter and cut a 4BA thread for at least half of the length. The next inch of the bolt is also reduced in diameter, this time to 0.23", to avoid contact with the front plate when the clamping bolt is fitted in position. Cut the bolt to a finished length of 2.125", and cross-drill 7/64" to take the Tommy bar. The Tommy bar, Figure 9, is simply a 1/4" length of 3/32" silver steel rod, threaded both ends 7BA (I discovered that 3/32" rod happens to take a 7BA die very nicely!). The two end nuts, Figure 10, are constructed from 1/8" brass rod, 3/32" long, drilled axially and tapped 7BA. The Tommy bar is passed through the cross-drilled hole in the clamping bolt, the brass nuts are then screwed in place, using Loctite if so desired. The clamping bolt assembly may then be screwed into the brake shoe and its action tested; a half-turn or so of the clamping bolt in either direction should be sufficient to lock/unlock the output shaft.



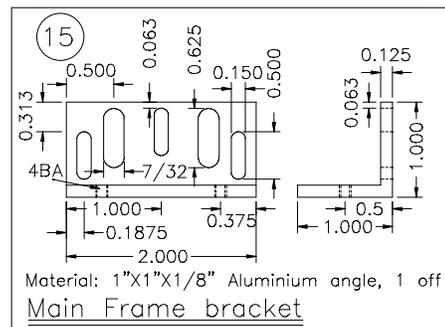
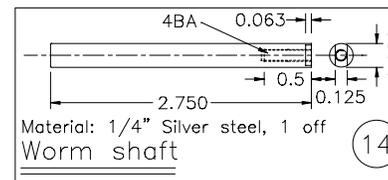
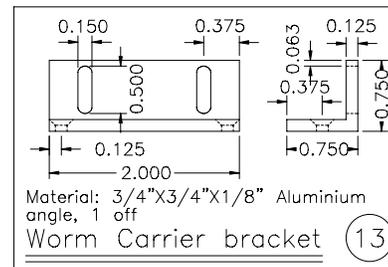
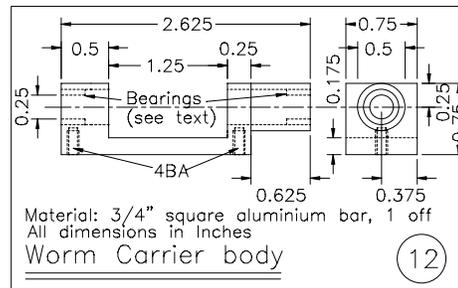
## The worm carrier assembly

Figures 12-15 show the components of the worm carrier and its associated mounting brackets. The worm carrier body, Figure 12, is machined from  $\frac{3}{4}$ " Aluminium bar; cut a length of bar to allow finishing to 2.625", face one end in the lathe, reverse and face the other end to length. Centre punch on one end the centre of the hole for the shaft bearing; this should be  $\frac{1}{4}$ " from one edge and  $\frac{3}{8}$ " from the adjacent edges. Return the bar to the 4-jaw chuck and adjust so that the centre punch lines up with the tailstock centre (assuming that the tailstock is accurately in line with the headstock). Turn the last  $\frac{5}{8}$ " of the bar to  $\frac{1}{2}$ " diameter. At the same setting, step drill the entire length of the bar to 0.375" diameter using the tailstock drill chuck. This requires some care and patience to avoid the drill wandering off line, but there is sufficient adjustment available in the positioning of the mounting brackets to cope with some inaccuracy here.

The next operation involves removing a considerable amount of material from the mid-section of the carrier to make a channel for the worm. This is most easily done using the milling attachment (vertical slide) or a dedicated milling machine, but is a simple (if energetic) job with hacksaw and file. The channel should be finished to the length of the worm, nominally  $1\frac{1}{4}$ " long, starting  $\frac{1}{2}$ " from the square end of the bar. The drawing shows the channel depth as 0.575", which gives ample clearance for the worm.

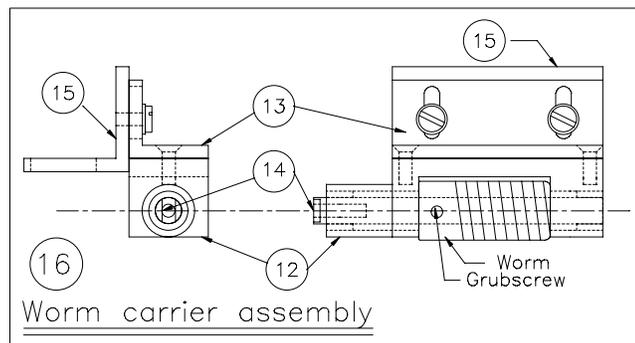
The worm carrier bracket, Figure 13, is constructed from a 2" length of  $\frac{3}{4}$ "X $\frac{3}{4}$ "X $\frac{1}{8}$ " aluminium angle. Two holes are drilled and countersunk for 4BA CSK screws on one face; these holes are used to mark the positions of the 4BA screw holes on the worm carrier body, which are then drilled and tapped. Two slots are cut in the other face of the bracket, as shown in Figure 5. The slots will carry 4BA screws/washers which screw into the corresponding holes in the main frame bracket. Assemble worm carrier body and worm carrier bracket using two 4BA CSK screws, as shown in Figure 16.

The bearings used in the prototype were Oilite bearings,  $\frac{1}{4}$ " long,  $\frac{1}{4}$ " inside diameter, 0.375" outside diameter, supplied by HPC Gears, part number QT 172-1. Insert the bearings into the two ends of the worm carrier body; they should be a push fit. If necessary, use the proverbial Loctite. As with the main spindle bearings, there



is no good reason why these bearings cannot be fabricated from suitable diameter brass rod if so desired.

The worm shaft, Figure 14, is a  $2\frac{3}{4}$ " length of silver steel rod; face one end and lightly chamfer the edge, reverse it in the lathe, cut to length. Centre drill the end with a No. 1 centre drill, then drill into the end for half an inch with a 4BA tapping drill, tap the hole 4BA. Two flats need to be filed on the tapped end of the shaft, as shown in Figure 5, to allow the slot in the indexing arm to engage with the end of the shaft. The length of the flat is shown as  $\frac{1}{16}$ ", but the primary requirement is that it does not exceed the thickness of the indexing arm.



The worm and its shaft can now be assembled in the carrier, as shown in Figure 16. A flat can be filed at a suitable position on the worm shaft to take the grub screw. Any end-float in the worm shaft is dealt with by withdrawing the shaft far enough to insert washers of shim material between the end of the worm and the carrier and re-assembling.

The main frame bracket is a 2" length of 1"X1"X $\frac{1}{8}$ " aluminium angle; 5 slots are cut in one face, as shown in Figure 15. The larger of these slots match those on the top plate of the main frame; the three remaining slots carry 4BA screws/washers which screw into the corresponding holes shown on the top plate. The bracket can be used as a marking guide for the screw holes on the top plate, which are then drilled and tapped 4BA. Temporarily fit the bracket to the top plate with 4BA screws. Two holes are drilled and tapped 4BA on the other face of the bracket. Use the slots in the worm carrier assembly as a marking guide; this also allows a check to be made on the engagement of worm and wormwheel, and any necessary adjustment made by altering the position of the holes before drilling.

The worm carrier and brackets can now be assembled with the main frame and adjusted to their final positions; the aim should be to position the brackets for minimum backlash in the worm drive, and of course to ensure that worm and wormwheel are properly aligned.

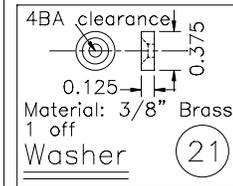
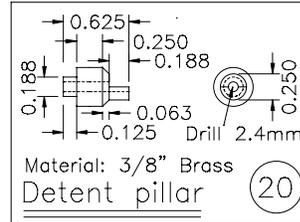
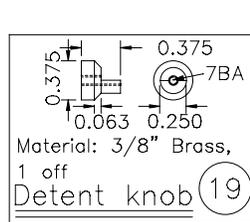
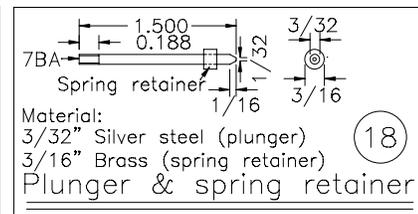
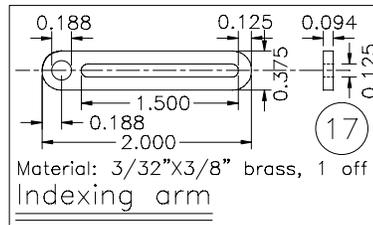
## The indexing arm and detent assembly

The indexing arm and detent is constructed from the components shown in Figures 17-21; Figure 22 shows the assembled arm and plunger.

The indexing arm itself is a  $2$ "X $\frac{3}{8}$ "X $\frac{3}{32}$ " strip of brass, see Figure 17. Radius the two ends, cut a  $\frac{1}{8}$ " wide axial slot, starting  $\frac{1}{8}$ " from one end and extending for  $1\frac{1}{2}$ ", drill a  $\frac{3}{16}$ " hole  $\frac{3}{16}$ " from the other end.

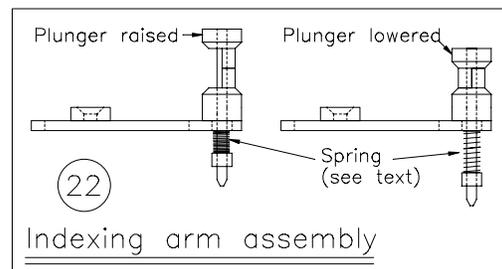
## A Dividing Head for the Peatol/Taig Lathe

The detent is a spring-loaded plunger that can be locked in the raised position by pulling the plunger out and rotating half a turn; the action, as illustrated in Figure 22, will no doubt be familiar. The plunger is a 1.5" length of 3/32" Silver steel rod, with one end turned to a taper, see Figure 18. The angle



of taper is not important as long as it will seat nicely in a 3/64" hole; tapering the last 1/16" of the plunger to leave 1/32" diameter at the tip is about right. The point should be nicely rounded off to avoid scoring the division plates when in use. A spring retainer is press-fitted onto the tapered end; this is simply a short length of 3/16" brass rod drilled 3/32" and Superglued in position. The other end is threaded 7BA to screw into the detent knob. The final length of the plunger should be checked and adjusted after assembly of the complete head, as it is preferable that its tip clears the surface of the division plate and sector arms when the plunger is in the raised position. Some adjustment of clearance can be obtained by loosening the worm's grub screw and adjusting the overhang on the worm shaft.

The detent knob and pillar, Figures 19 and 20 respectively, are a simple turning and filing operation; they can be turned "back to back" from a single piece of 3/8" brass rod, with the pillar end held in the chuck; drill an axial 7BA tapping size hole (2.1mm), part off the knob, drill the pillar 2.4mm (this is sufficiently over-size to allow the 3/32" plunger free travel), enlarge the axial hole at the narrow end of the knob for a length of 3/16" and tap the hole 7BA. File flats just in excess of half-way through the narrow portion of knob and pillar, to "halve" the axial holes. Fit the pillar to the hole in the end of the indexing arm, fix in place with Superglue. File the base of the pillar flush with the underside of the indexing arm. Fit the plunger, spring and knob, Lock-titing the threaded end of the plunger if you feel so moved. The spring used in the prototype was part of the return spring salvaged from a cheap retractable ball-point pen.



A simple cup washer, with a 4BA CSK screw, is used to attach the arm to the worm shaft. The washer, shown in Figure 21, is cut from 3/8" brass rod; mount a short length in the 3-jaw chuck, drill a 4BA clearance hole, countersink sufficiently to allow the screw to sit flush, then part off the washer. The finished thickness will need to be somewhere around 1/16" to 3/32" depending on the depth of countersinking, but this is not at all critical.

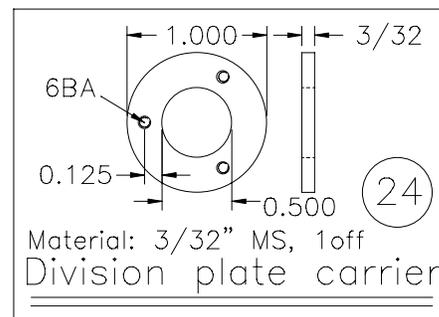
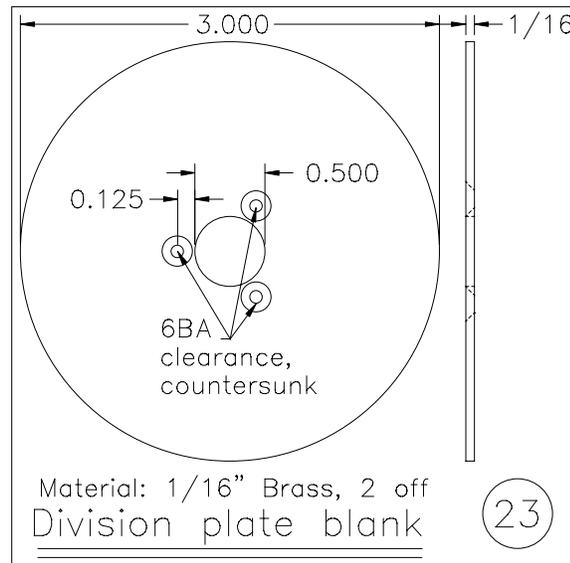
## The division plates and plate carrier

Once the indexing arm is fitted onto the worm shaft, the dividing head is operational, if only on the basis of the division possibilities provided by the 30:1 drive ratio. The next series of machining operations makes use of the partially completed dividing head in order to manufacture the division plates and their carrier.

Figure 23 shows a division plate blank, and Figure 24 the division plate carrier. The carrier is a simple steel washer, one inch in diameter,  $3/32$ " thick, with a central half-inch hole and three equally spaced holes drilled and tapped 6BA. The division plate blank is a  $1/16$ " thick brass disc, 3" in diameter, with a central half inch hole and three countersunk 6BA clearance holes to match those in the carrier. The countersinking should allow the heads of the screws to be sunk flush with the surface of the plate. The number of division plates required will vary according to the applications you have in mind, but the minimum required for the machining operations described here is two blanks, one of which will be used to make the protractor referred to earlier.

The blanks are, of course, ideally obtained ready cut to size, but if you have to do it the hard way, you start with a suitable piece of  $1/16$ " brass sheet. My approach was to mark out the circumference, roughly cut the blanks to size, clamp them together, drill two mounting holes fairly near the centre (but outside the central  $1/2$ " hole area) and mount the stack of plates (three in this case) on the lathe faceplate with tee bolts through the holes. It is then a relatively trivial job to drill the central  $1/2$ " hole and trim off the ragged edges till all the blanks are circular. My blanks ended up a little oversize, but this is not a problem; in fact, it would be possible to increase the division plate diameter to  $3\frac{1}{2}$ ", with corresponding adjustment of the indexing arm length, if so desired.

A simple stub arbor, detailed in Figures 25, is made up to facilitate the remaining operations on the division plate blanks. The dimensions shown assume that you have a  $1/2$ " capacity Jacobs chuck available that will fit the dividing head output shaft; if not, reduce the diameter of the shaft to suit the chuck you have available. The arbor, its washer (shown in Figure 26) and the division plate carrier are turned down from 1" mild steel rod. The



## A Dividing Head for the Peatol/Taig Lathe

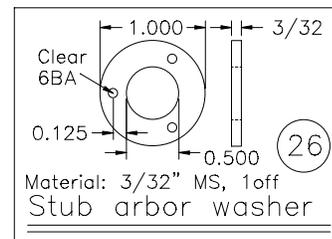
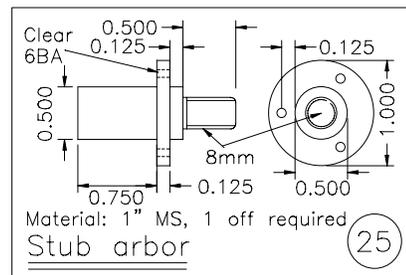
washer and carrier are stacked on the arbor and held firmly in place with the 8mm nut; the arbor is then mounted in the Jacobs chuck on the dividing head, and the latter is mounted on the cross slide with the output shaft in line with the lathe spindle. Mount a smaller Jacobs on the lathe spindle and fit a 6BA tapping drill. Offset the cross slide by 3/8" in preparation for drilling the three holes, lock it in position. Release the dividing head brake, rotate the indexing arm clockwise until it is vertical; this can be checked by lining up by eye against a handy vertical such as the edge of the main frame of the dividing head. Lock the brake and drill the first hole through the two washers and the flange of the arbor. Unlock, make 10 full clockwise turns of the indexing arm, lock, drill the second hole, unlock, 10 turns, lock, drill the 3rd hole. The division plate carrier is now removed and the three holes tapped 6BA. Re-assemble the arbor, this time with one of the division plate blanks sandwiched beneath the washer, carefully re-aligning the holes in the washer with the end of the drill. Fit a 2.9mm (6BA clearance) drill and repeat the drilling operation. Repeat for all the blanks.

Unscrew and remove the indexing arm from the worm shaft. The division plate carrier should be a tight fit over the turned section of the worm carrier; press it fully home, using a little Superglue to hold it permanently in place. Re-fit the indexing arm.

The first circle of holes can now be drilled in one of the indexing plate blanks. As discussed earlier, the first requirement is a 12-hole circle, to facilitate marking out the protractor. The drilling setup is unchanged from the last drilling operation, except that the cross slide is further offset so that the circle of holes will appear at a suitable position on the blank. As 12 is a relatively small number of holes, place this circle as near to the centre as possible, but avoiding any mounting holes drilled when machining the blanks. 6BA

screws and nuts can be fitted through the stub arbor, blank and washer to make absolutely certain that the blank will not rotate relative to the arbor. Fit a No.1 centre drill in place of the 2.9mm drill in the lathe, carefully drill the first hole, adjusting the stop on the saddle travel so that the result is a lightly countersunk hole in the division plate blank. Unlock, rotate the indexing shaft by exactly 2½ turns, lock, drill...etc. until all 12 holes are drilled. Stamp "12" between two adjacent holes, using small number punches, so that you can easily identify the number of holes in the circle at a later date without having to count them (a tedious business with large numbers of circles/holes). As mentioned earlier, the half turns are easy to judge by eye against a suitable vertical (the same one you used for judging the full turns). For the purists, it is a simple matter to drill a 2-hole circle in one blank, fit that blank to the division plate carrier with 6BA CSK screws, then cut the 12-hole circle in the second blank, but I decided life really was too short for that.

Now for the protractor. Fit the 12-hole plate to the division plate carrier and a fresh division plate blank on the stub arbor. Release the brake, adjust the indexing arm until the



plunger is on the same radius as the 12-hole circle. Rotate clockwise till the plunger seats in one of the holes, then lock the brake. Fit a sharp scriber in place of the centre drill in the lathe; this can simply be a short length of silver steel rod turned down to a sharp point. Adjust the offset of the cross slide so that the scriber will strike the blank 0.1" from the circumference. Use the saddle hand-wheel to press the blank against the scriber, traverse the cross slide until the scriber clears the edge of the blank. If you've done it right, this should result in a 0.1" long radial line scribed in the surface of the blank. Move the saddle to the right away from the scriber and traverse the cross slide back to the starting point for the next line. Release the brake, rotate the indexing arm clockwise by one hole, lock and repeat the scribing operation. This process is repeated round the entire circumference of the blank, 360 lines in all, but for every 5th hole, extend the scribed line length to 0.2" and every 10th line, extend the scribed line length to 0.3". This is a very tedious process, but the reward is a nicely marked out 360 degree protractor. To simplify reading the angles, it helps to stamp the number of degrees, say at every 30 degree mark round the circumference, using the smallest set of number stamps you can lay your hands on. With careful positioning of the numbers, there should be some space left towards the centre of the plate to fit in a few circles of holes. The marks on the protractor will not be terribly visible at this stage, but this can be fixed by coating the marked areas of the blank with a spirit-based black felt-tip pen and then polishing off the excess, leaving ink only in the grooves.

### **Using the protractor to cut hole circles in the division plates**

The protractor and division plate can now be swapped back to allow further circles of holes to be drilled in the division plate.

The choice of additional circles of holes in the division plates will depend greatly on the applications you have in mind. If you wish to divide a circle by a given number (N), the product of the drive ratio (R) and the number of holes in the chosen division plate circle (H) must be exactly divisible by that number. In other words, N must be a factor of  $R \times H$ . So, with no additional circles of holes, the 12-hole circle combined with the 30:1 drive ratio will give all the division possibilities that are factors of 360, in other words, 1, 2, 3, 4, 5, 6, 8, 9, 10, 12, 15, 18, 20, 24, 30, 36, 40, 45, 60, 72, 90, 120, 180 and 360. In each case, dividing 360 ( $R \times H$ ) by N gives the number of holes in the circle by which the indexing arm has to be moved for each division, so to get 90 divisions, the arm is stepped by 4 holes between each division.

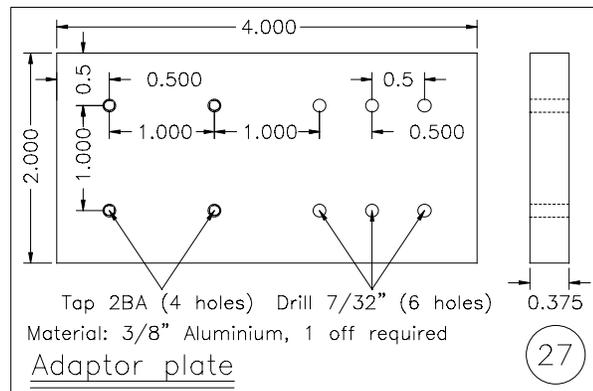
The protractor is, in effect, a 360-hole circle, so if the indexing arm is moved in whole degrees, the protractor gives the division possibilities of all the factors of 10,800 (I leave it as an exercise for the reader to work out the complete list!). So, if you wish to cut a circle of N holes using the protractor, 10,800 divided by N gives the number of degrees of rotation required between each division. In practice, it is possible to get acceptable accuracy for most purposes using the protractor, even in cases where a fractional number of degrees of rotation is required. For example, if you wanted a 7-hole circle, it would be necessary to rotate the indexing arm by 1542.86 degrees (four full rotations plus 102.86 degrees) for each division. If you were to round this up to 1543 degrees, the error in the positioning of the arm would be 0.14 of a degree for the first division, 0.28 for the second,..., and 0.84

degrees for the last. Given that this gives an error in the positioning of the output shaft of only one thirtieth of those amounts, this should not be a cause for concern in many cases, as I pointed out earlier. It is advisable when using the protractor in this way to construct a table showing the final position of the indexing arm and the number of whole turns (if any) for each division. If the calculation of all the positions is done to several decimal places and then rounded to whole degrees, the maximum rounding error for any one division will be less than half a degree, so rounding errors will contribute an error of up to 1/60th of a degree at the output shaft.

For many purposes, then, the 12-hole circle and the protractor will provide sufficient division capability between them without bothering to cut further circles of holes. However, it is often convenient to have a larger range of division possibilities available, if only to avoid having to calculate the unusual divisions in (fractional) degrees. As an exercise, I spent an evening working out the minimum number of hole-circles that I would need in order to provide all the division possibilities from 1 to 50, plus all the even numbers up to 100, plus 360. The result was a list of 16 hole-circles; 10, 26, 28, 29, 31, 32, 34, 36, 37, 38, 41, 43, 44, 46, 47 and 49 holes. This set also gives many division possibilities in addition to those mentioned, for example all the multiples of 5 up to 100. Adding circles of 21, 27, 33, 77 and 91 holes fills in all the multiples of 3 and 7 up to 100, and so on. However, in order to avoid spending inordinate amounts of time in the laborious process of cutting division plates, it is worth starting with a minimal set covering the divisions you are most likely to need, and cut extra circles later on as the need arises. I found that 1/8" between adjacent circles was about right, allowing at least 6 circles of holes per blank; it is just about possible (but tight!) to construct a 120-hole circle on the outer edge of the 3" blank, which would give rotations of one tenth of a degree per hole at the output shaft.

## The adapter plate

Figure 27 shows an adapter plate that provides greater height when the head is fitted to the vertical slide, useful when using the head for wheelcutting radial drilling, or other machining operations. The construction is straightforward and self explanatory. The four tapped holes allow the dividing head to be bolted to the adapter plate with 2BA bolts; the six remaining holes allow 2BA T-bolts to attach the plate to the vertical slide at an appropriate height and orientation.

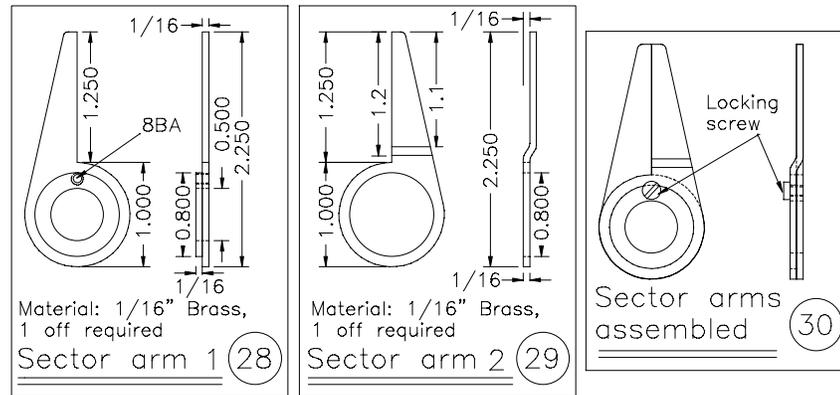


## The sector arms

Lastly, the sector arms. These are fabricated from 1/16" thick brass sheet, as shown in Figures 28 to 30.

## A Dividing Head for the Peatol/Taig Lathe

The two sector arm blanks are cut to shape using a piercing saw, fret-saw or similar, and are clamped together to finish the outer edges to shape. Sector arm 1 is drilled or bored to 1/2" diameter, sector arm 2 to 0.8"



diameter. A separate washer, 0.8" diameter and with a 1/2" hole, is made from 1/6" brass sheet and soft soldered to sector arm 1. (Alternatively, a 0.8" diameter blank could be soldered in place on sector arm 1 prior to drilling the 1/2" hole, if preferred.) Sector arm 2 should be a sliding fit over the 0.8" diameter washer, and is kinked as shown so that both fingers lie flush. An 8BA tapping hole is drilled as close as you dare to the edge of the washer, and tapped. The intention is that an 8BA screw will just lock both arms together when it is screwed home; it may be necessary to slightly reduce the thickness of the washer around the 8BA hole in order to achieve the desired effect.

The operation of the arms is straightforward; they are locked in position so that they uncover one more hole than the number of holes to be moved between each division. Sector arm 1 is rotated clockwise to rest against the plunger, the indexing arm is advanced clockwise until it reaches the other arm, and the plunger dropped into the hole. The kink in sector arm 2 prevents the arms from being opened out to an angle greater than about 240 degrees, so when it is necessary to traverse a number of holes that spans a greater angle, there are two possible solutions:

- Use the outer edges of the arms as the reference points, or:
- Use the arms in reverse; in other words, set the angle between the arms to uncover one more than the remainder of the holes in the circle and rotate the arms anticlockwise between divisions. For example, if the movement was to be 15 holes in a 20-hole circle (therefore normally requiring 16 holes to be uncovered, which would be greater than 240 degrees), set the arms to reveal 6 holes and move the arms anticlockwise between divisions.

### Further possibilities

That concludes the constructional details for this version of the dividing head. I mentioned earlier that I have been thinking through the design of a "Mark II" dividing head. I happened to pick up a MT1 live centre at an engineering show, thinking that I would somehow adapt it for use with the Peatol/Taig lathe. It occurred to me that if, instead of modifying the live centre, I was to build a replacement tailstock with an MT1 socket, it would be capable of taking any MT1 tooling I had to hand. It was a short extrapolation from this idea to re-designing the head, with a MT1 socket forming the output shaft in place of the

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modified drill chuck arbor. The versatility of the head would then be much improved, as any MT1-based work-holding device could be pressed into service. A little thought about easy ways to make an output shaft with an integral MT1 socket resulted in a potentially interesting answer; use a (non-hardened) MT1 to MT2 adapter sleeve as the starting point, and turn down the outer MT2 taper to a 5/8" diameter parallel shaft. Apart from the obvious advantage of allowing the use of MT1 tooling, the increased output shaft diameter will result in much improved rigidity. I was able to acquire just such a sleeve for a modest fee, and my rough work on the design so far seems indicate that it can be suitably machined without disastrously reducing the side-wall thickness (and therefore rigidity). Other likely modifications in Mark II will include moving the brake assembly from the front end of the shaft to the rear, to reduce overhang, and re-designing the main frame on the basis of a sole-plate (exchangeable for different sizes/designs for specific applications) with a solid aluminium block attached, the latter carrying the worm drive, indexing gear and brake assembly in place of the fabricated aluminium angle frame shown in the Mark I version. Tricky aspects of this design will include the need to bore out the worm wheel to 5/8" diameter to take a much more substantial shaft, but for the faint hearted, HPC Gears can supply such "specials" for an additional fee.

A simplification of this design (no indexing facilities or worm drive, fixed MT1 socket) could form the basis of a useful replacement tailstock, providing a much improved arrangement for sensitive drilling on the Peatol/Taig lathe. A "Deluxe" tailstock would result from attaching this device to an extra saddle and cross-slide; I understand from the supplier of the Peatol lathe in the UK that additional cross-slides are obtainable.

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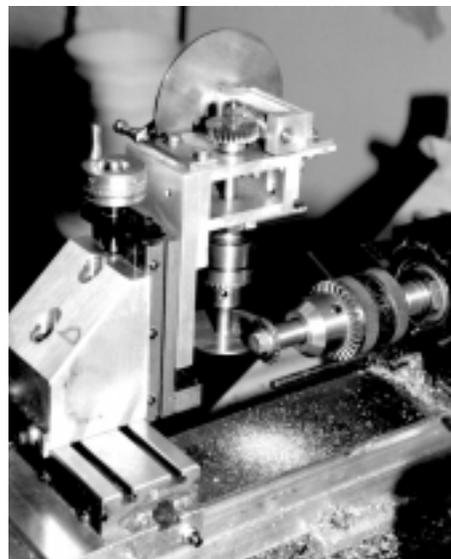
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**Peatol Machine Tools**, 19 Knightlow Rd, Harborne, Birmingham B17 89S, U.K.



**Wheelcutting in progress, viewed from the back of the lathe, the dividing head is mounted on the vertical slide with the adapter plate.**