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MODEL ENGINEERS'

WORKSHOP

THE PRACTICAL HOBBY MAGAZINE

WABECO CNC MILL
First impressions

**LATHE PROJECTS
FOR BEGINNERS**

TOOLPOST GRINDER
Adapting a mini-drill

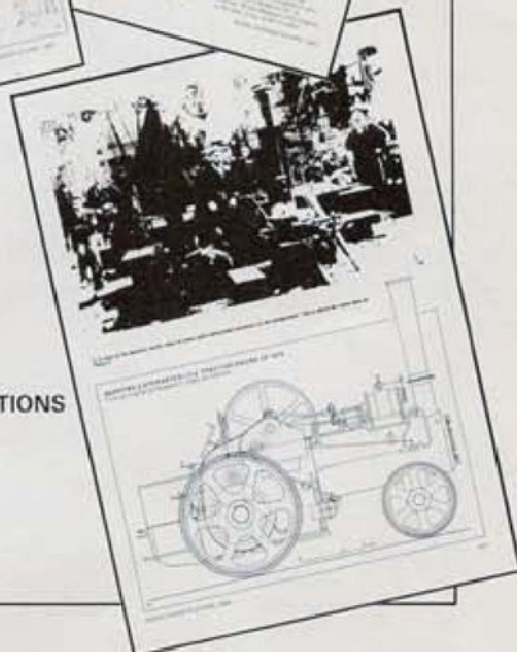
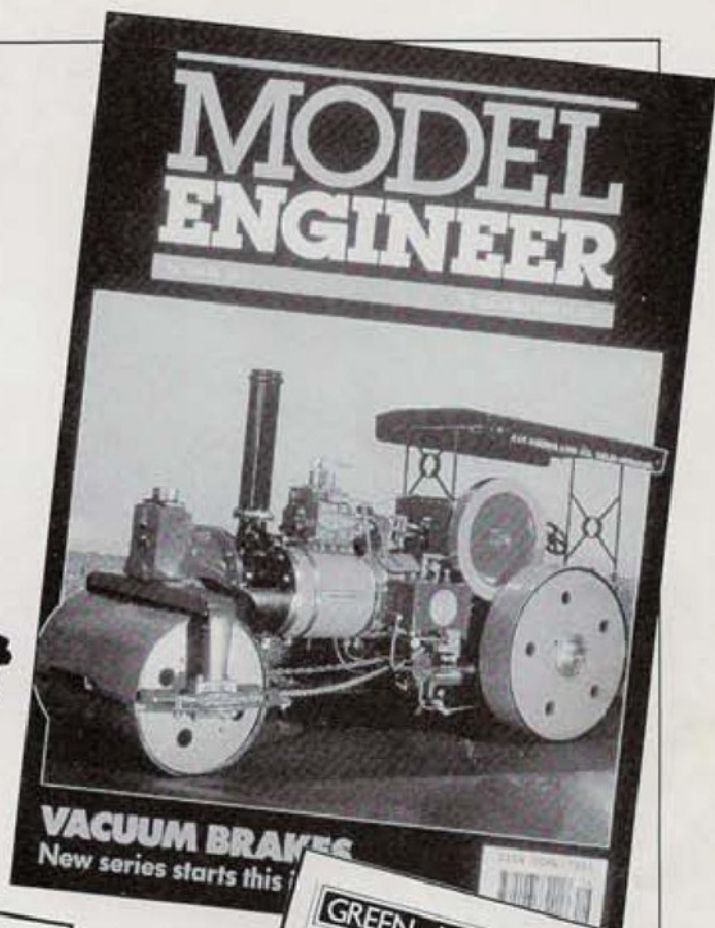
SUNSHINE AT HARROGATE

The 7th National Model Engineering
and Modelling Exhibition



THE MODEL ENGINEER
EXHIBITION & COMPETITION
29TH DECEMBER 2000
1ST JANUARY 2001

**SOMETHING
TO LOOK
FORWARD
TO...**
...every fortnight



There's something to anticipate twice every month in fascinating Model Engineer magazine! Whether your interests lie in live steam locomotive models, traction engines, internal combustion motors or stationary engines, world famous M.E. will inspire, instruct, advise and encourage. Model Engineer is published on the first and third Fridays each month and costs just £1.40 from all good newsagents; alternatively, you may care to ensure your regular copies through an annual subscription - a mere £33.60 for UK readers (overseas rates and airmail details on request).

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MODEL ENGINEERS' WORKSHOP AUGUST-SEPTEMBER 2000

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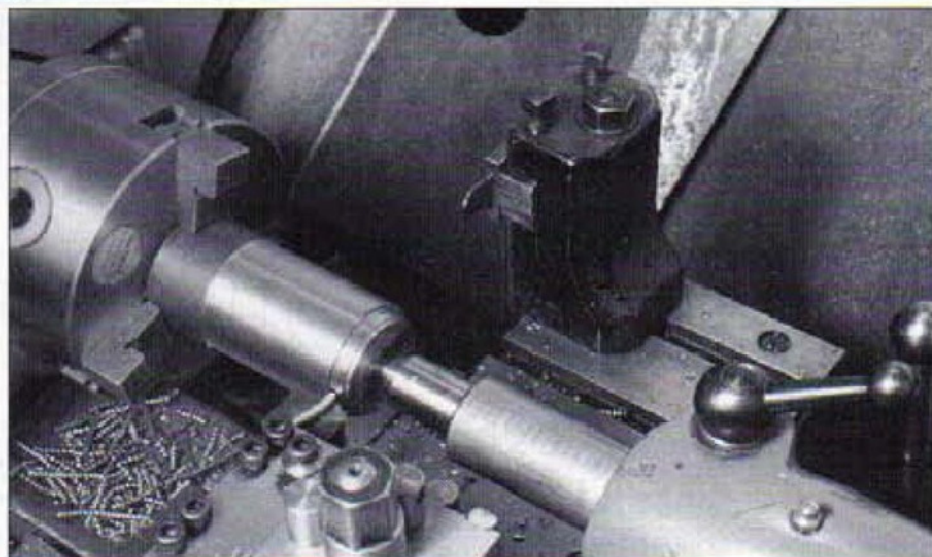
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Reader to reader

On the cover

There appears to be a growing interest in the modelling of machine tools. A visitor to the Harrogate exhibition, Don Hoey, brought his newly completed 1/6th scale model of a Myford lathe to show us. We look forward to seeing it on display to a wider audience. More items seen at Harrogate can be found on page 48.

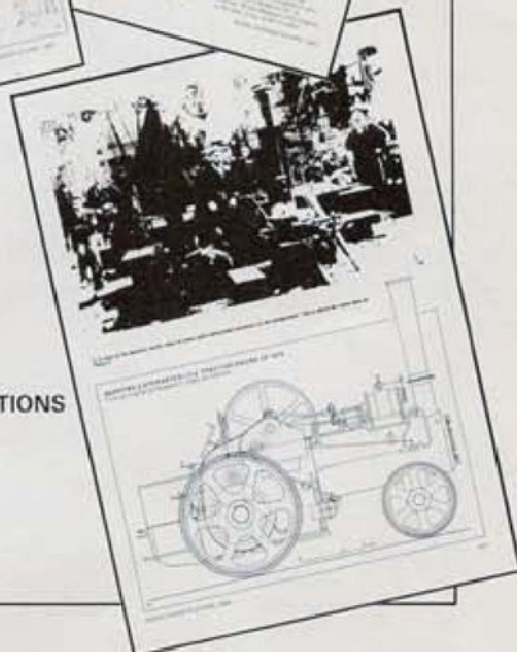
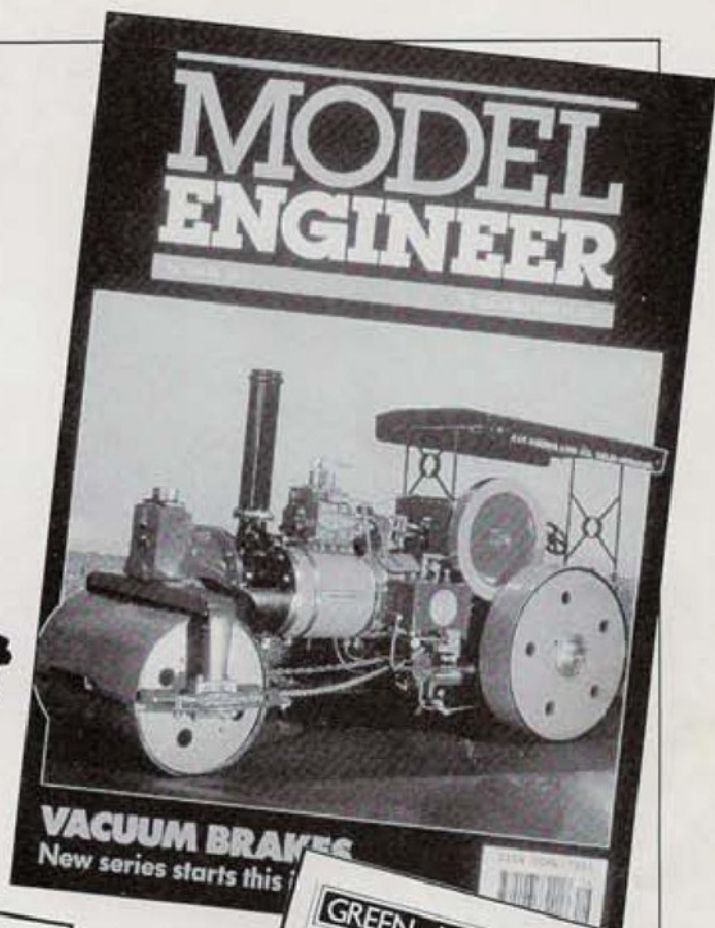


There has already been a great deal of interest expressed in our new beginners' series on lathe work. The introductory article starts on page 37.



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ON THE EDITOR'S BENCH

Re-launch of the Model Engineer Exhibition

For the past five years, the Model Engineer Exhibition has been staged as part of the larger International Model Show, first at Olympia and, last December at Alexandra Palace. On that occasion, due to the Millennium celebrations, it became necessary to move the event from its traditional date of the New Year holiday to early in the month. This timing did not prove to be very popular with either visitors or exhibitors as it was in the run-up to Christmas, when attention was inevitably concentrated elsewhere. Accordingly, a new date was sought, but it has proved difficult to find a venue of suitable size in the London area, the traditional home of this event, with a vacancy convenient to all parties. A tentative booking was made for early November, but following consultation with many of the interested organisations, it has been decided that a change of format would be beneficial.

For some time, the model engineering world has expressed the view that the IMS arrangement was not best suited to its interests and needs, being somewhat overshadowed by the activities associated with the branches of the modelling hobby promoted by the other magazines in the Nexus portfolio. The counter argument was that these attracted a younger audience who would then become aware of the more traditional aspects of the model engineering hobby and hopefully, in time, become involved.

The outcome of the debate is that it has been decided to drop the IMS concept and revert to the Model Engineer Exhibition format, this to take place over the New Year holiday at the Sandown Park Exhibition Centre which is located at Esher, to the south-west of London, just inside the M25. The event will take place from 29th December 2000 to 1st January 2001 inclusive.

The scope of the exhibition will be that covered by the three Nexus magazines, 'Model Engineer', 'Model Engineers' Workshop' and 'Model Boats'. The venue is capable of accommodating (probably outdoor) displays of live steam, so it is hoped to reintroduce the railway tracks, but finding room for the boat pool may not be possible this time.

The remaining aspects of the IMS will be dispersed to other events, mainly the

Sandown Model Symposium which is held in May and concentrates on model aircraft, cars and boating interests and to Euro Militaire, the autumn event staged at Folkestone, Kent.

The focus of the new event will, of course, once more be the long-established and prestigious competition, where the cream of the world's modellers display their work in the hope of gaining a medal, a certificate or one of the major trophies on offer. Steps have already been taken to overcome some of the difficulties which led to criticism over the trophy arrangements last time. The Loan sections will again feature prominently, both for individual exhibits and in the form of Club and Society displays. We warmly invite participation in any of the three aspects and have already received an enthusiastic reaction from some of the influential organisations who have remained steadfast supporters, but who welcome the return to the more familiar arrangement. The Competitors Handbook and entry forms for both the Competition and Loan sections will soon be available from our head office at Swanley.

Our regular trade exhibitors have been consulted during the decision making process and their concerns taken into account, mainly over costs and the selling environment. Accordingly, there will be no 'shell scheme' style stands and costs will be based on the provision of table-top stands, though of course many of the exhibitors provide their own settings. It is hoped that the new location and arrangements will allow exhibitors to optimise accommodation and staff costs, thus encouraging their participation.

Giving value for money to visitors has also been uppermost in the minds of those planning the new exhibition, so entrance fees have been set at £5 for adults, £5 for concessions and £2 for children (Advance ticket prices £5 for adults, £4 for concessions, £1 for children). On-site parking is free, with space for 3000 cars and there are also on-site caravan parking facilities. The venue can be reached by rail via Esher station and road access is good, the A3/M25 Junction 10 being just a few miles away.

The new arrangement once again gives the model engineering fraternity the opportunity to participate in 'their' exhibition, something which many have felt was missing over recent years. We are seeking to re-introduce some of the features for which space could not be found in the IMS era and would welcome views on those which readers would most like to see brought back or new attractions which would be welcomed. It is unlikely that we would be able to make arrangements for all of them to happen this year, but it would be helpful to know how people would like to see the exhibition develop in future. The Model Engineer Exhibition always was very

much an exhibition put on by modellers for modellers, and this is how we would like to see it again.

Health & Safety Executive Information Sheet - Safe operation of miniature railways, traction engines and road vehicles (Entertainment Sheet No. 12)

The group preparing this document having finished its deliberations and all the hurdles of the HSE departments having been cleared, it is now available for publication. In order for it to receive the widest possible circulation, the various representatives of the model engineering press agreed to try to find space to carry the complete document to augment the copies which the HSE will be distributing to any party expressing an interest.

Accordingly, the four pages at the centre of this issue carry a facsimile of the complete document. If you wish to remove it for reference, the suggestion is to slit along the centre fold with a very sharp blade over just the space covered by the two staples. It will then be possible to pull the folded sheet clear without affecting the rest of the pages.

It is also permissible to copy the document as many times as you wish, the only stipulation being that this must not be for advertising, endorsement or commercial purposes. Please acknowledge the source as HSE.

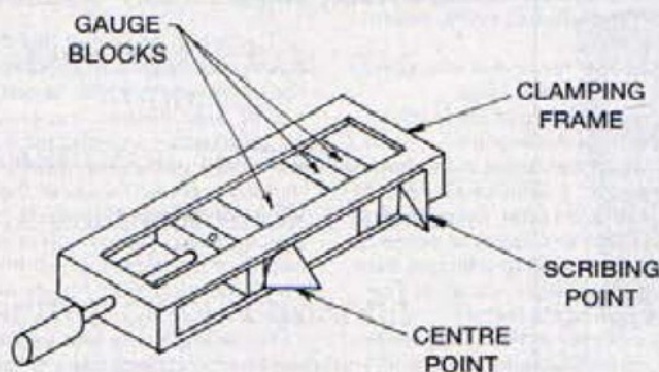
We feel that the publication of this document, which has been produced by representatives of the model engineering movement under the guidance of Dr. Terry Williams of HSE, removes the majority of the ambiguities and uncertainties which arose a couple of years back. The recommendations are in no way onerous and will be already in place in any well-ordered model engineering organisation which has contact with the general public. It will be a valuable aid for any club or society which needs to have dealings with local authority environmental health officers who are unlikely to have a depth of knowledge of our activities such that they are able to be sure of what is good practice. Demonstration of compliance with the recommendations made in this Information Sheet should remove any doubts.

Woking Precision Models

The photograph of the 'Potts' Universal Milling Attachment carried on the cover of our last issue has generated much interest. Although it has been available for many years, it is obvious that quite a few of our readers have not encountered it before. Although we stated that castings are still available from Woking Precision Models, we omitted to give a contact address. Apologies! They may be found at 10 New Street, Oundle, Peterborough PE8 4EA Tel. 01832 272868 Fax. 01832 272760. I believe that these premises are shared with another business, so if telephoning, I suggest that you ask for Mr Dennis Harris and make it clear that it is Woking Precision products in which you are interested.



CREATING HOLES



Drawing 1 Gauge Block Trammel

Introduction

Holes are an essential feature of mechanical engineering; in fact most parts can be considered as a pattern of holes joined together by solid material.

Holes can be made in many ways such as casting, forging, punching, sawing, oxy cutting, plasma cutting, electron beam & laser cutting, drilling, boring, broaching, ultrasonic abrasive cutting, electroforming, spark eroding/wire cutting and others. Although some of these processes can produce holes of various shapes, most holes are cylindrical. This article addresses these latter, and in particular the conventional processes of drilling, boring and reaming.

Character

Holes are defined by three characteristics - position, direction and dimension. Each of these is discussed below.

Position

There are two aspects to position:-

- (i) the identification of the location where the hole centre is required, and
- (ii) the making of the hole at this location.

Hole Centre

Simple Location

Hole centre location is most simply defined by crossed lines drawn on the workpiece using scriber, dividers, scaled rule and square to effect the marking. The lines can be made more easily seen by pre-coating the workpiece with some contrasting material such as 'markout blue' dye solution, copper sulphate solution (on iron or steel) or whiting in water or spirit suspension. With a sharp scriber, the lines are about 0.1 mm wide.

Very few texts give any indication of what accuracy can be expected with such marking out, but about 0.5mm or $\frac{1}{64}$ in. seems generally agreed for careful work. For marking from an edge, odd leg

dividers (jenny calipers) are convenient. For long radius requirements, trammels are used instead of dividers.

Improved Accuracy

The use of a surface plate and scribing block allows somewhat better accuracy in marking, to say 0.25mm. However, using a vernier height gauge instead of a scribing block and rule can improve accuracy to about 0.025mm with care. Also, radius requirements can be met using gauge blocks in a frame with centre points at each end, to at least this same accuracy - see Drawing 1. The actual marking is probably at best 0.05mm wide with the height gauge blade.

Jig Borer approach

This concept can be used also for less sophisticated machines than jig borers, and both the lathe and the vertical mill (or drill/mill) are suitable, provided due care is taken to eliminate backlash by operating the table drive screws in one direction only. The workpiece is moved by the appropriate screw by an amount read from its index dial (in two directions at right angles), at which stage the spindle axis is at the desired location.

With a jig borer these measurements are determined either by:

- (i) a metal scale viewed through a high powered optical eyepiece.
- (ii) an end standard, where bars, slip gauges or similar standards are inserted between the table and an adjustable stop attached to the machine carriage.
- (iii) an optical scale
- (iv) diffraction gratings with photocell sensors.
- (v) digital read-out units.

These days this latter (v) is available at moderate price for fitting to home workshop machines. This same approach is used on Computer Numerically Controlled (CNC) machines, where the required X & Y dimensions to the hole

The creation of a cylindrical hole is probably one of the most common workshop operations. Philip Amos discusses methods of location, production and finishing.

centre from a datum are buttoned in to the control unit as part of the program.

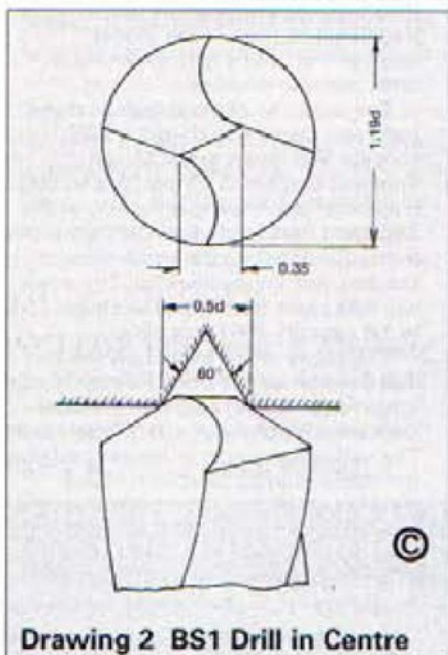
Hole Marking

Punching

Because a normal drill does not come to a point, but terminates in a small chisel end, there is a tendency for it to 'walk' sideways when it first engages the workpiece. Thus it is customary to centre punch the required location in order to induce the drill to stay where it is directed. Such centre punches usually have 90 deg. included angle points. However, the initial identification of the centre may be done with a prick punch with a 60 deg. included angle point, as this is somewhat easier to sight into position at the cross lines. When it is confirmed to be in the correct position, the indentation can be enlarged with a 90 deg. punch.

Using the marked centre point and dividers, a circle can be drawn of diameter equal to that of the required hole, and this circumference can be prick punched at intervals, so that the final hole can be demonstrated to be in the correct position (when half of each indentation will have been machined away - called 'halving the dots' in the trade).

Automatic centre punches - usually 60 deg. - are made to deliver a blow by compressing and releasing a spring in the handle. The pressure on this spring is



Drawing 2 BS1 Drill in Centre

adjustable so that differing blows can be delivered at will. The automatic centre punch is more convenient to use, and so easier to correctly locate than the hammer and punch set-up. Typically it will produce a maximum indentation in steel of about 0.5mm in diameter. The end of a BS1 centre drill ($\frac{3}{64}$ in. diameter) will just enter a 60 deg. centre punch indentation of 0.5mm diameter, as shown in **Drawing 2**.

Instead of the circle and dots approach cited above, toolmakers often mark squares (without dots) around the required holes, which then just touch at the mid points of the sides, so that positioning can be demonstrated to be correct, without any damage to the workpiece.

Correcting

If, at the start of drilling, it is seen that the drill is not cutting in the correct centre location - as depicted in **Drawing 3**, then it can be brought back towards location by chiselling a groove down the cone of the depression on the side towards which the drill is desired to move. This practice is usually related to larger size holes, with the workpiece held in a vice, but free to move to some degree on the drilling machine table. The correction must be effected before the drill point is cutting at its full diameter and may need to be repeated several times to fully correct the error.

Jig drilling

In commercial production, hole locations are frequently defined by drill guide bushes located in a jig into which the workpiece is clamped - see **Drawing 4**. If drilling only is required, a simple headless bush, pressed in to the jig may suffice, but if drill & ream or drill & tap operations are involved, a pair of slip bushes can be used within a liner bush pressed into the jig body, one for each process.

Drilling in the lathe

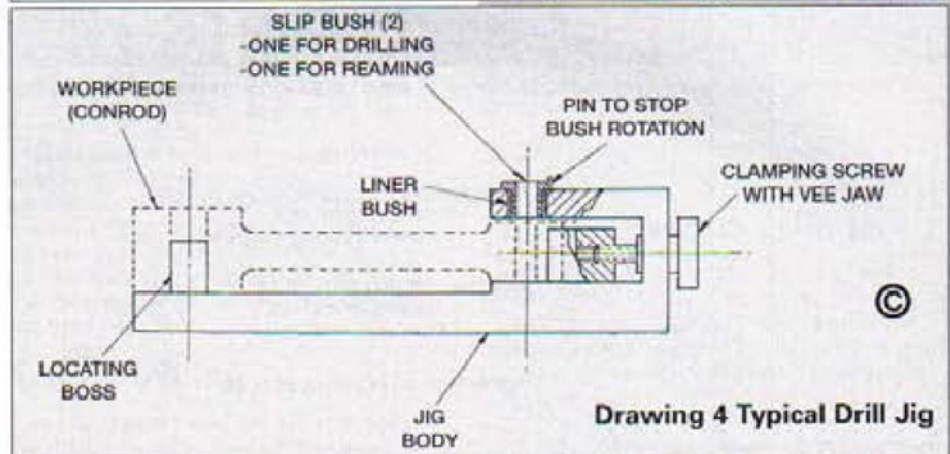
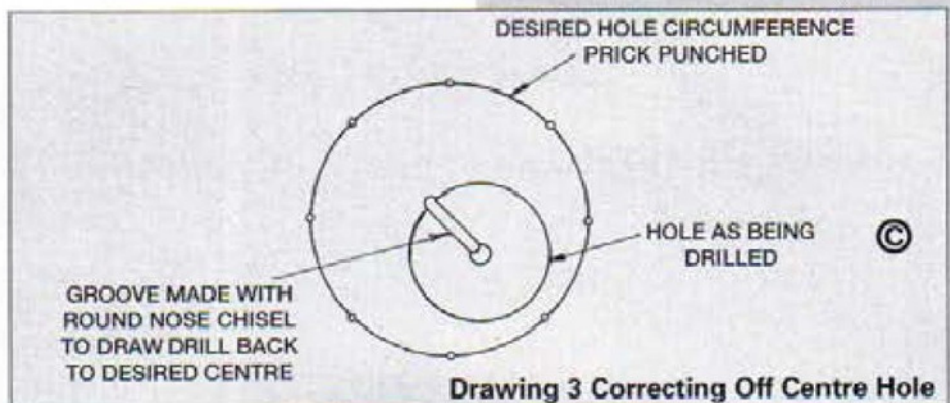
When drilling from the lathe tailstock, the drill may wander slightly from the axis. To obviate this, a solid support bar may be held firmly pressed against the side of the drill near its point, perhaps clamped in the saddle toolpost (**Photo. 1**). This bar prevents lateral movement of the drill point, causing it to act like a single point tool, carving out a depression which is axial, even if its diameter may be somewhat larger than the drill diameter. Once the drill is established as cutting axially, the workpiece will tend to maintain it in alignment, making it possible for the support bar to be removed.

Special Positioning Techniques

Over the years, a lot of clever chaps have devised a variety of means of improving accuracy and convenience in getting hole centres correctly positioned. Some of these are described below:

Centring in a 4-jaw chuck

The starting point of this technique is to line up the punch mark near the tailstock

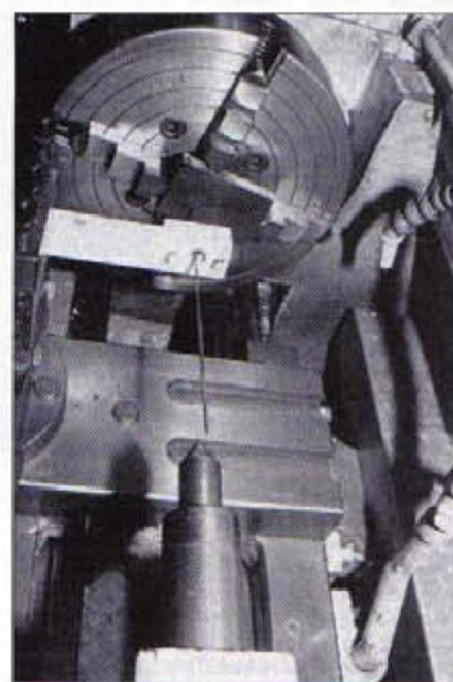
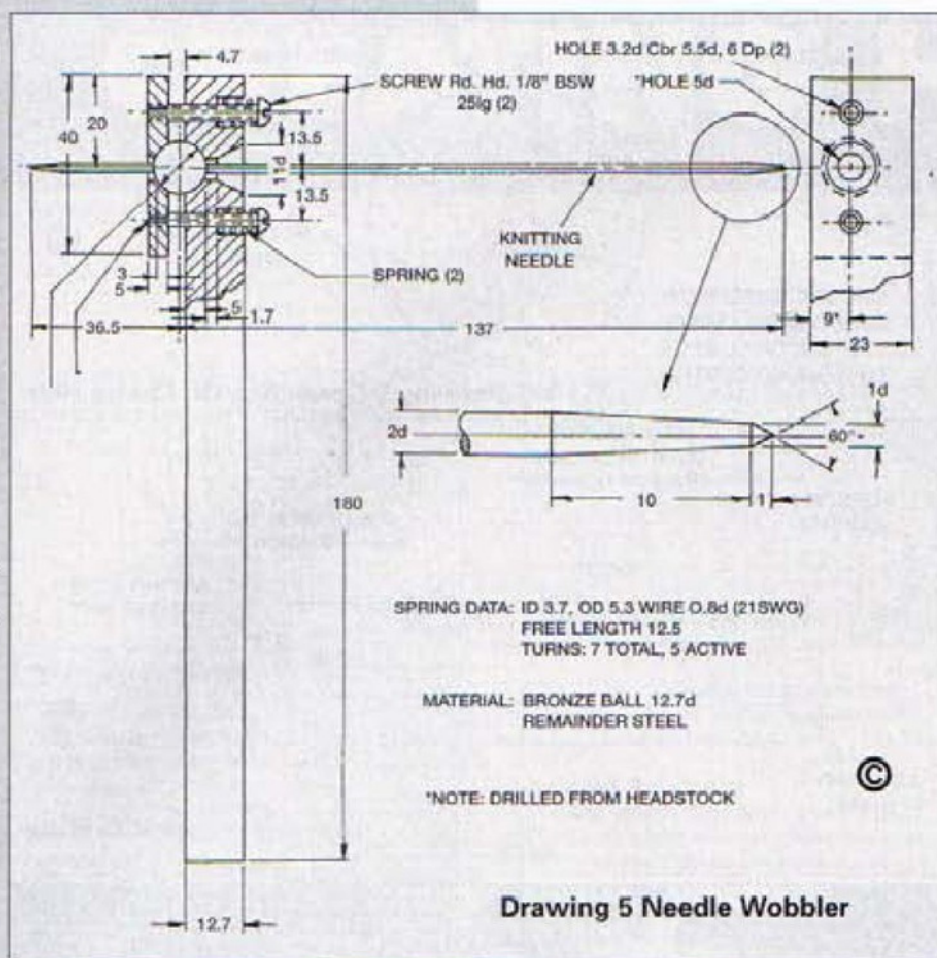


1. Providing side support for the drill by means of a bar held in the lathe toolpost.

centre point. In this way the work can be centred to within about 1mm.

Better results can be achieved by making use of a 'needle wobbler', as depicted in **Drawing 5**. This device has been described and illustrated by a number of notable authors - see *References 1, 2, 3, 4 and 5*. To operate it, the short end of the needle is engaged in the punch mark and the lathe spindle is turned around by hand. The other end of the needle will then move in a circular path around the point of the tailstock centre. By appropriately adjusting the chuck jaws, this circular path can be reduced in diameter, hopefully to zero, at which stage the punch mark is located on the axis of the lathe spindle. I made one of these devices some years back, adopting

the Ian Bradley concept described in *Reference 1* (see **Photo. 2**). It does work, but in my view not all that well. Consequently, I much prefer the spring-loaded plunger rod type of wobbler shown in **Drawing 6**. This has also been described by several authors (e.g. *References 6 and 7*). Mine follows the George Thomas design (*Reference 6*) where the wobbler is supported at one end by the punch mark and at the other by the tailstock centre. A dial indicator is set to bear against the side of the wobbler, near the workpiece end - see **Photo. 3**. As the spindle is rotated by hand, the dial indicator shows the direction of the required adjustments - effected twice in sequence at right angles. With this device it is not difficult to centre the punch mark



2. The 'needle wobbler' in action. With the fulcrum held in the toolpost, the pointed end of the shorter section is engaged with the centre dot in the workpiece. The amount and direction of off-centre can be deduced from the movement of the other end.

simplified if a dummy mandrel, such as described in *Reference 8* is available.

Drilling Machine or Vertical Mill

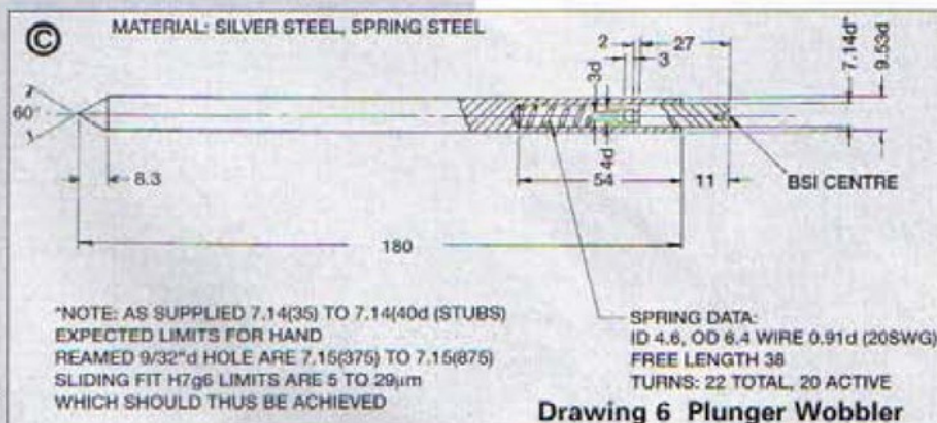
A lever type dial gauge can be used to centre toolmaker's buttons or holes with a workpiece clamped on a drill or mill table, in a similar way to that described for the lathe. You may, however, get a crick in the neck, as the dial indicator rotates with the spindle, so making it difficult to read over the complete rotation.

This problem may be overcome by the use of a co-axial dial gauge arrangement of the type shown in **Drawing 7** and described in complete detail for manufacture by Guy Lautard in *Reference 9*.

Shaft 'A' is held in the chuck and stylus 'B' engages with the toolmaker's button (or hole wall). Pressure on stylus 'B' moves rocker 'M', pushing the whole device upwards against spring 'C'. This causes flange 'D' to depress plunger 'G' of indicator 'I'. Body 'H' is held against rotation in a horizontal direction by rod 'E' engaging the drill/mill vertical column. The remainder of the device can rotate within body 'H'. Thus, when the drill/mill spindle and chuck rotate, the stylus 'B' consequently traces out the position of the toolmaker's button, with the indicator dial continuing to face the front where it can be easily read.

Wigglers

If a rod is loosely clamped in a ball joint in a drill spindle rotating at speed, it can be nudged towards the axis with any convenient stick - e.g. a pencil - and can in fact be made to spin exactly on the axis of the spindle. If such a rod is sharply pointed, it can then be used to accurately locate over the cross lines of a centre, especially with the aid of a magnifying glass (see **Photo. 9**). This is a more sophisticated version of the famous 'sticky



to within 0.01mm of the lathe axis - probably even closer with care and patience. Whether the drill will stay this close to the axis is a matter of conjecture.

Location of holes from each other or from workpiece edges

Toolmaker's buttons may be set in position using gauge blocks for inside or edge distance measurements (**Photo. 4**), and micrometers for outside measurements (**Photo. 5**). If you don't have gauge blocks, a disc turned to the appropriate diameter in each case will serve nearly as well. Another possibility is the use of inside calipers and a micrometer, but this is more fiddly. A vernier height gauge could also be used.

The buttons are shown in **Photo. 6**, mine being from Starratt, but they can be easily made in the home workshop from ground stock steel e.g. silver steel. The only essential is that their faces are machined exactly perpendicular to their axes.

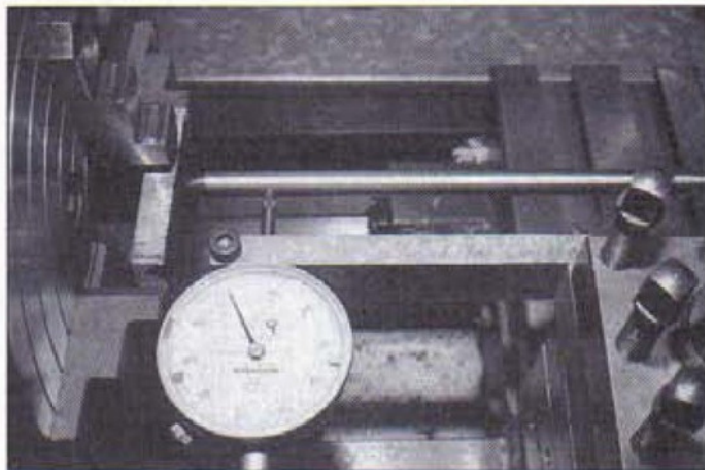
After the buttons are set in their required positions, the workpiece is adjusted in the 4-jaw chuck so that each button in turn is accurately centred, using a dial indicator - see **Photo. 7** - after which the hole is drilled, bored and reamed before repeating the procedure with the next button. A good step-by-step illustrated description of their use is given by Ian Bradley in *Reference 7*.

Centring an existing hole

If an existing hole in a workpiece is to be centred, as for example if it is to be enlarged, a lever type indicator (**Photo. 8**) can be used to monitor appropriate adjustments of the 4-jaw chuck.

Faceplate mounted work

The procedures used to centre work held in the 4-jaw chuck can also be employed with a workpiece mounted on a faceplate, but it can be a somewhat awkward job. This process is much



3. The 'plunger wobbler' in action. The dial gauge provides a more precise indication of the correction required.

pin' which is secured to the tip of the drill with Plasticine or similar material.

If the lower end of the rod terminates in a ball of known diameter, it can be moved until it just removes a smear of bearing blue (or of lipstick if that is more easily obtainable) from the side or top of the workpiece, thus defining the edge (or top) of the part (having due regard to the ball diameter dimension).

Such a device is called a 'wiggler'. It is available commercially, my set seen in **Photo. 10** coming from General Hardware, New York. It includes pointer, ball, small cylinder for small holes, and a bent arm for holding a lever type dial indicator. George Thomas, in Reference 6, gives information for their manufacture.

Edge Finders

Although 'wigglers' are efficient edge finders, there is another form of device which is easier to use and seems to be more accurate. It comprises a ground steel rod of some specific diameter, often 12.70mm, with its bottom 12.7mm of axial length separate, but attached to the remainder by an axial spring. This device is placed in the drill/mill chuck and, with the end piece slightly displaced sideways, it is rotated at moderate speed. The workpiece is advanced by the table screw until it just encounters the end piece. As the advance is then continued, the sideways displacement of the end piece is gradually reduced until, just at the point at which it becomes co-axial with the main rod, the end piece jumps sideways about 1 to 2mm. This then defines the edge position accurately, allowing of course for the half diameter of the rod - see **Photo. 11**.

This device is available commercially at moderate cost - again mine is from General Hardware - but it is probably not easily made in the home workshop. The makers claim that an accuracy of 0.005mm can be expected, although my own experience is that consecutive trials on the drill/mill reproduce to about 0.025mm, but that may be due to slackness in the table screw fits. The scales for these screws are calibrated to 0.05mm.

Hole axis direction

Prerequisites

Having identified and marked the position for the specified hole, the next

requirement is to ensure it goes in the appropriate direction usually perpendicular to the surface. If for any reason a different angle is required, a preliminary operation is needed to machine a small area, at right angles to the required angle, to allow the drill to work as intended.

Lathe drilling

If the hole is being drilled from the tailstock of a lathe, the drill can again be supported by a rod from the side as discussed earlier. In addition to assisting in centring the drill it will help the drill maintain its axial direction.

Drill/Mill

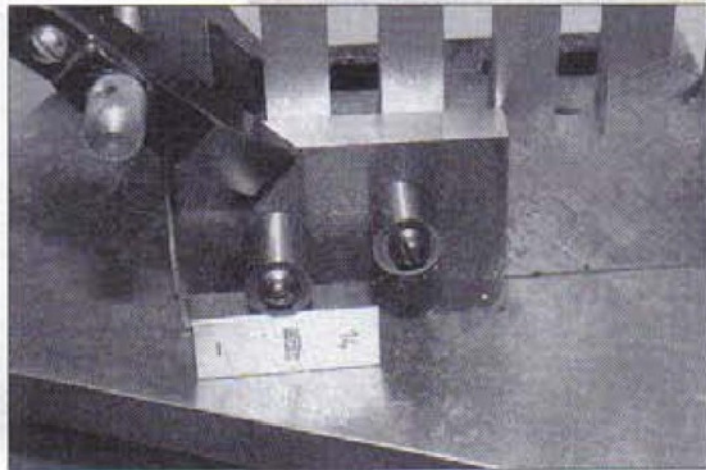
In a similar manner, when using a pillar drill or mill, a drill jig with a hardened, close-fitting bush will perform a similar function in keeping the drill perpendicular as well as correctly centred.

Whether to spin the drill or the workpiece?

Most authors advise spinning the work where this is possible. Although these two alternatives seem at first sight to be identical operations, there are conceptual differences, as shown in **Drawing 8**. With the drill spinning there would seem to be less corrective force to return it to the 'straight and narrow' than when the workpiece is spun. The actual shape of the



5. Setting centre to centre distance with a pair of toolmaker's buttons.



4. Setting edge to centre distance with a slip and a toolmaker's button.

hole being created in the latter case is a matter of some conjecture.

Drilling across cylinders

These are best treated as for angled holes - make a small flat on the side of the cylinder with a slot drill then start with a centre drill, which will have less tendency to wander on the flat than on the curved surface.

Achieving the required dimension

Progressive Drilling

For accurate work start with a spotting drill or a centre drill (I use a BS1 with a 1/8in. dia.), then a succession of drills of increasing diameter (I use 1/8in. dia. then increasing in 1/8in. steps), finishing to diameter with a single point boring tool and/or by reaming.

Larger holes

Drill/mills usually have draw bars to secure their chucks, but drilling machines and lathe tailstocks do not/ cannot provide these.

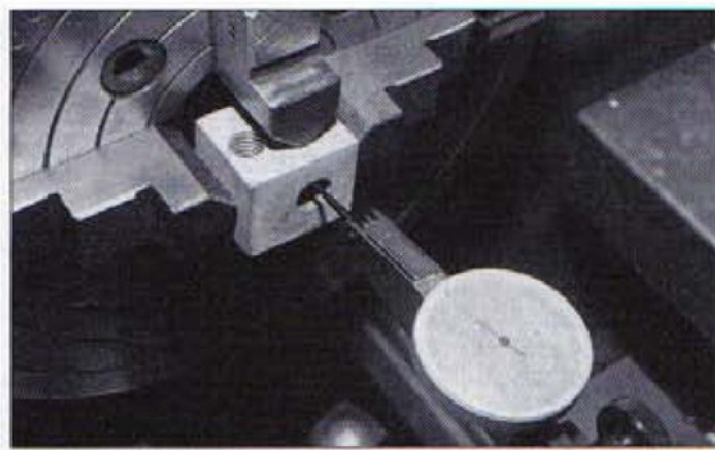
When drilling deep holes (say more than four diameters) it is usual to withdraw the drill from time to time to clear the chips. Now it may happen that due to jamming by the chips being created or other cause the drill 'hangs in' and the chuck shank separates from the quill or tailstock barrel, so that relative rotation of



6. A set of toolmaker's buttons.



7. Centring by means of a toolmaker's button.



8. Centring a previously drilled hole using a lever type dial gauge.



9. Centring a wiggler point over scribed cross lines.

shank and socket occurs with possible damage to one or both.

Furthermore, if the drill bites in, as sometimes happens with brass, it may move forward of its own volition, faster than the feed rate, and produce the same separation problem. These incidents seem more prevalent with larger diameter drills (e.g. reduced shank drills from 12.7 to 25 or 30mm dia.). There can be advantages in drilling from the saddle of a lathe rather than from the tailstock when using these larger drills. A split sleeve can be made (see **Drawing 9**) to fit the toolpost in a precise position, with the cross-slide marked with an index for easy positioning - see **Drawing 10**. If the sleeve caters for 12.7mm diameter shanks, then the one sleeve can be used for all the reduced shank drills. The position of the toolpost and cross slide can be readily checked with the 12.7mm drill being transferred from the tailstock chuck to the sleeve, and then being run into the just-drilled 12.7mm hole. This arrangement can also be used for precise power feed if desired.

Smaller holes

For holes of diameter less than say 10mm, boring is not easy as the tools are necessarily slender, and thus springy and weak. As the correction process of the single point boring tool operation is then not available, more care must be taken in the initial drilling. Thus the initial centre drill should be side supported. The next drill should be a stub drill because of its better stiffness, and also side supported, and finally a jobber drill of the same size used for finishing to length. These holes may best be brought to size with D-bits, or with toolmaker's reamers for through holes.

With very small holes - say 1mm and below - the use of a jeweller's five sided broach may be the best approach to finishing to size.

Finish & Dimensions

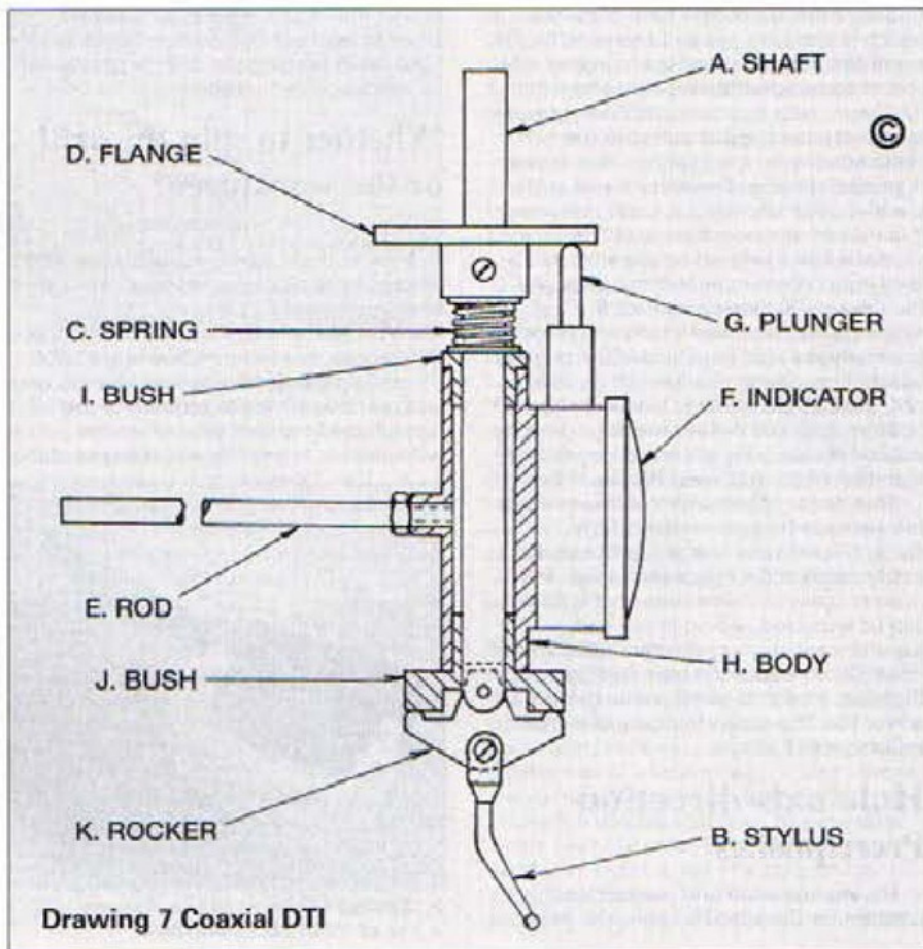
For the highest classes of workmanship, the boring and reaming processes may not produce the required standards, so to improve results various other processes have to be called into play:

- (i) Internal grinding may be possible with a high speed die grinder, or improvised in a machine like the Quorn - reference MEW 47. This process is common in tool rooms for precision drill jigs and for press tools.
- (ii) Honing, in which abrasive blocks are held in a rotating frame and spring

loaded against the bore of the hole, is a process frequently used in finishing the bores of internal combustion engines.

(iii) Superfinishing is a similar process to honing, but the frame reciprocates up and down the bore as well as rotating. This leads to there being a non-directional pattern in the finish, and is probably the best class of surface finish obtainable with a machining process.

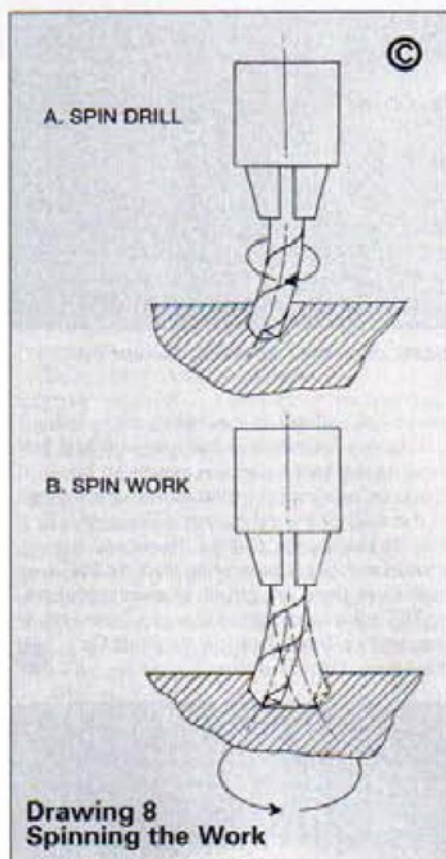
(iv) Lapping, in which abrasive powder, usually in slurry form, is moved against the bore by a rotating and reciprocating lap. This device is adjustable in diameter over a small range close to that of the bore, and is made of a softer material than the workpiece. The non-rotating item - lap or workpiece - is usually hand held and



Drawing 7 Coaxial DTI



10. The components of a wiggler set.

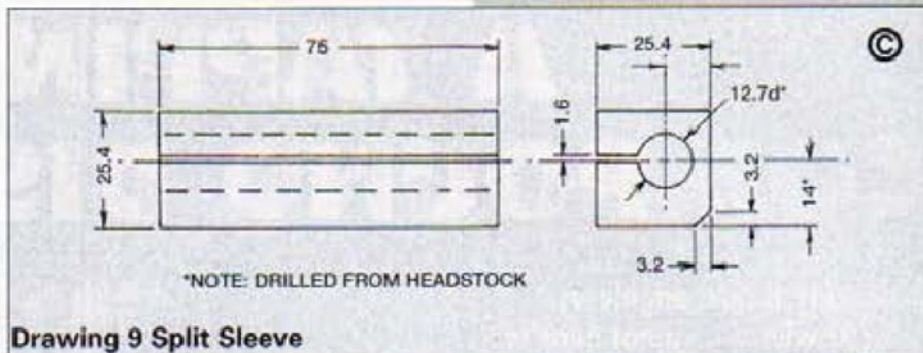


Drawing 8
Spinning the Work

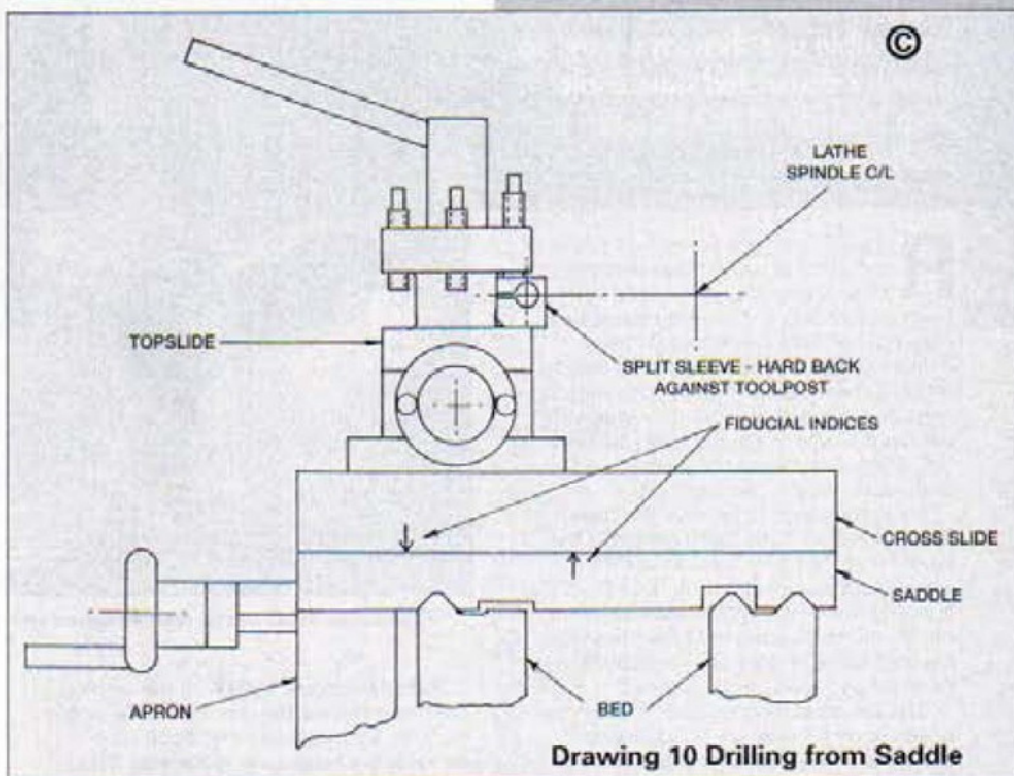
moved axially along the rotating member. This process is the one most used in the home workshop to achieve superior finish and dimensions.

Coated drills

As the chisel point of a normally sharpened drill really doesn't cut, but wears its way through the material, it is helpful if the drill material is as hard as can be obtained. The first material coming to mind is solid tungsten carbide, which is expensive. However, in relatively recent times coated drills (having a bright golden appearance from the applied Titanium Nitride surface layer) have come on the market at about three times the price of normal high speed steel ones.



Drawing 9 Split Sleeve



Drawing 10 Drilling from Saddle



11. The edge finder in action.

It may not be economically feasible to completely re-equip with coated drills, but purchasing just one to make the initial hole in progressive drilling can make sense. Each succeeding drill point goes down the hole of its predecessor and so only its cutting edges are used - no wearing through with the chisel point.

The TiN coated drills stay sharp a long time but can only be sharpened with green silicon carbide or diamond impregnated wheels. Even then, one is likely to grind away the coating, so probably the best notion is a new purchase. At about \$A3 (about £2.35 in a current UK catalogue) for a 1/8in. dia. TiN coated HSS drill, this is not too significant an increase over the standard variety.

Conclusion

Because of the importance of holes in the home workshop scheme of things, it seems worthwhile using all the devices and procedures available to ensure that the results meet the accuracy and quality standards desired - in position, direction, dimension and finish.

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4. A Man & His Lathe - L.H.Sparey - 1951
5. Machine Shop Methods - L.J.Milne - 1950
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A TAPPING COMPOUND DISPENSER

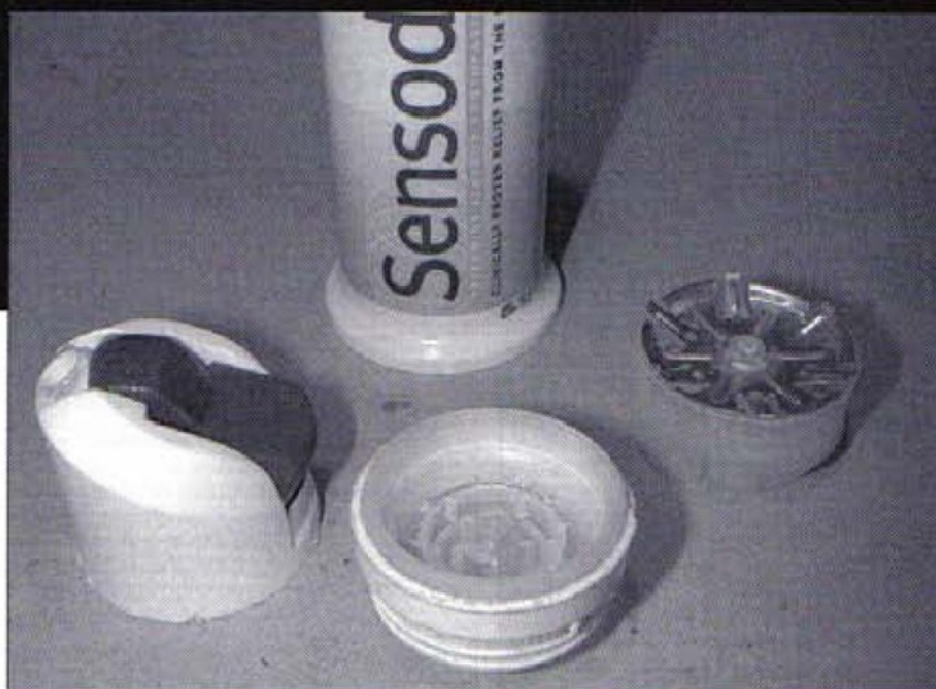
Like many model engineers, Peter Rawlinson cannot bear to see anything which may have a possible use thrown away, so another discarded household item has found its way into the workshop

Recently, my wife purchased a 'pump' container of tooth paste at a very advantageous price (it must have been a promotion). The tooth paste has now run out, and I wondered if the container could be re-used. I was able to remove the top, but this did not seem to help, so I decided that the only way into the 'works' was to cut the tube, so this I did, 6mm down from the pushed-on top and, luckily, just in the right place.

I was then able to remove the base plunger and to clean out thoroughly the whole unit. The way it works is very simple and straightforward, but I think that it would only work with a somewhat runny liquid. As the tapping lubricant that I use seemed to be of the right viscosity, it was filled up and tried, and it worked.

The cut does have to be at any critical position, and it may be necessary to fit a sleeve over the joint at some later time, but at the moment it is fine.

The base plunger must be pushed out of the tube from the bottom, as it is fitted with a disc spring which clamps to the outer wall of the tube and allows it to travel one way only (up), this being the only reason that the tube has to be cut.



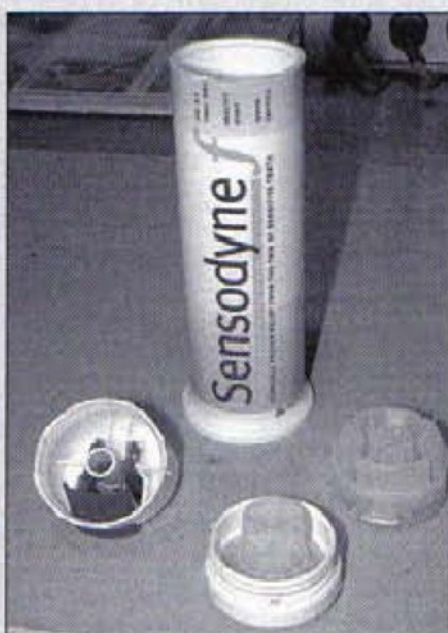
1. The components of the dismembered tooth paste dispenser, showing the spring.

Refit the top and refill with the tapping fluid, then replace the seal and spring unit in the tube. Do make sure that if you have removed the base cover to the seal, it is replaced, as otherwise the liquid will leak out. Operate the pump and at the same time gently push the seal and spring up the inside the tube until the tapping lubricant emerges. There you have a dispenser which will measure out small amounts and, as it is hand-held, can be offered up to a tap or

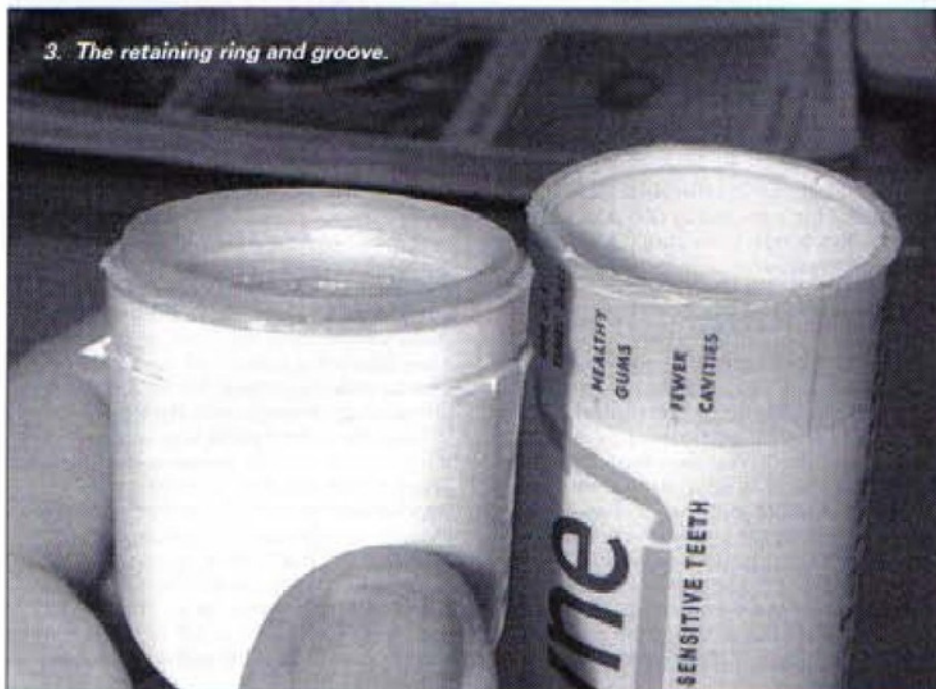
workpiece on drilling machine, mill or lathe.

I do not believe that the tube will last for ever, as the spring (which seems to be made from aluminium) cuts into the inside of the wall of the tube, and will eventually lose its sealing properties. However, it should survive a few refills and, as the quantities used are small, should last years.

The tube depicted is the only one I have checked so other brands may not be the same. Good hunting.



2. This view shows the seals.



3. The retaining ring and groove.

REPEATABLE HEADSTOCK LOCATION FOR A VERTICAL MILLER

David Machin tackles a problem experienced by many owners of small milling machines

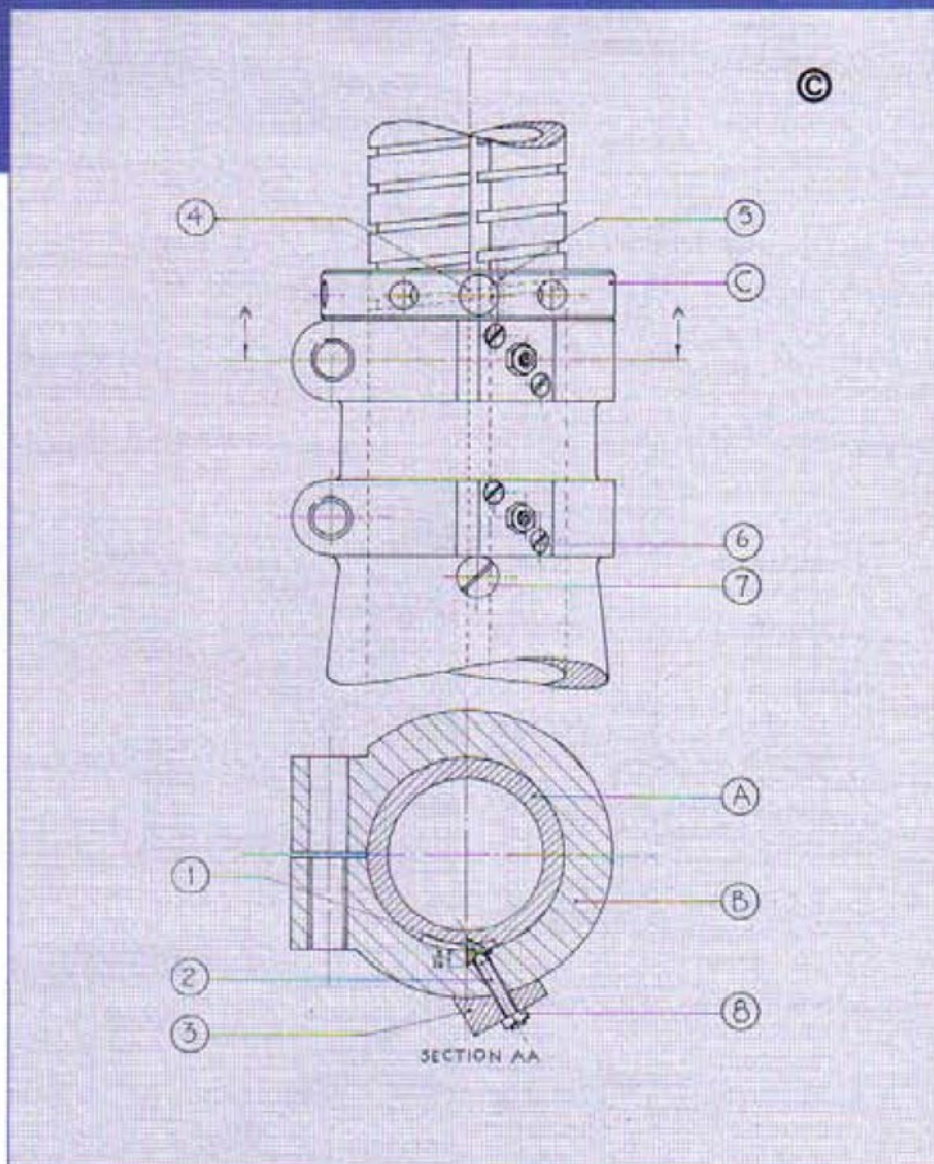
Owners of Westbury, Dore Westbury and similar millers will have, no doubt, met this most irritating of situations: Where, in planning a precision drilling job, you find that the quill stroke length is insufficient to cover the range of drill lengths required to complete the job without raising the headstock. Thus the planned precision cannot be met because, on releasing the column clamp bolts, the headstock location is lost.

By coincidence, I had been re-acquainted with just this situation the day before my visit to a Model Engineer Exhibition. It was therefore with some interest that I examined a Dore Westbury machine on the S.M.E.E. stand which had a triangular section key and keyway system to overcome this problem. I couldn't find a name, so cannot acknowledge the source. In any case, my thanks to the person who took the trouble to bring his machine, and inspired me to emulate his idea.

After the visit, on the Leeds-bound coach, a kind gentleman (whose name never asked, a fact which I now regret, if only to say "Thank You") remembered better than I, that an article on this had appeared in *M.E.*, and kindly sketched the rudiments of the system. He even remembered the name of the author of the article - what an amazing memory! On returning home I went straight for the excellent red *M.E.* index book, found the reference, (but only via the author index) and unearthed the back copy. The article was in the issue dated August 4th 1980, page 1013.

It appeared, that the author of the article - (now the late) David Urwick - was also the inventor of the system, the patent for which had expired long ago. In it he explains very clearly the principles of the system and invites readers to use it and specifically mentions vertical millers having round columns.

Briefly, referring to my general arrangement drawing, the principle is that a groove of V section is milled down the outside of the round tube, labelled part A, with one flat of the groove exactly on a



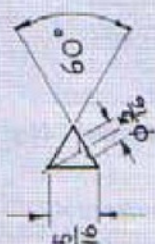
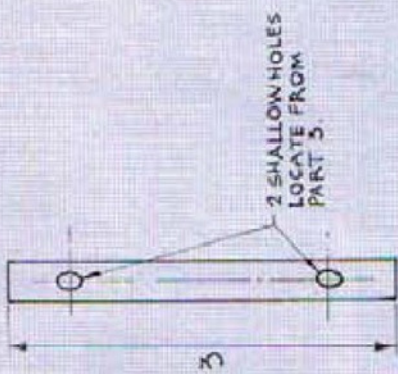
General Arrangement - Not all hidden detail shown

radial line, with a similar groove machined on the inside of the vertical column, labelled part B. A key of suitable section is fitted to locate the tube and column, the key (Part 1) being adjusted by fitting suitable 'gib' screws, Part 2. The settings are locked by nuts, Part 8. You will note that additional pieces of metal, Part 3, have to be fitted to the column to provide

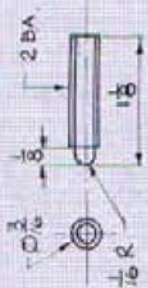
flat seatings, square to the screws and nuts. This was because I didn't want to risk weakening or cracking the vertical column casting by milling a flat seating in it.

This arrangement allows the column to be raised or lowered without losing the setting of the headstock and, in each case, the precise original setting is regained on tightening the column clamp bolts.

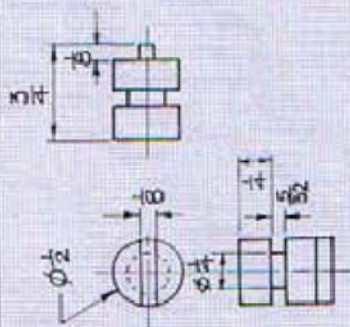
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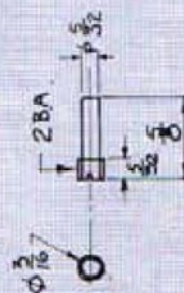
① KEY MAT- EN 6 IOFF



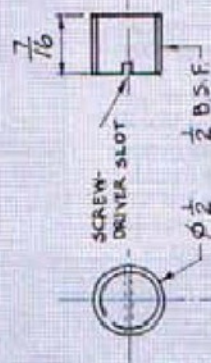
② MODIFIED ALLEN SCREW
1 OFF



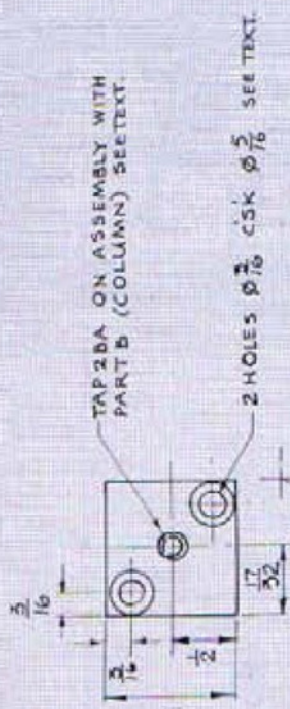
④ ELEVATING KEY IOFF
MAT- SILVER STEEL H.T.



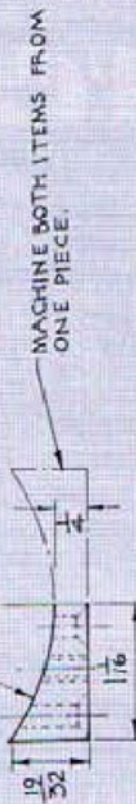
⑤ RETAINING SCREW IOFF
MAT- EN 1A B.D.M.S. OR FROM ALLEN BRUB SCREW



⑦ PLUG & KEY RETAINER
MAT- EN 1A B.D.M.S.



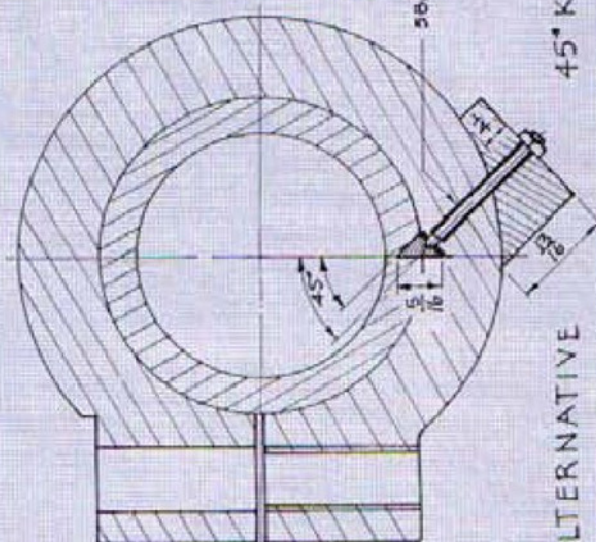
* CHECK FROM JOB



③ COLUMN EXTENSION PIECES FOR GIB SCREWS 20FF
MAT- EN 3B B.D.M.S.



ALL DIMENSIONS ARE IN INCHES.

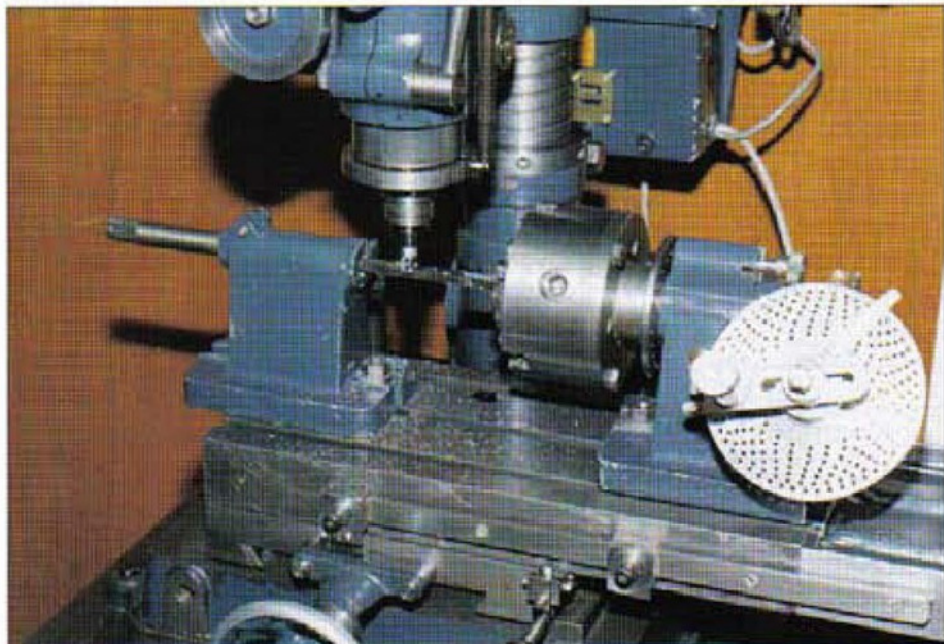


ALTERNATIVE

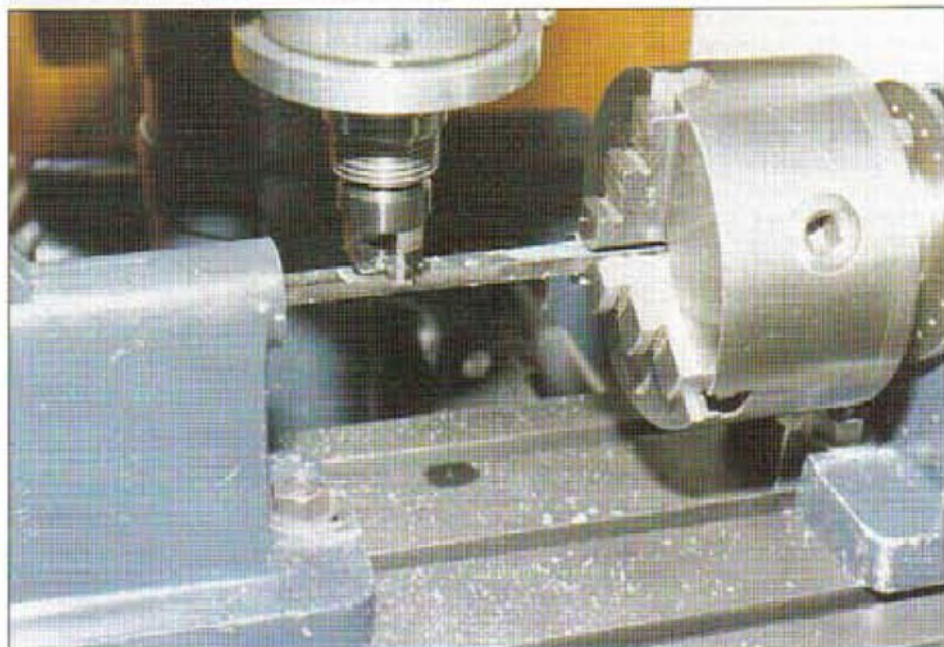
45° KEY SYSTEM. FIG 1

DETAILS ARE GENERALLY AS FOR 60° KEY SYSTEM.

3BA x 14



1. The set-up for milling the key. The unusual tailstock arrangement is explained in the text



2. Machining the key with a tungsten carbide tipped cutter

So, having said my mental Thank You's to the three people who had got me this far - not least the late David Urwick, I set about preparing to do the job. Since the tube, Part A, has to be milled along its length, it is necessary to have the use of another milling machine. My friend Frank readily agreed to allow me the use of his, so that was one obstacle out of the way.

A new key from an old file

David Urwick advises the use of a 45 deg. key, but as I already had a dovetail cutter of 60 deg., I decided to opt for that, and use a matching key. If you need to buy a cutter, then 45 deg. ones are readily available.

Not having any key steel (usually EN6) for Part 1, I looked around for a suitable material as, ideally, each of the sliding



3. The part completed key, still with the tapered and centre-drilled ends

surfaces should be of a different material or grade of material (except, of course, cast iron). I found an old $\frac{3}{8}$ in. three-square (triangular) file, and this proved acceptable.

This was softened by annealing by heating to bright red and cooling as slowly as possible. The usual practice is to cover and surround the job with coke or broken firebrick, heat up and cool the whole lot up together. Even with this procedure, I found two annealings necessary. The tang was sawn off and the job gripped in the 3-jaw chuck for facing and centre drilling in the lathe. The chuck and workpiece were then transferred to the dividing head (bolted to the miller table) as shown in **Photo. 1**. The tailstock set-up looks a little odd and perhaps needs explaining. My miller table is not very long and to support the centre drilled end of the workpiece, the centre point had to be put well back inside the dividing head tailstock, and the centre point (which is a parallel piece of bar) engaged well inside the barrel. The teeth of the old file were then machined off and since the metal - even in the annealed state - is still comparatively hard, I used a cutter with tungsten carbide teeth. **Photo. 2** shows the milling being carried out and **Photo. 3** shows the completion of milling of the key at this stage.

The dividing head greatly facilitated the accurate machining of the 60 deg. angles. For those without this facility, I can only suggest that a jig be made, similar to a vee block, but with an angle of 60 deg. (*Model Engineer* No. 4047 includes an article on making micro vee blocks by Ed Cooper of Canada, which shows this being done with a centre drill as the 60 deg. cutter). This would be made longer than the finished length of the key, and would allow clamping down a longer length of key material to the miller table, with the milling being completed between the clamps. For those intending a 45 deg. key, commercial 90 deg. vee blocks may be used, with a clamping arrangement as already detailed. For this it would be presumed that you would use a piece of square section bar and mill down to the section shown in the 45 deg. general arrangement drawing in Fig. 1.

Returning to the description, the extra piece containing the centre drilled end was sawn off and, to complete the key, the sawn end was faced and two of the milled surfaces scraped flat. Only two, because the third surface is merely the face on which the gib screws bear, and doesn't need the high degree of flatness required by the other two. It can be seen in

Photo. 4 that the key is still attached to the chucking piece to allow gripping in the vice. I also use an old file ground for use as a scraper, which can also be seen in the photo. Scraping is carried out by smearing a thin layer of engineers' blue on a surface plate (I use a piece of plate glass) and placing the surface to be scraped onto the blue plate. The high spots will then be revealed, the scraper then being used to remove these high spots. This is repeated until blue covers about 90% of the surface being tested. Having said all that, with hindsight, as yet unexplained, I would grind them.

Modifying the column

Machining the keyway along the column was next. As already stated, this needs another milling machine, the one I used having a traverse long enough to machine the keyway along the whole tube length at one setting - and my tube is of



4. Two faces of the key were finished by scraping

extra length. Incidentally, this means having to have a hole in the supporting bench top for my machine!

The tube was clamped to the table using (accurate) parallel packing. Packing is needed unless you are prepared to remove the T piece casting at the top of the column. I wouldn't recommend this, particularly if it was originally fitted as a shrink or press fit, as you may irrevocably damage the casting or tube (or both). I used a piece of 1in. thick bright drawn mild steel as packing. This was checked for straightness and more importantly, for consistent thickness, using a micrometer. This enabled the T piece to clear the table and also was a check on getting the keyway at 90 deg. to the cross tube, since the face of the T piece needed to be merely parallel with the table. This is not, of course, critical.

What is critical is aligning the axis of the tube parallel with the table ways of the miller. This was achieved by using a d.t.i. as shown in **Photo. 5**, which also shows the method of clamping. This alignment took some time to achieve since the table needs to be wound back and forth to make the necessary checks. Another point is that the d.t.i. stylus cannot be allowed to drop into the square thread grooves as the table is traversed, so the cross-slide index needs to be used to allow retraction of the tube during traversing, assuming that the cross-slide index can be relied upon for accuracy. Allowance also needs to be made for backlash.

I found that if the tube was merely nipped down and then adjusted parallel, subsequent tightening would alter the parallelism - very frustrating. I eventually found that the tube could be moderately tightly clamped at each end, and judicious tapping with a mallet, checking, further tapping with the mallet, and further checking, eventually achieved the required result. A further series of checks is necessary during final tightening down, a lengthy procedure, but very necessary if accuracy is to be achieved. More clamps were fitted in addition to the two end ones, as seen in the photograph. The bottom of the dovetail (or 45 deg.) cutter then needs carefully bringing to exactly centre height position of the tube, and machining can commence. An initial cut of around 0.015in. was taken, incrementally reducing the depth of cut for each successive pass. The reason for this is that, as the cut gets deeper, more of the angled face is exposed and therefore

the harder the cutter/machine has to work. Final cuts were around 0.002in. at the full depth of half the key width, i.e., 0.156 inch. **Photo. 6** shows the machining in progress. A fine feed and lubricant is essential to obtain a good and accurate finish.

Machining the column casting

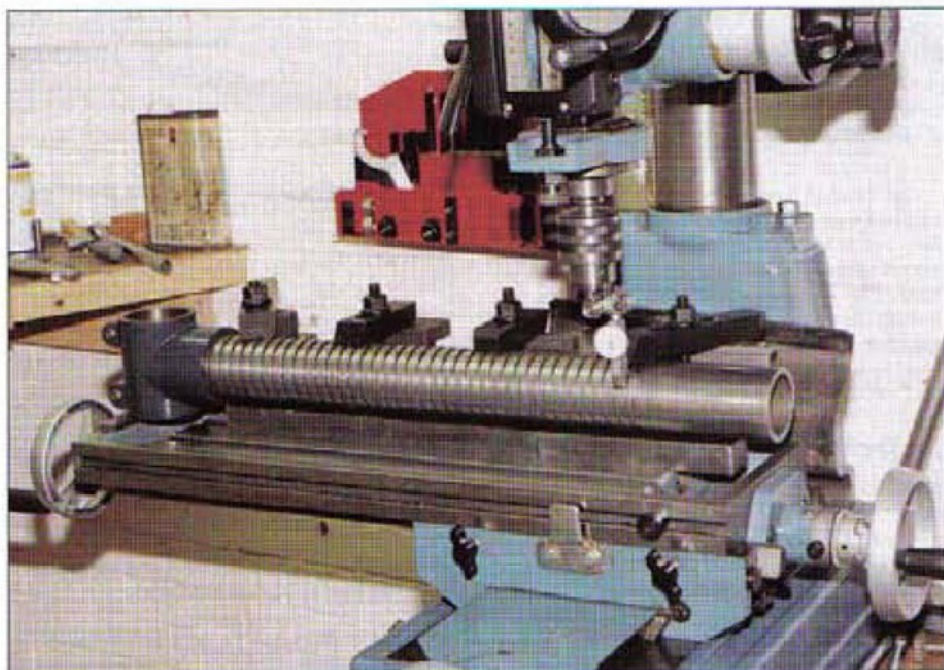
After some careful deburring and relieving of all sharp corners, using a fine file, the column tube was refitted to the column casting, to enable a line to be scribed on the top face of the casting to determine the position of the keyway to be machined into the column casting. This was done by the use of the previously made key, which could now be slid down the keyway until it reached the top face of the column casting. Firm finger pressure into the newly machined keyway on the tube, and on to the top of the casting now allowed the transfer of the exact position of the keyway. Further marking out was completed to show the depth requirement of the keyway, to ensure a clearance of about $\frac{1}{32}$ in. for the gib face of the key. The latter was not critical, of course.

The next stage was to prepare for grooving the column casting, and for this, I proposed to use the lathe as a shaping machine. The plan was to mount the column casting in the 4-jaw chuck, using the fixed steady at the outer rim to support the column. The groove could then be formed by racking a suitable tool backwards and forwards, progressively deepening the cut. This method needs a space for the tool to run into, (perversely known as a run-out hole!), so I drilled a hole at $\frac{7}{16}$ in. dia. (tapping size for $\frac{1}{2}$ in. BSF) in an appropriate position. This can be seen in the General Arrangement drawing. After the groove had been made, the run-out hole could be tapped and fitted with a plug to keep out swarf and also to prevent the key falling down the keyway and so make key retrieval easy. **Photo. 7** shows the run-out hole in the column casting, the latter positioned in

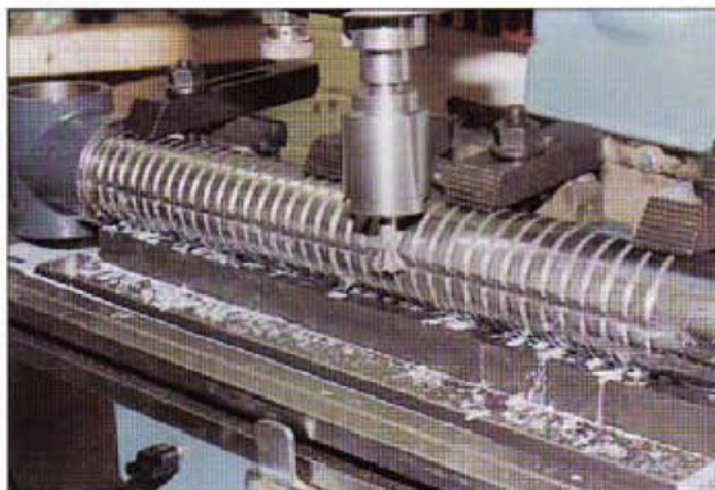
the lathe with the fixed steady adjacent. The set-up for grooving the column casting is shown in **Photo. 8**, the casting first being gripped (by its base spigot) in the 4-jaw chuck, and set to run true using the d.t.i. The bore of the casting needs to be concentric with the axis of the lathe. This takes time, but is necessary to achieve the required result. You will notice that the fixed steady had to be 'extended' to accommodate the casting. Great care is needed to adjust the fingers so as not to disturb the initial clocked setting. Since the column casting is not going to rotate, there is no problem that the surface on which the steady fingers bear is not machined true. In the absence of a spindle lock on this particular machine, the lowest speed setting had already been engaged. A very stout bar is needed on which to mount the tool. I used one of $\frac{3}{4}$ in. square section, as shown in **Photo. 9**, which allowed for drilling and tapping for two grub screws. The plan was not to try to take the whole width of groove with one tool as this would have probably put too much strain on the set-up. Instead, I used a $\frac{3}{16}$ in. square tool for the first cut, followed by a $\frac{1}{4}$ in. one, and finally one of $\frac{5}{16}$ inch. The tool shape is shown in Fig. 2. Note the clearance at the top, so that the only face taking a full width cut was the front one. Getting the 60 deg. angle must be achieved before grinding the relief, and a screwcutting gauge (for 60 deg. metric or UNF/C threads) can be used for checking the angle. For the 45 deg. tool, a template would need to be carefully made. If you have a tool and cutter grinder, then grinding the angle in either case is much easier.

To facilitate the fitting of progressively larger tool sizes, the $\frac{3}{4}$ in. bar was cross-drilled to a size to suit the 'across corner' dimension of each tool bit. Not ideal, but it worked and was quick!

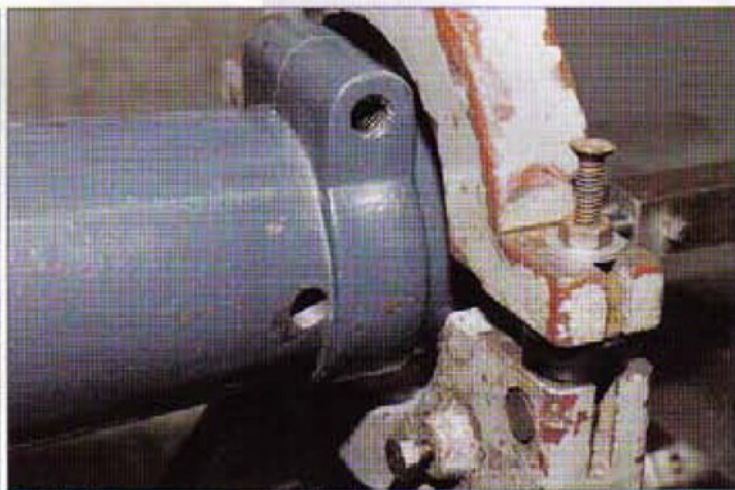
The actual metal cutting was easier than I had thought it would be, so this came as a pleasant surprise. **Photo. 10** shows the last stage of the 'shaping' being carried out. You will have noticed that I used my larger lathe for this, but this shouldn't stop you using a smaller one to



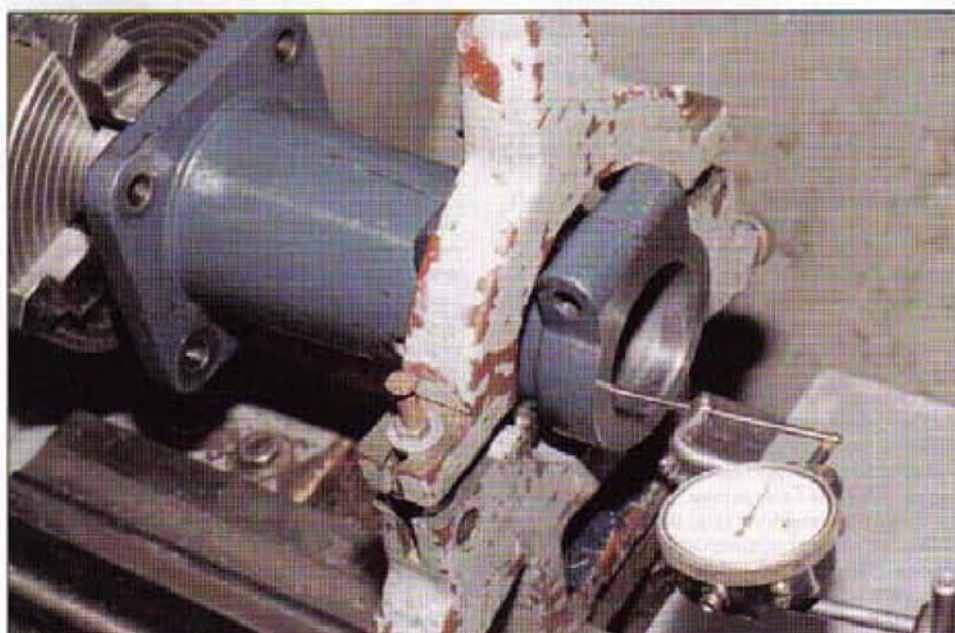
5. Setting the column on a larger milling machine. The decision not to remove the upper casting meant that careful packing was required



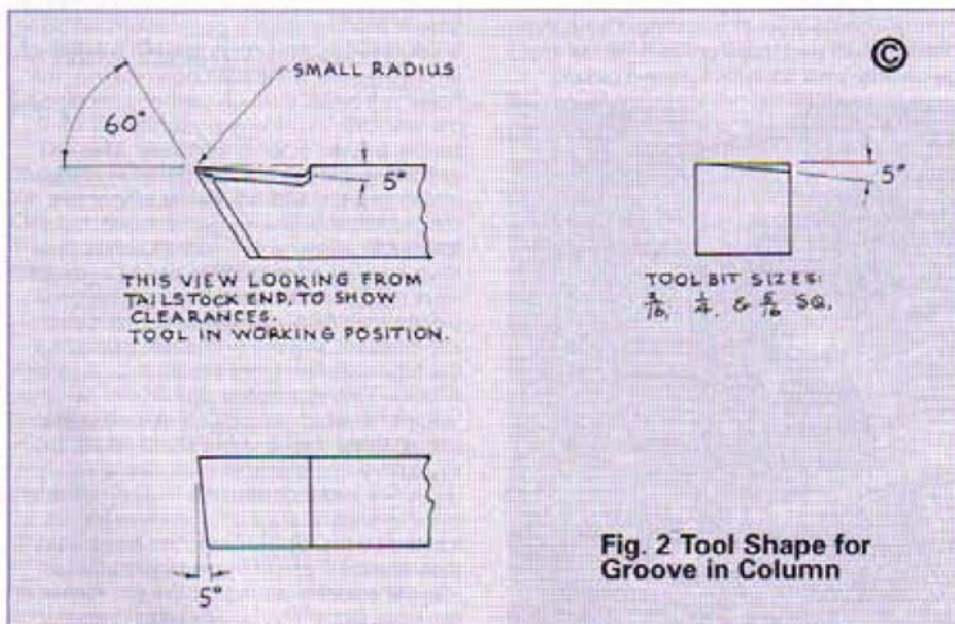
6. Machining the column with the 60 deg. dovetail cutter



7. The keyway run-out hole in the casting in which the column is housed



8. Setting the column casting in the 'extended' fixed steady



do the job, providing the casting can be chucked and supported, not necessarily by the lathe manufacturer's steady. A 'lash up' support - done carefully - can be

equally effective, or you may have a friend with a larger lathe or go to your evening school class to use one of their (usually larger) machines.

Adding the column casting extension pieces

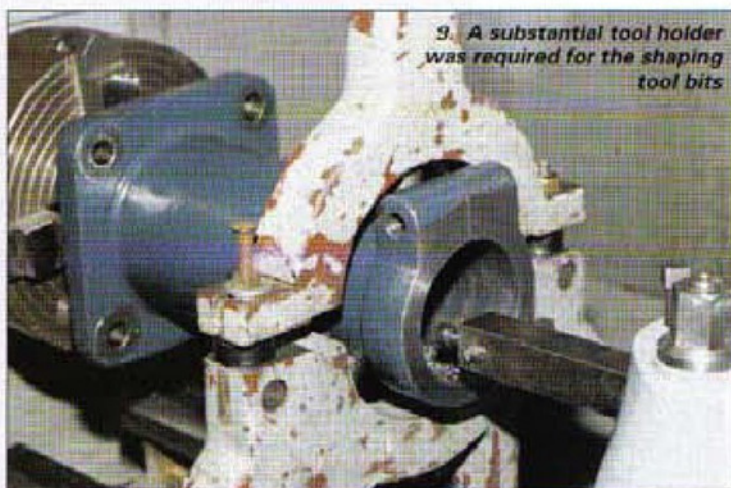
Next, the column casting extension pieces, Part 3, were made. These were machined from one piece of $1\frac{1}{2} \times 1$ in. section bright drawn mild steel (BDMS) and split into two after machining. This section was necessary because it has to be larger than the finished size to facilitate clamping to the face plate for machining.

First, though, it was necessary to mark out and drill, tapping size, the fixing holes (the ones for 2BA countersunk screws) shown on the drawing. This is necessary so that when the drill breaks through, it does so on a flat, square surface. A sloping or curved surface can result in drill breakage, because only one side of the hole breaks through first and the drill tends to bend towards the break through, i.e. the least resistance with, in many cases, disastrous consequences. The greater the slope angle, the more likely it is to suffer a breakage. The same applies to taps.

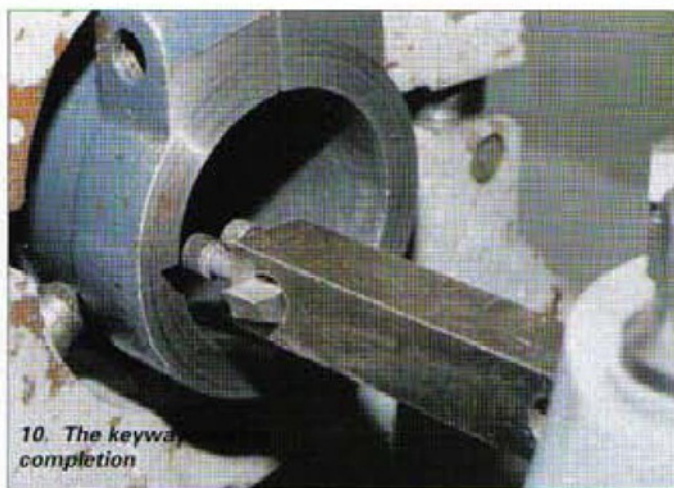
The set-up for machining the radius is shown in **Photo. 11**. Note the use of changewheels for counter-balancing, and the packing under the workpiece to allow tool run-out. Care is needed so that the changewheels don't get in the way of the tool as the faceplate revolves: it is essential to move the faceplate through one revolution by hand before switching on the motor!

Setting up for faceplate work can be frustrating to say the least, if trying to bolt components to the faceplate with the faceplate mounted on the lathe. Initially, I always set up with the faceplate flat on the bench. Nuts can then be nipped up finger tight, so that any small movements can be made without the whole lot collapsing (on to the protective wooden board which I hope you always place over the lathe bed for just this eventuality).

The difficult part is to set the workpiece to allow machining to the correct radius of the column casting, nominally 1.875 in., but check from your own machine. The method which I used was to fit the centre point in the headstock and measure the distance



9. A substantial tool holder was required for the shaping tool bits



10. The keyway completion

(radius minus chord height = $1\frac{17}{32}$ in.) from the centre point to the inside face of the piece of square bar. The latter needed to be set such that (a) the length of the bar was equally disposed each side of the horizontal centre line and (b) set vertical by turning the faceplate until the bar was truly vertical, checked by trisquare from the lathe bed. The distance was measured, initially by rule, and finally by gripping a scriber in the tool post at centre height and lining up the pointer with the centre point, zeroing the index, and winding the pointer outwards, using the cross-slide screw, until the pointer reached the inside face of the square bar. The measurement was then taken from the cross-slide reading. Adjustments were made until the correct distance was achieved. This did not give absolute precision, of course, but served the purpose.

Having tightened the nuts, a check was made of balance of the set-up. For this, I always loosen the belt so that the spindle has minimum friction. The opposing items are then set horizontal. If they stay there then a degree of balance, adequate for our purpose, has been achieved. If not, then changewheels are removed or added as required. Having made a final check that the changewheels are tightly restrained and also will not hit the tool, the motor can be used to make the final check for balance. I always start at the lathe's lowest (back

geared) speed, and keep trying the next faster one to find the highest speed which has no vibration. Assuming that the 'no vibration speed' is not faster than the correct turning speed for the metal being turned (nominally about 70 rpm for mild steel in this case), then this is the speed to use. The machining to radius was then completed. The cut was intermittent, of course, and therefore a stout boring bar was needed, taking small cuts.

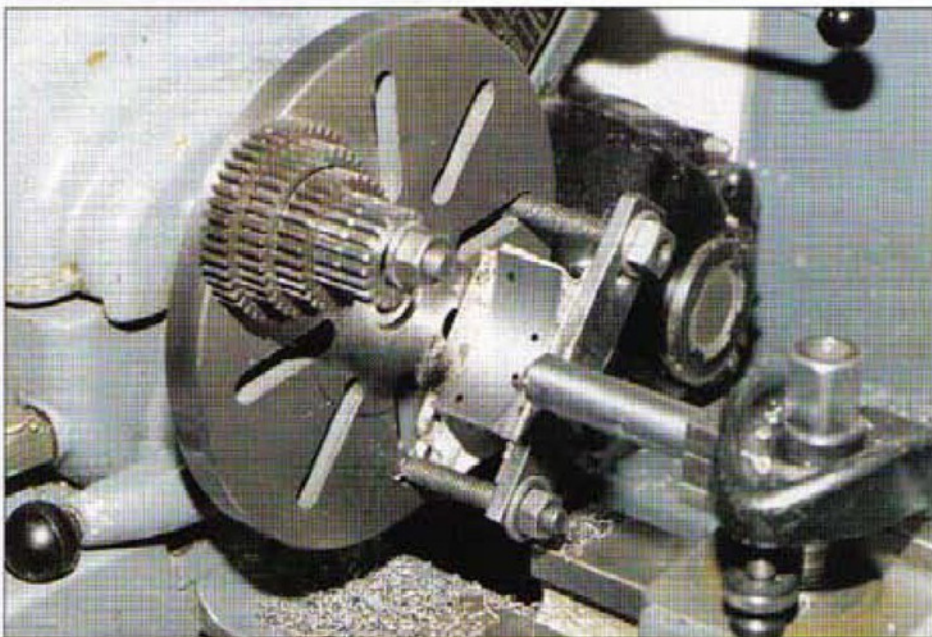
Next, the workpiece was removed from the faceplate, and metal was removed on the face opposite the curved one, to bring it to correct thickness. This can be machined in the miller or in the 4-jaw chuck on the lathe. I used the latter. Finally, the 'Siamese twins' could be parted by careful sawing and cleaned up, to produce the two parts.

The pieces were now clamped to the column casting in the correct position (relative to the keyway) for drilling and tapping for the fixing screws. This needed a lot of care in positioning to ensure the necessary alignment with the keyway.

Photo. 12 shows the method of clamping I adopted. For drilling the holes in the column casting, an elaborate set-up would have been needed to use the drilling machine and my drilling machine wasn't big enough. Instead, a pistol drill was used to drill through into the column casting. Using the previously drilled tapping size holes as a guide and great care, this proved quite

satisfactory. Since the holes were blind holes (i.e. not going to be drilled through) there was no problem with breaking through on a curved, sloping surface. However, only one hole could be drilled at a time because of the clamp, so it was necessary to first drill clearance size in the extension pieces and then tap into the cast iron to allow one screw to be fitted. The other hole could then be completed.

Having secured the extension pieces to the column casting, I could then 'plot' the position and angle of the tapped holes for the gib screws. Again, this needs great care. I worked back from the centre of the keyway and scribed lines round to the outer flat face of the extension pieces. These were then removed and set up in the drilling machine vise, checking that the drill bit would follow the prescribed angle, so that the holes could be drilled tapping size for 2BA, using the depth stop to avoid a break-through at an angle - in effect blind holes at this stage. The pieces were then refitted to complete the drilling through into the column casting, again using a pistol drill, following the line of the previously drilled holes as before. However, since these holes were critical, this time I took the added precaution of having a friend sight the drill, to be belt-and-braces sure. Since the keyway produces a square seating there is no problem with drill break-through. Note that tapping is left until final assembly. If the plotting is correct, the holes will break through centrally, relative to the key. One of mine was slightly out of centre, but the other was correct. The important thing is that the gib screws bear on the key. If the holes end up elsewhere, the only cure is to enlarge the holes, tap, fit lengths of screwed rod, using Loctite, then have another attempt. The mating surfaces were then cleaned up and the extension pieces were finally Araldited and screwed into position. When the Araldite had cured, the tube was fitted into the column together with the key, so that the latter could be 'spotted through' at tapping size. With the components disassembled once more, the key 'spottings' could be enlarged to clearance size (but note the shallow depth, since these holes are only there to be located by the gib screws). The holes were then tapped through the extension pieces into the column casting for the gib screws. It can now, hopefully, be seen why it was necessary to leave the tapping until this late stage. To complete this assembly, Part 2, gib screws, need to be dealt with. The gib screws can be made from rod, but I preferred to modify Allen grub screws. The



11. Machining the curved inner surface of the column casting extension pieces

12. Fixing the extension pieces



modification is simply to machine a short spigot on the screw where it will meet the key. The reason for this is to make the screws easy to remove, particularly after some year's service, otherwise the tightening can cause the end of the screw to mushroom where it bears against the key. The radius on the end is not critical.

To machine a spigot on the screw, it can be held in a split nut (a nut with a radial saw cut through one flat) to protect the thread. Such a holding arrangement is tenuous, so light cuts necessary.

Part 7, Plug / Key Retainer were made next, and fitted to the column. Care is needed to ensure that the plug, when screwed home, does not quite touch the column tube. If fitted correctly it will act as a retainer for the key, particularly important if the key needs to be removed and during initial fitting, before the gib screws are adjusted.

The plug, extension pieces and the immediate surrounding area were painted to blend in the modification with the rest of the column. **Photo. 13** shows the finished result.

A new head elevating key

The original head elevating key, as designed, is small and will not now bridge the gap across the newly machined keyway. Clearly a larger one is needed, so the drawing (Part 4) shows the details. Note the groove in the elevating key.

Since a larger hole is needed in the elevating ring, labelled C, to take the larger key, the original locking method, i.e., a simple grub screw bearing radially on the periphery of the key, cannot now be used because there is insufficient metal left for an adequate thread (**Photo. 14**). Instead, a tapping hole for 2BA is drilled in the ring, the centre line of which is on a tangent to the newly enlarged ($\frac{1}{2}$ in. dia.) hole as shown in hidden detail on the general arrangement drawing. This hole is tapped for a depth of $\frac{1}{2}$ in. to suit the thread length on the screw. Note that, for this drilling, a stub of $\frac{1}{2}$ in. dia. (expendable) steel rod will need to be shown in the newly drilled hole in the ring. Without the stub you could break the drill or at least cause it to go off-line as it breaks in to the cavity.

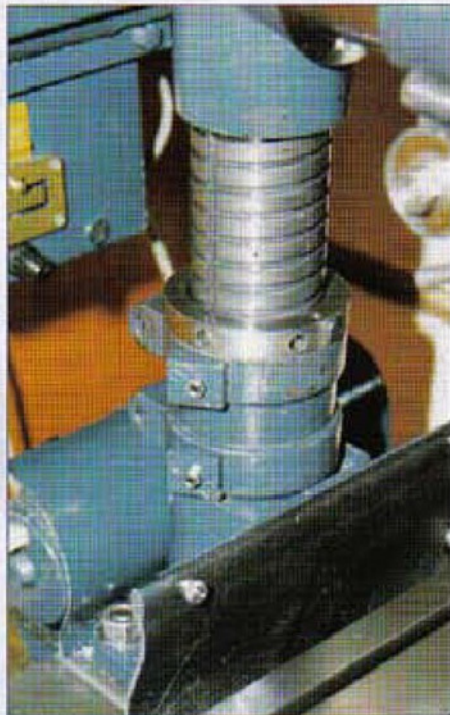
I then made a special screw, shown on the drawing as Part No. 5. This screw is fitted into the ring so that when screwed home, the spigot will enter the groove of the elevating key and lock it into position. The 'tail' of the screw will enter the tapping size hole at the bottom end and this will support it.

The making of the elevating key, (Part No. 4) is quite straightforward, and since you presumably made the first one, no further comments are needed, except to point out that the groove width should allow an adequate clearance for the spigot of the screw, Part 5. If the screw is made first, this can be used to test for clearance.

With all parts reassembled, the triangular key (in effect the gib) can be carefully adjusted to allow the column tube to move up and down but to closely fit into the keyway to achieve the required control.

Problems!

The final stage was to check the accuracy. The only way I could think of doing this was to use the set-up shown in **Photo. 15**. Here my largest try-square was damped to the table and a d.t.i. gripped in the drill chuck. First the headstock was moved to its lowest position and clamped. The d.t.i. was made to touch the blade of the try-square, and zeroed. The tube clamp was then loosened and the headstock raised and clamped at a height where the d.t.i. stylus would still be touching the try-square blade. The result was an error of 0.0035in. in 6in. - very disappointing. Various other try-square positions were tried with very strange (and inaccurate) results. I then checked the table geometry and it finally dawned: the table top was not flat! I hadn't checked it since I had made the miller, nearly 30 years ago; I know it was flat then and clearly it had warped since and was now hollow by 0.003in., but how to correct it? The very large lathe I used then wasn't available to me now. Putting it out to a specialist to be surface ground was one solution, but could I do this myself? It was worth a try and I later proved it could be done. My next article (to be published in Issue 68) may be helpful to anyone else who needs to do some surface grinding on their miller, particularly Quorn owners.



13. The modified components re-assembled



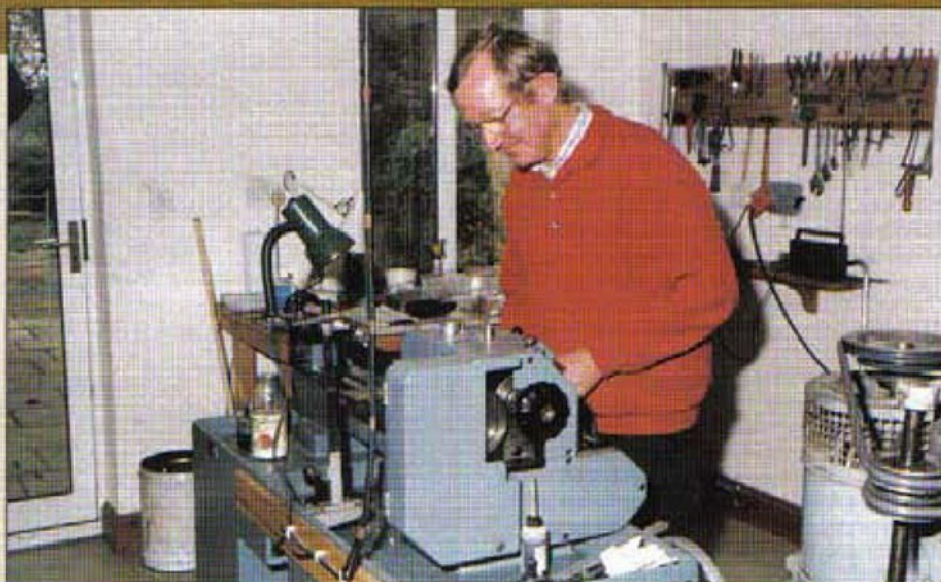
14. A new elevating key and retaining screw are required because the original key is not big enough to bridge the new triangular keyway in the column



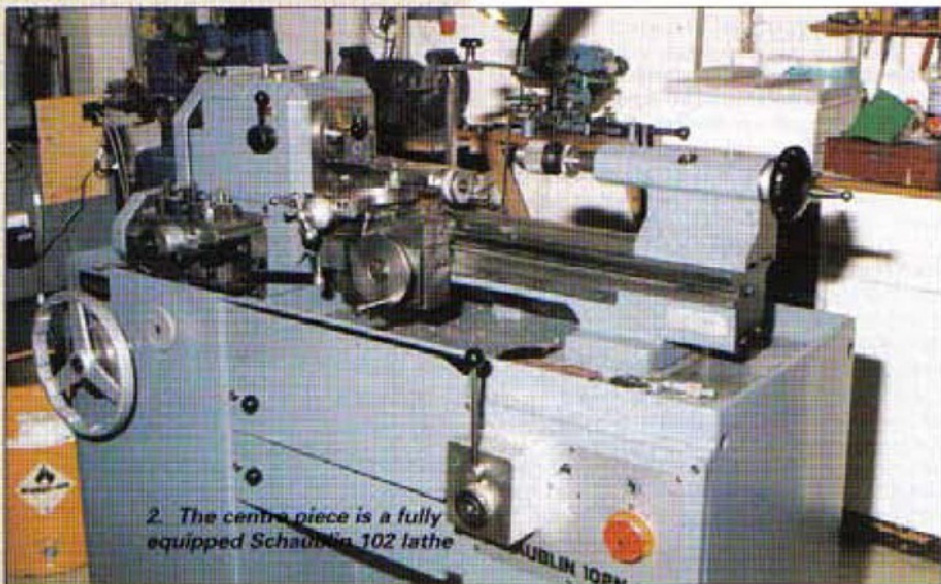
15. Alignment checks on the modified machine revealed that not all was well with the table. David Machin reveals how he overcame this in our next issue

WE VISIT DICK STEPHEN

Retired physiologist and university lecturer R. O. (Dick) Stephen is truly a master craftsman. He recently invited us to visit his home and workshop, where we were able to discuss his forward-thinking approach to hobby engineering, in particular, to clockmaking



1. Dick Stephen at home in his comfortable centrally heated purpose-built workshop. Designed as an integral part of the new house which he built 10 years ago, this 20 x 12 ft facility is wired with both single and three-phase electrical supplies



2. The centre piece is a fully equipped Schaublin 102 lathe

The first thing that the visitor to Dick Stephen's workshop notices is nothing to do with the spacious building, its layout or the equipment within. It is the view from the window! Situated on the edge of Rutland Water, the property is an idyllic location for active retirement for this former university lecturer.

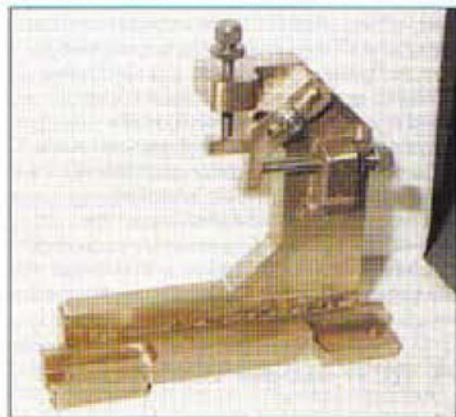
Dick came to Oxford from his

Johannesburg home in 1956 to gain a PhD in nuclear physics, but his interest subsequently switched to medical physics, particularly acoustics. His subsequent career took him all over the world, first to America, back to Oxford, then London, Glasgow, Australia, and finally to Leicester.

A long-standing interest in making things, since the age of six, Dick reckons, has led him to investigate many aspects,

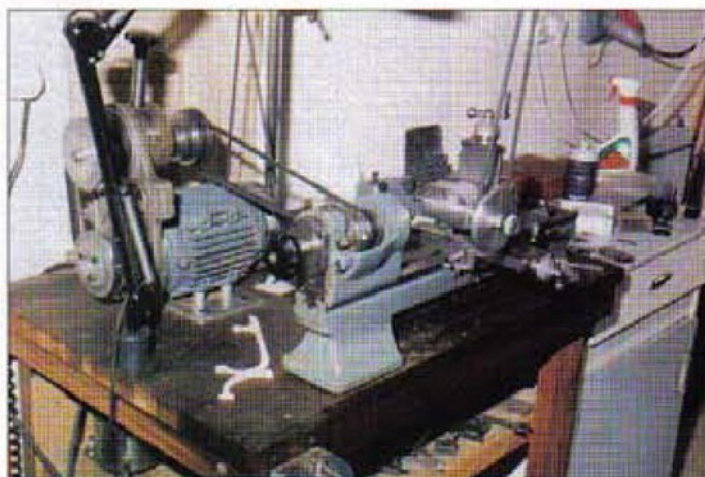


3. The substantial cabinet stand of the Schaublin incorporates conveniently accessible storage for the many accessories and attachments



4. When using the lathe to cut the threads on new leadscrews for a BCA milling machine, a rigid travelling steady was an essential requirement. Cast in aluminium bronze from a wooden pattern, the body provides rigid support for the adjustable fork

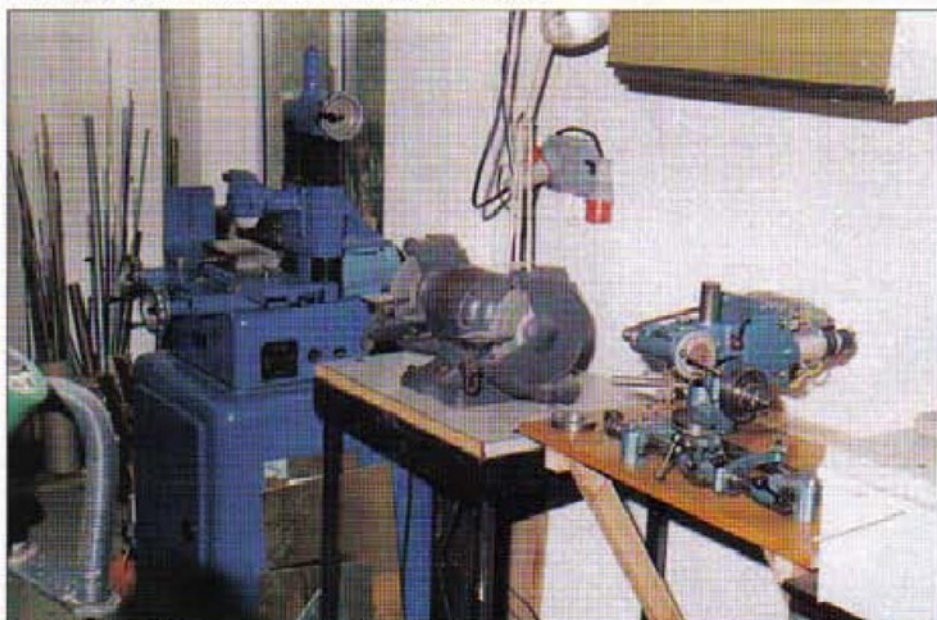
starting, like many of us, with model aeroplanes. An early yearning (now likely to remain unfulfilled, he thinks) was to build a miniature i.c. engine, kindling an interest in metal work, but it was with wood that he really honed his initial skills. A deep interest in music (Dick's wife is a music teacher) resulted in the building of a wide range of musical instruments, some 52 stringed instruments now having been completed. These include violins, cellos, pianos and harpsichords, the majority of which have gone to eager buyers, thus providing funds for a steady upgrade of the workshop. Very often this has been achieved by rescuing some derelict piece of equipment and bringing it back to life. A great advantage has been the availability



5. The second lathe in the workshop is also a Schaublin, this being a Model 70. Found in a tool shop in Perth, Western Australia, it had lain for five years without eliciting one enquiry. Obtained in part exchange for Dick's original Myford ML10, this screw-cutting machine is also fully equipped with dividing head, vertical slide and milling spindle. It is used extensively for cutting clock wheels. The drive system incorporates a variable speed unit.



6. The BCA milling machine, complete with Ortec digital read-out equipment has departed since our visit, to be replaced by the Wabeco CNC unit described in the next article. The BCA was acquired in a very run-down condition and restored in the workshop.



7. Another basket-case recovered from industrial use was the LIP surface grinder, of French manufacture. Most parts were heavily worn due to lack of maintenance, and extensive re-work was necessary. One of its many uses is now the very accurate re-sharpening of lathe tools. It is only with tools sharpened in this way that Dick finds that he can satisfactorily machine blued pivot steel. The off-hand grinder features a DC motor, and came from a WWII American Army maintenance workshop truck, while the Quorn was not built by Dick, but acquired at auction.



8. Two skeleton clocks built by Dick to his own designs. On the left is a spherical clock of unique design which won a Gold Medal and The Claude B Reeve Memorial Trophy at the Model Engineer Exhibition in January 1984. The time anywhere in the world can be deduced from its scales. The Inverted Y Frame clock on the right was built 20 years ago.

of a three-phase electrical supply, installed when the new house and workshop were built some 10 years ago. He considers that the original cost of laying in this supply has been offset by the savings made due to the lower cost of second-hand three-phase machinery.

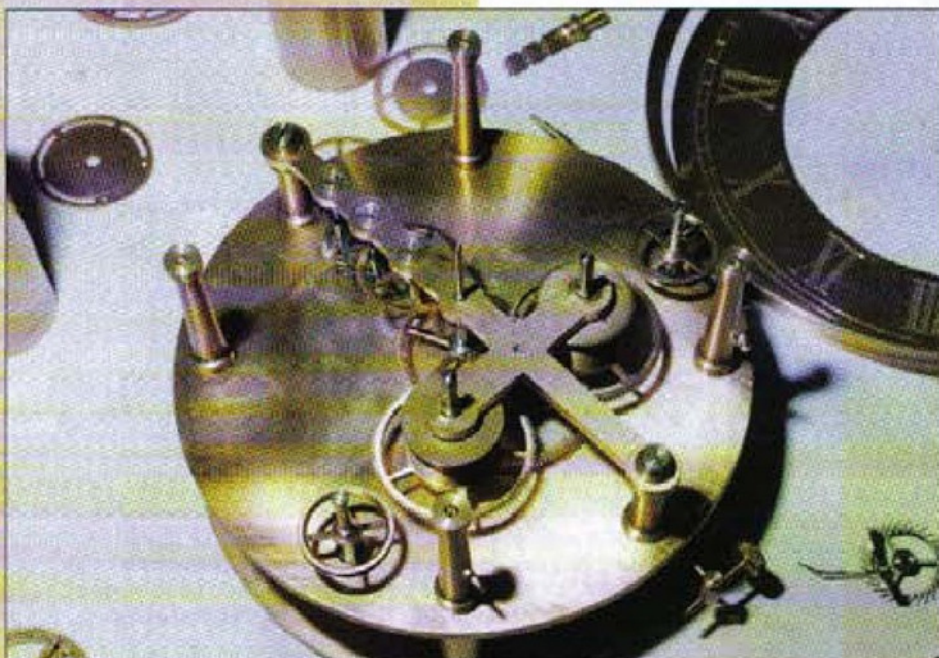
The main interest now is in clockmaking, not in reproducing traditional designs but in creating new and interesting mechanisms, as well as exploiting the potential of modern materials and developing techniques. His spherical clock which has the capability of indicating the time at any longitudinal position on the earth's surface, won a Gold Medal and the Claude B Reeve Memorial Trophy at the 1984 Model Engineer Exhibition. It features a large lever escapement, together with a chronometer-style helical balance spring.



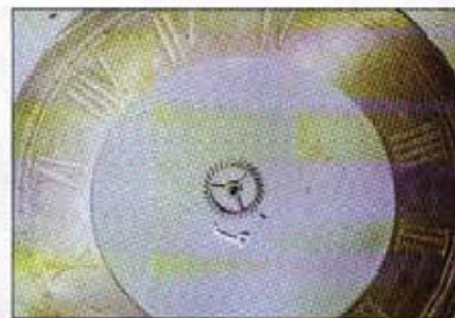
9. This elegant wall clock is one of four being built. Of the other three, one will go to Dick's daughter, and the other two are destined for America. A constructional series has recently been published in the *Horological Journal*.



10. Components of the clocks now under construction.



11. A close-up of the movement.



12. Dick is always ready to challenge the conventional wisdom on clockmaking. He has perfected the use of tungsten carbide for escapement pallets, thus reducing wear, and now makes all escape wheels from titanium. The lower weight of the latter reduces inertia and gives improved performance and reliability. He has promised to give us some hints on the machining of these rather exotic materials. The chapter ring was chemically etched but, in future, CNC engraving will be used



13. Keen to explore new avenues, Dick has established a small research laboratory in a spare bedroom. Current work includes an investigation into the effects on timekeeping of different methods of pendulum spring suspension and, seen here, the practicality of using carbon fibre rods in compensated pendulum.



14. The rig allows the expansion characteristics of the carbon fibre rod to be ascertained



15 The view from the workshop could provide a distraction!

Dick's view is that the escapement mechanism is the heart of any timepiece and it is the weak spot in most amateur built examples. He is planning to describe a new clock which will incorporate a Remontoire escapement in our sister magazine *Model Engineer*.

The recent acquisition of the Wabeco CNC milling machine has opened up a whole new range of possibilities, he feels, but says that these developments should not discourage the owners of more traditional workshops from having a go at producing precision items. The main advantage of such new equipment will be to allow the manufacture of components much more quickly, thus allowing us to get on with the next interesting project!

We look forward to seeing more of Dick's imaginative designs.



THE WABECO MILLING MACHINE

Clockmaker Dick Stephen describes his experiences with the CNC version of the Wabeco 1200 Series Milling Machines

I paid my annual visit to the Model Engineer Exhibition last Christmas, an occasion which usually entails a thorough ferreting through the various stands selling all those bits and pieces one needs to stock up with after a year in the workshop. My workshop was at the time reasonably well equipped with a couple of lathes, a BCA Mk3 Jigbore with digital readout, and a small surface grinder. I certainly wasn't on the look-out for any more equipment but, in the process of my wanderings I passed the Pro Machine Tools Stand and was instantly attracted to the Wabeco CC-F1210 CNC milling machine, which was being demonstrated. I was impressed by what I observed and spent some time watching proceedings, then carried on with my wanderings, thinking about what I had seen. At this point I had better tell readers what my model engineering interests are. For the last 30 years I have been into clock making and, having recently taken early retirement, my interest has become a bit more serious. The really time consuming jobs in making a clock are crossing out the wheels, making the plates for a skeleton clock and engraving the dial. Unless one is a genius with a graver, and I am not one of these, dials are something one gets someone else to do! The more I thought about the Wabeco machine, the more I realised how it could make my life a lot easier and relieve me of some of these time consuming jobs. Having easily found a buyer for my BCA at a reasonable price, a couple of weeks later I visited Pro Machine Tools in Stamford and bought the machine that had been demonstrated at the Show.

I have now had the machine in my workshop for several weeks and have been able to assess its potential.

General impressions

The F1210 is a very solid well made machine. The general finish is good, the slideways are obviously precision ground and carefully adjusted and the leadscrews are also of high quality, as can be judged from the feel of the machine when operating it manually. Backlash is minimal on all three axes. The one I have is a metric machine, which is what I wanted, but you would need to consult Pro Machine Tools if you wanted an Imperial one. The X and Y leadscrews are 4mm pitch and the Z leadscrew 2mm pitch. The motor is a generous 1400 watt unit and is more than adequate for 2mm plus cuts in mild steel. The motor is fully speed controlled and easily adjusted over the

range 180 to 3000 rpm. Initially, the speed control is a little disconcerting if you are used to a motor firing up as soon as you turn it on. There is delay of about a second while the speed controller responds before the motor runs up to the set speed. I recently used the machine running at top speed for an extended time, when the motor housing became too hot to touch after about 15 minutes. I felt that running the speed control electronics or the motor at these temperatures for any appreciable period may possibly cause problems, but the manufacturers have assured me that the speed control electronics and the motor can be run for extended periods at temperatures up to 100 deg. Centigrade with no deleterious effects to either.

The graduations on the micrometer dials were not filled in black on the machine and with my deteriorating eyesight, I found it difficult to read the divisions. A bit of black enamel paint soon fixed the problem. Maybe the factory could do the same!

Operating the miller, a light, the control box and the computer requires four leads to be plugged into the mains. To avoid having four cables on the floor waiting to trip up the unwary, I have bolted a switched 4-way mains distribution block onto the back of the cabinet and taken the single lead over the ceiling of the workshop to the mains socket in the wall. Incidentally the bracket for safety screen makes an excellent mounting for a light.

The CNC miller as a manually operated machine

The machine arrived with the stepper motors already installed and wired up to the control unit. The first thing I noticed, as soon as I turned the handles to move the table, was how stiff everything felt. Turning the handles rapidly also produced a nasty knocking sound. It was immediately obvious what the problem was; rotating the leadscrews also caused the stepper motor armatures to turn, converting the motors into a dynamo! The emf so generated was being fed back to the field coils, which were attempting to rotate in the armature in opposite direction - hence the resistance and the knocking noises. Connecting the stepper motors to the control box via 4-way plugs and sockets attached to the covers surrounding the motors easily solved the problem. The plugs and sockets which I fitted can be seen in the accompanying



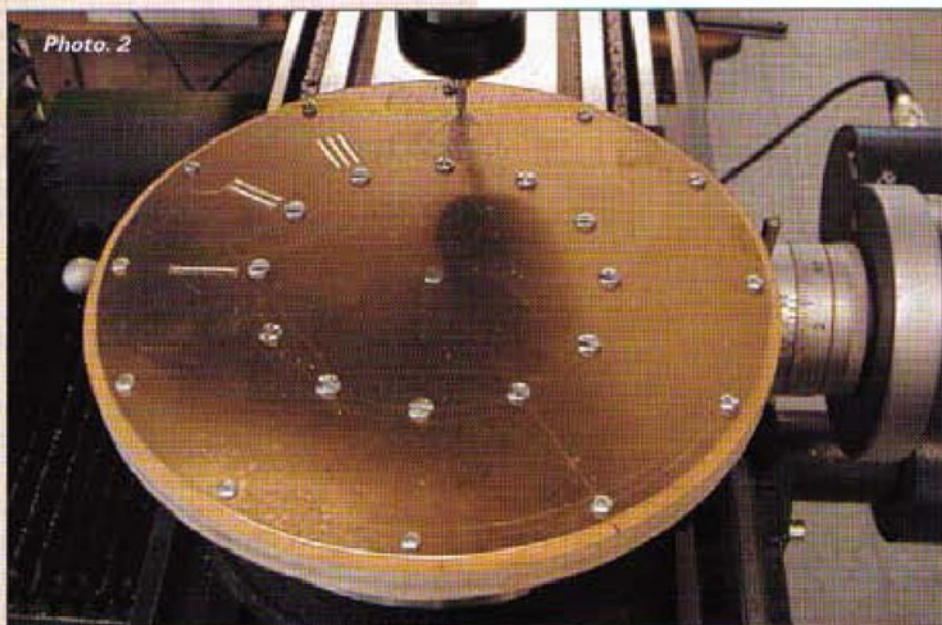
photograph, **Photo: 1**, of the machine in my workshop. This enables the motors to be easily disconnected and completely solves the resistance problem. I have also had a response from Wabeco, stating that all CNC machines will, in future, be fitted with switches to isolate the stepper motors, so curing the problem. It is most gratifying to see how responsive Wabeco are to suggestions for improvements to their machines. It certainly gives one confidence in their products.

The CNC aspect of the machine

One of the features of the CNC package with the machine that attracted me was the ability of the program to use drawings stored in .dxf format. This offered the potential of using one of the excellent CAD drawing programs currently available, such as Autocad or Turbocad. I am familiar with Turbocad as I have been using it for several months for the drawings of a 'How to make' clock series I have been writing. Suffice it to say that the road to competent familiarity with the CNC program was a somewhat bumpy one, not helped by the manual provided with the machine. Let's say I have seen a lot better manuals than the one provided! I understand that a new improved one will be available by the time this reaches press.

Access to the program requires a 'dongle' to be plugged into the printer port of the computer. It would have been a lot easier to attach the printer cable had nuts rather than screws been fitted to printer cable end of the dongle. I hope this will be

Photo. 2



sorted out in future models. The printer port needs to be appropriately configured for the dongle to function. Instructions to enable those not expert in MSDOS to carry out this task would be very helpful; I initially had problems. The printer cable is plugged into a control box, which operates the stepper motors. I personally would have liked to see the control box fitted with a neon warning light so that one could see at a glance if the box is turned on.

The program comes with its own drawing package which I find reasonably

easy to use, though very limited compared to Turbocad. I have found that Turbocad, used for all the initial drawing, supplemented where necessary with the drawing facilities of the program, works very well. I initially had problems when using the program for converting .dxf files to the .frs files used by the machining program as there were no instructions at all covering this in the manual. This has been rectified, I understand, in the new manual. The whole learning exercise wasn't helped by idiosyncrasies in Turbocad, which had me tearing my hair

out for a few days. Roger Nielson of the UK office of PClathe, the machine software developers, was most helpful in sorting out my problems. Had I not been reasonably computer literate, the whole exercise would have been a lot more tiresome. I understand that Pro Machine Tools will be offering a one-day training course. If you are not well up in computers, I would advise taking this course. All the problems are now behind me and are past history. I have to say I now find the package really excellent and the results obtained using the CNC facility have surpassed my initial expectations.

The accuracy of the machined parts made so far is excellent, 0.02 to 0.04mm (1-2 thou) accuracy being routinely attainable. I can see all sorts of possibilities and potential for the machine and expect it to become an indispensable item of workshop equipment. **Photo. 2** shows a dial for one of three Vienna regulators I am making, in the process of being engraved. I use titanium for my escape wheels. Crossing out wheels in this material is not at all easy as it is quite difficult to machine. I crossed out a blank escape wheel using a tungsten carbide burr in about 45 minutes, the end result being perfect, requiring no further work apart from a bit of polishing. By hand, this job would have taken at least a full day!

I can, without hesitation, recommend the Wabeco CC-F1210 to anyone thinking of buying a milling machine. The manual version is, in my opinion, far better value than most similar machines on the market. The CNC option, if you can afford it, really is the icing on the cake, once you get to grips with it.

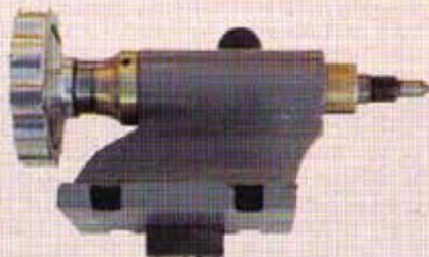


IN OUR NEXT ISSUE

Coming up in Issue No. 68 will be

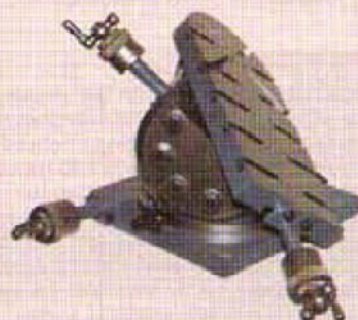
A TAILSTOCK FOR A DIVIDING HEAD

Norman Hurst describes how he fabricated this neat unit.



Issue on sale 8th September 2000

(Contents may be changed)



A TILTING COMPOUND TABLE

This versatile milling machine attachment won the Bowyer-Lowe Trophy for Geoff Allen.

MANUAL METAL ARC WELDING

Trevor Marlow describes the process and gives some hints and tips.



A DIRECT INDEXING ATTACHMENT FOR A MYFORD DIVIDING HEAD

At recent model engineering exhibitions we have marvelled at the work of Raymond McMahon of Carrickfergus, Northern Ireland. Here he tells us of a modification to a workshop accessory which helped to speed up production

Some while ago, I was putting the finishing touches to a model hot air engine which necessitated re-cutting the heads of standard 12BA hexagon headed bolts, two sizes of heads being required, 0.060in. and 0.070in. across flats. I had over 70 bolts to re-cut, and using the Myford 60 : 1 dividing head, I eventually got through the exercise, counting one to ten as I turned the handle before each cut. Needless to say, when I went to bed that evening, I was still counting hexagon heads instead of sheep!

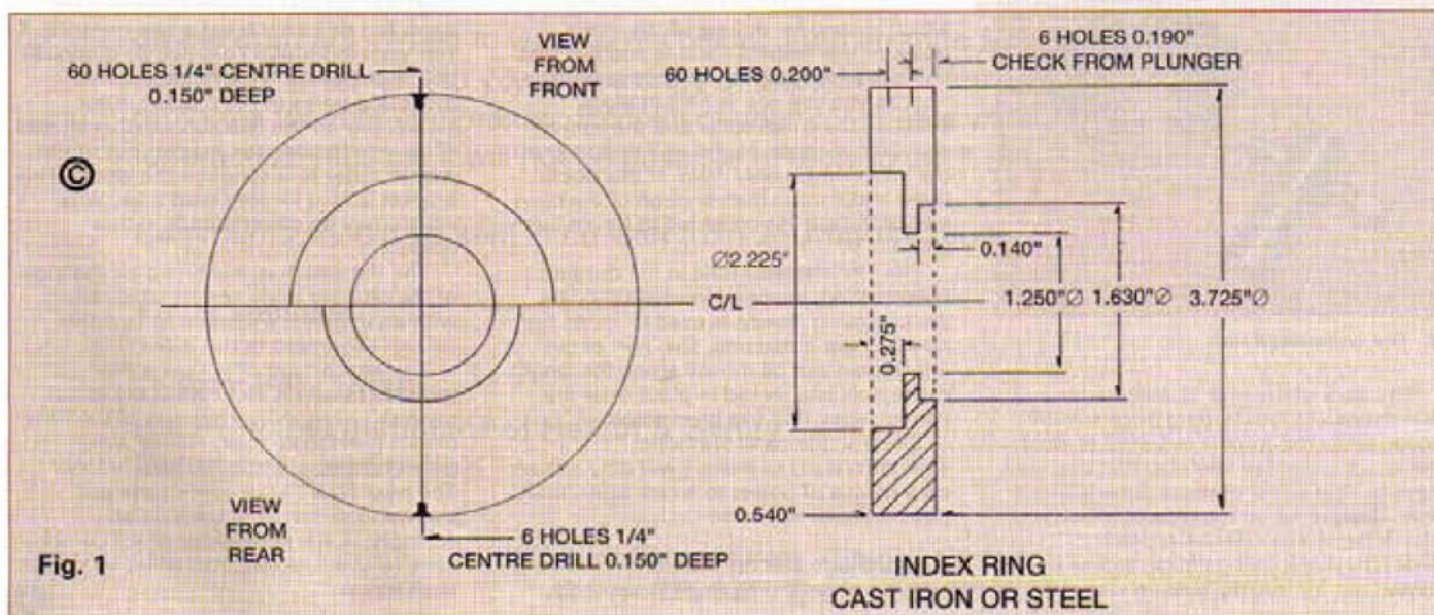
After this marathon of head chopping, I longed for the advantage of direct indexing. A few years ago, I had the use of a dividing attachment that could be used either direct or through the worm wheel as in the Myford unit. Surely, I thought, it ought to be possible to carry out a

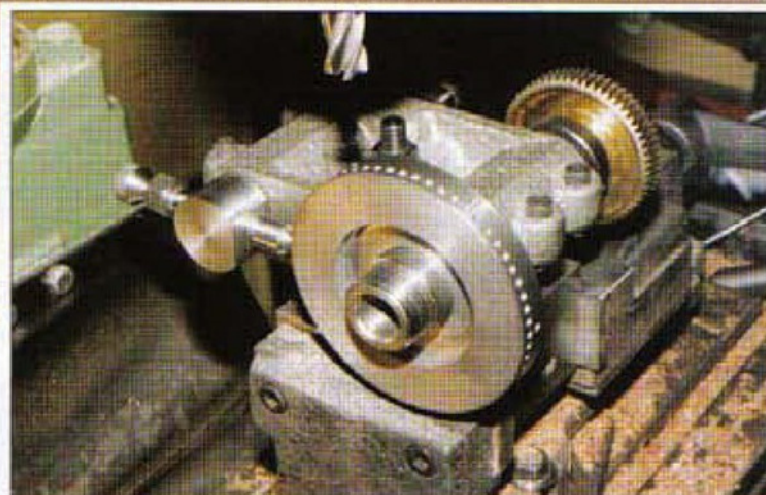
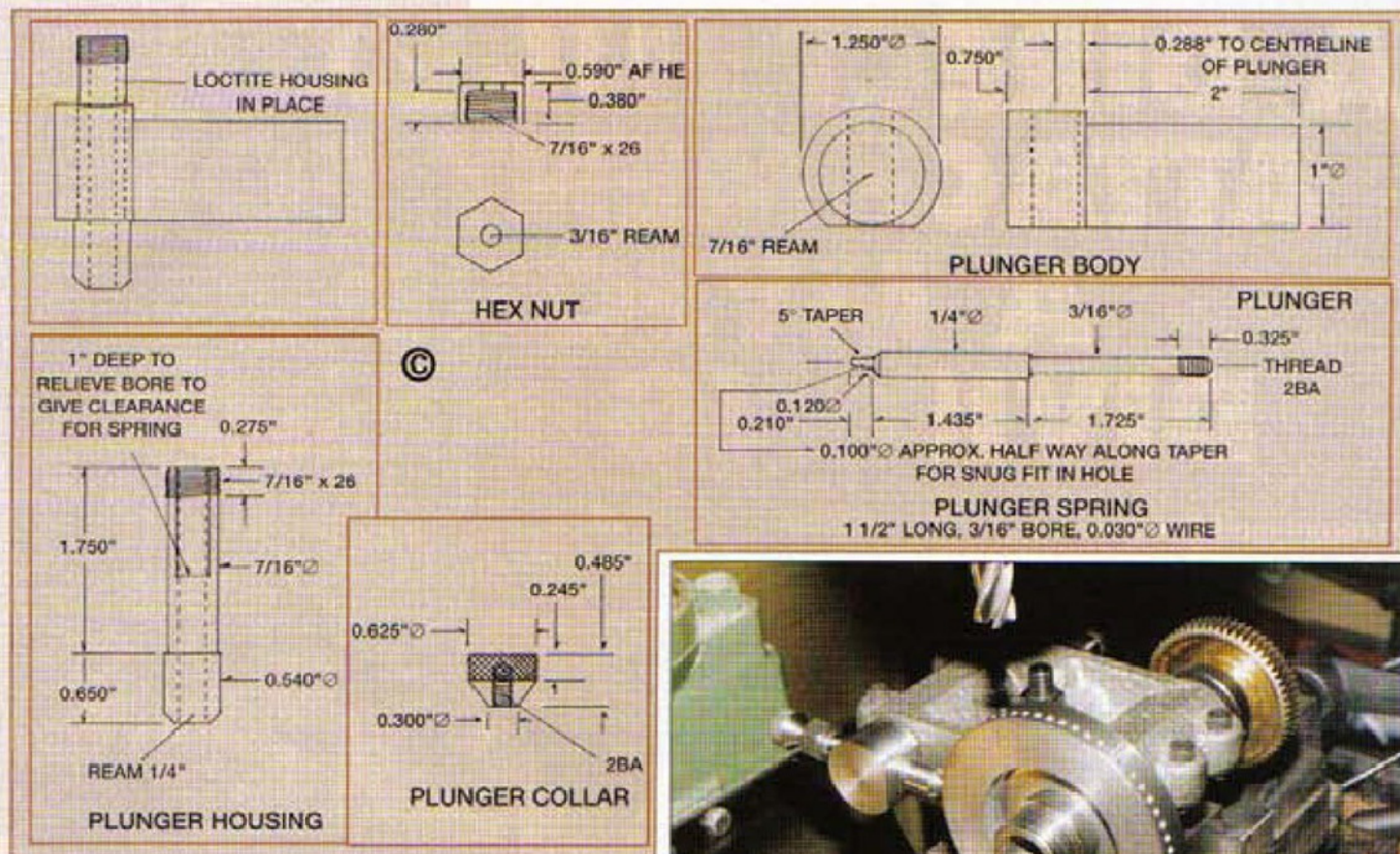


1. Machining a hexagon with the direct indexing device in position.

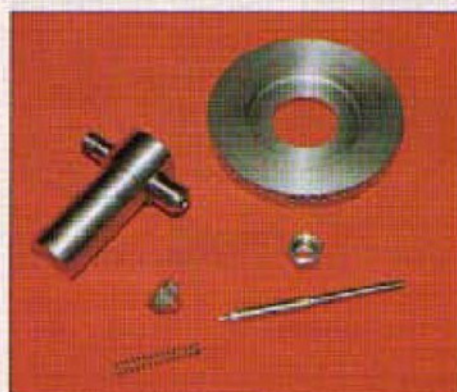
modification which would give me the advantage of being able to use both systems. After all, if you are only cutting hexagons and the like, the accuracy of the worm attachment is not always necessary. If you have a quantity of hexagons to cut, as one does from time to time, think of the hours one would save.

The solution I came up with was quite simple. An adapter index ring was made up, my thinking being that if one used an adapter ring rather than having the index drilled directly on to the chuck body, one could use various types of other chucks, the exception to this being the standard 6in. 4-jaw chuck.





4. The index ring in position on the spindle nose.



2. The components of the unit



3. The completed unit.

The back of the ring is recessed to accommodate the dividing head spindle collar, while the front is recessed to clear the chuck shoulder. You may find that you have to alter some of these dimensions a little, depending on the type of chuck you use. Mine is a standard 4in. 3-jaw GRIPTRU direct fitting chuck, and as it turned out for me, the system was also

Fig. 2

suitable for my 4in. 4-jaw independent, the 4in. 4-jaw self centring and the 3in. 3-jaw self centring.

The ring is wide enough to accept two index circles, so I chose 6 and 60 as this range, I thought, would cover me for most applications. In my instance, the material used for this part was cast iron, but a steel disc would do although the former material is easier to drill. You also run less chance of breaking the Slocombe drill which is used for drilling all the index holes. In this respect, I would suggest that you use a new one for this operation. The ring, as you can see, is held in place between the chuck collar and the spindle shoulder because, as the wall thickness of the index ring is only $\frac{1}{8}$ in. at this point, there is still more than enough of the plain part of the spindle collar left to locate the chuck.

The 1in. diameter hole in the dividing head casting, intended to accommodate the extension steady, is used to locate the new plunger index unit. This part of the attachment can be moved along the length of the hole and locked in place once the correct index ring has been selected.

Since all the parts are quite straightforward to make, I will only remark on a couple of points to which one should pay particular attention:-

(1) make sure that the bore of the index ring is a close sliding fit on the spindle,

(2) when machining the spring-loaded plunger, make sure that it is also a very neat fit in its housing, as any slackness here will show up on the accuracy of location and dividing.

The parts for this attachment can be made up in a few hours and will save very many more hours, depending on your indexing requirements. Finally, one has to unscrew and remove the existing quadrant bracket for this system to be used, but this only takes a few minutes. If you wish (although I did not do it myself) one could possibly elongate the two mounting holes in the bracket. After slackening off the two screws, this should allow you to slide the bracket out of the way in order to disengage the worm. This bracket is also located with a key way, which may be of assistance in this respect.

The flat which is machined on the side of the plunger body can be used, along with an engineer's square, to facilitate correct alignment to the index ring.

The attachment only took a few minutes to set up and I was able to cut my first hexagon in a fraction of the time than it previously took. Thanks! why didn't I come up with this idea before? The next time I have some hexagon screws to re-machine I will do so willingly, in the knowledge that I do not have to count to ten, multiplied by six for each screw.





Health & Safety Executive
Field Operations Directorate Scotland

Head of Sector : Mr S J North

Your Reference:

Our Reference: L0011

June 14, 2000

Dear Reader,

**HEALTH & SAFETY AT WORK ETC. ACT 1974 -
PASSENGER CARRYING MINIATURE RAILWAYS: GUIDANCE ON SAFE
PRACTICE**

The Miniature Railways Liaison Group has now completed its work on preparing a free information sheet on the safe operation of miniature railways, miniature traction engines and miniature road vehicles (ETIS 12) which you will see published in your magazines. Copies are also available from HSE Books.

The next task that the liaison group has set itself is to up date and revise the document previously published by the Railways Inspectorate entitled *Technical Note 3: Guidelines on the application of the Health and Safety at Work etc Act 1974 to miniature railways*. This document was first made available in August 1992. It is now significantly out of date in terms of modern goal setting guidance.

The group has prepared a consultation version of the document which amounts to a revised draft running to 23 pages. Those persons who are interested in commenting on the draft are invited to write to my office. I will arrange for a copy of the draft document to be sent to you with a copy of the printed information sheet and a proforma for your comments. Receipt of your comments will be acknowledged but for practical reasons it will not be possible to reply to each person individually.

Comments should be sent in no later than **31 August 2000**.

Yours faithfully

TERRY WILLIAMS
HM Principal Inspector of Health & Safety
Entertainment Section

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☎ 0141-275-3077 📠 0141-275-3015

Reducing risks - protecting people



Safe operation of miniature railways, traction engines and road vehicles

Entertainment Sheet No 12

Introduction

This information sheet is aimed at model engineers operating miniature railways, miniature traction engines or miniature road vehicles as a hobby activity, either under the patronage of a club/society or as individuals. It is relevant where rides are given to the public for payment, either directly or indirectly, or, where the activity takes place in a public place. In both these cases the Health and Safety at Work etc Act 1974 (HSW Act) applies. By following this guidance you will normally be doing enough to comply with the law.

If the ride is operated in circumstances where the Act does not apply, the information below may still be helpful to operators.

Organisations which employ people or operate commercially will also need to refer to *Fairgrounds and amusement parks: Guidance on safe practice* HSG175 and other relevant guidance issued, or legislation made under the HSW Act.

This information sheet is needed because it would be too stringent to apply the fairgrounds' guidance to private clubs and societies. Operators of miniature railways, miniature traction engines or miniature road vehicles need more specific guidance. However, the fairgrounds' guidance does contain useful information on the management of health and safety by different dutyholders when the public is involved. It is suggested that you should obtain a copy for reference.

The guidance in this information sheet has been prepared after consultation with the:

- Federation of Model Engineering and Modelling Societies;
- Ground Level Gauge 5 Association;
- Midlands Federation of Model Engineering Societies;
- Northern Association of Model Engineering Societies;
- 7 $\frac{1}{4}$ " Gauge Society;
- Society of Model and Experimental Engineers;
- Southern Federation of Model Engineering Societies;

- representatives of the model engineering press; and
- representatives of model engineering manufacturers.

It describes the application of the HSW Act to private clubs, managing health and safety, risk assessment, steps and checks for the safe operation of equipment, reporting accidents and duties when buying and selling equipment.

Application of the HSW Act to private clubs

The Act places general duties of care on employers and the self-employed to conduct their undertakings without risk to the health and safety of others. Some of those to whom this guidance is addressed may not fall within this group of dutyholders, but their activities may create risks to themselves, those who help them on a voluntary basis and members of the public. HSE considers it good practice for those who carry out such activities to provide the same level of health and safety protection as they would if they were dutyholders under the Act.

The Act also places certain duties on any person to provide plant and equipment which is safe, so far as is reasonably practicable, for the use by other people, ie the general public, and for buying and selling.

Managing health and safety

Health and safety can easily be achieved and effectively managed by adopting the following key stages.

Setting your policy

Prepare a clear health and safety policy statement (see following example). Attach to the policy statement details of the organisation and arrangements (rules) for the health and safety of everyone involved.

The Society intends to conduct itself in such a way that there is no unacceptable risk to the health and safety of employees, members, visitors or others who may be affected.

Members of the Society should realise that their acts or omissions could affect the health and safety of other people and other members of the Society. They should therefore comply with the Society's own rules and regulations.

Organising yourself

If you apply a system of steps and checks for all equipment used, you will ensure that you operate safely. This information sheet contains suggested steps and checks. Individual operators need to set up similar systems to those used by clubs or societies.

Planning and implementation

It is recommended that for each running session you appoint a person-in-charge who has the authority to ensure that laid-down procedures are followed. Many accidents are caused by human factors rather than by equipment failures. Ensure that everyone involved in the operation is competent, ie they have suitable knowledge and expertise for any tasks they undertake.

Measuring your performance

You need to monitor your safety record on a continuous basis and particularly after any incident which has caused an accident or near miss.

Reviewing performance and making changes

You need to carry out a review whenever circumstances show that it is necessary and think about what changes are needed, if any.

Risk assessment

You should carry out a risk assessment; this is nothing more than a careful examination of what, in your activity, could cause harm to people. This then enables you to decide whether you have taken enough precautions or if you need to do more to prevent harm to people. The outcome of risk assessment is more important than the method used. The control measures which are identified by the risk assessment need to be fully documented.

You should carry out a risk assessment regularly and review it at least every three years, or sooner if modifications or new equipment change the way you operate. See the following example for guidance on the ranking of risk.

Risk ranking	Action required
High	Take immediate action to reduce risk
Medium	Should be avoided - take action if possible to reduce risk
Low	Acceptable - but monitor the situation
Negligible	No action required - but don't be complacent

Steps and checks

Inspection

One of the ways you can reduce risk is to arrange for regular inspections to be carried out by someone who is competent to advise. This person will normally be a member of the club or society concerned. In this context 'competent' means they have the knowledge and expertise in relation to the equipment concerned. These people should know their own limitations and not be expected to understand everything. If they are presented with a particular issue outside their field of knowledge they should seek the opinion of someone more suitably qualified.

These inspectors need to be of such standing, and 'independent' in their judgement, that their views are respected. 'Independent' in this respect means that they should not normally inspect their own work or anything with which they have been closely involved.

Construction

It is important that all equipment that has any bearing on safety is designed and properly constructed so as to be fit for its intended purpose. Most equipment is designed to well-proven standards and established practice.

The design and construction of any equipment that departs from these established practices should be assessed to make sure that its safe operation is not impaired. It is recommended that anyone who publishes a design, checks that the design is safe. Supporting information should be available. Designs are preferably checked before manufacture.

Initial test/first use

You need to ensure that models or equipment are examined and tested before they are first used. Any steam-powered model should undergo and pass an appropriate boiler testing procedure.

Maintenance

Maintenance should be carried out regularly depending on usage, operating environment and where it is shown to be necessary after any incident.

Periodic inspection

You need to inspect all models and equipment periodically and subject them to re-testing where appropriate. You need to record these periodic inspections. Some equipment, eg boilers, will be covered by other relevant testing procedures (see further information at end of leaflet). The frequency of inspections, like maintenance, will depend on factors such as usage, operating conditions and the environment in which the equipment is used. Older

equipment may, for example, require more frequent inspection.

You should ensure that a competent person checks those parts of equipment which could affect its safe operation before any member of the public is allowed to use or ride on the equipment.

Keeping records

You need to keep all inspection records for as long as practicable, to enable a complete history to be formed and to help with future risk assessments.

Reporting accidents

You should keep an accident book to record all accident details, no matter how minor. Any accident arising from a work activity and resulting in a member of the public being taken to hospital for treatment must be reported to HSE. Try to record full details, together with names and addresses of witnesses, as soon as possible after the incident.

Buying and selling

When models or parts are sold, by the trade or through a business, for use at work, or in a way which might affect the public, the seller has a duty of care to ensure that they are suitable for the purpose intended and that sufficient information is provided for safe operation. If the seller has no technical knowledge of an item (such as a second-hand model bought through an agent) it can be sold provided that the buyer is advised that safety improvements may be necessary to bring the item up to modern standards. This advice should be recorded in writing between the two parties concerned to avoid legal action.

Private sales of equipment between individuals not intended for use at work, or other use which in any way might affect the public, are not covered by the above requirements.

Further reading

Fairgrounds and amusement parks: Guidance on safe practice HSG175 HSE Books 1997 ISBN 0 7176 1174 4

Management of health and safety at work. Management of Health and Safety at Work Regulations 1999. Approved Code of Practice and guidance L21 HSE Books 2000 ISBN 0 7176 2488 9

An introduction to health and safety HSE Books 1997 INDG259 Free leaflet

Five steps to risk assessment HSE Books 1998 INDG163(rev) Free leaflet; also available in priced packs, ISBN 0 7176 1565 0

Managing health and safety: Five steps to success HSE Books 1998 INDG275 Free leaflet

Passenger carrying miniature railways: Guidance on safe practice Due to be published spring 2001

Further information

Boiler testing procedures are available from the secretaries of the following organisations, namely the:

- Midland Federation of Model Engineering Societies;
- Model Steam Road Vehicle Society;
- Northern Association of Model Engineers;
- 7 1/4" Gauge Society; and
- Southern Federation of Model Engineering Societies.

While every effort has been made to ensure the accuracy of the references listed in this publication, their future availability cannot be guaranteed.

HSE priced and free publications are available from HSE Books, PO Box 1999, Sudbury, Suffolk CO10 2WA. Tel: 01787 881165 Fax: 01787 313995. Website: www.hsebooks.co.uk

HSE priced publications are also available from good booksellers.

For other enquiries ring HSE's InfoLine Tel: 08701 545500, or write to HSE's Information Centre, Broad Lane, Sheffield S3 7HQ. Website: www.hse.gov.uk

This leaflet contains notes on good practice which are not compulsory but which you may find helpful in considering what you need to do.

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LATHE PROJECTS FOR THE BEGINNER

Newcomers to our hobby frequently ask us where they can obtain basic instruction in machining processes. When possible, we direct them to schools and colleges which offer short courses or which still run 'model engineering' evening classes. Unfortunately, these seem to be less widely available than in years gone by, so we have asked former Editor, Harold Hall to devise a series of articles in which practical, useful projects are described and which covers the basics of lathe work.

When first asked to provide this series, my initial reaction was that it was very likely to be very much a repeat of my series "The Beginner's Guide to the Lathe", featured in the magazine a few years back, and thought therefore that it may not be such a good idea. On reflection however, realising that a project based guide was being suggested, began to understand that it was quite different. Of course, there will be some duplication, but this is always the case, even with articles from differing authors if they cover a similar activity. Having spent a short while as editor of Model Engineers' Workshop, I am also aware that many have limited time for workshop activity and these, even if experienced, will find the projects useful, as most can be completed in a matter of a few hours.

Machines

At this stage I do not intend to go into detail regarding the items to be made through the series, though some thoughts on the required equipment is, I feel, necessary. Of course a lathe is essential, though for some this may be a machine available at the local technical college. As the projects are aimed at those with limited turning experience it will be assumed that other processes (typically milling) are even more of an unknown quantity and their use in the series will therefore be limited. A drilling machine will be required, but using the lathe for drilling as an alternative will be briefly considered.

The series will be written assuming a lathe of around 90mm bed to centre height and fitted with at least 100mm diameter chucks. Larger lathes are unlikely to impact on the articles in any major way though smaller lathes may impose some limitations, so comment may be made through the series if considered appropriate. If a small lathe is being used, then there may be benefit from making some smaller than specified. In this case, I would advise taking copies of the drawings and marking them up with the new dimensions in advance of manufacture.

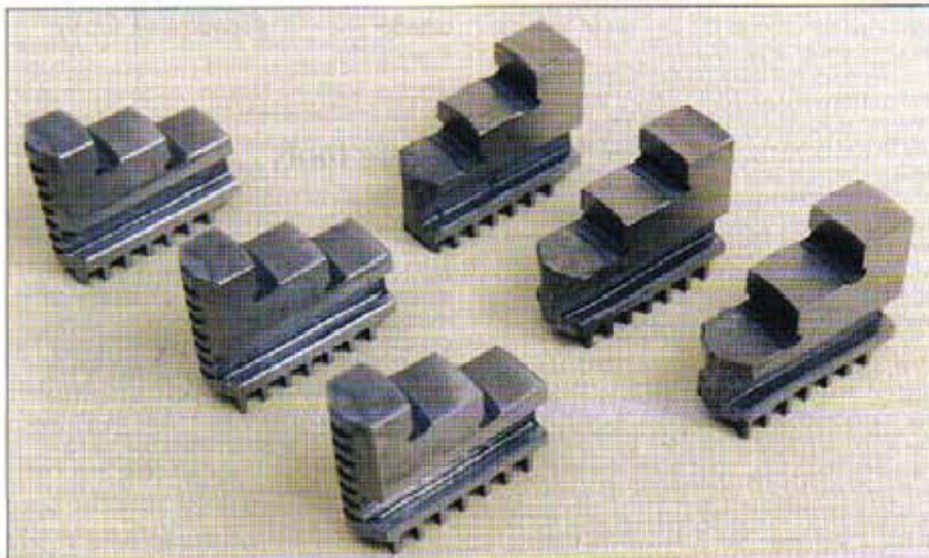
Whilst the use of cutting tools with replaceable tips considerably reduces the amount of grinding necessary to produce and sharpen lathe tools, some specials are bound to be required. An off-hand grinder is therefore a necessity.



Chucks

Having dealt with the machines, there are a number of accessories that are a must, suitable chucks being a priority. In view of their importance, a few words of advice are appropriate. Some readers will

no doubt consider that, due to its ease of use, a 3-jaw self-centring chuck is the one to acquire if funds will only run to one chuck, but this is not so. Whilst a 3-jaw, even if old and worn, will be accurate enough for most work, there will be a significant number of instances where this is not the case. The beginner may not



1. Normal (right) and Reverse (left) chuck jaws



2. Left- and Right-hand knife tools

even be aware that, when material is placed into a 3-jaw chuck, the work piece is unlikely to run true, perhaps a total indicator reading (TIR*) of up to 0.1mm, more if measured at a point some distance from the jaws. This can cause serious problems with concentricity when an item has to be removed and replaced, say to work from either end. Even a so-called precision chuck, with a price tag to go with its accuracy, will be unable to meet the most demanding requirements. The 4-jaw chuck with independently adjustable jaws, is therefore a necessity as, being able to adjust each jaw individually, precise centring is possible. Of course, where a 3-jaw is adequate, I will use one and this will be evident in the published photographs. Where a reader has only a 4-jaw, this will be quite satisfactory, only slowing down the operation a little due to the effort required to get the part to run sufficiently true.

A very necessary accessory for the 3-jaw chuck is the set of reverse jaws, which enables larger diameters to be held. These may be seen on the right of **Photo. 1**. A new chuck will always be supplied with these additional jaws, but if you have obtained a second-hand chuck, they may well be missing. It may be possible to obtain replacements, but they would still need to be ground in situ to achieve accuracy. A 4-jaw chuck may be used for the larger diameters, as the method of construction permits the one set of jaws to be used either way round.

Changing the jaws on the 3-jaw chuck is straightforward, needing only a little care. One set is removed by turning the chuck key in the opening direction until the scroll which controls jaw movement disengages from the curved grooves in the back of each jaw, when it will be possible to remove the jaw from its slot. Examination will reveal that slots and jaws are numbered. These must always be matched, and the jaws replaced in order, 1, 2 and 3.

To re-fit either set, turn the key in the closing direction until the leading edge of the scroll approaches slot No. 1 (turn until the scroll is just in view then turn it back a fraction). Push No. 1 jaw hard into the slot and turn the key in the closing direction until the scroll engages with the jaw. Move to No. 2 slot, then No. 3, repeating the process each time. Correct assembly can

be checked by completely closing the jaws. Any error will be immediately obvious.

Independent 4-jaw chucks also have their jaws numbered and should be assembled with like numbers together, though they will, of course, go together in any order.

No matter what type or size of chuck or variety of jaws used, it is necessary to be aware of the maximum size of work which can be safely accommodated. The data supplied with it when new should make this clear, that for my 100mm chuck quoting a maximum of 33mm. Whilst the jaws will open and grip even more, some of the scroll disengaging from the teeth on the jaws, placing more load on those remaining engaged. All too often, jaws are found to have broken teeth, so it is not advisable to go beyond the maker's recommendations. If these are not available then careful observation of the scroll (visible when the chuck is opened) and its engagement with the jaws, should make the limitations clear. If the chuck has three scrolls then, for light duty work only, opening to a point where only two are being used may be acceptable.

The Fixed Steady

I consider this to be a very underestimated lathe accessory. Many operations would, at best, be very difficult without one and in some cases, totally impossible.

Cutting tools

Knife tools

A variety of cutting tools will be required, with the knife tool being that most used. This comes in both left- and right-handed versions, as can be seen in **Photo. 2**. There is often confusion over the terminology because the one widely known as the right-hand has its cutting edge on the left face and cuts to the left (towards the chuck) and vice-versa. The origin seems to be that, if used as a hand tool, the name is taken from the hand in which it would naturally be held, and I will keep to this convention throughout the series.

Because of the potential for error, I would advise caution when purchasing

such tools - make it clear in your order the precise form of the tool required. Knife tools may be ground from high speed steel or may be bought ready made with brazed tungsten carbide tips or as replaceable tip tools.

Boring tools

Boring tools will also be needed, one suitable for a minimum bore of 6mm of around 20mm deep and another capable of dealing with larger diameters - 20mm and more, with a depth of 50mm. The smaller tool will most certainly be ground from high speed steel, while the larger could take the form of an inserted high speed bit in a larger bar or be a replaceable tungsten carbide tip type.

Parting-off tool

Parting-off is probably the most dreaded of all turning operations, but is a task that must be conquered. Removing the part from the chuck and cutting it off with a hacksaw whilst it is held in the vice is a possibility, and one that we shall adopt initially but hopefully, before the end of the series, parting-off will have been mastered.

I know that many will be tempted to use the hacksaw to cut off a part whilst it is still held in the lathe - we all have. I would strongly recommend against this because, even with a block of wood to protect the lathe bed and the saddle moved well down the lathe, it is still possible to catch ones knuckles on cutting tools or other sharp projections. What must NOT be done UNDER ANY CIRCUMSTANCES is to carry out this operation with the lathe running.

We therefore need a parting-off tool with say, a 1.5mm wide tip for diameters up to 20mm and a second wider tool, say 2mm for diameters up to 50mm. Whilst these can be used mounted in the conventional position on the top slide, the availability of a rear tool post will significantly ease the task, so the acquisition of such an accessory cannot be too strongly advised, particularly if larger diameter work is to be handled. A rear tool post is a relatively simple object to make and would form a worthwhile project.

Special form tools

Some specialised tools will also be required for operations such as thread cutting. These will best be discussed at the point in the series where they become necessary.

Dial Test Indicator (DTI*)

A Dial Test Indicator is required, as components for some projects will need centring in the 4-jaw chuck to a level of accuracy which is difficult by any other means.

Smaller Items

Hard and Soft centres and suitable driving dogs will be necessary for turning between centres. When facing the end of a part supported by the tailstock centre,



SK1

machining the end fully to the drilled centre is impossible if a conventional full hard centre is used. The method of overcoming the problem is to use what is called a 'half centre'. In fact, it is more a case of a 'five eighths centre' as it is not cut away totally to the centre line. The cut-away permits the cutting tool to access the face of the workpiece right up to the drilled impression (see drawing Sk 1). I use a small half-centre made from silver steel, held in the tailstock drill chuck. This avoids the expense of an additional centre and is quite adequate for finishing the end of a part otherwise turned between conventional centres. Why not make this a mini project before turning starts in earnest in the next issue?

A drill chuck, complete with an arbor to match the socket in the tailstock barrel (usually a Morse taper) will be required, as will a 25mm (1in.) outside micrometer. Additionally, a larger micrometer (25 to 50mm or 1 to 2in.) will be useful, as will be a 150mm vernier. Other simple items will be required and we will attempt to make some of these as the work progresses. In fact, some of the items required will have to be made, as they are not available commercially. An important lesson to learn here is that, even if a task can be undertaken with the equipment to hand, it can often be carried out more simply, more quickly, or more accurately, by the addition of a simple home-made accessory. Examples of this will certainly surface during the series.

Material

The materials required will be detailed with each individual project and, in the case of mild steel, are likely to be of sizes that are already available in an established workshop, though some larger sizes will no doubt have to be purchased.

I would strongly recommend that all mild steel should be of a genuine free-cutting grade, perhaps necessitating the purchase of fresh stocks from a reliable source, rather than relying on unknown materials that are to hand or acquired as 'job lots' on the surplus market.

If, as a beginner, you have yet to build up a stock of materials, do ensure that any materials you purchase are of a known



3. The Mini gauge being put to use before the fine adjustment system was fitted

grade, as one supplier's so-called 'free cutting mild steel' may be quite different from that from another. I would suggest steel to BS970 1983 ref. 230M07 is obtained, (very similar to the older specification BS970 1955 ref. EN1A, still frequently encountered) and an end marked with an identification (perhaps simply stamped FC), so that its grade is known when used in the future - but don't forget always to work from the unstamped end! For non-UK readers, 230M07 is an international standard and is likely to be recognised by your local supplier.

Even more easily machined is a similar grade, but with lead added, having the reference of 230M07Pb (EN1APb). The lead content makes it very easy to machine, but makes it unsuitable for welding. It is, of course, a little more expensive and not available in as wide a range of shapes and sizes.

I cannot stress too strongly the benefit of taking such an approach, advice given from bitter experience. My recent project, a gear hobbing machine which featured in previous issues of this magazine, had two almost identical spindles, one having a slightly larger diameter than the other. Having completed the first satisfactorily, I was surprised to find that the finish being obtained on the second was much inferior. Using the same tools, but re-sharpened in view of the problem, trying differing speeds and feeds were all to no avail. The only answer was that the material, being a different diameter, was of a different grade. I have for, some time, purchased only 230M07 and marked it on one end for later recognition, but this was obviously material obtained before I took this approach.

In order to give some experience in turning cast iron, one of the later projects selected uses a casting which is readily available for a few pounds from one of the regular advertisers. Another project will require two ball bearings, but again of a type which are not that expensive, so that the series will provide a range of useful items, but with relatively limited expense.

In-depth detail

With the series being aimed at the beginner, descriptions and photographic evidence (often more useful than the text for complex set-ups) of methods used will be more extensive than is the norm. Machining operations will, in some cases, call for greater precision than perhaps is necessary, purely to acquire the experience of working to fine limits. Similarly, set-ups will err on the side of caution, both for safety and experience, typically in the use of the fixed steady where perhaps, with greater first-hand experience, the use of a steady could be avoided. I would therefore say, please do work to the methods described, then, in the future, taking your own approach when knowledge of the various operations and the ability of the machines you are using is gained over years of use.

The newcomer may be forgiven seeing the turning process is being simply a matter of choosing the correct cutting tool for the job, the correct speed, the correct rate of feed and making a decision as to whether or not to use a cutting lubricant. As important as these factors are, they do have considerable tolerance as to their choice, but in most cases, the critical decisions are the methods to use - typically, whether to use the 3-jaw, 4-jaw, faceplate or to turn between centres. Of even more importance, in many cases, is the sequence for carrying out the machining of a component. It can be very frustrating to have machined a part to a stage where it is found to be difficult to progress further because of problems in holding it securely and accurately for the remaining operations. An example of this would be the need to support a part with a fixed steady, but not having left a suitable portion of the component where the steady can be applied. Frequently, the difficulty in machining a part will be due to its design and if this is someone else's, there may be less scope to overcome the problem, though some minor changes

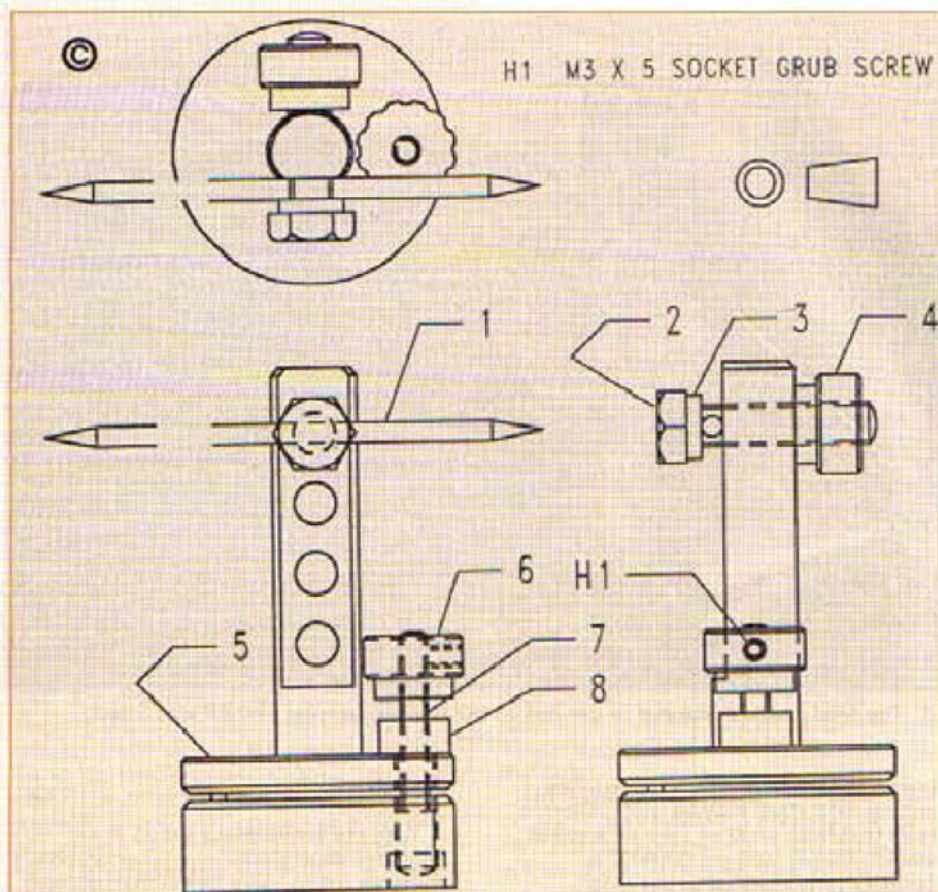
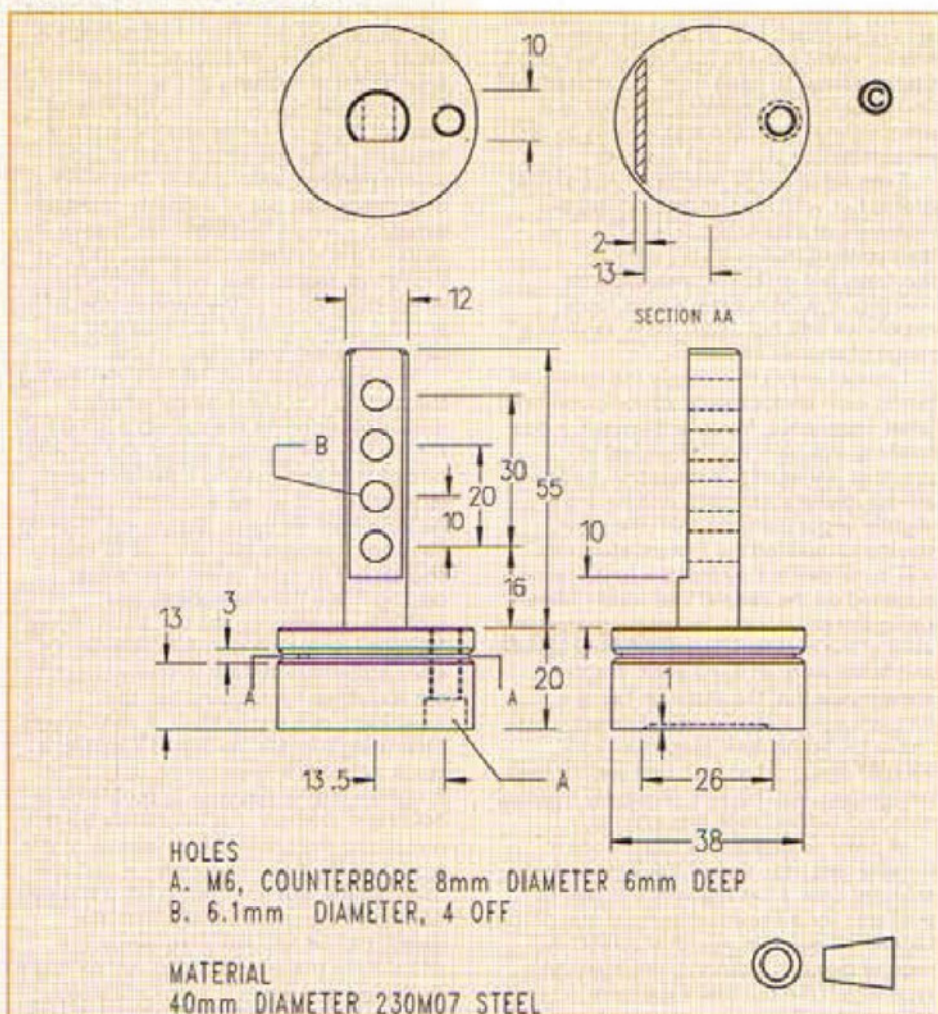


Fig. 1 Mini Surface Gauge.



Item 5 Base

may be possible. If you are producing your own design, then manufacturing the item on the available machines should be an essential and early consideration of the design process.

Metric dimensioning

Much has been written regarding the use of metric dimensions as opposed to Imperial, and this is not the place to expand still further on the subject. Components described in this series are though dimensioned almost exclusively in metric (or, more correctly in 'Système Internationale' or SI) units. Only where a part is to marry with a genuine Imperial dimension will the Imperial value be given. Realising that many readers will have Imperially calibrated machines, some guidance is necessary, especially as the articles are aimed at the novice.

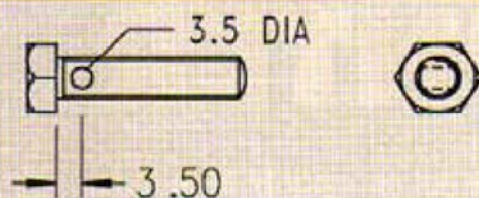
The complications in working to metric dimensions on an Imperial machine are much overstated. In fact, it is quite easy, so replacing your machinery with metric calibrated ones is quite unnecessary, the answer being in having metric measuring equipment, rather than converting the quoted metric dimensions to their Imperial equivalents. Many measuring instruments such as rules, verniers and height gauges are dual calibrated, so we are left only with micrometers.

Purchasing a 0-25mm micrometer and, if possible a 25-50mm one, is a relatively cheap way out of the problem if the approach described below is taken. In recent years, the advent of electronic digital measuring equipment has given us the best of both worlds, conversion between the two systems being achieved at the touch of a button.

When carrying out machining operations few, if any, will attempt to arrive at the final size by taking just one sizeable cut, but will work on the basis of measure, large cut to get closer to size, measure, small cut to get very close, measure, final very small cut to arrive at size. With that approach, the following will make working to metric dimensions on an Imperial machine a very easy operation.

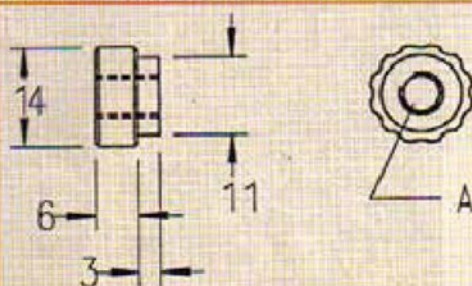
Measure the part and determine how many millimetres have to be removed; set the depth of cut on the basis that 1mm equals 0.040in. (40 thou.). This will, of course, introduce a small error, but as the part is to be measured again before making a further cut, the error will be of no importance. When getting closer to the size required, work on the basis that 0.1mm equals 0.004in. (4 thou.). Again, this will introduce an error, but now very small, this being eliminated by further measurement. Depending on the level of precision required, this last approximation may get you close enough. However, if the part requires still greater accuracy then, after measuring, work on the basis that 0.01mm equals 0.0004in. (0.4 thou.). As 0.01mm actually equals 0.0003937in., this is an error of 0.0000063in. which is quite insignificant, even if you are taking a cut of, say, five times this amount.

The point to realise is that the errors introduced by using these conversion



MATERIAL
STEEL HEX HEAD SCREW
M6 X 25 LONG

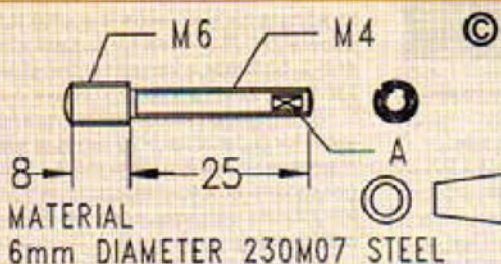
Item 2 Scriber Screw



HOLES
A. M6

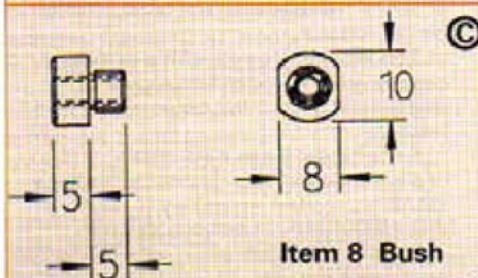
MATERIAL
15mm DIAMETER 230M07 STEEL

Item 4 Scriber Nut



MATERIAL
6mm DIAMETER 230M07 STEEL

Item 7 Adjuster Stud



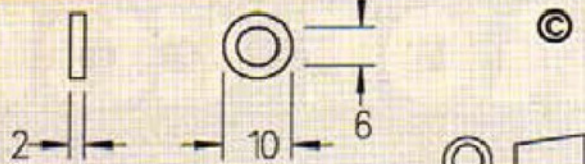
Item 8 Bush

MATERIAL
10 DIAMETER 230M07 STEEL

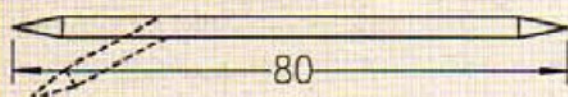
factors are being eliminated at each stage by the part being successively measured using metric dimensions.

Our first project - A Mini Surface Gauge

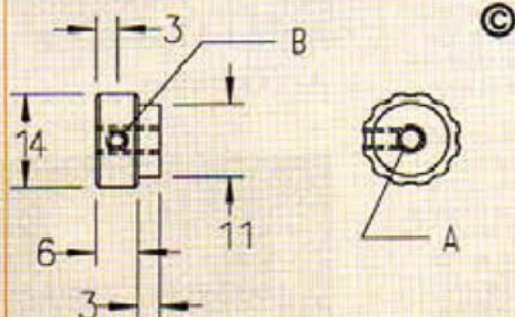
Often, when marking out very small items on the surface plate, a conventional size surface gauge is unwieldy, so our first



MATERIAL
10mm DIAMETER 230M07 STEEL
Item 3 Scriber Clamp Washer



MATERIAL 3mm DIAMETER SILVER STEEL
Item 1 Scriber
NOTE Scriber can be bent if preferred.



HOLES
A. M4
B. M3

MATERIAL
15mm DIAMETER 230M07 STEEL

Item 6 Adjuster Nut

project, to be described in detail in the next issue, aims to overcome this by providing

us with a mini gauge. Its design (Fig. 1) is somewhat unconventional, intentionally so, as it is intended to be made using just basic parallel turning. The almost completed gauge is seen in Photo. 3, though at the stage the photograph was taken, the adjustment assembly had not been fitted.

The approach to a project

Having decided that a project is to be undertaken, there are a number of preliminary actions that should be considered a must. First, and vitally important, is to study the drawings so that you fully understand what has to be made and, in particular, how the parts inter-relate. In industry, part drawings would include tolerances, so that parts made at different times, and perhaps in different locations, can be guaranteed to fit together when brought together for assembly. In the home workshop this is rarely necessary as the second part can often be made to fit the first, regardless of the actual dimensions. If tolerances were quoted and a small error was made

in the first part, few would be prepared to scrap this if a small adjustment to the size of the second would permit a successful outcome. Understanding the drawings is therefore an essential part of this approach.

The next stage is to make sure that you have the required materials and the necessary tooling - drills, taps, dies etc. Finally, as far as is practical, determine the manufacturing methods going through the process in the mind and jotting down the salient points.

So as to get the first project off to a flying start therefore, the drawings for the gauge are published in this issue. This will enable you to study these in detail, ensuring that the required materials and tooling can be available for a prompt start with the publication of the next issue. However, in this case, do not start to make the item or even give undue thought to the method of manufacture, as this will be the major purpose of the content of the next instalment.

Terminology

For the benefit of newcomers to the hobby it may be helpful if I

include a few definitions of terms (indicated thus *), which may not have been encountered previously.

TIR. Total indicator reading When a part is running out of true an indicator will deflect positively on one side by the amount of the eccentricity, but at 180 deg, from this position, the deflection will be negative, again by the same amount. The movement of the indicator is therefore twice the value of the error and is called the 'Total indicator reading'.

DTI. Dial Test Indicator. Strictly speaking, this is a measuring instrument for measuring small differences in position. It usually has a small swinging arm which is applied to the workpiece, and measuring range is of the order of only +/- 1mm. This compares with a 'Dial Gauge' or 'Dial Indicator' that senses movement by means of a direct acting plunger which bears on the workpiece, and which has a range of 10mm plus. The two terms are often confused and used interchangeably, even in manufacturers' catalogues. Of course a Dial Indicator or Gauge can be used in place of a Dial Test Indicator, but will usually be less sensitive.

TRADE COUNTER

Please note that, unless otherwise stated, Trade Counter items have not necessarily been tested. We give news of products and services which have been brought to our attention and which we consider may be of interest to our readers

Low Melting-point Alloys from MCP

A new leaflet from Mining and Chemical Products lists seven MCP low melting-point alloys formulated for precision modelling and casting.

Pointing out that low working temperatures (below 300 deg. C) allow cheaper mould materials to be used, the leaflet highlights features general to the range and provides guidance on their use. The constituents and properties of each grade are itemised in a table.

Melting at temperatures between 125 and 245 deg. C, MCP alloys are manufactured under ISO 9002 quality-control standards from virgin materials to ensure consistent performance and reduced scrap levels. They include grades particularly suited to fine detailing, high surface finishing, large modelling, hand casting and polishing.

Two lead-free grades are available, one of them a pewter-type alloy complying with the latest EC legislation.

Mining and Chemical Products Ltd, The Mill House, Laverstoke, Whitchurch, Hants RG28 7NS (Tel. 01256 897200).

Spring/Summer 2000 Book News from Camden

The latest book list from Camden contains 72 pages, each of which appears to be packed with more information than ever. The first section, covering a dozen pages or more is entitled "Engineering Practice and Skills" and lists close to 300 books, magazines and videos covering topics as diverse as blacksmithing and building a spark eroder.

Other sections list publications covering all aspects of the use of steam power on land and sea, industrial archaeology, aviation and all recognised branches of model engineering (plus some not so widely recognised!).



Book News is an entertaining read in itself, and well worth a call to Camden.

Camden Miniature Steam Services, Barrow Farm, Rode, Bath, Somerset BA3 6PS Tel. 01373 830151 Fax. 01373 830516 Web Site: <http://www.camdenmin.co.uk>

A New Range of DUPLEX Brand Machining Accessories



As reported in recent issues, the well-known name of DUPLEX is now an integral part of the Boneham & Turner product range and is being promoted by them as product grouping aimed at widening conventional machine tool application at an economical cost. The brand name and the rights to manufacture the DUPLEX range of economically priced grinding heads and toolpost grinders was acquired by B&T during 1999. These have now been partially re-engineered and the series added to by the Mansfield based firm.

A new motorised rotary table which has the ability to accept tee-slotted face plates up to 225mm diameter or magnetic and 3-jaw chucks has been developed and is aimed at the same economically priced market sector as the rest of the range. It is driven via a toothed belt from an infinitely variable 24v DC motor to a speed of 150 rpm. The table bearings are heavy duty angular contact capable of taking up to 30 Kg centred load or an eccentric load of 20 Kg at 100mm radius. The body casting of the unit is alloy to reduce weight.

Boneham & Turner Limited, Nottingham Road, Mansfield, Nottinghamshire NG18 4AF Tel. 01623 627641 Fax. 01623 429003 www.boneham.co.uk

New high accuracy torque wrench

Of particular interest to anyone involved



in engine assembly will this new miniature torque wrench from Norbar Torque Tools Ltd. Designated the Model 5, it covers the range 1 - 5 Nm and offers the convenience of interchangeable 1/4in. hexagonal bits as well as a 1/4in. square drive which can be rapidly removed and replaced with another fitting.

The Model 5 is claimed to be accurate to $\pm 3\%$, which exceeds the $\pm 4\%$ tolerance allowed by ISO 6789 for torque wrenches and is half that allowed by the standard for screwdrivers.

This high accuracy makes the Model 5 ideal for light assembly work in electro-mechanical applications such as automatic gearboxes and fuel injection systems, the electronics industry, aero- and model engineering.

Unlike most other miniature torque wrenches the Model 5 is said to remain accurate regardless of the hand position on the wrench.

The Model 5 comes with a carrying case which has space for storage of additional bits and the optional stepless ratchet.

Each Model 5 has a traceable calibration certificate issued by Norbar's UKAS accredited laboratory to satisfy an ISO 9000 quality assurance system.

Pre-set "P" Types are also available for applications where users are not authorised to adjust the torque setting. The pre-set versions have a scale so that the torque setting can be seen at a glance, but not adjusted. "P" types are supplied with coloured end seals to identify the wrench for example to the torque setting or a particular operator.

Both the adjustable and pre-set Model 5 wrenches are available in three versions with scales: 1 - 5 Nm; 10 - 50 lbf.in; or 10 - 50 kgf.cm.

Norbar Torque Tools Ltd., Beaumont Road, Banbury, Oxon. OX16 7XJ Tel. 01295 270333 Fax. 01295 753643 <http://www.norbar.com> E-mail: enquiry@norbar.com

A TOOLPOST GRINDER FOR A HARRISON L5 LATHE

Eric Eadon of Rotherham shows how he adapted a mini-drill to carry out small bore grinding tasks

Development

This project started about four years ago when I needed to grind the jaws of my out-of-true and bellmouthed 3-jaw chuck. The only source of power that would hold a 'mounted point' was a mini-drill that I occasionally use to de-burr parts. The mini-drill looked small and not very powerful, but I was desperate, so I tried it and it worked (**Photo. 1**). The operation took quite a time and the rigidity of the drill bearing housing left a lot to be desired, but I don't envisage grinding the chuck jaws more than once every ten years, so I was not unduly concerned.

About three years later, a night school friend, interested in radio-controlled aircraft, decided to make a miniature jet engine. During its construction I made some suggestions as to how to improve the balance and smoothness of the turbine assembly which runs between 80 and 120,000 rpm. Eventually I was asked to machine some lost-wax turbine castings which had been made from Inconel 713C. The hole through the centre is 8mm diameter by 13mm long and needed to be parallel and have a diametral tolerance of -0.000in. to $+0.001\text{in.}$ Until I actually got to machine one, I had expected to hold them in a jig, then drill, bore, face and with a 'doctored' reamer get the tolerance easily. Beware! Inconel 713C is a very exotic material - the reamer would not touch it and high-speed

drills and boring tools needed regrinding about three times, no matter how slow I ran the machine or what cutting fluid I used.

To cut a long story short, I ended up using a tungsten carbide 7.5mm dia. drill at 150 rpm, which lasted about four holes before a regrind, then boring with a tungsten carbide boring tool, 0.002in. cuts at 150 rpm. I still couldn't get a parallel hole, neither could I get the correct diameter. By now, (after about three weeks on the turbine job), all I had was a jig and four or five 7.5 to 8mm holes, none of which was anywhere near the standard required. Based on the 3-jaw chuck experience, I decided (actually I had very little choice) to try grinding the holes, still using the mini-drill and the toolpost holder,

but this time using a separate rigid quill housing (**Photo. 2**).

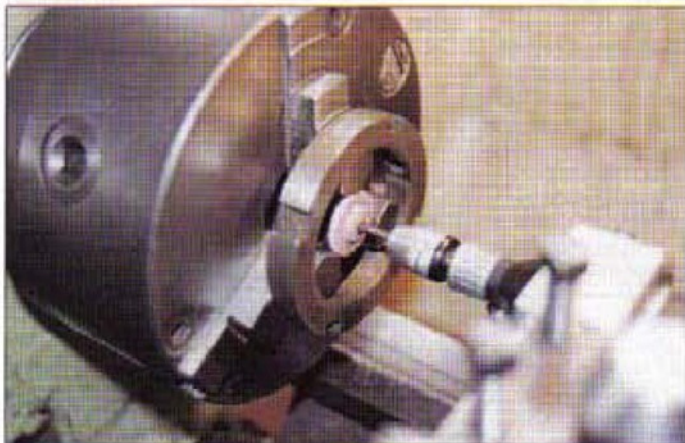
My main doubts were:-

- would the bearings soak up too much motor power?
- would the motor burn out before I had finished the required number of turbines?

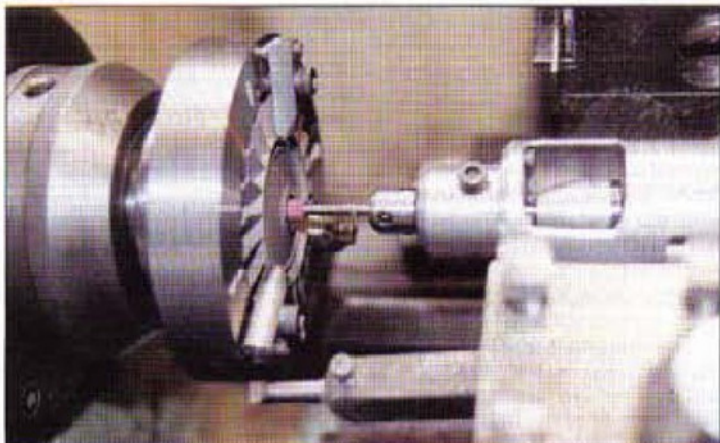
Neither happened, the motor ran cool and the quill ran at virtually undiminished speed.

The toolpost grinder

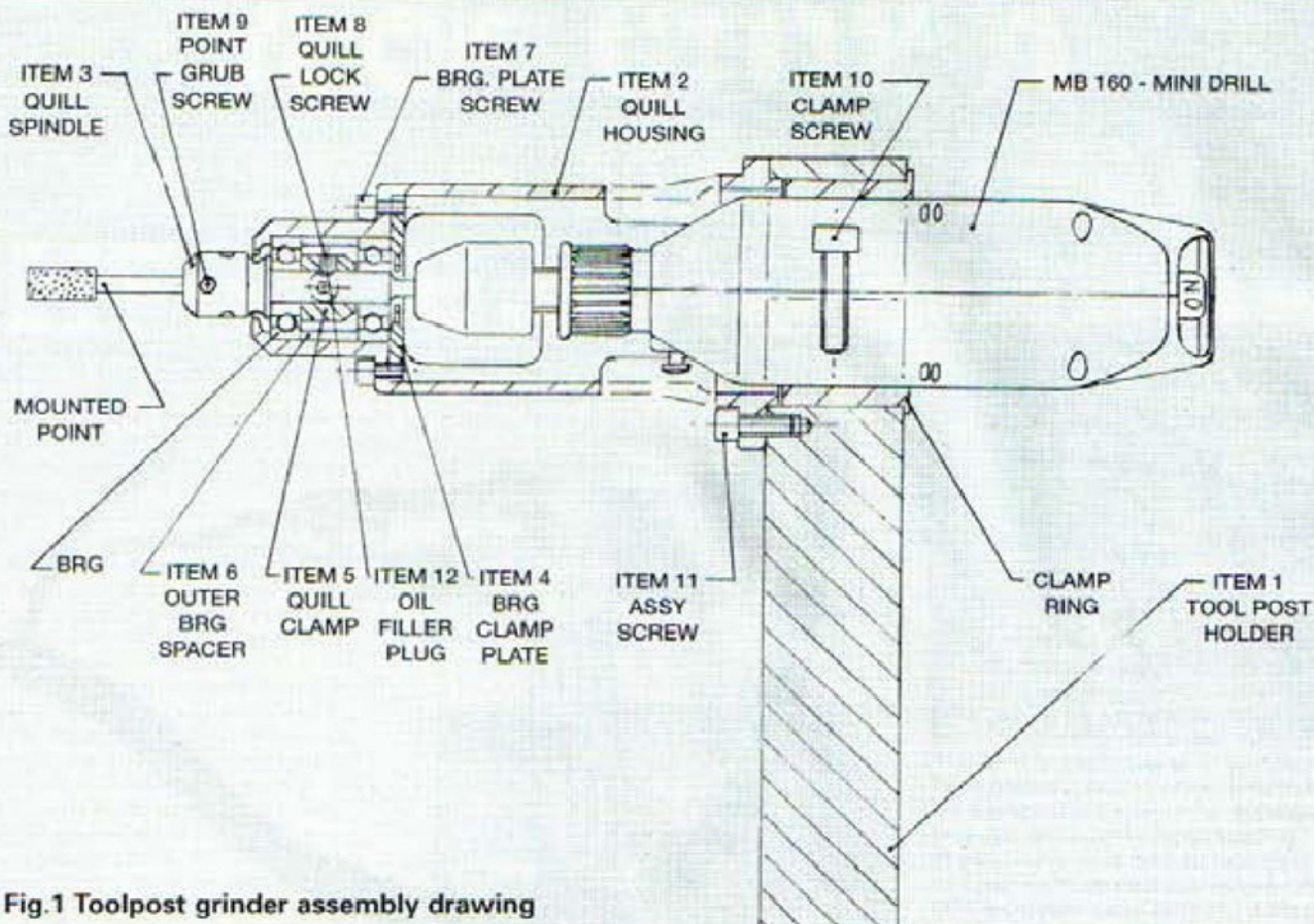
The general arrangement of the toolpost mounted holder for the mini-drill is shown in Figure. 1. All the dimensions



1. The original application of the mini-drill - re-grinding the lathe chuck jaws



2. Finishing the bore of a cast turbine wheel using the new quill assembly



given in the attached detail drawings are those required to suite my Harrison L5 lathe, the MB160 mini-drill and two off 1/4in. bore ball races found in my odds and ends box. I used cast aluminium for the toolpost holder, a piece of 2 1/2in. dia. HE30 aluminium acquired from night school for the quill housing and a bit of round stainless for the quill itself. Most metals will do the job, but stick to steel for the quill. You will need to adjust the dimensions to suit your own lathe, bearings and drill.

Item 1: Toolpost holder

The mini-drill was supplied with a plastic ring for use in the pedestal drill clamp. I used this ring to allow a little compliance and to protect the field windings. The shank, milled to fit the toolpost, was held in the toolpost and, with a centre drill in the headstock, the position of the drill body centred. The drill clamp hole was bored to take the plastic ring to a comfortable push fit. The clamp screw hole was then drilled, counterbored, tapped and the 45 deg. faces cut, but I found it advisable not to cut the clamp slot until the whole thing had been test assembled.

Item 2: Quill Housing

The important points with this item are concentricity, i.e. ball race housing to toolpost holder, location spigot and the light push fit of the ball races in the housing. The latter is a bit of a problem because it is way down at the bottom of a 3³/₄in. deep hole. The piece of 2¹/₂in. dia.

HE30 aluminium for the housing was 4in. long and was first roughed out, both inside and out, leaving about 1/32in. all round. I then finished turned the front outer form, the 0.44in. dia. bore and the inner oil recess (Figure 2).

The next operation was not the obvious one. Milling the four side cut-outs made it easier to see, through the rotating windows, what the tool was doing when boring the ball race housing. With the work held by the outside of the ball race housing, the toolpost holder spigot and location face could be machined. Boring the housing required a very stiff boring tool. Achieving the required bearing push fit was made easier by using the ball race as a plug gauge. A piece of screwed rod was fitted through the bore of the race, secured with two nuts and washers to stop swarf getting into the ball tracks (Figure 3).

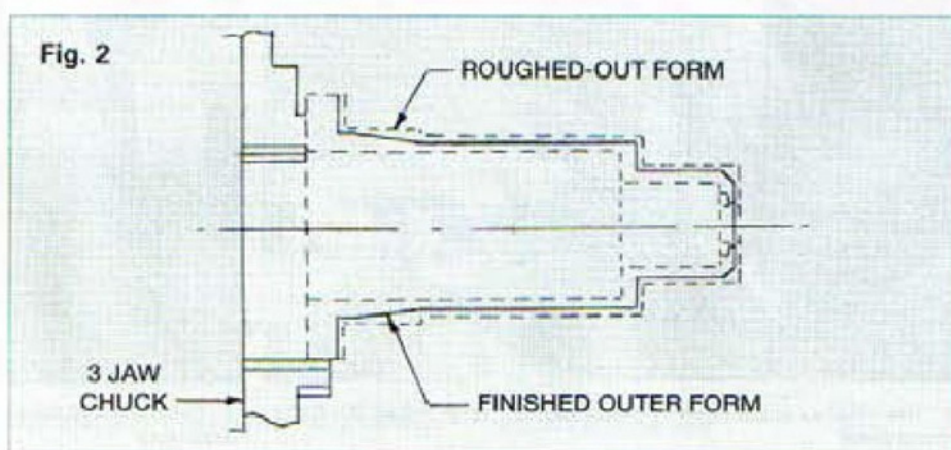
The next step was to de-burr and radius

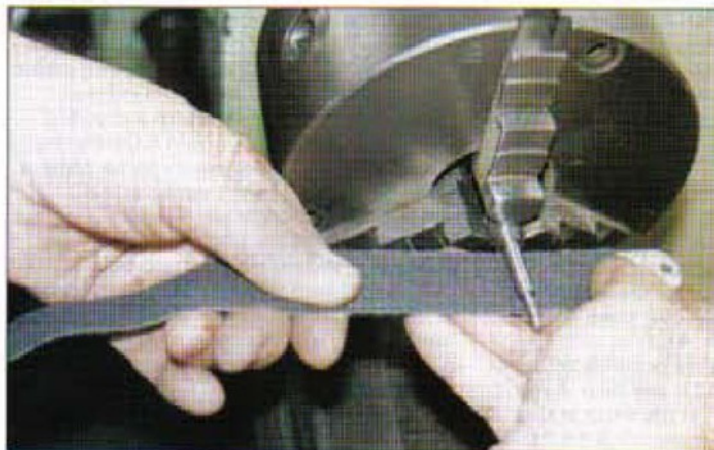
the edges of the cut-outs, but the holes for the toolpost holder bolts, the bearing clamp and the oil filler were left until later. I went on to make the quill bearing assembly parts.

Item 3: Quill spindle

The hole for the mounted point, the spindle diameter and the drive shank must be concentric and the spindle needs to be a light push fit in the bearings. I achieved this by holding the round bar in the 3-jaw chuck with about 2 1/2 in. protruding and then:-

1. Turning the spindle nose with it's oil filling lip then drilling, boring and reaming the mounted point hole.
2. Using a left-hand knife tool, turning the $\frac{1}{4}$ in. diameter to size $+0.0005$ in. to $+0.001$ in.





3. Bringing the bearing location of the quill to size. Extreme care needs to be exercised when carrying out this operation

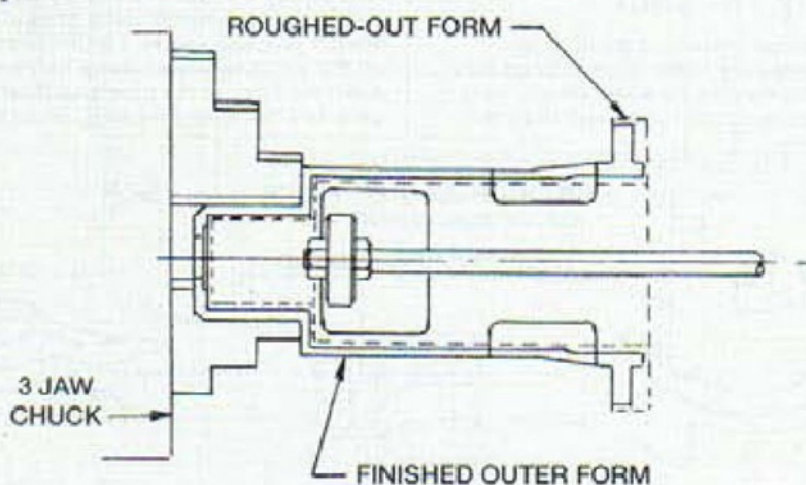


4. Dressing the mounted point with a carborundum stick

3. Turning the 0.120in. diameter drive shank before parting off. This produced a quill with all its diameters concentric, but the bearings still would not fit.

4. With the spindle held in the 3-jaw chuck by its nose, the required fit for the bearings was created by reducing the 1/4in. dia. section with fine emery cloth. A word of warning here - THE FINGERS MUST BE KEPT CLEAR OF THE CHUCK JAWS AND THE STRIP OF EMERY CLOTH MUST NOT BE ALLOWED TO WRAP ITSELF ROUND THE ROTATING WORKPIECE. It must be backed by a firm strip of material - I used a 6in. steel rule. This operation is best done from underneath the spindle so that you can see where the material is being taken from. If you have machined the spindle to more than 0.002in. oversize then do the same thing but with a very smooth file, then follow with the emery cloth (Photo. 3).

Fig. 3



Item 4: Bearing clamp plate

There is nothing complicated here, it just being necessary to make the O/D a close clearance fit in the housing and clamp it in position through the quill hole. To mark the holes out on the correct radius, I made a small punch from silver steel (Figure 4) and used it as shown. It can be used for these holes and the three housing to toolpost holder holes. If you are using aluminium for the housing, then the punch won't need hardening.

Items 5 & 6: Quill clamp and outer bearing spacer

The outer spacer length was established by measuring the depth of the quill housing (an electronic vernier is perfect for this), subtracting twice the bearing thickness and adding 0.005in. This additional length provides adequate 'nip' on the bearings when assembling the components to drill the oil and clamping screw holes. Don't drill them until you reach that stage.

Bearing assembly

I would suggest that anyone attempting this project should turn up two dummy bearings, O/D - 0.002in., I/D - 0.002in. and

exact width. It is possible to use the bearings themselves, as I did, but it is difficult to get the drilling swarf out of them and I would use dummies next time. With the (dummy) bearings, the quill clamp and outer spacers assembled and the clamp plate screwed on the quill spindle was inserted and held in position with finger clamps across the spindle nose and the front housing cut-outs (Figure 5). With all held secure, it was now possible to drill through one side of the housing and the two spacers and to just dimple one side of the spindle. After dismantling and thoroughly cleaning the bearings (or discarding the dummies), the hole in the quill clamp (Item 5) could be tapped 4BA and a second hole drilled opposite. With the clamp assembled back on the spindle and locked it into the dimple with a quill lock screw (Item 8), the second dimple was produced. Dismantled again, the other side of the quill clamp was tapped. It is necessary to mark up which end is which and also which grub-screw goes to which dimple.

The two remaining jobs were to open out the hole in the outer bearing spacer (Item 6) to 3/16in. and to drill and tap the quill housing oil hole out 2BA. A small flat formed a seating for the oil plug. It was now time to thoroughly clean and de-burr all the bits ready for the final assembly.

Final Assembly

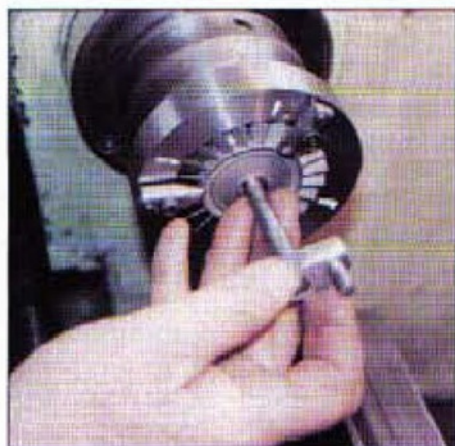
The sequence I used was as follows:- Fit the front bearing, the outer bearing spacer (Item 6) and the oil filler plug (Item 12) through the outer hole to locate it.

Slide the quill spindle (Item 3) into position and slide the quill clamp (Item 5) complete with quill lock screws (Item 8) over the spindle followed by the back bearing, then clamp the assembly together with the bearing clamp plate (Item 4) and screws (Item 7).

Remove the oil plug and tighten the two quill lock grub-screws (Item 8), thus clamping the quill between the front bearing and the spacer. This controls the quill endfloat, along with the mini-drill when the chuck is tightened.

The next operation was to position the quill housing onto the toolpost holder, clamping them together and centre punching the position of the holes with the same punch as before. After drilling through the flange to spot the tool holder, the holes for the retaining screws were drilled and tapped 6BA, allowing a test assembly of the whole unit.

All that was left to do was to trim around the holder flats, saw the clamp slot, fit the clamp screw and the job was finished.



5. A plug gauge is used to check the bore size

Using the unit

I find that 'mounted point' shank diameters vary. That is why I fitted four clamp screws (like a 4-jaw chuck) so that they can be set to run true. Before the

unit is run for any length of time, the bearings must be lubricated. I used a centrifugal fling type seal to save power, but expected lots of oil loss. In practice a good squirt of sewing machine oil at the start lasted 40 turbines - about 4 hours running.

During its use it will be necessary to dress the mounted point, but diamonds are very expensive so I use a carborundum stick, very lightly hand-held against the mounted point. I did 30 turbine holes with one 1/4in. diameter point before it was worn out (Photo. 4).

Take as little material as possible off by grinding, and to this end it will help if you arrange to bore and grind the work at the same setting. Don't try measuring the bore with callipers, they are not accurate enough. Before you start, make yourself a plug gauge with as good a finish as possible - something like the one shown in Photo. 5.

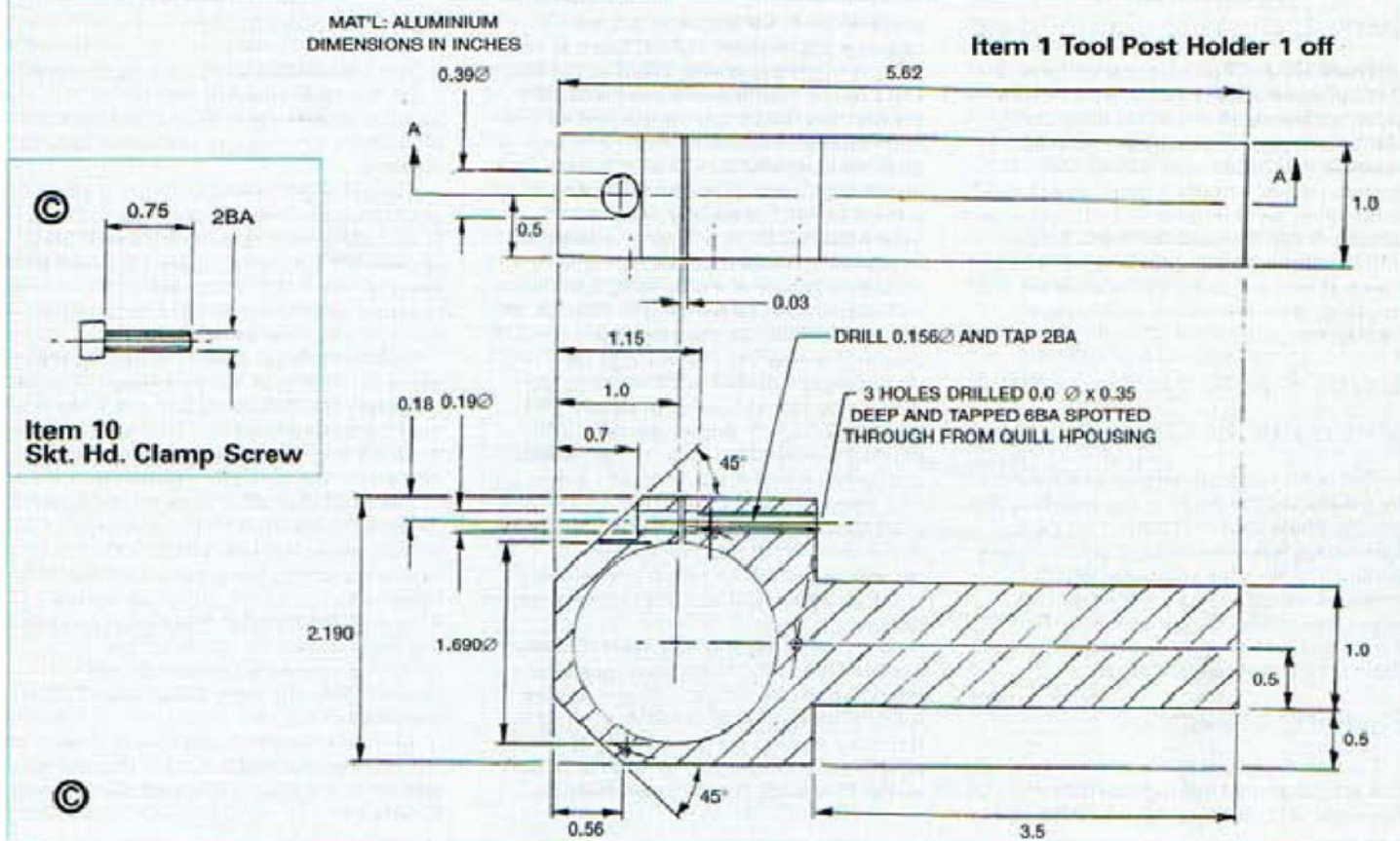
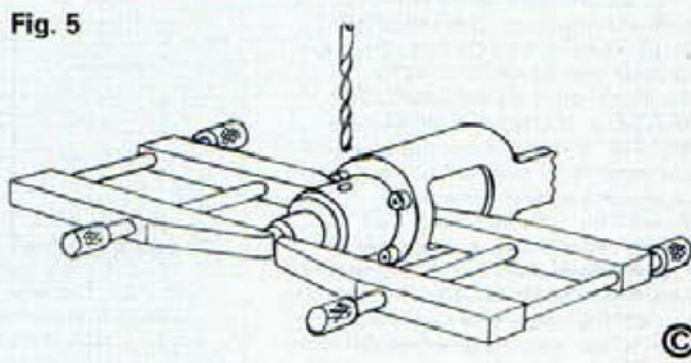
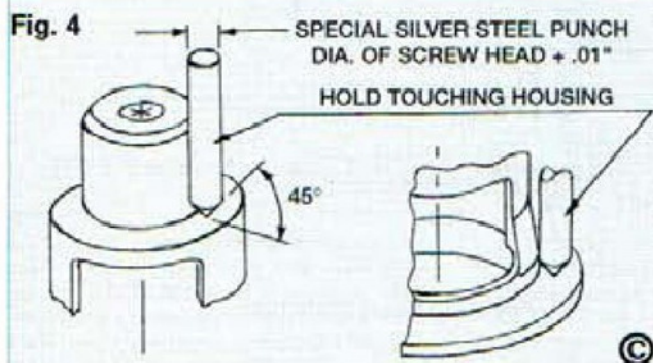
Touching the work can be a problem, especially if the metal being ground doesn't produce sparks. I find it best to set the grinding wheel about half way down the bore of the hole and, with the work and the wheel rotating, move the

cross-slide until the mini-drill revs drop. Note the dial reading and use this as an approximate zero. A cut of 0.001in. a side is reasonable maximum. I found that about four passes to and fro increased the hole diameter by about 0.001in.. In other words, it is necessary to be patient. Things happen slowly, especially if accuracy is the criterion. Check frequently with the plug gauge and beware of the hole becoming bell-mouthed. I had the work turning forward at 150 rpm and mainly traversed out of the hole at 0.020in./rev., or by hand if I wanted to concentrate on a particular place.

Safety

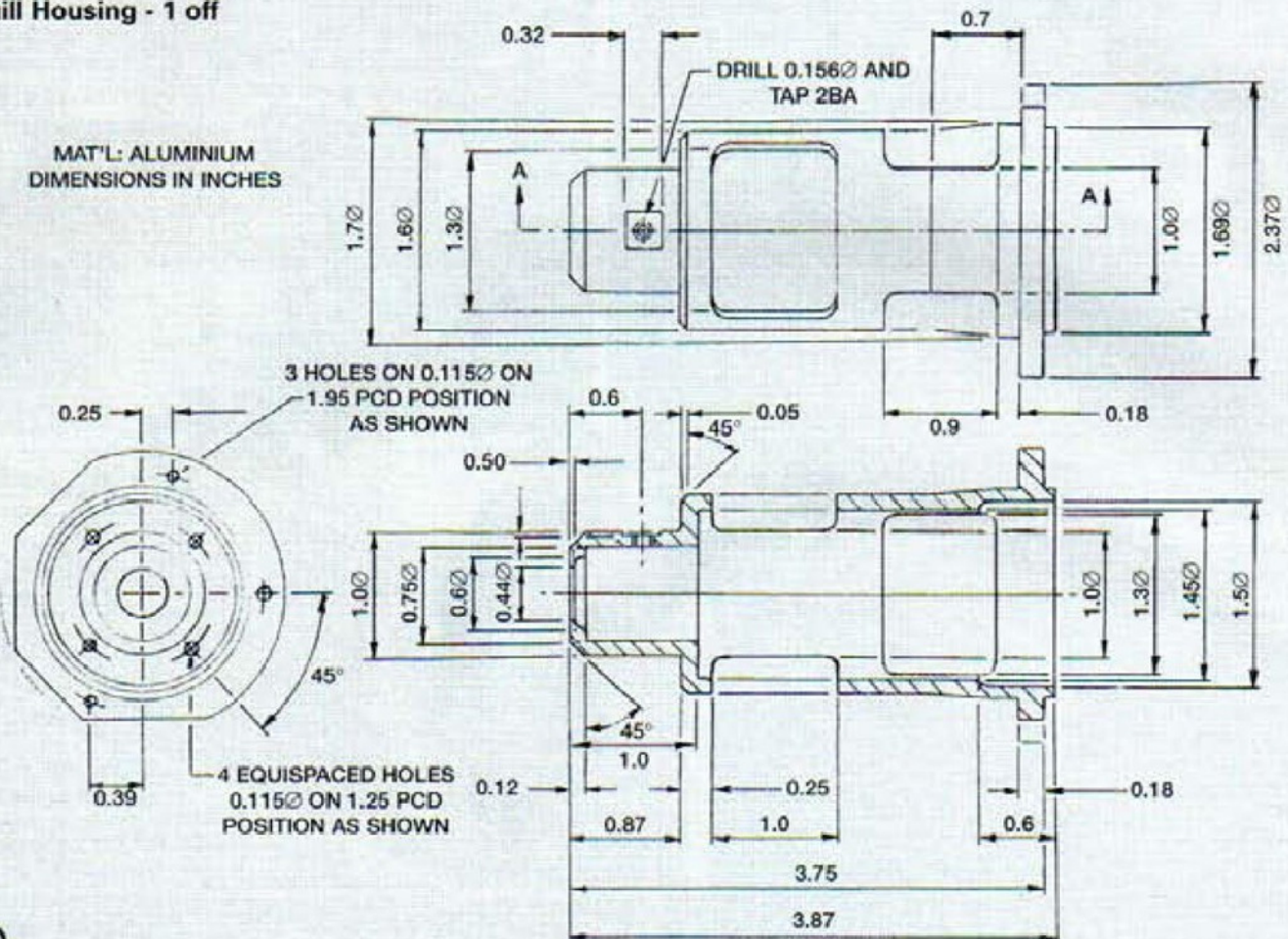
Whenever the mounted point is out of the work SWITCH OFF. Never try the plug gauge in the hole when the mounted point is running. The plug is sure to grab in the hole at some point and to remove it you will have to twist and pull hard, causing it to come out in a rush. A fast turning mounted point hurts, at the very least!

Happy grinding.



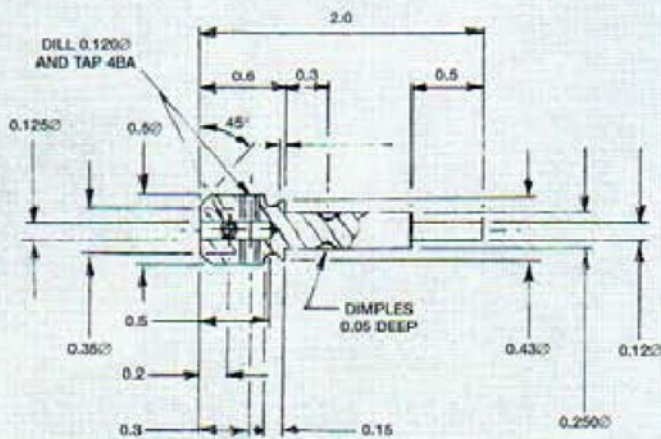
Item 2
Quill Housing - 1 off

MAT'L: ALUMINIUM
DIMENSIONS IN INCHES



©

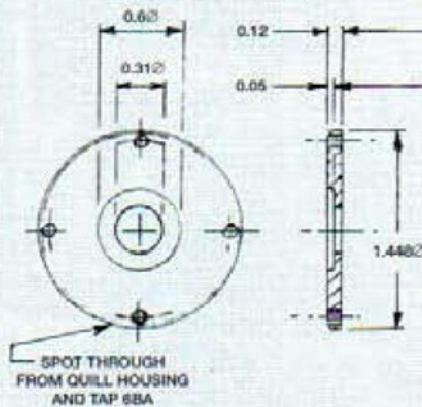
MAT'L: STAINLESS STEEL



Item 3
Quill Spindle 1 off

©

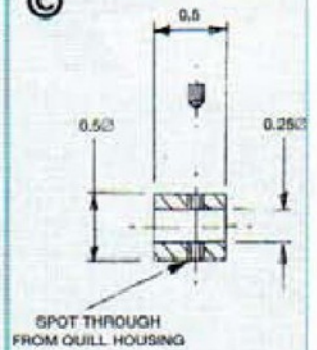
MAT'L: ALUMINIUM



Item 4
BRG Clamp Plate 1 off

©

MAT'L: ALUMINIUM



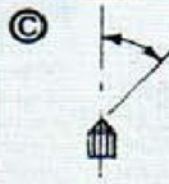
Item 5
Quill Clamp 1 off

©



6BA SKT HD CAP
SCREW x 3/8 LONG

Item 7
BRG Plate Screws 4 off



4BA SKT HD GRUB
SCREW x 3/16 LG
POINT FORMED AS
SHOWN

Item 8
**Quill Lock
Screws 2 off**



4BA SKT HD GRUB
SCREW x 3/16 LG
POINT FACED FLAT

Item 9
Point Grub Screw 4 off

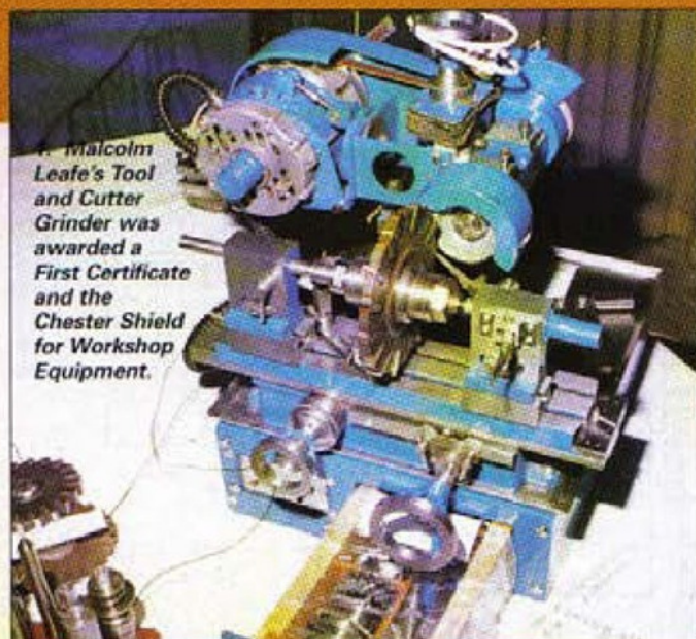


2BA SKT HD CAP
SCREW x 1/4 LG

Item 12
Oil Filter Plug 1 off

SPRING IN YORKSHIRE

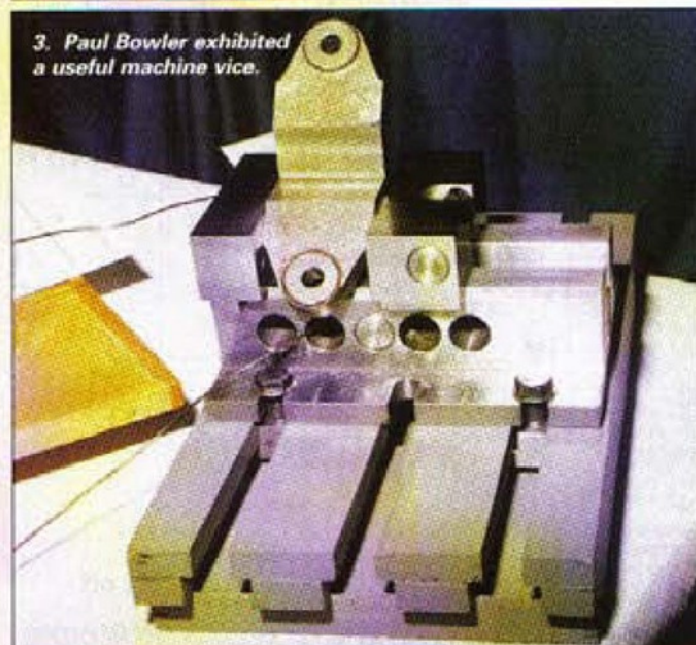
Some items of interest from the 7th National Model Engineering and Modelling Exhibition, as seen by the Editor



1. Malcolm Leafe's Tool and Cutter Grinder was awarded a First Certificate and the Chester Shield for Workshop Equipment.



2. In addition to the main machine, the accessories for Malcolm's grinder were well presented.



3. Paul Bowler exhibited a useful machine vice.



4. A swing head surface grinder, based on a design described by Alan Jeeves in these pages some years ago was entered by Peter Newby of Tyneside SME.

By putting the date of the Harrogate Exhibition back by about a month, the organisers managed to find some sunshine for this ever-popular event. This was particularly appreciated by the 'live steamers' operating outside the Flower Hall and by those exhibitors located in the two tented annexes to the main hall. It had been hoped that the promised extension to the hall would be available this year, so that these annexes would not have been required, but this was not to be. We live in hope for next year.

As always, this event was well supported, attracting a total of 38 clubs

and societies and 64 trade stands. The number of exhibits was pleasing, at over 1000, but the majority of these were on the club stands, which prompted Chief Judge, Jim Burlingham to appeal to the clubs to get their members to enter in the competitive sections. The quality of the exhibits in all areas was high, and there is no doubt that a number of the items on loan would have won awards, particularly as, this year, marking was against a standard for certificates, rather than on a 'First, Second, Third' basis.

Also new this year was the introduction of a number of trophies, presented by 'Friends of the Exhibition', creating a fine display of silverware. As in recent years, my colleague, Mike Chrisp of *Model Engineer* and I were privileged to be invited to take part in the presentation ceremony, an event which always gives us great pleasure. Mike will be reviewing the notable models in *M.E.*, so I will concentrate on a few highlights of the workshop equipment on display.



5. Another of Paul Bowler's entries was a simple but versatile dividing device.



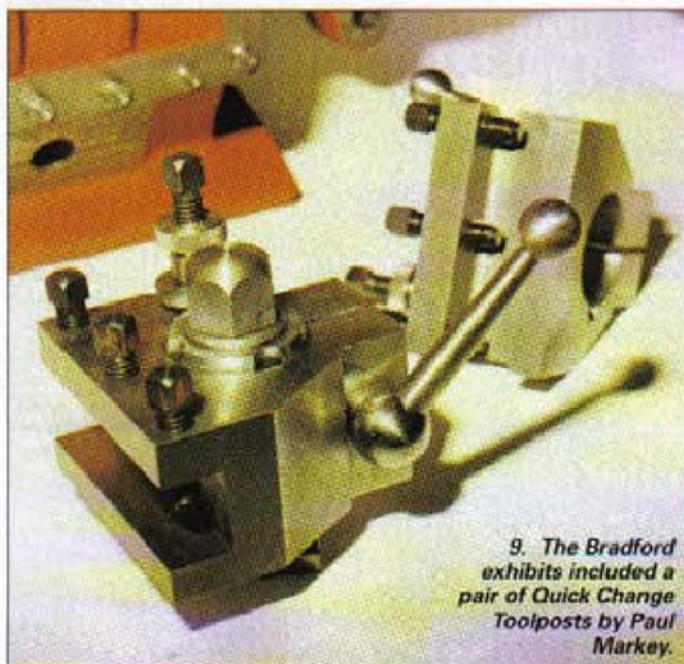
6. Barry Jordan's complete collection of small machines was nicely displayed. His milling machine was awarded a First Certificate.



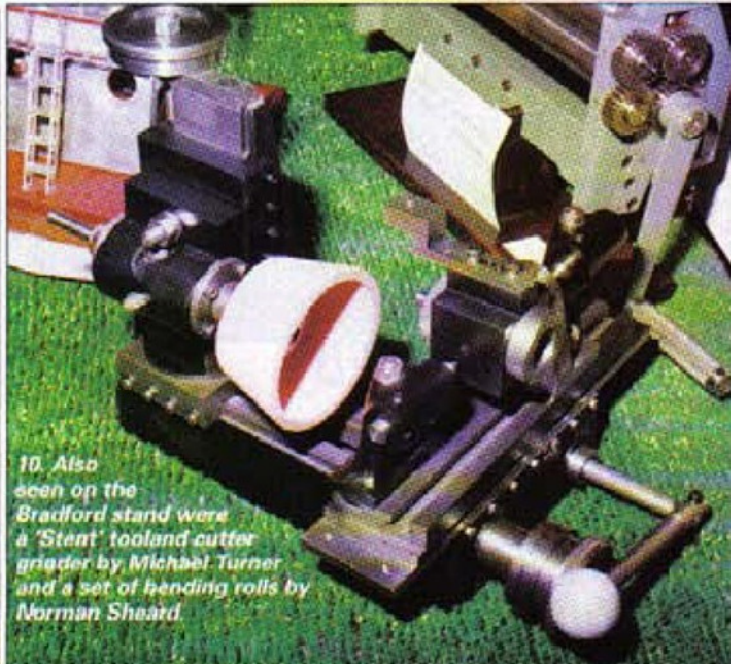
7. Contributor Derek Brown was delighted to see a number of sets of small pipe bending tools to the design which he described for us recently, remarking that all were displayed in cigar boxes similar to the one shown in the article! This example was by M Proctor of the Scunthorpe Society



8. Bradford and District Model Engineering Society won the Northern Association of Model Engineers Shield for the Best Club Stand.



9. The Bradford exhibits included a pair of Quick Change Toolposts by Paul Markey.



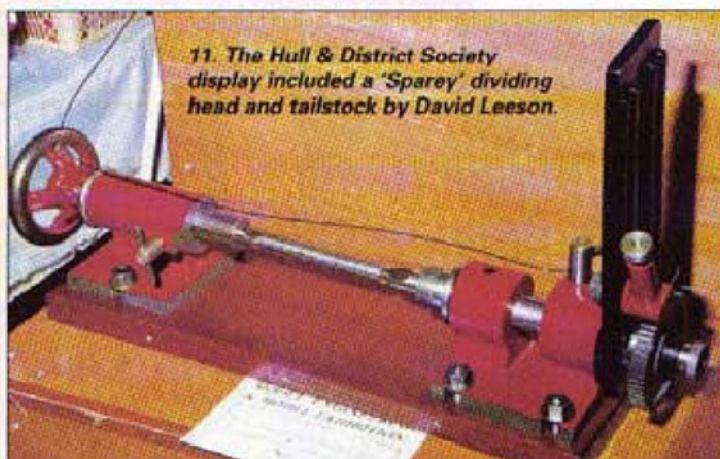
10. Also seen on the Bradford stand were a 'Stent' tool and cutter grinder by Michael Turner and a set of bending rolls by Norman Sheard.

Just two First Certificates were awarded in this category, going to Malcolm Leafe for his Tool and Cutter Grinder and to Barry Jordan for his Precision Milling

Machine. The former was also awarded the new Chester Shield, presented by our friends at Chester UK.

Contributor Raymond McMahon, over

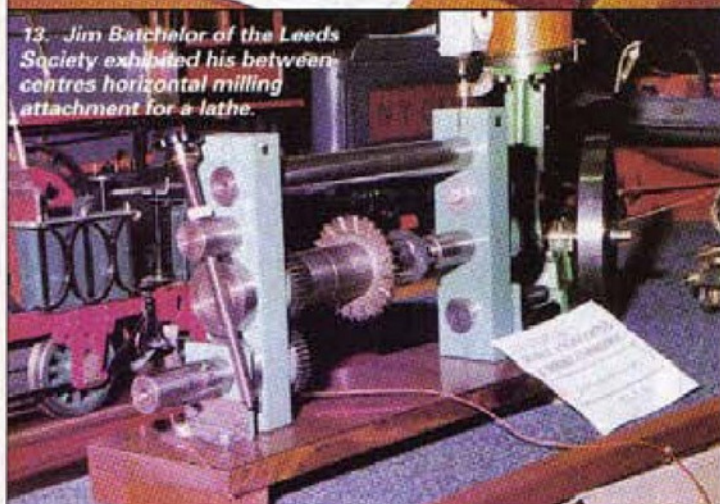
from Northern Ireland deservedly won the Barry Jordan Trophy for Best in Show with his brilliant model of a Pumping House. This delightful exhibit has been marvelled



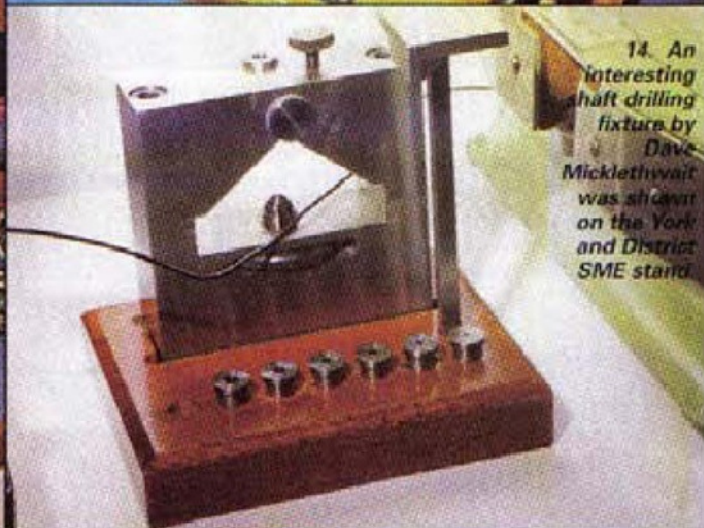
11. The Hull & District Society display included a 'Sparey' dividing head and tailstock by David Leeson.



12. A substantial keyway slotting tool by John Britton was seen on the Grimsby and Cleethorpes MES stand.



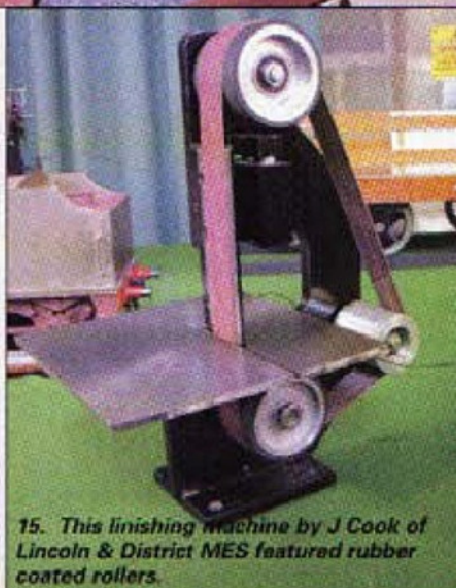
13. Jim Batchelor of the Leeds Society exhibited his between-centres horizontal milling attachment for a lathe.



14. An interesting shaft drilling fixture by Dave Micklethwait was shown on the York and District SME stand.

at by all who have seen it at recent exhibitions. Raymond also gave us a sneak preview of his latest project, a piece of workshop equipment, the description of which we hope will grace these pages in the not too distant future.

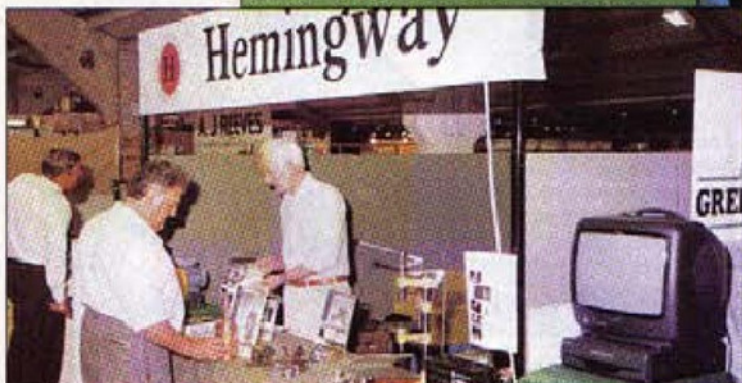
The friendly atmosphere at this event and the hospitality provided by the organisers makes this a highlight of the year. We look forward to next time.



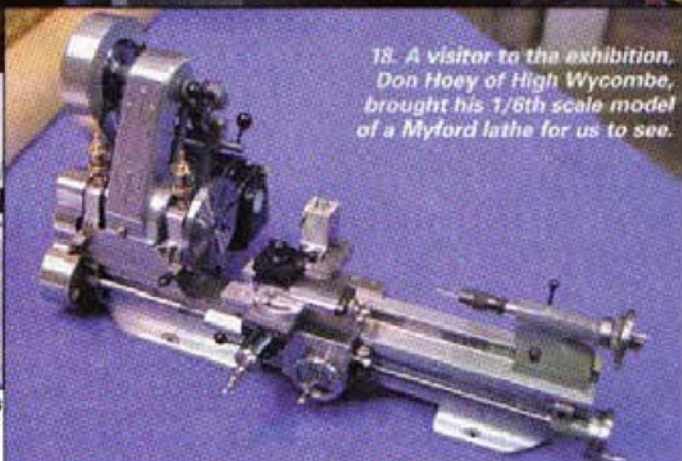
15. This finishing machine by J Cook of Lincoln & District MES featured rubber coated rollers.



16. Exhibition Manager, Lou Rex (pictured right) made the draw for the Chester Mini Lathe donated by Chris O'Hare of Chester UK (left). The winner was Stephen Walker of Kirkby in Ashfield, Nottingham.



17. Regular advertiser John Corlyon of Hemingway prepares his stand before opening time on the final day, while Tony Green of Tony Green Steam Models examines a small vertical boiler.

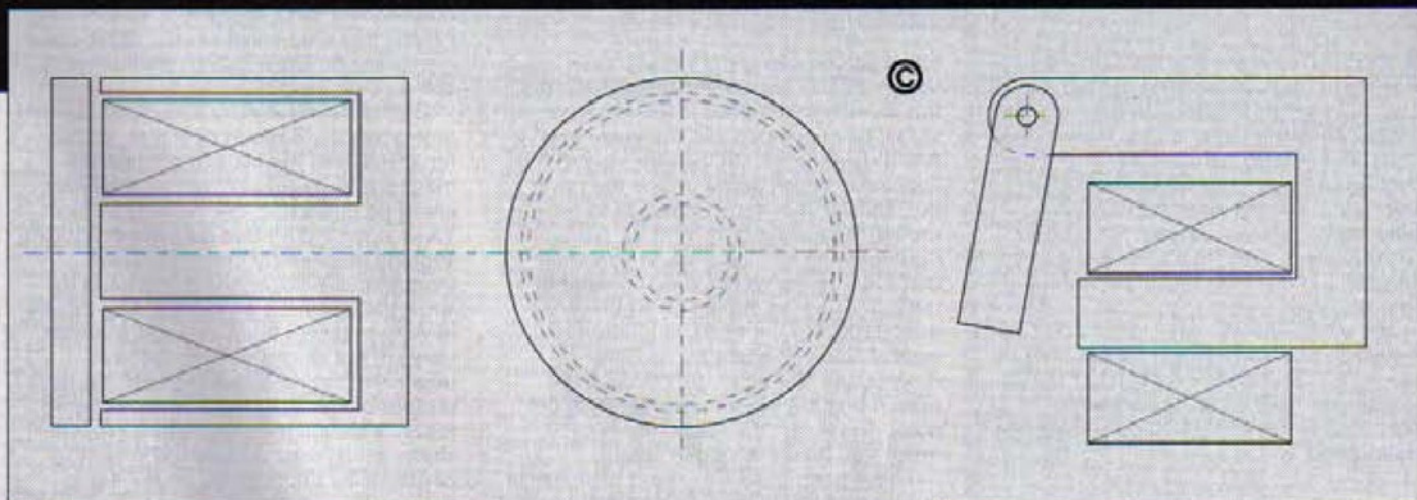


18. A visitor to the exhibition, Don Hoey of High Wycombe, brought his 1/6th scale model of a Myford lathe for us to see.

ELECTROMAGNETIC DEVICES

Part 2 - Designing Electromagnets

Tony Claridge continues his series by carrying out a number of Design Studies



The first thing we need to do before designing an electromagnet is to specify the force which it must exert and the stroke over which it must exert it. The shape of the device will depend on whether it is to be a short stroke device (or even one which merely holds something as long as it is energised, such as the magnets which hold office fire doors open until the fire alarm operates, when they release the doors, allowing them to close) or a long stroke device, often called a solenoid. It is worth remembering that, with either type, the force will increase over the length of the stroke.

A typical Design Study

By way of an example, we will work out a design for an electromagnet which opens a small poppet valve. It could also be used to engage or disengage a friction clutch. The key items in the specification are:-

Stroke	2mm
Force	10Kg at the start of the stroke.
Electrical supply	12v dc

At the outset we need to realise that the force exerted by the magnet varies as it moves through its stroke. It will be designed to deliver the specified force at the beginning of its stroke, and the force will rise as it completes its travel. The

Fig. 1

general shape of the device can be chosen from several alternative forms, some of which are shown in Figure 1. For the intended application, a cylindrical concentric form is the first choice. This shape has the advantage that the delicate winding is protected from accidental damage, though it is also more difficult to dissipate the heat produced in it when it is energised. It is necessary to decide whether the device is to be rated for continuous or intermittent duty, since this will determine the amount of space required for the winding.

Estimating the force available

We first need to know how to calculate how much force can be produced by a short stroke magnet. It can be shown that a magnetic field stores energy, not unlike the energy stored in a spring when it is put under strain, or by a spinning flywheel. We will probably invoke both these analogies as these notes expand. The energy stored in each element of the magnetic field is proportional to the product of B and H , so the total energy stored in the whole magnetic field is the sum of the energy stored in each part. Again, the two mechanical analogies have corresponding properties. The analogy of stress times strain in elements of a spring is a direct equivalent.

The way in which we move from stored energy to force is to consider a minute movement of the armature (the usual name for the moving part of an electromagnet) and relate this to the change in the energy stored in the field. By considering the smallest possible travel of the armature, we can claim that the value of flux density (B) does not change. The force is then calculated as the change in stored energy divided by the movement. Readers who are familiar with the branch of mathematics called the 'calculus' will recognise this method. Remembering that

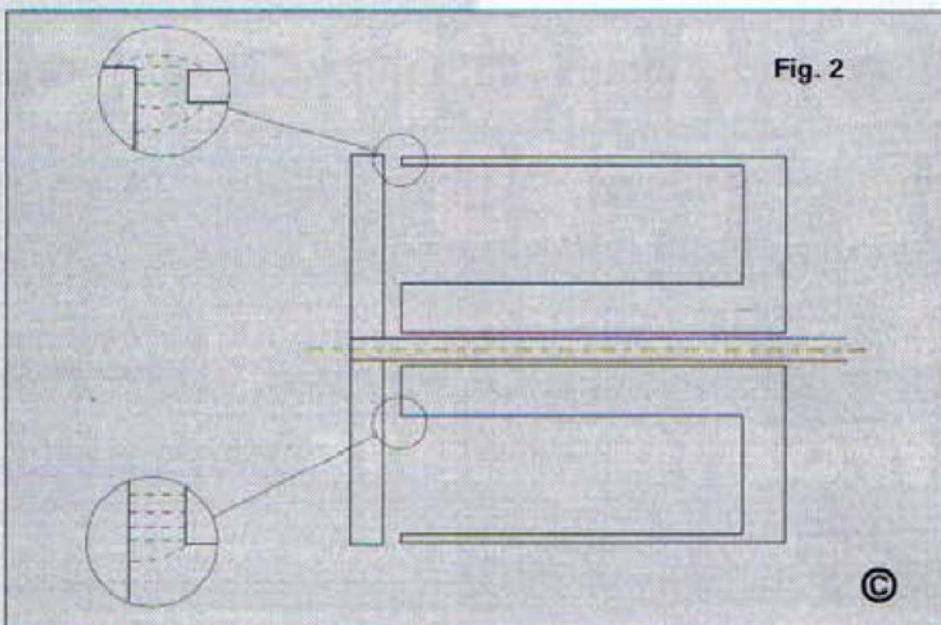


Fig. 2

the iron parts have a relative permeability of perhaps 1000, it can be seen that the $B \times H$ product per unit volume in the iron is negligible compared to that in the air gap, where the relative permeability is 1. Consequently, we can calculate the mechanical force by dealing only with what happens in the air gap. This makes the derivation of the force formula much simpler, and does not make the resulting figures invalid.

The full theoretical analysis of how to arrive at a suitable formula for the force is beyond the scope of these articles, but can be found in most of the textbooks on electromagnetism. We will jump straight to the formula, which is:-

$$\text{Force (Kg)} = 0.0406 \times B^2(\text{tesla}) \times A(\text{sq. mm})$$

Now the magnetic properties of ferrous materials are such that a very large MMF is needed to achieve flux densities (B) in excess of 1.5 tesla. A better choice, unless size is at a premium, is no more than 1.2 tesla.

Re-arranging the formula above, we get:-

$$A = \frac{\text{Force}}{0.0406 \times B^2}$$

and inserting the values we have chosen, we get:-

$$A = \frac{10}{0.0406 \times 1.22} = 171.2 \text{ mm}^2$$

The chosen configuration has two poles, the central core and the outer ring, and this total area is for both poles. However, the relatively large flux fringing on the outer pole greatly reduces the attraction developed at this pole, and as a first approximation we can disregard it. This is explained in more detail below.

It is now possible to prepare an initial outline of the design, which is shown in Figure 2. You will see that a pushrod passes through the central core to actuate the clutch or valve which the device is intended for, and it is necessary to adjust the diameter of the core to allow for this. Before we settle the dimensions, we have to bear in mind that the lines of force will tend to spread out given half a chance and the air gaps are just the chance they want.

The enlarged views in Figure 2 show what happens. This has two effects. Firstly, the flux density in the gaps is less than we would have planned and the value of $B^2 \times A$ is thus reduced. On the other hand, A is increased, which partly offsets the lower flux density. It is not worthwhile to go into too much analysis of this effect; rather, remembering its existence, in particular that the fringing will be much greater at the outer ring, as shown on Figure 2, we assign most of the force generation to the central pole and add a bit onto the dimensions "for luck". By the way, the reason that the fringing is greater on the outer ring is that the ring's thickness is much less than the air gap length.

I have postulated a pushrod diameter of 3mm and a clearance hole of 3.2mm to accommodate it. The dimensions shown on Figure 4 are derived on the basis of allowing generously for the effects I have described. You will have noticed that the whole approach to choosing the dimensions is very much "make a rough guess". If necessary, the size and shape can be adjusted as the calculations proceed.

Estimating the Amp.turns required

You will recall that in Part 1 we talked about μ_r , the relative permeability. The trouble is that this is not a fixed figure. It depends on such things as the exact constituents of the ferrous material and its heat treated or workhardened state. Consequently, we depend on graphical information presented on what is called a magnetisation curve. A selection of these curves are shown in Figure 3. What the curves show is the magnetising force needed (in amps/metre) for different values of flux density (in tesla). Before we make use of the data, there are some points to be made. Firstly, the relative permeability is the slope of the curve. You can see at once why it does not have a fixed value. Secondly, all the curves show a marked increase in the required magnetising force as the flux density rises. Finally, there are considerable variations in the curves for the reasons mentioned above.

One of the difficulties about getting hold of trustworthy B/H curves is that, except for specialised magnetic materials, the magnetic properties of ferrous materials are of no interest to the majority of users. You can get exhaustive data about alloying content, mechanical properties, heat treatment and so on, but if you need to know the magnetic properties, you mostly have to measure them yourself. Even so, they are not constant. Both the heat treatment and mechanical stress can have profound effects. In fact a Swedish firm makes a torque meter for ship's propeller shafts which uses the change in relative permeability under stress as the input parameter.

Although for decades, people have gone on about the virtues of 'Swedish iron', in actual fact ordinary mild steel serves quite well enough for our purposes, though it is best in the annealed condition. Swedish iron is fairly close to being pure iron, with nothing alloyed with it. Iron from the Lowmoor steel works in Bradford was just as pure. The curves show that cast

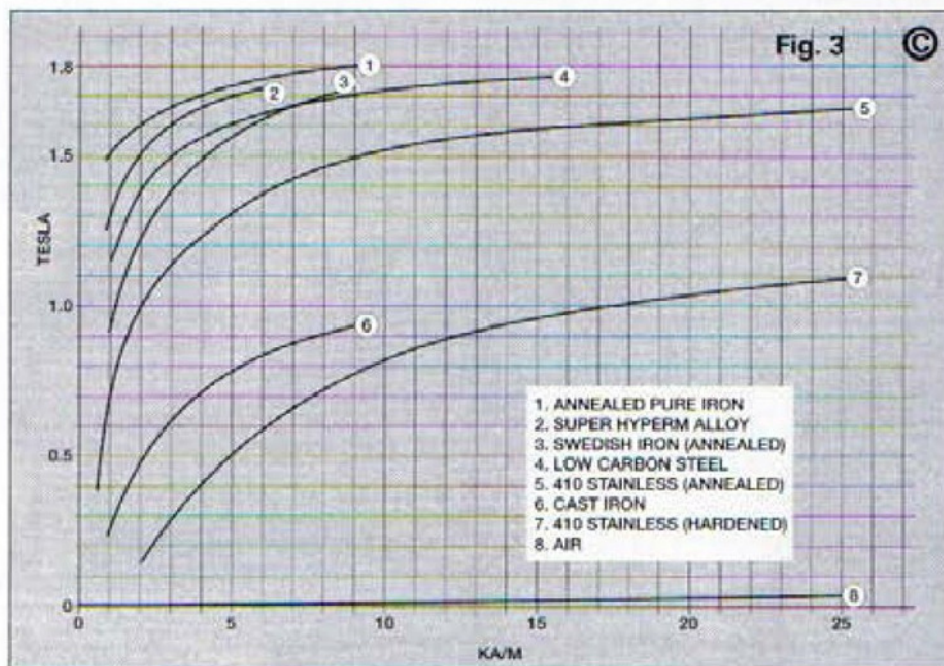
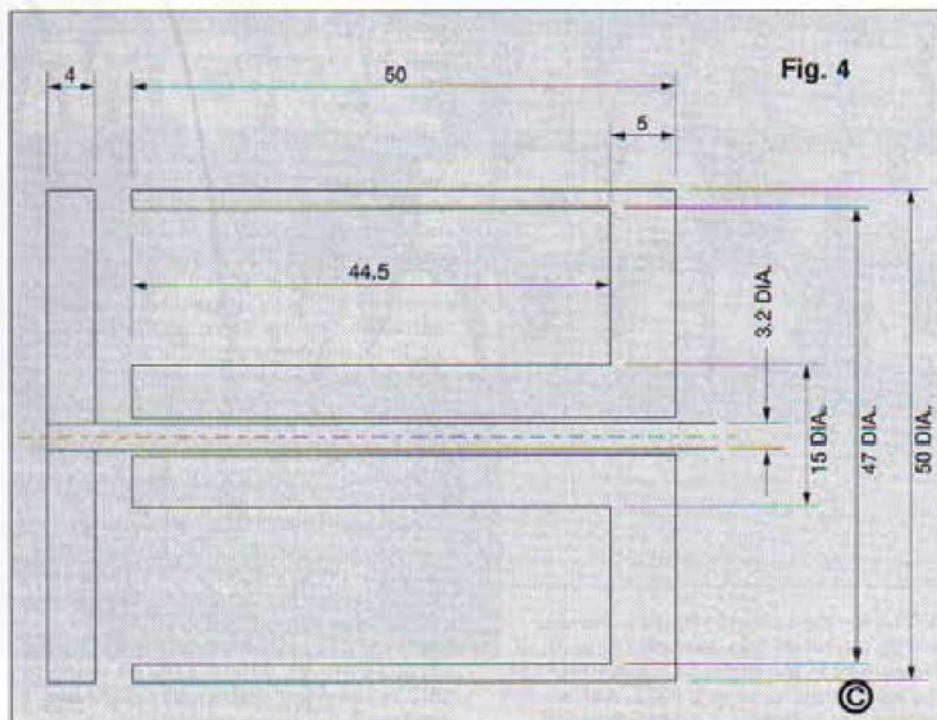


Fig. 3



iron is a lot less easy to magnetise than steel, and that stainless steel is also not as good as ordinary black mild steel. When the chromium content of stainless steel gets close to twenty four per cent, then it may cease to be magnetic, depending on the heat treatment state. At around thirty per cent it is never magnetic at all. There are many exotic alloys, chiefly of nickel and iron, which have quite outstanding properties, but these don't have any relevance to our work. We will stick with mild steel for this study.

Fortunately, by far the greater part of the MMF which we need is used to magnetise the air gap, and consequently the exact magnetic properties of the ferrous parts are not very important. This will become clear as the design evolves.

In choosing the dimensions of the iron parts of our electromagnet, it is important to ensure that there is an adequate cross-section to carry the field all round its circuit. The end part of the 'pot' must be thick enough, as also must the armature disc. If we were looking for the fastest response time, we could taper the armature's thickness or drill a circle of lightening holes towards its outer diameter to achieve a constant cross-sectional area. Remember that as the radius of the disc gets smaller as the field flows from the outer ring to the centre core, the circumference reduces, and strictly speaking the disc thickness should be increased as the lines of force approach the centre. In practice, don't bother unless response time is important, when low weight becomes a factor.

MMF calculations

Here I am going to jump the gun a bit. Normally it is necessary to do a bit of trial and error in order to converge onto the dimensions needed for our electromagnet. For this study I have made use of my own experience, and also done some preliminary calculations, so that we can go straight to the final size and proportions. Figure 4 shows a cross-section of the chosen size

and shape. There are two points to be made about it before we do the calculations. Firstly, if the push-rod which passes through the middle of the centre pole is made of a magnetic steel, then it will tend to stick to one side of the bore. It should preferably be made of non-magnetic material, but if not, then a tiny bush at either end will serve to keep the rod central. The second point is that even mild steel retains a little magnetism when the current is switched off. In order to let this die away and let the armature go, a small air gap is put into the magnetic circuit. In this design the centre pole is made to be about 0.5mm shorter than the outer ring. With a differently configured magnetic circuit it is sometimes arranged that a blind rivet is driven into the face of the iron so that its head prevents the armature from closing up the air gap completely. When this is done the rivet is usually called the 'reluctance stop'. Now we can get down to the nitty-gritty:-

MMF for inner pole air gap:-

$$B = 1.2 \quad l \text{ (length)} = 2.5\text{mm}$$

$$H = \frac{1.2 \times 10^7}{4 \times \pi} = 955000 \text{ A/m}$$

$$\text{MMF} = 955000 \times 0.0025 = 2387 \text{ amp.turns}$$

MMF for outer pole air gap:-

$$B = 1.0 \text{ (allowing for fringing)} \quad l = 2.0\text{mm}$$

$$H = \frac{1.0 \times 10^7}{4 \times \pi} = 795000 \text{ A/m}$$

$$\text{MMF} = 795000 \times 0.002 = 1592 \text{ amp.turns}$$

MMF for total iron path:-

Because I know that this is a small part of the total MMF, it does not merit detailed calculation; hence:-

$$B = 1.2 \quad l = 150\text{mm approximately}$$

For mild steel, H at 1.2 tesla is 1200 A/m (from Figure 3)

$$\text{MMF} = 1200 \times 0.15 = 180 \text{ amp.turns}$$

$$\text{Total MMF} = 4159 \text{ amp.turns.}$$

Force at the end of the stroke

Just as the armature reaches the end of its travel, the total air gap is 0.5mm. We guess that the value of B will have risen to 1.7 tesla. Actually this was my second guess. The first one was too low.

From the BM curve for mild steel, 1.7 tesla needs 9000 A/m.

$$\text{MMF for the iron} = 9000 \times 0.15 = 1350 \text{ amp.turns}$$

$$\text{Gap } H = \frac{1.7 \times 10^7}{4 \times \pi} = 1.353 \times 10^6$$

$$\text{Gap MMF} = 1.353 \times 10^6 \times 0.002 = 2706$$

$$\text{Total MMF} = 1350 + 2706 = 4056$$

This is close enough to the MMF developed by the coil to be an acceptable approximation. With little fringing on the outer pole now that the gap length is small compared with its width, we can credit both inner and outer poles with contributing to the force, which thus becomes:-

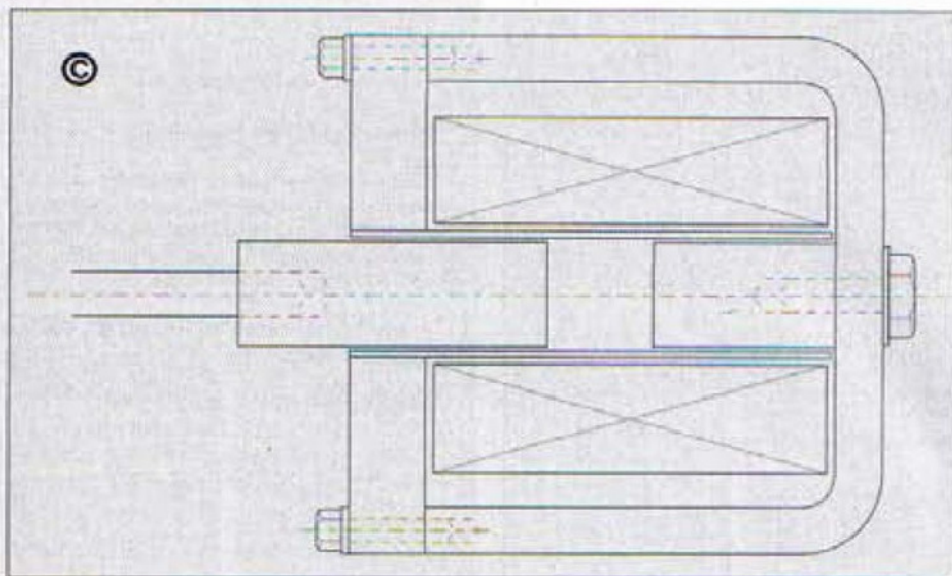
$$0.0406 \times 1.72 \times 360 = 42.24 \text{ Kg.}$$

Designing the winding

We require the winding to supply around 4200 amp.turns when energised from a 12 volt DC source. To begin with we must decide the mean length of a turn of the winding. This is estimated by calculating the circumference of a circle halfway between the smallest and the largest diameter of the coil. In this design we can take this to be 100mm. Next we come to a very useful trick which leads us to the correct wire size in one step. In order to understand it let us calculate the



1. A simple solenoid. The brass sleeve mentioned in the first article is clearly visible.



size of wire needed for a single turn coil. We need a current equal to the total amp.turns, i.e. 4160 amps. Applying Ohm's law, which in this case says that the current (I) is equal to the voltage (V) divided by the resistance (R):-

$$R = \frac{12}{4160} = 2.885 \times 10^{-3} \text{ ohms}$$

The next step is to calculate the cross-sectional area of copper wire which will have this resistance over a length of 100mm. The formula for this is:-

$$\text{Resistance} = \frac{\text{resistivity} \times \text{length}}{\text{cross-sectional area}}$$

The resistivity of copper is 17.24×10^{-6} at 20 deg. C. It increases by 0.4% for each degree. We have to remember to use a system of consistent units, of course and the value for resistivity is in microhms/mm/mm². The calculation thus becomes:-

$$\text{CSA} = \frac{17.24 \times 10^{-6} \times 100}{2.885 \times 10^{-3}} = 0.5976 \text{ mm}^2$$

Now all we have to do is select the nearest standard wire size, but before we do I should explain how choosing the wire size first is the right way to proceed.

Clearly wire of this size would melt instantly if we passed 4000 amps or so through it. But instead of a single turn, let us choose ten turns. Then the resistance

will be ten times higher and the current will be ten times less. However, a tenth of the current in ten times as many turns has the same amp.turns as before. With a hundred or a thousand turns instead of one, the same rules apply. The key thing, though, is that the power (the watts) used goes down as the number of turns rises. Remember that the wattage is volts times amps. More turns means less amps.

So:-

For a constant length of turn and supply voltage, the wire size fixes the amp turns and the wattage goes down as the number of turns goes up. The prudent designer thus provides enough winding space to fit in enough turns to keep the temperature rise to an acceptable figure. The winding space on Figure 4 represents an informed choice. Later we will check its adequacy. However, before doing this we will take a look at a long stroke magnet, that is a solenoid.

A Solenoid Design Study

It will have become apparent from the preceding study that where the length of an air gap is large compared with its other dimensions, the problem of flux fringing arises. The shape of a solenoid has evolved so as to keep this problem under control. Figure 5 depicts a typical solenoid, the key feature being that the air gap is located within the bore of the winding. Solenoids range from small, with strokes of 5mm which measure maybe 20 x 20 x 40mm overall to big ones with strokes of 60 to 90mm with overall dimensions of around 200mm diameter x 200mm long. A typical application for the latter is remote closing of large electrical circuit breakers.

You may recall from the last instalment that a winding of this shape deploys nearly all its MMF on setting up the magnetic field inside its bore. It follows that solenoids are found sometimes with no external return flux iron. However, it is often important to locate the axis of the armature co-axially with the fixed member of the iron flux path, and a flux return path of adequate cross-section is commonly used. Doing this has the advantage that the spread of the return flux is confined,

rather than stretching out in all directions. Stray flux can sometimes interfere with the action of some other part of the mechanism.

Before going on to the MMF calculations, I will draw your attention to a most important detail of the design. Since we are using an outside structure to locate and guide the armature as well as to furnish a path for the return flux, there will be a powerful side force pulling the armature. In theory it could be perfectly centred so that the sideways forces cancel out. In reality this is equivalent to balancing a nail on its point! It is therefore vital to fit a bush to centralise the armature and thus minimise the side force. As we are working steel on steel, the bush, made of brass or something similar is also acting as a bearing. It is helpful to extend the bush, which should be of minimal wall thickness (say 0.3mm) right through the solenoid. It then acts as an armature guide and also stops the latter from rubbing the inner wall of the coil bobbin. One other factor needs some thought. When the armature moves, where is the air going to go? We need an escape path for it if we don't want the movement to be pneumatically damped, though this may be of value in some applications. A 'keyway' along the armature or the stationary member will do.

I have left the most important aspect of the solenoid to the end. Why do we not suffer serious fringing effects? The explanation is that, with the air gap being halfway down the length of the coil, any of the lines of force which start to spread out, i.e. to fringe, immediately lose the benefit of some of the turns of the winding. In the ultimate, a line of force which tried to go outside the entire coil would not link with any of the winding, and thus could not exist. The consequence is that the degree of fringing which takes place is considerably reduced. It doesn't disappear altogether of course, but it is a lot less. To close, we will do some initial calculations on a solenoid with an armature diameter of 20mm and a stroke also of 20mm.

This time we will start by postulating that the gap's flux density (B) is 1.0 tesla. The force will then be:-

$$\begin{aligned} &0.0406 \times B^2 \times \pi \times r^2 \\ &= 0.0406 \times 1.0^2 \times \pi \times 10^2 \\ &= 12.75 \text{ Kg. (at the start of the stroke)} \end{aligned}$$

The corresponding value of H is:-

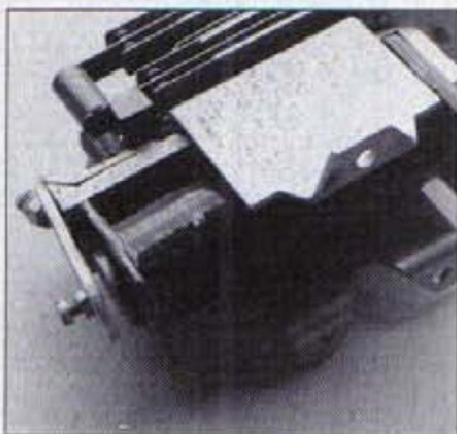
$$\frac{1.0 \times 10}{4 \times \pi} = 795800 \text{ amps/m}$$

and the MMF is

$$H \times l = 795800 \times 0.02 = 15920 \text{ amp.turns.}$$

This looks as if the coil will have a short time rating, but further calculations will have to wait till the next instalment because I have used up all the space which the editor can allow in this issue.

In the next issue we will go into the construction and manufacture of windings and also discuss permanent magnets, which are an alternative way of getting MMF, but without having to use electrical power to do so.



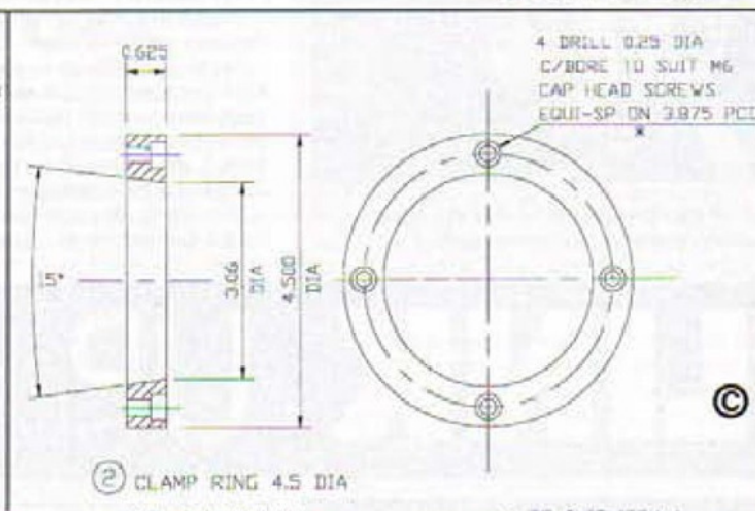
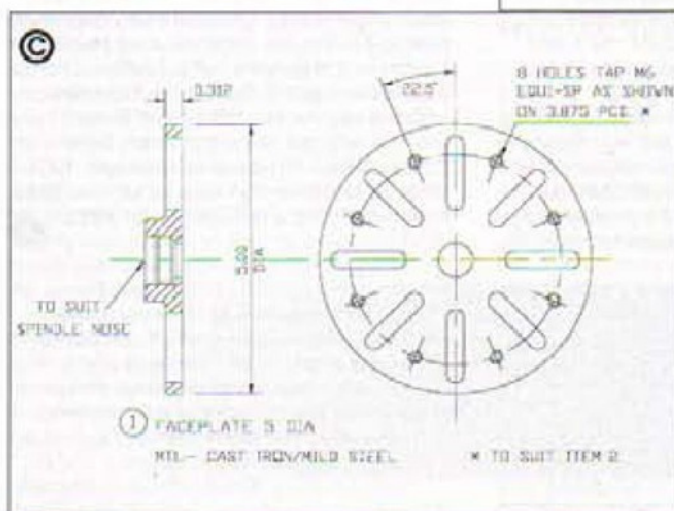
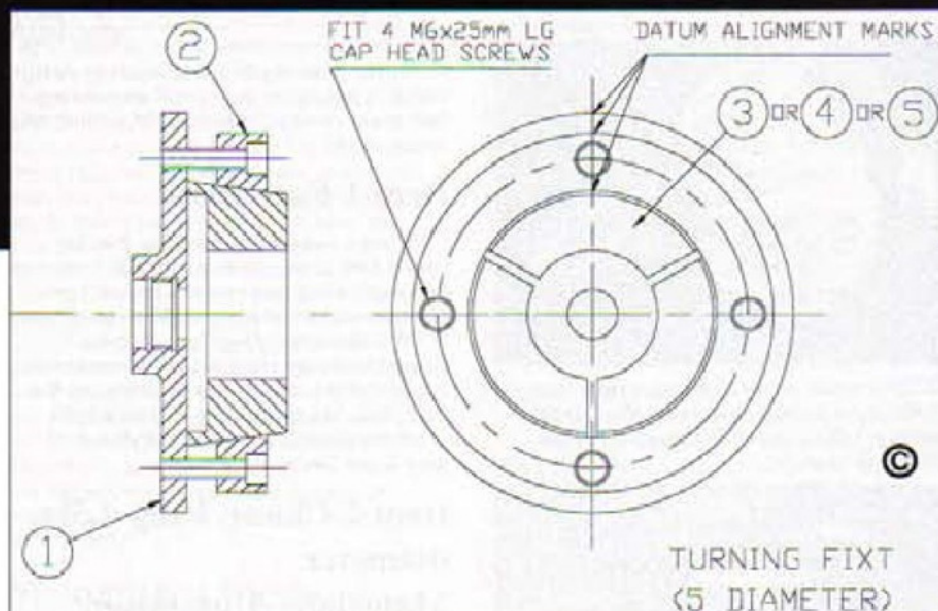
2. A relay of a type which uses an armature which rocks on a knife-edge hinge. The reluctance stud is an adjustable screw on this relay.

MORE ACCESSORIES FOR THE SMALLER LATHE

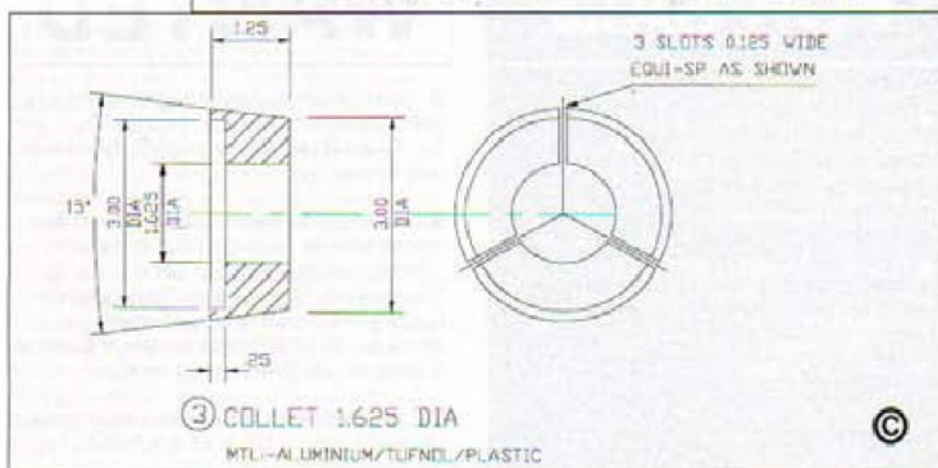
Having previously described devices for holding larger end mills and Morse taper tools on a small lathe, Jack Neave now adds an even larger collet holder.

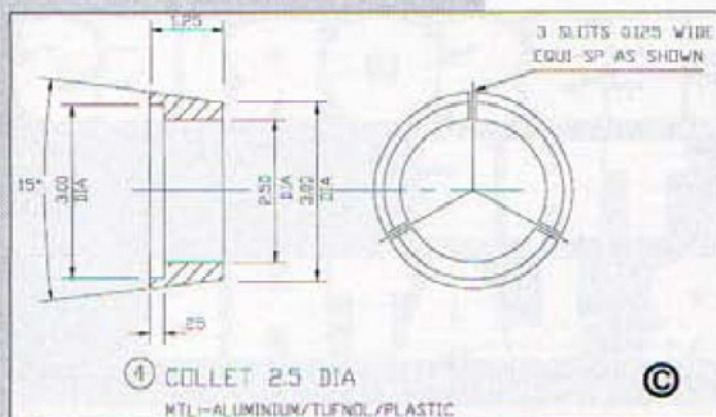
The 'Super' Collet Fixture (Fig. 1)

The subject of an earlier article was 'A Simple Collet Fixture' ('Accessories for the Smaller Lathe' - Issue 51) based on a 3in. diameter catch plate. This design proved very useful when used with smaller end mills, but a larger version of this design was now required. A 'Super' Collet Fixture has therefore been designed and produced, based on a 5in. diameter face



1. The component parts of the super collet fixture. In the foreground the modified face plate and the clamp ring, at the rear three alternative diameter collets, the centre one of aluminium, the other two of Tufnol

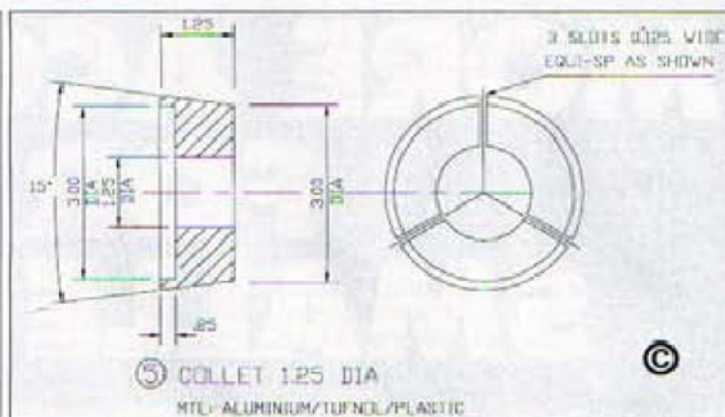




2. The super collet fixture set up in the lathe for a milling operation. The cutter with a 1.25in. shank is clamped in the aluminium collet



3. A flywheel being held in the super collet fixture ready for machining.



plate, to accommodate larger cutters. The assembly drawing shows the larger design which is based on the use of an existing face plate without impairing its continued use as such.

Item 1 Face Plate

Select a suitable existing 5in. dia. (or larger) face plate, preferably made from cast iron. A dividing head should be used to position and drill the eight M6 tapping holes (5.1mm diameter). Only four of these tapped holes are required for this assembly, but the others will always be useful on the face plate. Tap the holes M6. These hole positions must correspond with those of Item 2, the Clamp Ring.

Item 2 Clamp Ring 4.5in. diameter

Material:- Aluminium

Finish machine to outside dimensions. Position, drill and counterbore the four holes to suit M6 cap head screws. These hole positions must match the corresponding M6 holes in Item 1, the face plate. Set up Item 1 in the lathe and screw Item 2, the Clamp Ring, to it with suitable parallel packing between them (about 0.25in. thick). Bore the centre hole out to 3.06in diameter at an included angle of 15

deg. Witness mark the two items so that they can always be assembled in the same orientation.

Items 3, 4 & 5 Collets 1.625, 2.50 & 1.25in. dia.

Material:- Tufnol, Aluminium or Plastic

From bar stock, face the end and machine the end recess. Centre drill & drill a 0.375in. dia. hole through, part off to length. Repeat this procedure for the second collet. Fit the first collet on a suitable mandrel and turn the 15 deg. included angle taper. Use Item 2, the Clamp Ring, as a gauge and try to get this between 0.062in. and 0.125in. from the front face of the collet. Repeat this procedure with the second collet.

Set up the first collet blank (Item 3) in the lathe using Items 1 & 2, taking care to line up their witness marks, as shown in the assembly drawing. Drill and ream the centre hole to 1.625in. (or required) diameter. Make a witness mark on the collet blank to line up with Items 1 and 2. Repeat this operation with the second and third collet blanks (Items 4 & 5) but make the centre bore 2.50in., 1.25in. (or required) diameter. All three collet blanks can now be slit into three segments using a 0.125in. wide cutter.



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FOR SALE

● Very large quantities of 18DP changewheels, internal and external thread gauges and all sizes of dies for Coventry die heads.
Tel. Derek 02083 933302

● Five division plates for Wyssbrod 125 automatic wheel and pinion cutting machine £50 (fraction of original cost).
Tel. J. Hammond 0121-249-1520 (Moseley, Birmingham)

WANTED

● Change wheels for a Raglan 5in. Little John lathe: 32t, 36t, 45t, 48t and 52t.
Tel. David Read 01344 454743 (Bracknell) day or evening

● Drawings/dismantling information for the spindle of an Eagle Mk2 surface grinder. Are the makers, Victa Engineering, Hamworthy, Poole still trading but under another name?
Tel. Tony 01670 823232 (Northumberland)
E-mail: tony@lindisun.demon.co.uk

● Can anyone help me with a new project, please? I need a piece of machinery

needing repair, TLC, completing or whatever.
Tel. Ken Nunn 01284 704848 (Bury St. Edmunds)

● M.E.W. back numbers 38 and 52.
Tel. Ian Gurton 01582 713770 (Hertfordshire)

● I would like to make contact with readers who own EMCO FB2 milling machines and who have made improvements or made new attachments/accessories.
Jaques Laporte, 8 Impasse de Clos, Villemartin, F-91150, Morigny-Campigny, France Tel. 01-60-80-01-79
E-mail: jactosh@free.fr

SCRIBE A LINE

Constant Velocity Joints

From Anthony D Rhodes, Berkeley, California

In Issue No. 60 Harold Hall discusses the need for constant velocity transmission of rotary motion in the driveline, or 'flexible coupling', between the change gears from the hob drive and the worm drive of the work head on the College Engineering Supply Gear Hobbing Machine.

He is absolutely correct about this requirement because, if the gear blank speeds up relative to the hob, the hob will cut away excessive material on one side of the gear tooth and insufficient material on the other side, and when the gear blank slows down, the sides with excess and insufficient cutting will be reversed. These failures of constant relative velocity between the hob and the gear blank will result in a non-involute curve on the working surfaces of the gear teeth which will produce gears incapable of transmitting constant velocities within the mechanisms of which they are intended to become a part.

Mr. Hall seems to believe that he has provided a constant velocity driveline. 'Tis not so!

He refers to Figure 4 on page 34, saying that "a constant velocity output is achievable providing the details in Figure 4 are complied with", leaving the impression that he has complied with the specified details. I have no complaint with conditions 1 and 2, they are merely a matter of proper construction of the driveline. But condition 3, parallelism of the input and output shafts, is achievable in only one situation, that is when the hob being used has the same helix angle as the gear being cut.

In all other cases the shafts MUST be non-parallel. All spur gears will have a helix angle of 0 deg., requiring the work head to be set over at the hob helix angle, and most helical gears will also not match the helix angle of the cutting hob.

What is required is a true constant velocity universal joint, such as the Rzeppa-type used on a large number of front wheel drive cars. In this type of joint there is a one-to-one relationship in rotational angularity between the input and output shafts of the joint. Every fractional degree of input rotation is matched in output rotation. This condition is necessary for generating-type gear cutters, which includes hobbing machines as well as gear shapers and planers. The Rzeppa joint is not the only c-v joint which could be applied to the application at hand, it's merely one that comes to mind which is reasonably compact, a distinct requirement for this hobbing machine. Unfortunately I have not been able to find a commercial source for Rzeppa or any other c-v joints in a size appropriate to this machine, nor have I

found plans for do-it-yourself construction of c-v joints. If any reader knows of any commercial sources or d.i.y. plans in a size appropriate to this project it would help greatly if they could inform all of us.

Cutting sheet metal

From Geoff Bradfield, Victoria, Australia

Harold Hall's article on cutting sheet metal in Issue 62 is very interesting. May I add an observation on jig saws? I learned from a friend, who happens to be joiner, that there can be advantages in cutting with the jig saw from the underside of the work. You must be careful to keep the sole plate in close contact with the material all the time but, with a little practice, the saw cut is easily adjusted in relation to the line, whether it be straight or curved and saw dust falls out of the way. Another plus is that the smoother cut is on the face side. The material and the off cut must both be adequately secured as two hands are necessary to hold the saw. As with all power tools, take particular care where your fingers are positioned, as they are out of sight at the critical time.

Securing a bush

From J R Sutton, Belfast

I read with great interest the letter from Ted Wale, Porters Lake, Nova Scotia (Issue 59) on balancing the design of a salvage. It took me back to when I was an apprentice in one of our larger textile mills. The method he described was regularly used for bushing gear wheels and pulleys, though we did not have the luxury of using Loctite; in fact rather than using pins for retaining the bush, it was our practice to use grub screws of a suitable size because they could be salvaged and used the next time round.

As an apprentice, the first time I was given this job to do, I fitted the bush successfully and then proceeded to pin it with two grub screws, one at 0 deg. and the other at 180 degrees. On presenting the finished job I was mildly rebuked for having pinned it incorrectly. It was explained that I should have pinned it as shown in Figure 2 of Ted Wale's article (i.e. with three axial grub screws at 120 deg.) and not as I had done. I asked why, but no-one in our workshop was ever able to give me a satisfactory answer. Being then young and enthusiastic, I raised this question many times during my technical education, but still no-one could answer me. Why should we adopt one method as opposed to the other? I now wonder whether any of your readers can supply the answer to this question which has been lying in the back reaches of my mind for so long. "It's wonderful the unanswered questions one finds there".

Etching printed circuit boards

From Clive Noakes, Halesowen, West Midlands

Recent issues have made much of the difficulties of evenly and quickly etching printed circuit boards. For the convenience of those who have restricted time and want etched boards but without hours of construction work, I offer the simplest and most effective of tips which I learned from a BBC engineer twenty-odd years ago.

Technique

Support the PCB copper side down in the etchant so that there are a few millimetres of clearance underneath for debris to fall away. That's all there is to it. Upside down is the key.

Supporting the board

Plastic clips or nylon bolts and nuts could be used to support the board under the surface but I have always floated boards on the surface tension of the etchant which is a trick easily mastered. Having donned the Marigolds (or plastic bags!) grip the PCB lightly by the edges with your extreme finger tips and make sure that the surface is evenly wetted when the board is carefully laid on the surface, starting at one end so that air bubbles are not trapped underneath. If the solution bursts over the edges of the board while you are lowering it onto the surface you will have to take it off again, wash off in water and dry the 'top', edges and your gloved fingers again before the surface tension will support the board. Incidentally, it floats easier if the edges are smoothed with 220 or finer abrasive paper.

Etchant

A saturated solution of ferric chloride in warm water is convenient as it generates no gas while etching. It is easy to get from electronic component suppliers, and can be used at any temperature from ambient to comfortably hot (50 deg. C). I sit mine on the radiator while etching, hopefully having remembered to pour out the solution half an hour earlier so that it can warm up and any froth can burst. Freshly dissolved solution should be left for an hour or so to let entrained air escape.

Etching

Having submerged (or floated) the board it should be taken out of the solution after a few seconds to see if any air bubbles or greasy patches are preventing proper wetting of the areas to be etched. If bubbled bits are wiped over with a finger to wet them they should be OK when submerged again.

No further attention is required until the job is done, when usually the shadow of the copper track can be seen through the back of the board while it is still floating. You can of course lift the board off at any

time to have a look at progress. With warm fresh etchant only a few minutes are needed - it really is amazingly better than swilling about face up under the etchant, with or without mechanical assistance.

If a trapped bubble has left an unetched blob of copper, knife, file or route it away rather than put the whole board back into the etchant or you may get under-cutting of fine tracks.

Usage

I have used this technique for hundreds of boards and I would suggest that a litre of etchant (about five pounds sterling) would last for at least a square foot of board, probably two, with no keeping problems over many months, if not years. Well-used etchant will go black with much sediment which should be decanted off. When etching times get excessive (your decision) chuck it and get some new! Ferric chloride is of course poisonous, very aggressive on many metals and stains fingers if touched, so plastic containers and plenty of water to wash things are golden rules.

Being water based, this etchant allows you to use almost any paint, adhesive tape or etch-resist transfers as masking to patch or even draw your circuit. The corollary is that any grease is taboo so a wash in detergent (for the PCB) before etching is advised if there is any doubt.

On centre drills and bevel gears

From Peter Dawes, Orange, New South Wales

1. Philip Amos' article on mandrels (M.E.V. Issue No 64, p45) showed plain mandrels with a conventional centre hole at each end. However, when a mandrel is used with a tailstock set-over by more than a couple of degrees, the centre holes do not fit properly on the centres.

Now, I once bought some centre drills that had a concave 60 deg. taper that produces a 60 deg. convex-sided taper in the workpiece, and one that automatically fits a straight-sided centre for any angular offset within reasonable limits. For large angles, the centre does not contact the sides of the hole at the same point on each side and this gives rise to a very slight twisting moment, the effect of which is to try to bend the arbor. It is still, though, a vast improvement over a straight hole.

This type of drill should always be used for work with offset centres. The trouble is that I've lost or broken the ones I had and they cannot be ground in the home shop without special equipment. Now I don't know where to buy them again or what they are called. Can anyone help?

There is another way of dealing with offset centres and this is to use a ball-ended centre, fitting into a conventional centre hole. Still another version, and on the same theme, is to use a loose ball in a standard hole but with a cup-shaped centre.

2. In Issue No 60 p34, Harold Hall says that bevels can be cut by tilting the work spindle and otherwise cutting them identically to spur gears. Unfortunately they will be very crude gears. True bevels

CANNOT be cut by hobbing - full stop. The reason is that the tooth width on a bevel varies from outside to inside and a hob must of necessity cut a fixed tooth space and fixed tooth width. The teeth can only mesh together properly at one point on the face. Jacobs showed pictures of bevels that had very obviously skinny teeth on the inner end and also showed pictures of skew bevels that were probably cut by milling with a single point form tool (M.E. - 11-9th Mar, 1976, p281) but he didn't elaborate on how he made them.

Another evening class and a cry for help

From Richard Masters, Sawbridgeworth, Herts

Harlow College run a NVQ Level 2 course in workshop practice. It is held on Thursday evenings from 6.30 to 9.30pm. The course tutor is Ian Jackson, and the college can be contacted on 01279 868000. The course is run on a modular basis and students can start at any time of the year. It covers bench fitting, turning, milling, and arc welding and is run in a well equipped workshop with model engineering and larger sized machines. Some students have been attending for many years. It also happens to be the former place of work for Bob Loader, who is a regular contributor to your magazine!

I am about to purchase a Boxford CNC slant bed lathe, model 240 TCL. It is working mechanically, but the BBC computer, which provides the numerical control, is not! Has any one converted this type of lathe to run on a PC? Is it a simple job to change computers and get new G code software? Alternatively, does any one have a working BBC Master computer, or know where I might obtain one? I would be interested in any help or advice. My phone number is 01279 723088 and fax number is 01279 427337.

Materials for electromagnets

From Vic Varga, Oakville, Ontario

I have built an electric clock known as the EUREKA, based on measurements taken from the original and an article from *Model Engineer* dated 1949. I had encountered problems with the electromagnet which should provide sufficient motive power on a 1.5 volt battery. The core of the magnet is supposed to be 'soft iron'. As none of us here knew what that was, we tried several grades of readily available steels, as-made and heat treated, but failed to match the performance of the original, all else being equal as far as we can ascertain. Presumably soft iron is a low- or no-carbon spec. Can anyone help us by giving the proper spec. for soft iron and perhaps the names of suppliers? We need only four pieces, $\frac{7}{16}$ in. diameter and 4in. long. We are quite used to paying the Post Office exorbitant charges to get 'stuff' over here, but this should not weigh that much!!

P.S. what is the modern/currently used material for cores of electromagnets?

By coincidence, our contributor Tony Claridge touches on this subject in this issue, suggesting that heat-treated mild steel should suffice, but has also provided us with the information that a company called Goodfellow (Tel. 01223 568068) can supply small quantities of a wide range of materials required for scientific purposes, and may have something suitable. They are based in Cambridge and have an office in Philadelphia USA. They have a Web site at www.goodfellow.com.

Tool holder article - some corrections

From John Brittain, Doncaster, South Yorkshire

I must first thank Messrs Coote and Swallow for their kind comments concerning my article on 'Avoiding the use of packing' and hope that they find the system worth making.

Inevitably, when committing oneself to print, one runs the risk of errors arising from a number of sources. Perhaps therefore, with the Editor's permission, I may be allowed to point out one or two of the more glaring variety.

1) In diagram 3, the height of the toolpost has unfortunately been clipped from the drawing and should have been shown as 65mm.

2) In diagram 5, the dimension reading 'centre height' should of course have read centre height to cross-slide (my omission, I'm afraid). Similarly, in diagram 5 entitled 'rear toolpost', it is patently obvious that the device illustrated is a front toolpost.

Dividing head puzzle

From Dr Geoffrey Walsh, Edinburgh

Last year I bought a used dividing head from a small engineering concern in Gloucestershire. There is a plate for direct division with 18, 20, 22, 24, 26 & 28 holes. The worm has a ratio of 75:1. I have been told that this is quite an unusual figure.

The device bears the label:-

Brown & Sharp Mfg. Co.
Providence, R.I. USA.

The number on the label, 3325, suggests that there was a long production run of this type. The plate attached to the worm has been lost, I believe it had just one circle of 20 holes.

From the same concern in Gloucestershire, I have also now acquired a Myford dividing head. There is no provision for direct division, but the worm ratio of 60:1 seems more suitable for many purposes, the mandrel is hollow and there is a tail stock. Neither of these features, useful for minor engineering projects where versatility is often important, is present in the Brown & Sharp head.

Was this Brown & Sharp dividing head designed for a special purpose? Perhaps it came over during WW2 as part of Lend Lease, when probably many American machine tools arrived, in the prelude to D-day? A Myford chuck fits the spindle.