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AUGUST 2014

THIS MONTH'S **FEATURE PACKED** ISSUE IS **BURSTING** WITH **IDEAS!**

COVER FEATURE

THE FRAME MAN KEN SPRAYSON ON MOTORBIKE FRAME DESIGN

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On the Editor's Bench

On my Bench

Not unexpectedly, if you look at my bench this month, you'll see a lathe. It's a fifteen year old mini-lathe that's suffered the indignity of almost continual 'improvement'. I mention it this month as I have just completed a major project to fit a half-horsepower 3-phase motor on the back. The motor drives the spindle via a poly-v belt, and has seriously upped my capacity for producing swarf, if nothing else. I'm going to put the details of the conversion, including programming the inverter, which may be useful to owners of other machine tools, on the website soon.

The Frame Man

I know a number of readers of *MEW* customise and even build their own bikes from scratch. I was recently talking to a reader who broke a generous fistful of UK national motorcycle speed records on bikes 'cobbled together' in his shed. Custom bikes will always have a fascination for hobby engineers, whether we make them or just spectate. So, in this issue I'm delighted to bring you an article by Ken Sprayson on the design of motorcycle frames. His autobiography, *The Frame Man*, tells how he made 'specials' for the likes of Mike Hailwood and Geoff Duke. He went on to work with John Ackroyd and built the frame for Thrust 2, in which Richard Noble broke and held the land speed record for fourteen years. It's particularly good to be able to include some of Ken's historic photos of classic frames such as the Norton 'featherbed', and a pleasure to read someone acknowledged as a 'master of the art' offering advice to the 'kitchen table designer'.

Bike fans can look forward to our next issue, which will feature a contrasting article by Shaun Wainford on the very different approach he takes to producing his custom bikes, such as the *Barbarian*, largely using a CNC approach.

Taking a Break

Readers will see that Terry Gorin's Unimat series has taken a short break and Marcus Bowman's beginner's CNC series will be doing the same. This is to allow me to print some excellent articles by authors whose work has been waiting in the wings, but don't worry – Terry will return next month and Marcus is already working on a more advanced project (again with a motorcycling flavour) for those who have been following his series.

Stepperhead

Some of the content that has been on hold includes the concluding parts of Alan Jackson's acclaimed *Stepperhead* lathe. The series broke off in issue 210 having just introduced the lever locking topslide. Over the next two issues we will complete this description, and later Alan will return to describe the milling head and review his overall experience in using Stepperhead. I also plan to upload some further technical and setup information on the lathe to the model engineer website.

Bristol 2014

The next major exhibition of the year, is Bristol Model Engineering and Hobbies Exhibition which is to be held at Thornbury Leisure Centre near Bristol on 15th to 17th August. Expect to see a wide range of models as well as a trade exhibitors.

As 2014 marks 150 years from the opening of the Clifton Suspension Bridge, it's been arranged to have a 16-foot model of Brunel's famous bridge. There is also the promise of a Ffestiniog Railway Hunslet and an Aveling and Porter steam roller in steam, as well as the usual range of radio control and other demonstrations. For more information and advance tickets, visit the website at www.bristolmodelengineers.co.uk/Exhibition/exhib.htm

SNO CAT

After I highlighted the Sno Cat as my personal favourite at the Harrogate exhibition, I was contacted by the builder, Alan Spencer. He told me that Peter Fuchs, the son of the explorer and leader of the Trans-Antarctic Expedition, Sir Vivian Fuchs, had stayed in touch with him throughout the project. As well as information from the family archive, the Tucker Corporation in Oregon and the BP archives gave him great assistance. The picture shows Alan on the right and Peter on the Left, with the model in the year it won a 2nd certificate at Harrogate.

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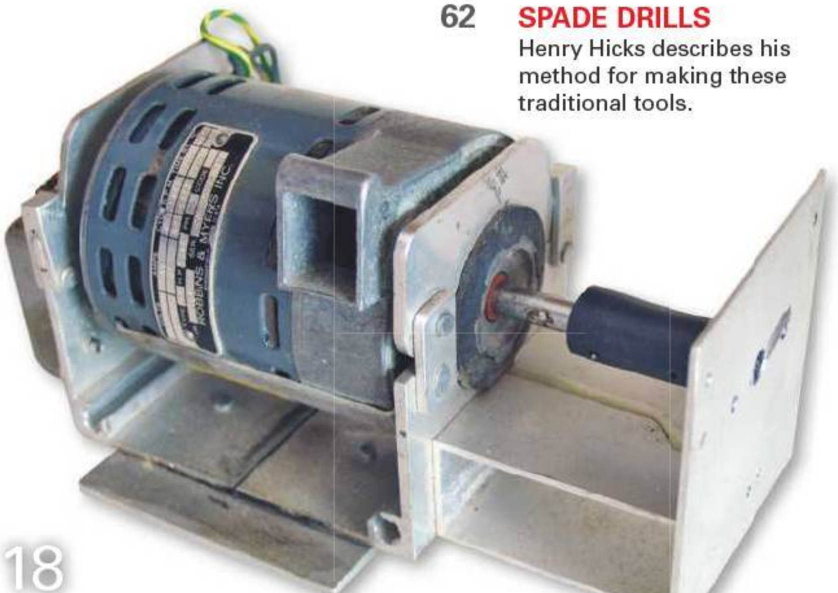

See page 58 for details.

Coming up...

in the September issue

AIMING HIGH

Darren Conway challenges us to work to tight tolerances with his high-precision live centre.

PLUS Albert Bishop discusses the use and care of measuring instruments, Terry Gorin describes the gear train addition to his Unimat SL, Tony Weale uses toothed belts to slow down an Asian 9x20 lathe and lots more to interest every hobby machinist.

Regulars

ON THE COVER

This Reynolds Velocette frame was made for Geoff Duke in 1958 by Reynolds' master frame builder, Ken Sprayson.

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Rotary Table

A simple Rotary Table by T. Daish. This straightforward design is notable for its low profile.

Rear Toolpost

A retracting rear toolpost by Stan Bray. A useful accessory to extend the cross slide of most lathes and carry parting or other tools for second operations.

Passenger Comfort and Safety

Bill Perrett of Southampton DMES wrote a history of 25 years of model railway passenger car development. It appeared in Model Engineer between December 1987 and July 1988. The series includes detailed drawings for the construction of a 5 inch gauge driving/ passenger car with brakes and other refinements.

PASSENGER COMFORT AND SAFETY

Bill Perrett continues his description of Southampton D.M.E.S. passenger vehicles

Join the Conversation

Be part of one of the liveliest and friendliest hobby engineering discussion boards on the internet. Hot topics on the forum at the moment include:

- *Starting out with a milling machine*
- *Homebrew rotary table software*
- *Building the James Coombes (with chips)*
- *Using riffler files*

And let us know what you are up to in your workshop through the ***'What did you do today?'*** thread!

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Designing Motorcycle Frames

Known as 'The Frame Man', Ken Sprayson is a legend among motorcyle frame builders.

It would appear from the odd mention in past issues of *MEW (and on our web forum, Ed.)* that there are among us a number of motorcycle enthusiasts, some of whom would have an interest in making their own frames to create a 'special'.

A 1958 Reynolds Duke Velocette frame of duplex design with a single downtube.

Originally, frames were constructed with traditional bicycle methods of tubes hearth brazed into cast or forged lugs that provided the steering head, bottom bracket etc., that is the joints. With the advent of all welded frames in the 1950s and the availability of home welding kits, frame building became something that could undertaken in the home workshop. (An article by the author on tube bending appeared in *MEW* issue 146). For the amateur in the home workshop, his 'design' is usually arrived at by propping up the wheels and balancing the engine on a box between them, before shaping the tubes around them. In a way, this is how the professional designer begins, except that while the 'one off' man works with actual components, the professional works with pencil and paper. While this may seem too academic, a properly made drawing will show the true relationship and the correct layout for the important items such as head angle, trail, wheelbase and so on, which will be explained later. It is also much easier to erase a line on a drawing than have to cut out a tube that has been located incorrectly. Furthermore, one has a permanent record of the work done, and if after trial of the finished project, modifications are required, these can be worked out before carving up the original.

We must, therefore, start our project, not in the workshop but on the kitchen table, with a clean sheet of paper. For the enthusiast the object of such an exercise is usually to build something that he considers better than the standard machine as supplied by the manufacturer, often for a sporting activity. Such things as being lower, lighter and better handling, hopefully being achieved.

First step is to establish the scale that will be used. This can be half, quarter or whatever suits the size of the paper, providing it can be measured off to full size for your project. To the engineer, scaling from a drawing may be contrary to his teaching, but in this case it is the way things are done. To start the design, wheel size is determined and the wheels, complete with tyres, drawn in their respective positions, setting the wheelbase. This would range from 52ins to 56ins, depending on what activity the finished project will be used for. A trials bike will normally have a shorter wheelbase than a racing machine, to enable it to manoeuvre on a trials section more easily. Other considerations on wheelbase, would be the

Fig. 1

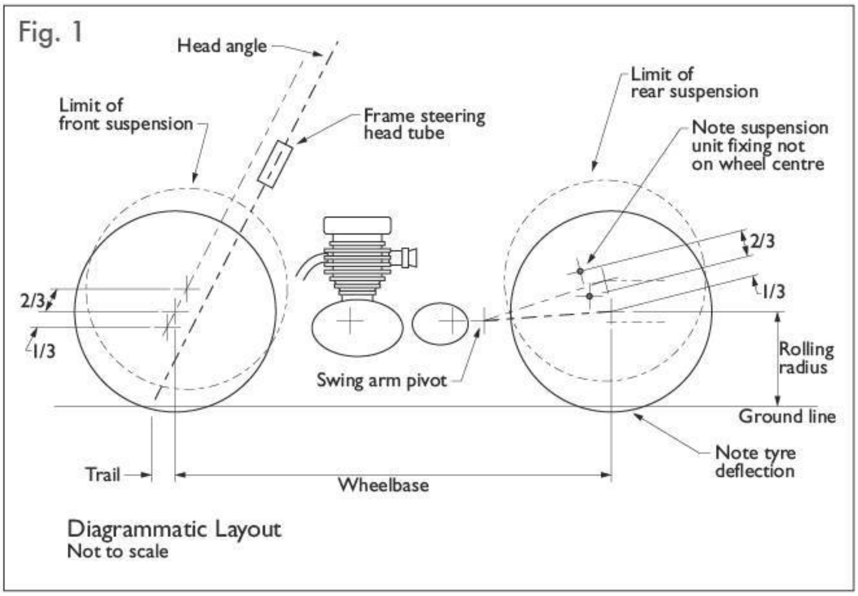
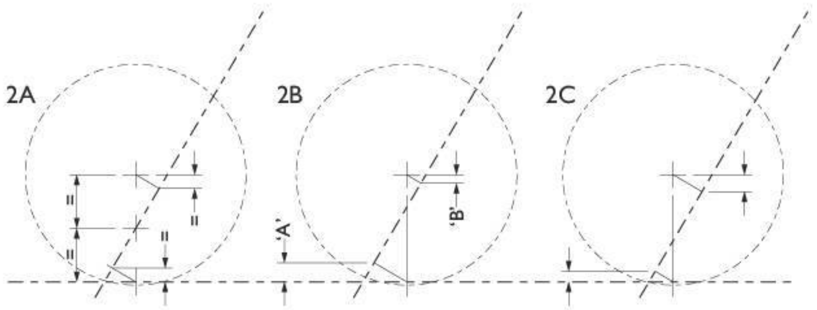


Fig. 2



Theoretically if the wheel is turned through 90° as in 2A, the rise of the tyre contact patch equals the fall in the wheel centre. In 2B the difference between 'A' & 'B' must be taken up by the frame lowering, resulting in the weight of the bike & rider tending to turn the wheel to reach its lowest point, which will affect steering stability. In 2C the opposite effect results in the steering tending to straighten up when cornering.

machine's size (125cc, 500 etc.) and also weight distribution. The latter is often only determined after riding the finished project, though 50/50 front and rear, with the rider seated in a riding position is usually the aim, with any bias being towards the front. In practice, even with the engine as far forward in the frame as possible, it is difficult to get too much weight forward.

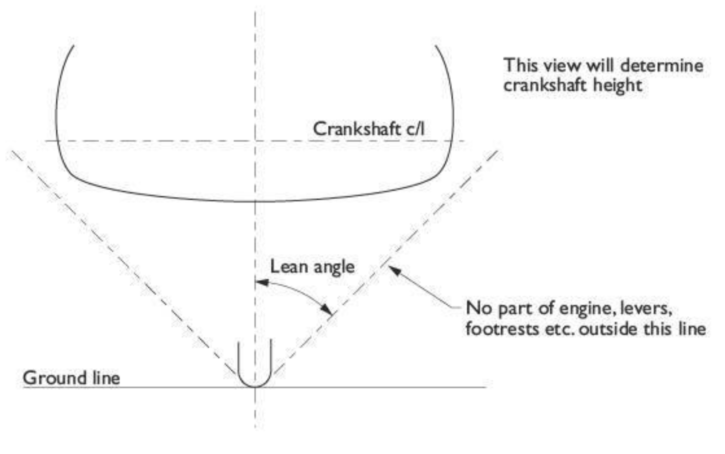
With the wheels drawn in, what we next need to know are the limits of travel of the front and rear suspension, from full extension to full compression. As a datum, from which all measurements are taken, a 'static' position is established. This is with the machine stationary and the rider seated. Motorcycle suspension is predominantly working on the first two-thirds of compression, 'full bump' only occurring when hitting such as potholes, or in this day and age, 'sleeping policemen'. The static position is therefore determined as being ⅓ of the suspension unit's or the front fork's full travel. From the static position drawing in ⅔ to full compression will give the maximum height to which the wheels will travel. Allowing ¾ inch clearance for tyre fling at speed will determine the lowest position for the mudguard and rear frame tubes and at the front, the fork yokes. When using a propriety front fork, the height of the bottom yoke on the finished layout would have to be arrived at by first measuring the fork length and its travel. It is often found with a telescopic fork that there is no preload on the springs and to allow for this, static is usually determined as half of the forks travel instead of the ⅓ for the propriety units used on the rear. As rear wheel travel is determined from the position of the rear swinging arm pivot, this can only be finalised after positioning the engine/gearbox, (**fig. 1**).

The next thing to look at is steering geometry, which for the frame design will be set by the angle of the head tube. Steering geometry is determined by three basic dimensions: the head angle, the trail and the rolling radius of the wheel. Head angle and trail provide the castor action that is necessary to keep the wheel pointing in a forward direction. The amount of trail will determine the sensitivity of the steering, more trail gives heavier steering, reducing the trail will make the steering lighter. Other factors will also affect the handling qualities of the bike when ridden, factors which are best illustrated by **fig. 2**. Head angles vary on a range of manufacturer's machines, but for our 'special', 27 degrees is a good compromise.

Having drawn in the basic geometry, attention can now be turned to the engine position. For this, a rough outline of the engine needs to be drawn to the same scale as the basic layout. This will determine the major pickup points and also the general outline round which the frame tubes will be positioned. Don't forget the carburettor and the exhaust pipes! Also needed is a front view of the engine sufficient to determine its width, usually just the crankcase outline. This will show the lowest point at which the engine can be positioned, determined by the angle of lean to which the bike will be subjected. Lean angle can be extreme as seen in the motorcycle racing on television, but for general riding an angle of 55 degrees would be quite adequate. This is shown in **fig. 3**. For the lateral position, as said, the engine should be as far forward as possible, taking into consideration the clearance of the front wheel on full compression and the aforementioned exhaust pipe(s). Engines can be unit construction, where the gearbox is incorporated into the crankcase, or the gearbox can be a separate item. In either case, the rear swinging arm pivot should be as near to the final drive sprocket as possible. This pivot should be on a straight line between the final drive and the rear wheel spindle, the pivot of course being part of the frame construction. In determining the engine position, the chain line must also be taken into consideration, as the final drive must line up with the rear wheel sprocket. The chain line must also be clear of any frame tubes. The rear swinging arm can be a simply designed 'fork', but must be of adequate size to resist torsional loads imposed by the rear wheel. Tube in the region of 1¼ inches diameter by 14swg is usual for this component. This should complete the basic layout of the major components of the motorcycle which have to be held together by the frame.

Frame design will be to a certain degree, a matter of choice, so, what are the basic requirements? A frame's basic function is to hold together the motorcycles working parts, but this must achieve the optimum amount of rigidity and torsional stiffness in the final machine. From the earliest days of the motorcycle, the engine was often used as an integral frame member. As far back as 1918, an Institute of Mechanical Engineering member wrote a paper describing the lack of rigidity in this

Fig. 3



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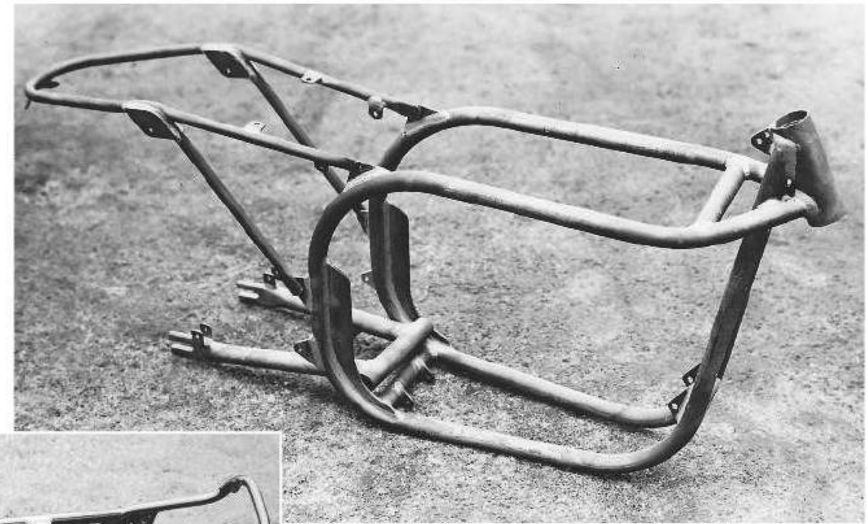
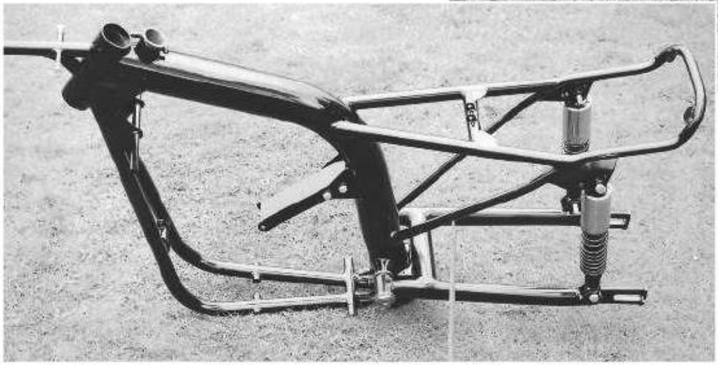


The original Norton Manx Featherbed Frame 1951. The first all-welded quantity production frame.



A 1960 Geoff Duke frame the large frame tube was used as an oil reservoir.

type of construction, where any rigidity relied on the mechanical joints retaining the engine. Therefore, however the engine is held, whether in a cradle or under-slung, the frame should still have the aforementioned properties without relying on the engine as a member.

Although aluminium 'chassis' are the most common for today's larger motorcycles, steel tube is still favoured for the 'special'. For duplex tube frames such as the Norton 'featherbed', diameters range from 1¼ inch O/D for the heavier machines to1 inch for lightweights. Where a single top or down tube is used, these would be of larger diameter, from 1½ inch upwards depending on the design. Rear frame/seat tubes can be ¾ inch o/d. Gauge thickness is dependent on the material's specification and the welding medium. 16swg (0.064 inch) would be satisfactory for material of tensile strength in the 40 – 45 tons per square inch range. For mild steel (<26 tons per square inch) the gauge should be increased to 14swg. (0.080 inch). Referring back to the drawing, the tubes should be drawn in to join up the positions already laid out, head tube, engine pickup locations and rear suspension mountings. If a cradle type frame, make sure there is clearance for engine removal.

Design, materials and welding medium will all have an effect on the fatigue life of the finished structure, Fatigue failure results from constant stress reversals at changes of section in the structure's design. This can be best illustrated by a saw cut or notch in a length of material. When a bending load is applied at the ends, the stress that would normally be evenly distributed along its length is concentrated at the notch or cut. Constantly reversing this stress will result in eventual failure at that point, the severity of the 'notch' and the number of reversals (millions, for a motorcycle frame!) determining fatigue life.

Taking this into consideration, it can be seen that where the lighter gauges are used, irrespective of tensile strength, the welding medium needs to be conducive to making the change of section, (the welded joint), as compatible to the material thickness as possible. This is especially important with the light gauge higher tensile materials. For this bronze welding, where the ductility of the weld fillet is an asset, is recommended. Arc welding, both stick and MIG/C02, will produce a much harder fillet often with a pronounced notch at the edge. This would only be used for welds on mild steel, where the thicker material reduces the change in the cross sectional area from the parent material to the weld fillet.

Having completed the design, chosen the material specification and produced any tube bends, a means of holding the component parts in position for welding is needed. Unless a quantity of frames is to be built, a simple fixture is all that is required. Essentially, a flat and level base, on which a centre line is marked is the first requirement. From this base, a means of positioning and holding the head tube is required. This must be held vertically square to the base, on the centre line and at the correct angle. A simple method of achieving this is shown in **fig. 4.** To hold the main frame tubes and to control the width, simple 'angle plates' are required, which for one offs could even be wood,

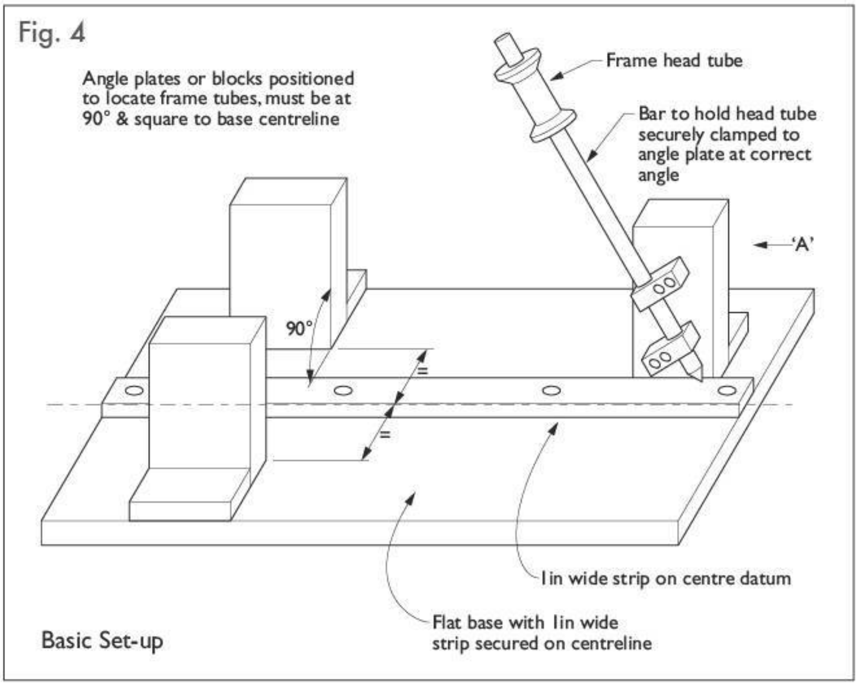
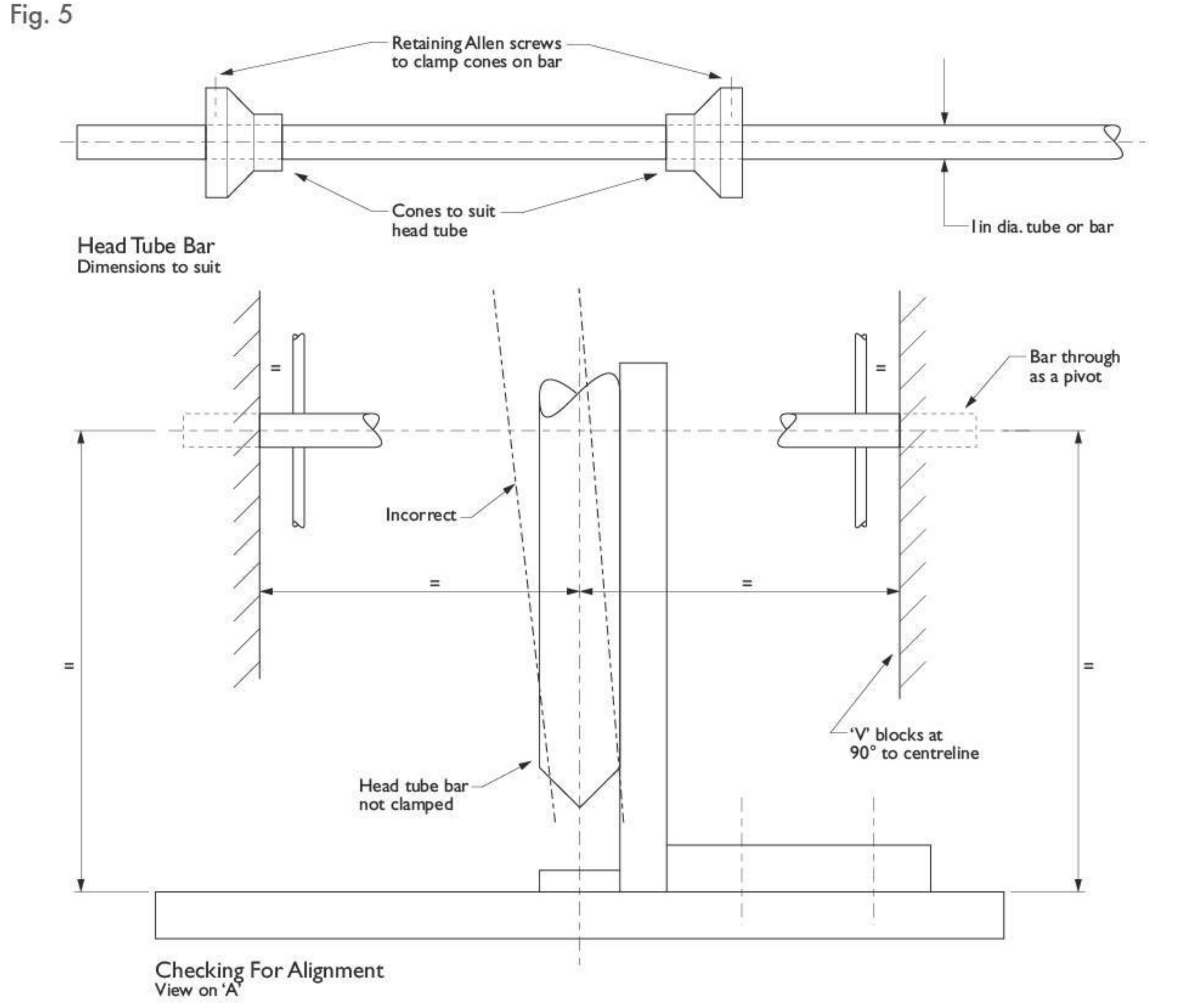


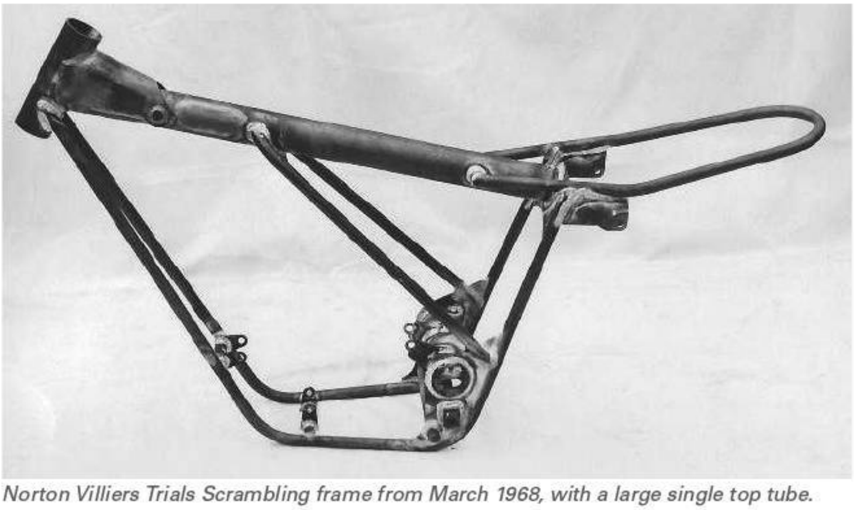
Fig. 5



but must be positioned from the centre line. All these positions would be scaled from the drawing as previously mentioned, the most important thing being to maintain the alignment of the steering head, through the frame and square to the swinging arm pivot. Having located all the frame tubes and tack welded all the joints, the frame can be taken from the fixture and fully welded. Included in the fixture there should be at least one of the engine mounting positions. After welding all the frame joints, the remaining engine mountings can be located using the engine itself as a jig. This is done last as natural contractions and distortions during welding can be expected.

The final requirement is to check the finished frame for alignment. The essential for this is the squareness and centring of the steering head with the swinging arm pivot. This can be checked by mounting the frame on a bar through the swinging arm pivot, resting on v-blocks, positioned on your base relative to, and at 90 degrees to, the centre line. With the pointer bar that has been used to initially locate the head tube replaced, the vertical accuracy of the steering head can be accessed. Jacking the frame up to the head height measurement from the drawing, the head angle can also be checked, though this need only be to within about ¼ degree, (**fig. 5**).

Any reader undertaking this project will soon find that this article will only give him the basics for setting up, the actual frame design being left to his own ideas. Should he require further information or have queries, it is suggested that these could be answered through the medium of Scribe a Line, where I will endeavour to give answers. ■



Norton Villiers Trials Scrambling frame from March 1968, with a large single top tube.

On the Wire NEWS from the World of Hobby Engineering

Workshop Opportunity for Yorkshire Model Engineers

Scarborough and District Model Engineering Group, are based at Yorkshire Coast College. Ted Fletcher tells me they have concluded yet another successful year. Apparently they hire the workshop for a series of two hour evening sessions, ten before Christmas and ten in the New Year and share the total cost. During the last season 2013/14 members have been busy making special parts for off road cars, locomotives, traction engines, and tools and equipment for their home workshops. Ted says they are a mixed bunch of like-minded people with a notably wide age-range from 19 to 80, all busy doing their own thing. The college has a dozen industrial lathes (some brand new) and three milling machines as well as surface and cylindrical grinders, a bending machine and power guillotine, up to 6mm. They also have welding equipment available to use at no extra cost. Most years they have one or two members deciding to have a rest year, due to other commitments, so should any reader be interested in joining the group please contact Ted at **g4egb@yahoo.com** or 01723 362537.

Expo

I've been looking through the pages of the latest Expo catalogue. As always there's a great range of small precision hand tools and airbrushes. They've greatly extended their range for the railway modeller and it's great to see the Superquick card building kits – there's one my dad made for me when I was a boy that I must get! Although most of the content is at the 'light' end of engineering, some of the products like telescoping brass and aluminium tube could be just what is needed for workshop projects. The big appeal, though, are the huge number of 'pocket money price' items that will tempt any maker of models.

New Telephone Number for Toolco

Machinery supplier Toolco have been in touch to let us know they have a new contact telephone number, it is now **01453 767584** with immediate effect.

Direct Indexing

Des Bromilow offers another way to use the junk box to solve an engineering problem.

In a workshop primarily designed for the restoration of veteran motorcycles, a certain amount of motorcycle parts (neither vintage or veteran) will find its way into the pile of 'useful junk' - some of these are used to provide a solution for indexing the spindle of a lathe.

The sprockets used in many machines, not only motorcycles, are all labelled and drilled to match a mandrel which is made to be inserted into the back of the headstock spindle. A simple taper/plug arrangement is used to grip the spindle, and a spring loaded detent is attached to the headstock to lock the sprocket once it has been turned to the desired position.

As seen in the photo, the typical sprockets tend to be multiples of unusual numbers, (19 for example) which would be impossible to directly index off a 60 tooth bullwheel.

This system is used regularly for indexing the spoke holes in a wheel hub, or vent patterns on veteran exhaust systems. ■

38 and 54 tooth sprockets ease awkward division problems.

Turning Small Items on a Unimat SL Lathe

John Garnish makes a few changes to help with making tiny cannon barrels.

Most of my workshop time these days is taken up by REMAP projects (making or adapting equipment for people with disabilities), but I am a ship modeller at heart. Having run out of space around the house for large glass cases, I decided that my next project would be a miniature. So it was that I found myself faced with the problem of turning a number of 18th century gun barrels, of different calibres, at 1/144 scale. This article explains how I modified my Unimat SL lathe to ease the task. Most of the dimensions that I quote are either illustrative or non-critical; anyone intending to carry out similar modifications should check the dimensions of their own lathe and adapt the ideas accordingly.

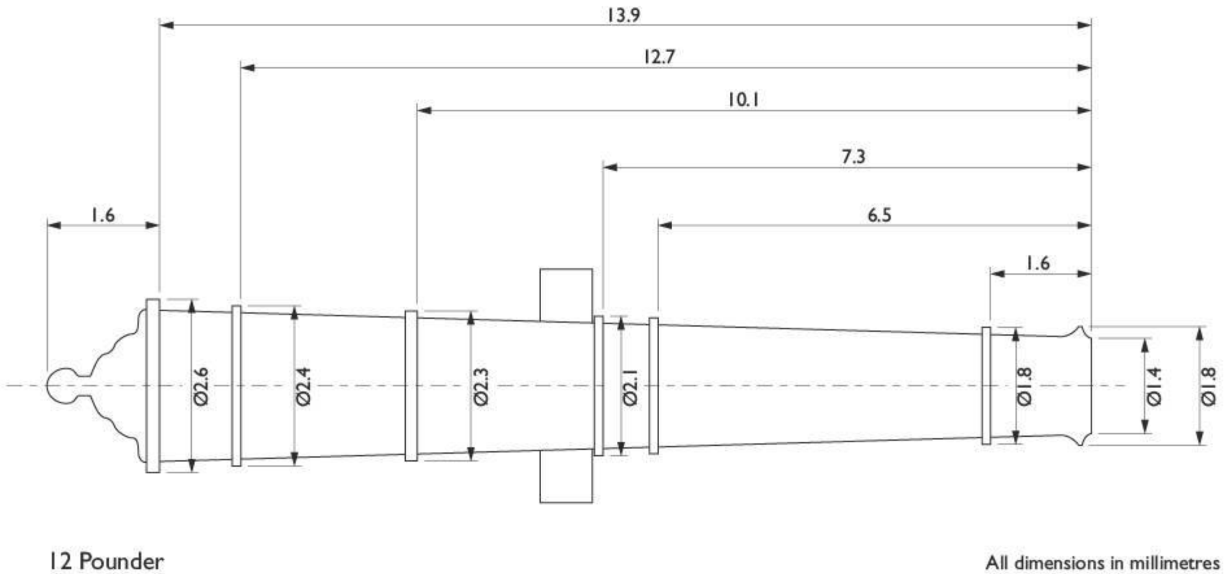
One of the original handwheels.

A glance at **fig. 1** illustrates the nature of the modelling problem - and this wasn't the smallest of the guns! Turning the diameters on the Unimat wasn't too difficult, once the headstock had been set over to the correct taper, but trying to keep track of distances along the barrel was a different matter. A few trials convinced me that I needed a more idiot-proof system than doing mental arithmetic of increments while watching the calibrations on the rather small scale engraved on the hub of the leadscrew handwheel. This hub is 17.2 mm diameter, with 20 divisions but only the '0.5' and '1.0' positions actually marked – in 2 mm high digits (**photo 1**).

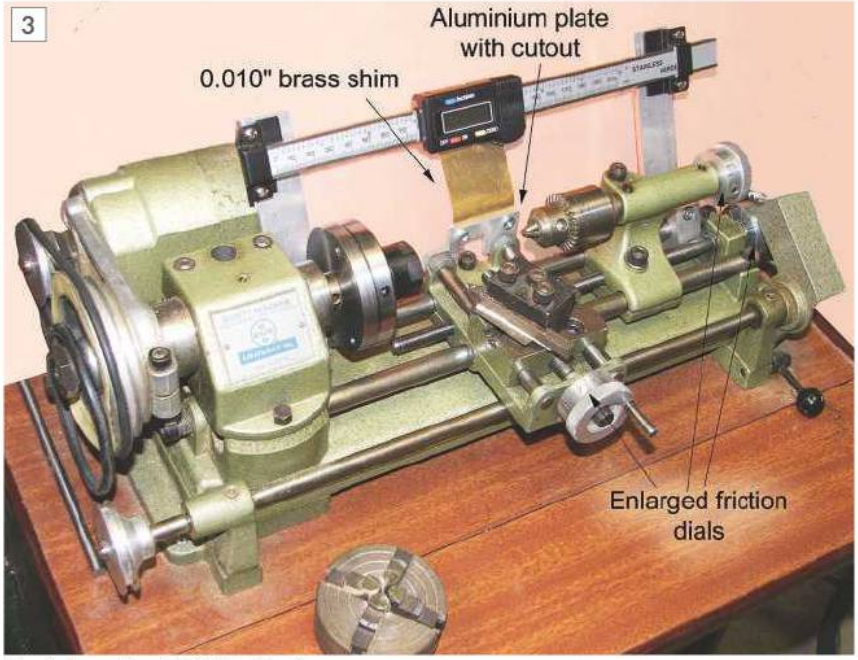
As a first step, I decided to make larger, more readable dials for the leadscrew, cross-slide and tailstock and while I was at it to make them friction dials that could be zeroed easily. These are no more than thick aluminium discs that fit over the hubs of the existing handwheels. They could be given a further degree of sophistication by putting a thin band of knurling along one edge, but that would reduce the space for the numbers. In practice, knurling has not proved necessary.

All this work could be done on the Unimat itself, but it was easier to use my Myford ML7. The discs were turned to an outside diameter slightly smaller than that of the handwheels, and bored to give a clearance of about 0.05 mm over the handwheel hubs. It is interesting to note

Fig. 1



Two modified handwheels.



The lathe with a DRO fitted to the rear.

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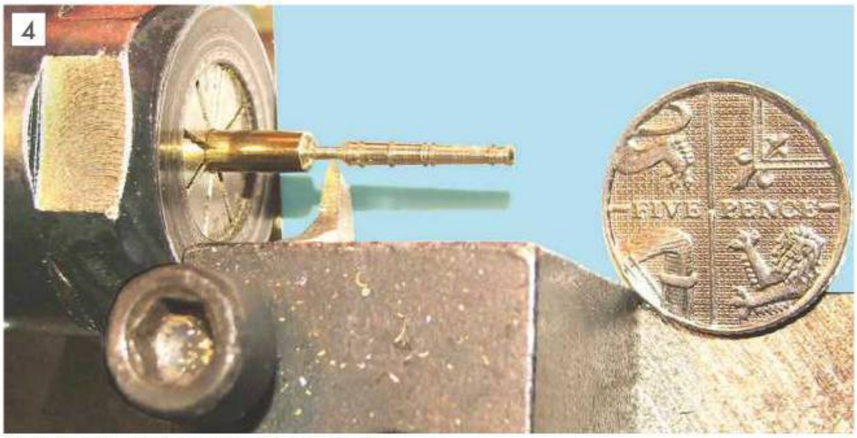
that the diameters of the three handwheel hubs differed by about 0.2 mm, so each new dial was purpose-made for its own handwheel. All three screws on the Unimat have a 1mm pitch, so the three new dials were engraved with 10 long and 10 short divisions, giving a precision of 0.05 mm. For the leadscrew dial, the divisions were also repeated radially across the dial face, making it easier to align the readings with the fiducial mark on the lathe casting. Finally, the dials were number-stamped. For ease of reading, the numbers on the leadscrew dial have their bases towards the leadscrew, while those on the cross-slide have the numbers facing the operator and therefore increasing from right to left (**photo 2**).

To give the dials a friction-set capability, each was tapped radially for a M5 grub-screw, with a 1mm thick pad of polythene at the tip of the screw. I happen to have some 5mm dia polythene rod, but a suitable disc could easily be cut from a suitable plastic bottle. This provides an appropriate degree of friction without damaging the original scales on the handwheels.

This improved the situation, in that the leadscrew dial could be re-zeroed after each section of the gun barrel had been turned to size, but it meant that any errors along the length would be cumulative. Given that the differences between different sizes of barrel at this scale are only fractions of a millimetre, it was decided that a further step would be necessary – a mechanism for giving an absolute reading of position along the workpiece.

The obvious solution was a 200mm linear digital scale; the problem was where to fit it so that it could be read easily without obstructing any of the moving parts of the lathe. Eventually, I settled on a pair of aluminium brackets clamped to the rear bar of the lathe bed and supporting the scale behind and about 8 cm above the lathe bed. The sliding indicator unit was then coupled to the cross-slide by a 38 mm wide strip of 0.010 inch brass shim bolted to a removable aluminium plate, attached to the cross-slide by drilling and tapping (M4) the ends of the two cross-slide rails. The arrangement is shown in **photo 3**. Note the cut-out in the aluminium plate to allow access to the carriage clamping screw.



Turning one of the small cannon barrels.

The brass shim provides complete stability in the direction of slider travel while providing a small amount of flexibility in the lateral and vertical directions to accommodate any slight misalignment in the mountings.

So far, I have not come across any situations where the measuring device impedes the operation of the lathe. If one such arises, however, the device can easily be removed by removing the M4 screws holding the plate to the cross-slide clamp, slackening the brackets on the linear scale and lifting away the complete unit.

After all that, did the modifications do their job? The answer is a definite "yes". One result can be seen in **photo 4**, but the real success was the ease with which this could be replicated in the desired quantity.

Even if you don't have quite so obscure a problem, I suggest that improvements along these lines are worthwhile for anyone using a Unimat – especially if your eyesight is beyond the first flush of youth!. Although this particular model of the Unimat has long been superseded, it should not be difficult to adapt the ideas to the newer models. ■

Readers' Tips

We have £30 in gift vouchers courtesy of engineering suppliers Chester Machine Tools for each month's 'Top Tip'. Email your workshop tips to **neil.wyatt@mytimemedia.com** marking them 'Readers Tips', and you could be a winner. Try to keep your tip to no more than 400 words and a picture or drawing. Every month we will chose a selection for publication and the one chosen as Tip of the Month will win £30 in gift vouchers from Chester Machine Tools. Visit www.chesterhobbystore.com to plan how to spend yours!

This month's winning tip comes from George Conway. He found a tweak to improve repeatability of his collet chuck:

Here is a quick and easy solution to improve the operation of an ER25 collet chuck. I have been trying to perform multi-tool programs on my cnc mill. To achieve this I need to have several milling chucks so each cutter used could be pre-set and offsets measured. To keep the cost to a minimum I decided to try the less expensive ER25 collet chucks. This worked to a point but I noticed that occasionally the cutter would slip slightly during the plunge part of the cycle causing an error in the depth produced. My collets are metric and go up in 1mm intervals. There wasn't a problem if I was using a nominal metric size cutter, the slippage generally occurred when using imperial tools slightly larger than nominal size forcing the collet to be compressed to just under its 1mm maximum.

When I looked closely at the design of my collet chuck I noticed the bore was tapped with two different threads. The top end was obvious and tapped M10 to engage in a drawbar. However I realised the other end of the bore was actually tapped M12 x 30mm deep. This I suspect was used to hold the part during the manufacturing processes.

My simple tip which I hope will prove useful to other *MEW* readers is to make a depth stop from a M12x30mm grub screw with a small flat machined on the end. The operation of which should be self-explanatory. The depth stop on my expensive milling chuck tapers to a point to locate in the dimple in the end of some cutters, however, the grub screw could not be guaranteed to run true so I felt that this may actually do more harm than good.

George Conway, County Durham

A short and sweet tip from this month's runner-up, Ian Priest, who receives a book from the Workshop Practice series.

Having read Peter Shaw's article on through-bore boring prompted me to remember the following tip which you might feel like passing on.

When manufacturing multiple components with matching bores, such as for instance locomotive cylinders, instead of using one through boring bar, prepare two. The first is used to rough the bore out to say finished size plus 0.010 inch, the second is set to finished size. The result is two bores exactly the same size. Another advantage of through-bore boring done in the way described is that the bores will be parallel.

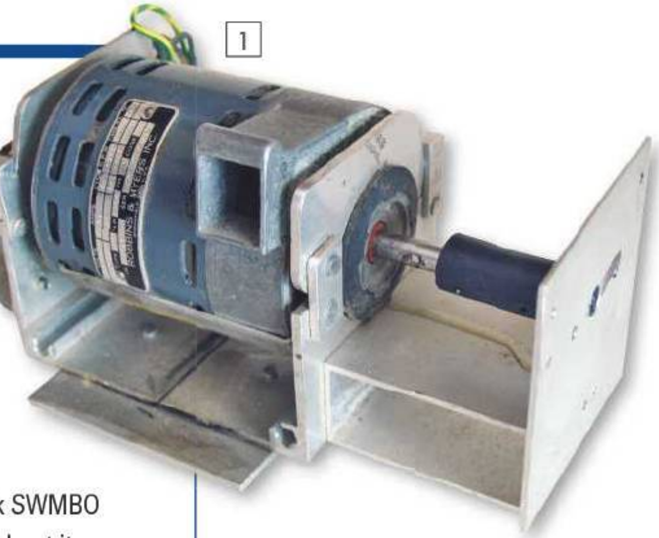
Ian Priest

A Centrifuge

Marcos Diniz makes a simple but effective piece of equipment that could have a number of workshop applications.

Why in the world would I need a centrifuge? Well, when you think about it, they may have lots of interesting uses. Mine came about because I have a condition in my eyelids (no, I don't have to thank old age for this one) and if I don't apply an ointment they itch like the dickens. In the tubes, the ointment is lavishly mixed with air bubbles, and if I don't get rid of the air, the tiniest squeeze will bring out half the ointment. A centrifuge will send the ointment to the bottom and the air towards the nozzle, where they belong. I'm already considering a bigger model to get the water drops out of the salad (don't you think SWMBO might like that?) My wife, who is a virologist, is very excited about its possible uses for lab work in poor countries. All you need are a few changes to accommodate more test-tubes or whatever.

1



The motor and cradle around which the centrifuge was made.

Now to business. A few years ago I made a peristaltic pump, but the volume was too small, it didn't do the job intended. However, it was interesting to make. From this project I kept a small synchronous motor (1/35 HP) in a cradle made of aluminium extrusions araldited and riveted as needed (**photo 1**).

All I had to do was come up with a way to hold two spinning tubes. Sorting through odds and ends (not an easy task as I moved house recently and the workshop is still 'a work in progress' and it'll remain that way for a while), I found some aluminium 50 x 50 x 2mm square tubing. This looked about right, so I cut a 55mm long piece (to stay on the safe side; my hand-sawing is not very precise at times) and turned it into a 50mm cube.

Also, I found a ball-bearing with an 8mm ID and an incredibly battered piece of aluminium that made a nice housing for the bearing. The brass bushing isn't meant as a bearing; it is there to cover a central hole which is too large and unsightly (**photos 2** and **3**). I intended to use one of the blank mountings I ordered years ago from a friendly foundry (**photo 4**) but couldn't find them until they were no longer needed (good old Murphy! Never sleeps on the job!).

To turn it into a cylinder I used my 'master and slave chuck' (**photo 5**) - thank you Tubal Cain!. The bearing housing was screwed to the cradle with two M4 screws. I threaded the holes but added locknuts, just for luck (**photos 6** and **9**). You'll notice I left the C-spanner in the chuck, another item made by my founder friend (alas, he passed away some years ago and the breed seems to have become extinct). I know keys left in chucks are a never-never thing (to me as well, of course), but I just wanted to mention how easy it is to make one from a wooden mould and help from a foundry. All it needs is a bit of cleaning up and a hole for a silver steel dowel. Sorry, I couldn't resist the opportunity to make some mouths water; now and then I tend to boast about something, normally something someone else made...

Boring two 31 mm holes for the plastic tubes on opposite sides of the 'cube' was easy, as I have a 4-jaw self centring chuck (**photo 7**). This is a posed photo, taken after the job was done. I apologise for the

2

The battered bearing housing...

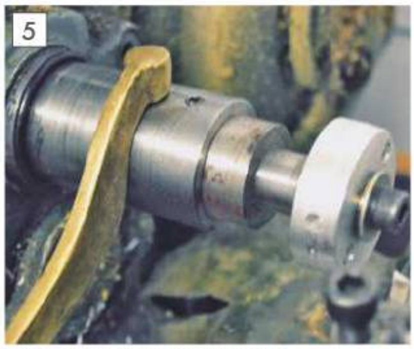
3

...from both sides

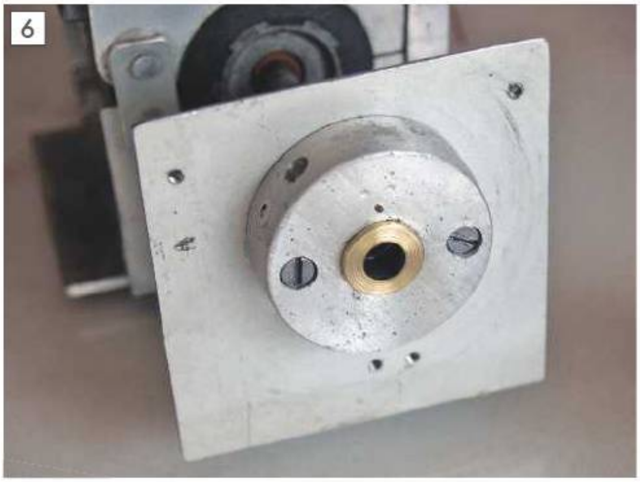
The unused blank mount.

4

5

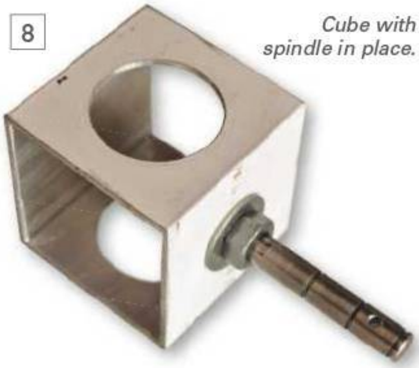


Tidying things up in a master and slave chuck.



The housing in place.

Boring the cube.



Cube with spindle in place.

My wife, who is a virologist, is very excited about its possible uses for lab work in poor countries.

bad lighting and for leaving the allen key in one of the screws; better conditions are on the 'to-do list'. Actually, most of the photos were taken on my kitchen counter marble top. You may also notice I'm a fan of the 3-way turret, (my gratitude to Dave Lammas). One of the remaining sides was centrally drilled 8 mm for the spindle.

This was made from a 53 mm length of 8 mm silver steel, threaded M8 at one end for about 12 mm (enough for two nuts, two washers and the 'cube' wall). Without removing it from the chuck I assembled everything and, as expected, I had to remove the cube and second nut and true up the face of the first nut. After reassembly it ran without any noticeable eccentricity. **Photograph 8** shows the rotating assembly.

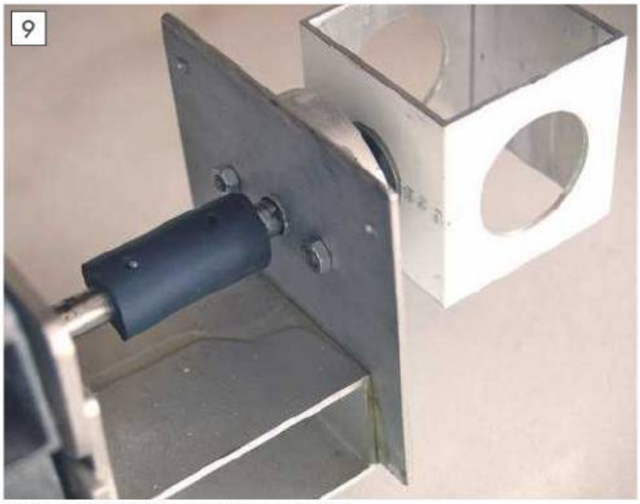
As I wasn't too confident of my ability to get the two spindles perfectly aligned, I made a link from a piece of very thick walled rubber tube. I used a dowel to fix it to the motor spindle and intended to do the same on the other end but on assembly I found there was enough friction to spin the centrifuge. Of course, in a scaled-up version, with a heavier spinning part, I don't believe I could get away with this (**photo 9**). Sorry about the excess Araldite, still from that past job; I decided a lot of scratches wouldn't look better.

I assembled the whole thing, placed two ointment tubes (never try to run it unbalanced, but you may use some kind of counterweight) in the plastic tubes. They are a kind of plastic test tube, easy to get from a lab. I made a temporary connection with two crocodile clips (**photo 10**). You'll notice I hadn't cleaned up the bearing housing yet) and gave it a try. It went like a dream. There was no noise, no vibration and no explosion! After 5 minutes I found I could squeeze out the air from the tubes without wasting any ointment.

All that remained was making a box from some wood off-cuts and wiring it properly. There was a choice: I could run it horizontally or vertically. I opted for the former, which means I have to place it near the edge of a counter top to give the tubes enough room to spin without hitting anything. The result can be seen in **photo 11**.

I think it took me longer to find the right materials than to make the centrifuge and I'm very glad I made it; and everything used was already in the workshop, even the plastic feet for the box. ■

The finished centrifuge in its box.



A simple flexible coupling was used.

The simple working parts of the centrifuge.

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Repairing G-Clamps

Neil Greenaway brings a selection of well-used g-clamps back into good order.

Over the past few years I have found my collection of rough looking G-Clamps has grown somewhat as a result of my magpie nature! The general fault found is that the swivel foot on the end of the screw has been lost, leaving a ball-end to bear on any workpiece. My normal use for the G-Clamps is for holding parts during welding, however, with just a ball-end bearing on materials it is difficult to maintain alignment all of the time.

I decided to rectify matters with replacement swivel feet.

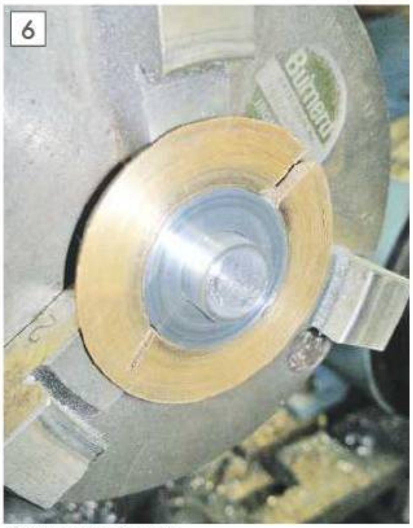
The BMS 'slugs'.

A temporary collet from a plumbing fitting.

A slug held in the collet.

Facing off a slug.

Centering the embryo foot.



Turning the 'neck'.

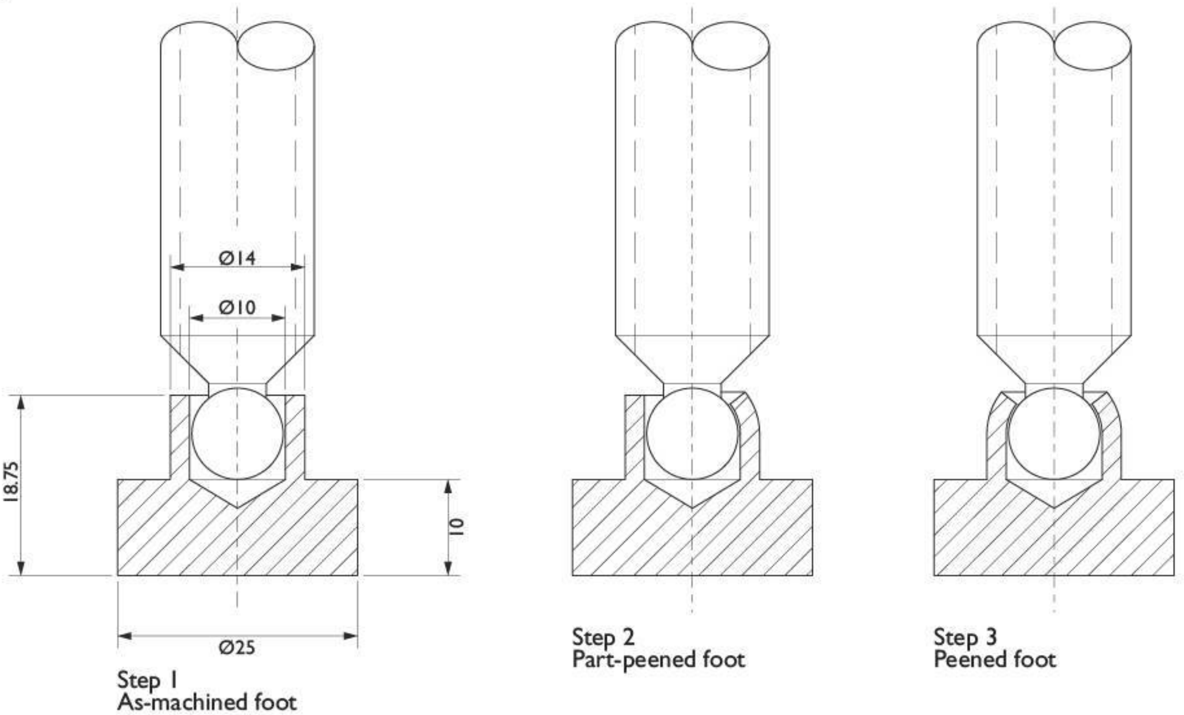
Available Options

A little research revealed that 'McMaster Carr' sell a series of replacement clamp pads of various sizes. These cost between \$3 and \$5 each. They consist of a pad fitted with a ring of 'teeth', much like the grab ring on a push fit plumbing fitting. When the ball end of a clamp is pushed through this ring of teeth it will not permit the ball end to be removed. Having quite a collection of clamps needing attention the costs would escalate quite quickly, so I then considered machining replacements from mild steel, similar to those fitted at the time of manufacture – the clamps were all made by Record tools. Having been from a reputable manufacturer I considered them worthwhile repairing.

Fitting the foot to a clamp.

Peening over the neck.

Fig. 1



Foot And Peening Stages

New swivel feet

The project for replacement swivel feet started with sawing off to length many 'slugs' of 25mm diameter BMS bar at 20mm long (**photo 1**). To hold these in the lathe, a temporary collet was made from a redundant back-nut from a plumbing tank fitting. This was chucked on the flats of the hexagon and faced off true and then bored to 25mm for a depth of 9mm. In order to permit the collet to close on the slugs I placed a saw-cut through the diameter (**photo 2**).

The slugs were gripped in the collet (**photo 3**) and faced off each end (**photo 4**) to a length of 18.75mm. The end of the foot was then centre drilled (**photo 5**) and drilled to a depth of 8.75mm with a 10mm drill. Finally the shoulder was turned, leaving a 'neck' with 2mm wall thickness (**photo 6**) which would subsequently be peened over around the ball end on the clamp screw.

To complete the project the as-machined foot was set onto the ball end of a clamp, and the clamp tightened onto a piece of heavy steel plate (**photo 7**) in a bench vice (to act as an anvil). A 4oz hammer was used to strike a drift against the side of the thin wall neck and peen it over against the ball end on the screw (**photo 8**). The peening was rotated around the foot until the foot was fully enclosing the ball-end (**fig 1** and **photo 9**). The drift used was the side of a cold chisel, and it was struck on an area along the shank above the hardened cutting edge. Some surface bruising did occur to the upper face of the foot, however, this was not considered significant to the operation of the tools.

The screws were also cleaned up of any surface rust and given a coating of light hydraulic oil, and the result was a set of serviceable clamps ready for use when welding. ■

A selection of clamps with their new 'feet'.

CNC in the (Model Engineers') Workshop

Part 16

This series of articles starts with the fundamentals and covers many aspects of CNC programming and machining. The series is not specific to one make or model of machine tool, but it does feature Mach3 software throughout.
There is a support website for the series at:
www.cncintheworkshop.com

Marcus Bowman completes the etched metal folder.

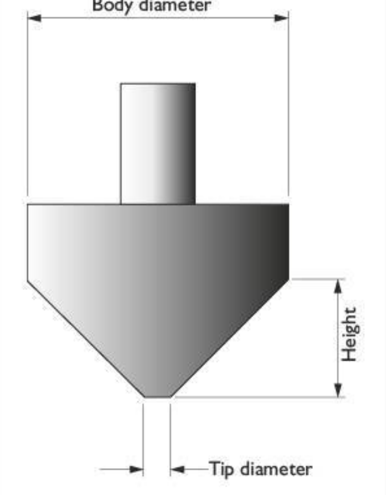
Machining the sloping nose

The nose is angled at 45 degrees to the vertical and matches the angle on a typical countersink, so the easiest way to machine the slope is to take a couple of cuts using a countersink as a milling cutter. The challenge is in knowing where to position the cutter.

You really need to know the dimensions of your countersink quite accurately, and to do that you will need to make some trial cuts.

First, check that your countersink has a 90 degree included angle, as some countersinks deliberately have an 82 degree angle. If the angle is stated as 90 degrees, assume that it is, unless the countersink has been resharpened.

Fig. 82

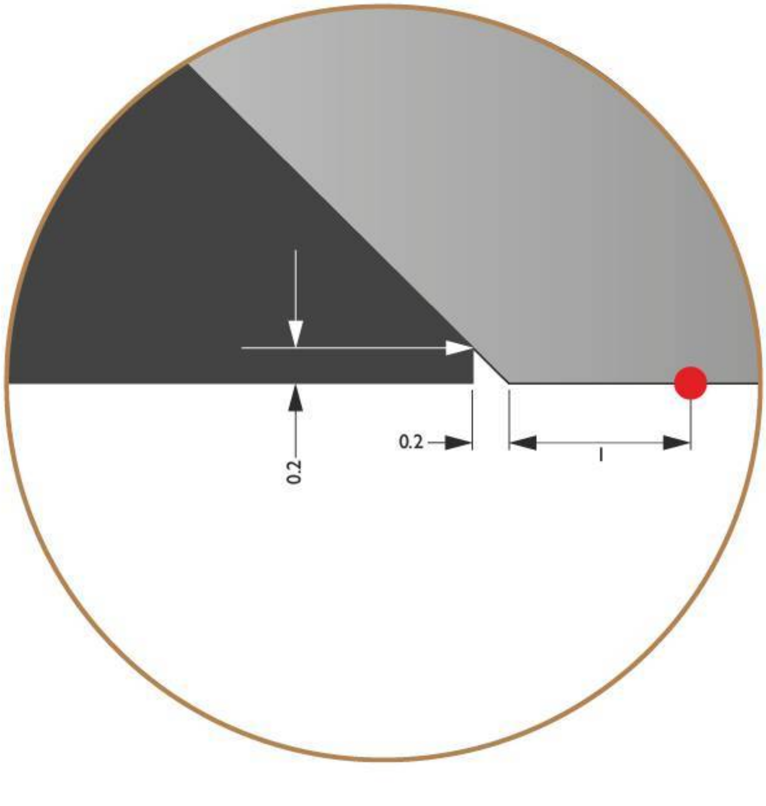


Depending on how the flutes are arranged, you may be able to measure the diameter of the plain section above the angled nose (**fig 82**). Or it may be stated on the cutter (as mine is). The missing dimensions are the height of the angled portion and the diameter of the tip on the bottom end.

The height can be measured by taking a trial cut. Move to the side, away from the fixture, then use a twist drill to produce a sizeable hole in a scrap block of material. Make the diameter just a couple of millimetres smaller than the full diameter of the plain section above the countersink. Mount the countersink, set Z0 at the top face of the work, then take a series of trial cuts down into the hole, until the countersink just produces a plain section at the top of the cut (**fig 83**). The height of the tapered section of the countersink will be halfway between the current and the previous depth of cut. An alternative approach is to cut deeper, to produce a pronounced plain section at the top of the hole, then measure the depth of that, perhaps using the protruding tail of a digital calliper. The height of the tapered section of the countersink will be the depth of cut minus the depth of the plain section.

Once you have the height of the tapered section, you can calculate the width of the flat tip on the end of the countersink:

Fig. 83



98

A professional touch for the folder...

tip diameter = diameter of the full body – 2 x height of the tapered section
For example:
diameter of full body = 13.4mm
height of tapered section = 5.7
tip diameter = 13.4 – 2 x 5.7 = 13.4 – 11.4 = 2mm

The nose geometry and the placement of the cutter is shown in fig 83, and the CP should be placed 1.2mm away from the face of the nose, at Y46.2. Because the cutter will take a relatively broad cut, take it clear of the face, at 48.2 and take a series of smaller cuts along the face, say 9 cuts at 0.2mm, followed by a final climb cut of 0.2mm. The program will have a very simple structure, and might use just one subroutine. It will look a lot like the program to face the nose at the start of this section on machining the clamp plate, except that it is the Y cut which is varying and not Z. Start with Y at 48.2, and subtract 0.2 each time you call a subroutine to cut the face. There is a completed program on the support website.

Embellishing the reinforcing bar

The reinforcing bar is mechanically fine, but lacks a certain aesthetic appeal. Before removing the fixture, put the bar back in place. Then set the WO to the centre of the bar. If your WO is currently as set for the front left edge of the finished clamp bar, move to X75 Y12.5 and set X0 Y0 at that point. We can now add a logo to the bar.

There are two approaches to this. The logo creates relief lettering, meaning that the tops of the letters are at the same level as the top surface of the bar, but the surrounding section of the bar is machined away, so that the letters effectively stand proud of their surroundings (**photo 98**).

Method 1 uses an engraving cutter to remove all of the surrounding material.

Method 2 recognises that there are some largish sections to be removed and uses a 2mm diameter end mill to remove the larger areas first, then uses an engraving cutter to remove the smaller areas to finish the detail which is too small for the 2mm end mill. Method 2 uses two programs; one for each cutter.

Both methods use an engraving cutter with 15 degree half-angle (30 degree total included angle) and a 0.2mm tip. This is a common and readily available shape of cutter.

The support website contains a single program to use for method 1, and two separate programs to use for method 2. Method 2 is quicker, but requires a tool change between programs. You choose. I used method 2, but the logo is small, so either method will do just fine. If you use a standard end mill, keep it lubricated.

If you are able to use a 2mm single flute cutter designed to machine aluminium you won't need to bother.

Once the logo has been machined, remove the bar. Choose an attractive colour and either paint the surround or fill it with cold enamel (which, despite its name, requires the work to be heated to 150C, which perhaps raises a trades description issue?). I used cold enamel because I had it to hand; and I put the work in the oven along with a small steak pie. Happiness all around.

Machining the knobs

The knobs require a different kind of work holding arrangement. They could be machined at the end of a square or rectangular section bar, held vertically in the vice, but I chose to use 1inch round bar, held vertically in a chuck.

A bed mounted chuck is a very handy accessory, but there are some safety issues you should bear in mind. I began with a chuck adapter (**photo 99**) designed to be bolted to a piece of material. The adapter has the same thread as my lathe chucks, because it is handy to be able to transfer from lathe to mill and back again. However; despite the apparent benefits, I should tell you this will not work satisfactorily. First, the adapter as supplied did not have a flat back, so that required attention. Second, the adapter had only two small holes for securing bolts, and they are on peculiar pitch centres. That's not a major problem, but the arrangement is not sufficiently secure, as the two bolts form a single axis across which rocking can take place. Again, that's something which can be altered by adding two additional bolt holes.

But the final straw is that the chuck will not screw onto the adapter sufficiently far to bottom against the end of the thread or against a flat flange. The result is that it is virtually impossible to guarantee that the chuck will not unscrew as cutting forces attempt to turn it and slacken it. The practical result is that work is spoiled and cutters endangered as the chuck moves violently during a typical cut.

My advice is not to use an adapter like this with lathe chucks which simply screw onto the lathe nose. Instead, remove the backplate from a chuck and mount it directly onto a sturdy plate, inserting countersunk screws through the plate from the underside. You now have a really useful accessory which you will use time and time again. If you are feeling flush, dedicate a chuck to this task, leaving it on the plate.

Photograph 100 shows a 4 jaw self-centring chuck mounted on a 16mm plate which has holes arranged to match the mill table tee slot centres, just like a vice plate. Do remember to orient the chuck so that you can reach the key hole and turn the key!

Figure 84 shows the dimensions of the knobs which are machined upside down by creating a circular outer diameter; a smaller diameter short boss; and 6 holes whose centres are outside the periphery of the knob.

Begin by chucking a piece of bar sufficiently long for two knobs, two parting off allowances and an extra length

99

A plate-mounted chuck spigot...

100

...and a chuck fitted, but see the caveat in the text.

Table 4: Multiply the values in the table by the PCD to find the X and Y co-ordinates of the centres of the 6 equally spaced circles. The centre of the PCD is assumed to be at X0, Y0.

Circle no.	X	Y
1	0	0.5
2	0.43301	0.25
3	0.43301	-0.25
4	0	-1
5	-0.43301	-0.25
6	-0.43301	0.25

for gripping while the second knob is being cut. Drill a 4.2mm hole down the centre, deep enough for both knobs and a parting off allowance (roughly 3mm). Tap it M5 now, or wait until later. Use hand tapping, perhaps assisted by a manual chuck-held hand tapping guide. The outer diameter is created using a series of circular cuts, descending as each cut progresses, so these are spirals, of the kind you have used before (*MEW* 212).

The boss uses similar cuts, but of a smaller diameter. Each scallop is formed from a series of similar circular cuts which, because their centres are outside the periphery of the knob, only cut where they overlap the main body of the knob. Begin by trimming the top of the bar level and flat. The bar should have been cut squarely within 0.5mm. Set the Z height by lowering the cutter to almost touch the end surface, and set Z0.5 at that point.

Surfacing will take place at Z0, to avoid the complication of having to reset the Z height within the program after surfacing. It is possible to do that, but we need to use some additional techniques which would complicate things at this stage, A simple approach works best, for now.

Set the X0 Y0 at the centre of the bar.

Surface by using parallel passes, or circular passes as shown below:

```
(Trim top edge)
M98 P160
```

and the subroutine

```
O160 (Trim top edge)
(Assumes CP is at X0 Y0 Z10)
(Exits with CP at X0 Y0 Z10)
G0 X-10 Y-17
G0 Z0
G1 X-10 Y0
G2 X-10 Y0 I10 J0
G1 X-5 Y0
G2 X-5 Y0 I5 J0
G1 X-2 Y0
G2 X-2 Y0 I2 J0
G0 Z20
G0 X0 Y0
M99
```

The periphery of the knob can be trimmed by roughing oversize then climb milling to finished size, using:

```
(Trim periphery of knob)
#41=0 (Initialise depth of cut)
G0 X-15.2 Y0 (Initial positioning
move clear of the surface)
G0 Z0.1 (Positioning just above
the top surface)
M98 P170 L11
(Spiral cuts down below depth of knob)
G3 X-15.2 Y0 Z#41 I15.2 J0
(Level cut around periphery)
G0 Y-17 (Move clear)
G0 X-15 (Go to new radius)
G1 X-15 Y0 (Start cut)
G2 X-15 Y0 I15 J0 (Climb mill periphery)
G1 X-15 Y17 (Move clear)
G0 Z20 (Safe Z)
G0 X0 Y0
```

and the subroutine

```
O170 (Trim periphery of knob: one pass
anti-clockwise)
#41=[#41 - 1] (Make depth of cut 1 lower)
G3 X-15.2 Y0 I15.2 J0 Z#41
(Spiral down to depth)
M99
```

The boss is cut using the same technique:

```
(Trim periphery of boss)
#41=0 (Initialise depth of cut)
G0 X-11.2 Y0 (Initial positioning move
clear of the surface)
G0 Z0.1 (Positioning just above
the top surface)
M98 P180 L4 (Spiral cuts down to the
depth of the boss)
G3 X-11.2 Y0 I11.2 J0 (Level cut)
G1 X-11.2 Y-17 (Move clear)
G0 X-11 (Go to new radius)
G1 X-11 Y0 (Start cut)
G2 X-11 Y0 I11 J0 (Climb mill periphery)
G1 X-11 Y17 (Move clear)
G0 Z20 (Safe Z)
G0 X0 Y0
```

and the subroutine

```
O180 (Trim periphery of boss: one pass
anti-clockwise)
#41=[#41 - 0.5] (Smaller cut because end
cutting as well as side cutting)
G3 X-11.2 Y0 I11.2 J0 Z#41
M99
```

The scallops are more of a challenge, because we need to find the centres before they can be machined. The knobs were designed in a CAD program, so I could have shown the co-ordinates of the centres on the drawing, but it is worth knowing how to find them when they are not given. That also allows you to experiment with the size and positions of the scallops, to improve the look and feel of the knobs.

There are at least three techniques we can use, but one simple method is to use machinists' tables which show how to work out the X and Y co-ordinates of sets of circles where the pitch circle diameter is known, **fig 85** shows values used to calculate the co-ordinates of the centres of each circle in a regular pattern of 6 circles of diameter 1unit, and **table 4** shows how this relates to each hole.

Multiply each factor by the PCD of the pattern (30mm in this case) to find X and Y. Instead of doing the calculation manually, let Mach3 do it for us. For convenience, put the PCD into a parameter (#43 in the following program segment) and multiply each of the factors from table 4 by the contents of #43 to find the X and Y co-ordinates of the centres of the holes. Then use those co-ordinates to position the CP ready to machine each hole in turn. This approach allows the PCD to be altered easily, and Mach3 will then automatically adjust the centres of the 6 circles.

The machining sequence is similar for each hole, so once the CP is in position for a hole, use G92 to temporarily make that position X0, Y0 so that we can use the same subroutine for each hole. Remove the temporary offset using G92.1 at the end of the subroutine, to restore to original co-ordinates before moving to the next hole position.

```
(Create scallops)
F100
G0 X0 Y[0.500*#43]
M98 P190
G0 X[0.43301*#43] Y[0.250*#43]
M98 P190
G0 X[0.43301*#43] Y[-0.250*#43]
M98 P190
G0 X0 Y[-1*#43/2]
M98 P190
G0 X[-0.43301*#43] Y[-0.250*#43]
M98 P190
G0 X[-0.43301*#43] Y[0.250*#43]
M98 P190
F100
G0 Z20
G0 X0 Y0
```

Fig. 84

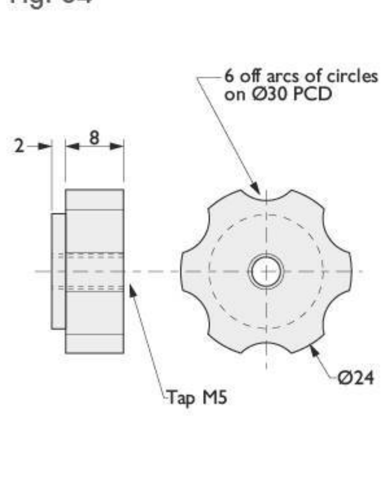
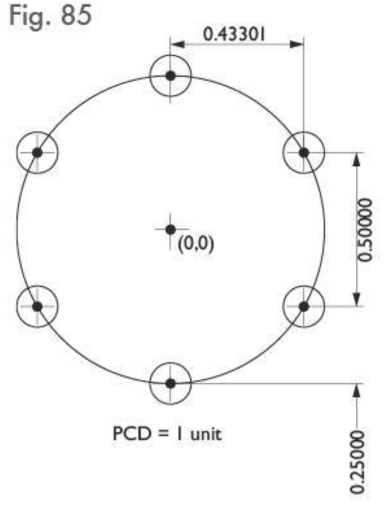


Fig. 85



and the two subroutines
(one of which calls the other)

```
O190 (Cut one scallop)
(On entry assumes CP is at centre
of scallop, and Z#41)
(On exit X and Y are the same as at entry,
and Z20)
(Uses G92 to temporarily shift the origin)
(to make the centre of the scallop 0,0)
(Offsets are removed before exit back to
the main program)
G92 X0 Y0 (Apply an offset to make
the current point 0,0)
#41=-2 (First 2mm removed when
cutting boss)
G0 Z[#41 + 0.01]
G2 X-1.9 Y0 I-0.95 J0 (Entry curve
within circle)
M98 P192 L18
G2 X-1.9 Y0 I1.9 J0 (Flat bottom)
F50
G3 X-2 Y0 I-0.05 J0 (Small semi-circular
entry curve out to periphery of finish cut)
G3 X-2 Y0 I2 J0
G0 X0 Y0
G92.1 (Remove offset, restoring original
co-ordinates)
F100
G0 Z20
M99
O192 (Scallop: spiral cut down)
(On entry assumes X-1.9 Y0)
(Exits with X-1.9 Y0)
  #41 = [#41 - 0.5]
  G2 X-1.9 Y0 I1.9 J0 Z#41
  M99
```

Note the entry curve within subroutine O190:

```
G2 X-1.9 Y0 I-0.95 J0
(Entry curve within circle)
```

That is an entry curve inside the circular cut out, taking the CP from the centre of the circle to the periphery.

Then, later in O190, there is a tiny transition curve as the CP is put into position for the finishing cut. The cutter is already at X-1.9 Y0 and needs to go to X-2 Y0, so there is a small entry curve there:

```
G3 X-2 Y0 I-0.05 J0 (Small semi-circular
entry curve out to periphery of finish cut)
```

In both cases, the direction of the entry curve is the same as the movements which follow, so one is a G2 and the other a G3 command. This is all to give a smooth transition as Mach3 interpolates positions by looking ahead. These small refinements to basic coding make all the difference to the finished job.

There is a completed program on the support website which you can run to machine a knob. Once machined, remove the bar and part the knob from the bar using the lathe (which is a good example of how handy it would be to be able to take the chuck from the mill to the lathe).

Return the bar to the mill and machine another knob.

Completing the folder

Turn two studs with M5 threaded ends (**fig 86**) to fit the knobs, and trim them to length so that each stud is just long enough to leave a couple of threads protruding above the tops of the knobs.

Polish the plates and the bar until they gleam. Use 600 grit wet and dry, followed by 800, then 1000 and 1200 grit. Use a full sheet of each grade, spread on a flat surface, and move the plates back and forth across each sheet with even pressure. Keep them flat to the sheet, to avoid rounding the faces or edges.

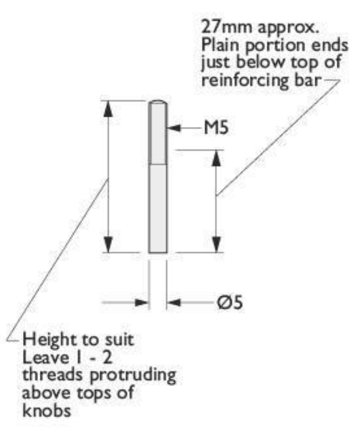
As you change from one grade of sheet to another, carefully clean the work so that no grains of the previous grade remain on the surfaces. Don't touch the edges; they should already have a nice finish from the cutter.

Make the plates sparkle with a final polish using Brasso or Solvol Autosol. Loctite the plain ends of the studs into the base. When the Loctite is dry, clean any excess then assemble the folder.

Put your sunglasses on, and admire another impressive job.

Pride of place on the front shelf, I think, angled to catch the sunbeams.

Fig. 86



COMING UP...

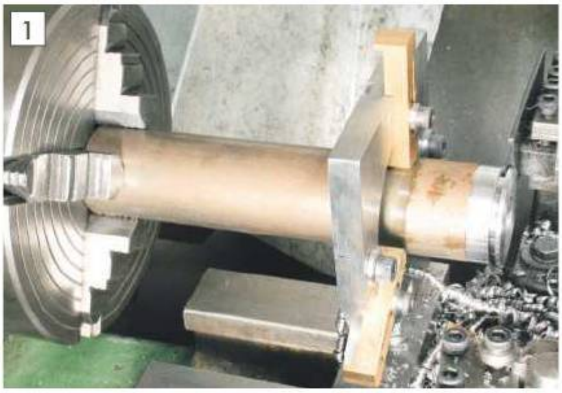
Marcus Bowman's series will be taking a short break, but will continue after the summer looking at techniques involved in the making of a Motorcycle Steering Yoke.

Avoiding Material Wastage

Harold Hall's **HINTS**

Harold Hall keeps a big bar out of the scrap box just a little bit longer.

Given the need to make a 40mm diameter washer, 3mm thick, how would you go about it? Probably, like I would have done in my early metalworking days. That would be to cut a shortish length from from a 40mm diameter bar and place it in the lathe's chuck, from where the material would be drilled and parted off.


Facing a washer with soft jaws.

With the washer finished we would then be left with a very short length of 40mm steel which may never find a use. Even worse, if you needed to make a largish quantity you could end up with a number of short pieces.

If now faced with the situation, I would add the available length of 40mm bar to the four jaw, setting it to run true adjacent to its jaws. With that done, the fixed steady would be added adjacent to the chuck and set to the material's diameter, then moved towards the end of the bar with sufficient material projecting to make the required washer.

Even at a distance from the chuck parting off is no more difficult than adjacent to it, in fact, it may be minutely easier. **Photograph 1** shows the setup at the parting off stage. The washer would then be faced on the parted off face whilst held in the three jaw chuck using soft jaws, (**photo 2**).

If more than a single washer is to be made, sufficient material for, say, three can be set projecting from the steady and then if even more are required the steady can just be slid back a little and more washers made.

If you do not have a four jaw chuck then at 40mm diameter a three jaw can be used providing it is within say 0.05mm TIR (total indicator reading) and the piece of material is around 250mm long, or longer. For a piece of material much shorter then a four jaw is all but essential. Of course, this is dependant on the diameter of the bar being machined the smaller the diameter the less critical the situation.

The method is not limited to larger diameters but it is at these diameters where the real savings in cost and materials will be had.

If you are not conversant with using the lathe steadies then an article was published in the magazine (**ref.1**). ■

REFERENCE

1. Using a lathe's Steady, *MEW* issue 174 page 10 or Harold Hall's website at http://www.homews.co.uk/page83a.html


Parting off a washer.

British Association Threads

Size	Top Diameter		Pitch		Stock size (approx)		Clearance Drill Size		Tapping Drill Size			Hex Size A/F		Hex Size A/corners	
	inch	mm	TPI	mm	inch	mm	No.	mm	No.	mm	Inch	Inch	mm	Inch	mm
0	0.2362	6	25.4	1.00		6	B	6	6	5.20		0.413	10.49	0.477	12.11
1	0.2087	5.3	28.2	0.90			4	5.3	15	4.60		0.365	9.27	0.421	10.71
2	0.1850	4.7	31.4	0.81	3/16		13	4.7	21	4.10		0.324	8.23	0.374	9.50
3	0.1610	4.1	34.8	0.73			20	4.1	29	3.50		0.282	7.16	0.33	8.27
4	0.1417	3.6	38.5	0.66			27	3.6	31	3.10		0.248	6.30	0.286	7.27
5	0.1260	3.2	43.1	0.59	1/8		30	3.2	36	2.75		0.220	5.59	0.254	6.45
6	0.1102	2.8	47.9	0.53			34	2.8	42	2.37	3/32	0.193	4.90	0.223	5.66
7	0.0984	2.5	52.9	0.48	3/32	2.5	39	2.5	45	2.10		0.172	4.37	0.20	5.04
8	0.0866	2.2	59.1	0.43			43	2.2	50	1.85		0.152	3.86	0.176	4.46
9	0.0748	1.9	65.1	0.39			48	1.9	52	1.60		0.131	3.33	0.151	3.84
10	0.0669	1.7	72.6	0.35			51	1.7	54	1.45		0.114	2.90	0.132	3.34
11	0.0590	1.5	81.9	0.31		1.5	53	1.5	56	1.25		0.103	2.62	0.12	3.02
12	0.0512	1.3	90.7	0.28			55	1.3	58	1.10		0.090	2.29	0.104	2.64
14	0.0394	1	110	0.23		1	60	1	66	0.82		0.083	2.11	0.096	2.43
16	0.0311	0.79	134	0.19			67	0.79	71	0.65		0.069	1.75	0.080	2.02
18	0.0240	0.62	169	0.15			73	0.62	76	0.50		0.062	1.57	0.07	1.82

The Beauty of Acrylic

Glenn Bunt gives us an appreciation of this useful material.

I was fed up with getting covered in swarf and coolant flying in my face, even when wearing safety goggles the debris from turning always managed to get behind my safety glasses. So what I'm describing here is how to make a clear acrylic shield which will be positioned between the machinist and the lathe or mill.

You can buy a chuck guard for the Myford, available for later models and something that can be retro-fitted to earlier models. It may have been the result of a Health and Safety audit at Myford or perhaps the fact that they were supplying schools and rotating parts had to be guarded.

The guard, as expensive as it is, doesn't address the major issues of turning i.e. that swarf and coolant will fly up and land down the front of your shirt!

Have you noticed how really hot swarf always manages to have a homing instinct for your exposed skin! Just ready to find that ideal position where an emergency extract from under the shirt is nigh on impossible.

The Acrylic Guard/Shield

Now it won't stop a chuck from flying off and causing a great deal of damage but then I don't know of anything other than a fully enclosed steel guard that will. It will protect the operator from flying debris and coolant and make everyday turning a drier and more pleasurable experience and certainly reduce the swarf collection building up under the t-shirt.

Acrylic benefits

The great thing about acrylic is that it can be gently heated to achieve a desired and permanent shape.

Photographs 1, **2** and **3** show the shield/guard fitted to my Myford. **Photographs 4** and **5** shows an acrylic guard fitted to my Tom Senior Mill. Both are held in position by adjustable arms that I found in a scrap bin, but these can be made in the workshop by a model engineer. Shield arms can also be made by adapting equipment that is designed for other uses.

1

2

3

Acrylic guard fitted to myford lathe.

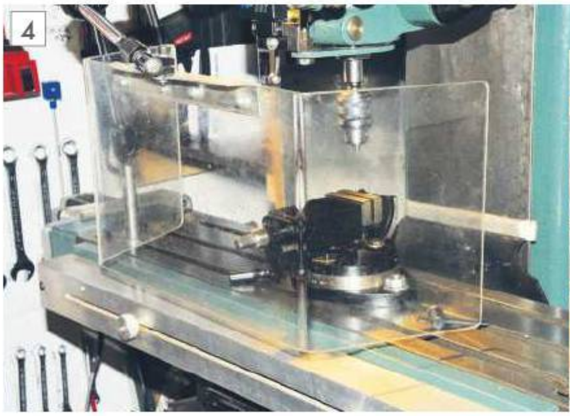
An example of this is using one of the legs of a 'gorrilla pod' tripod (available on eBay) and fitting a magnet to its base.

Photographs 6 and **7** shows another application for acrylic - which is a guard around belt drives, protecting the belt from ingress of oil and swarf. That in photo 7 is fitted to my Tom Senior CNC conversion and is protecting the z-axis belt and pulley.

Cutting Acrylic

Cutting acrylic is not particularly easy as it tends to weld back together when it gets hot. I find using a jigsaw fitted with a coarse cutter (around 6 tpi) and cutting at a rapid rate works best. An example of the type of jig saw blade I use is shown in **photo 8**.

A piece of acrylic that has just been cut is pictured in **photo 9**, and typically there are bits of acrylic adhering to the edge.



Acrylic guard fitted to milling machine.

Stepper motor belt guard.

Guard for Z-axis drive.

Jigsaw blade for cutting acrylic.

This requires finishing with Aluminium Oxide paper (coarse 60 grit) to remove the welded acrylic and achieve a good straight edge. **Photograph 10** shows the much better finished edge after working with abrasive paper.

Heating and Bending acrylic

Acrylic is not cheap so make your mistakes with cardboard. Having cut out some cardboard and defined the shape of your guard, mark on the acrylic the positions where the bends will be required - I use a black marker pen to do this. To clamp the acrylic whilst working it I generally use a work mate. The acrylic is clamped between to pieces of metal bar at the point where the bend is to be formed.

Note! Wear a pair of thick gloves to protect your hands - the acrylic gets very hot and can burn. Heat is applied to the bend joint by a hot air gun - the type used for stripping paint etc will do fine.

Photograph 11 shows the type of hot air gun I use. Gently heat the joint whilst moving the hot air gun side to side - do not dwell in one place for too long as this will deform the acrylic and create little bubbles inside its surface. Not only will this look unsightly but it may also induce a weakness in the acrylic structure.

Without warning the acrylic will start to bend and become quite soft. At this point it's important to hold the sheet at the angle you require and also to make sure the bend radius is constant along the bend. This can be facilitated by placing a plate of metal material against sheet where bend is located and using it to help form the bend.

It is also important to make sure the acrylic does not become too soft or floppy which may create some unwanted bends and shapes. After hot forming the acrylic it should be left to cool down naturally - any acceleration of this process will introduce a weakness in the acrylic.

Drilling Holes

Holes can be drilled in the acrylic either before or after forming the bends. I find that a centre drill works best with acrylic - using it to drill right through the material.

Supporting Acrylic

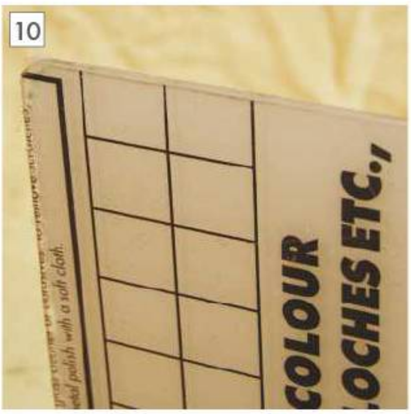
On my guards I've used aluminium angle bolted to the side of the acrylic shield to help support the structure and secure it to the adjustable arm.

Summary

I've found the acrylic home made guards described in this article very useful. They allow me to move around the workshop when milling components, especially when my machine is in CNC mode. It also makes turning on the lathe more comfortable - I still wear glasses but these now are reading glasses and not required for protection.

My wife also reports a dramatic reduction in rust spot stains from swarf stuck in my shirts and jumpers! ■

A poor finish after cutting acrylic.

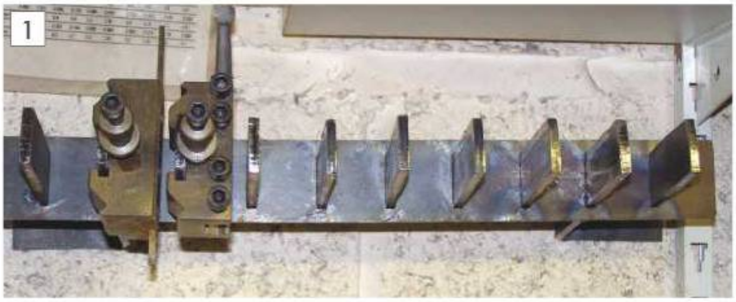


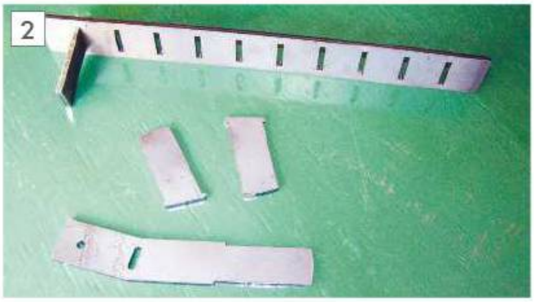
The cut after finishing.

A hot air gun as used for shaping acylic guards.

Quick Change Tool Post Stand

Malcolm High has an elegant solution to storing quick-change toolholders.





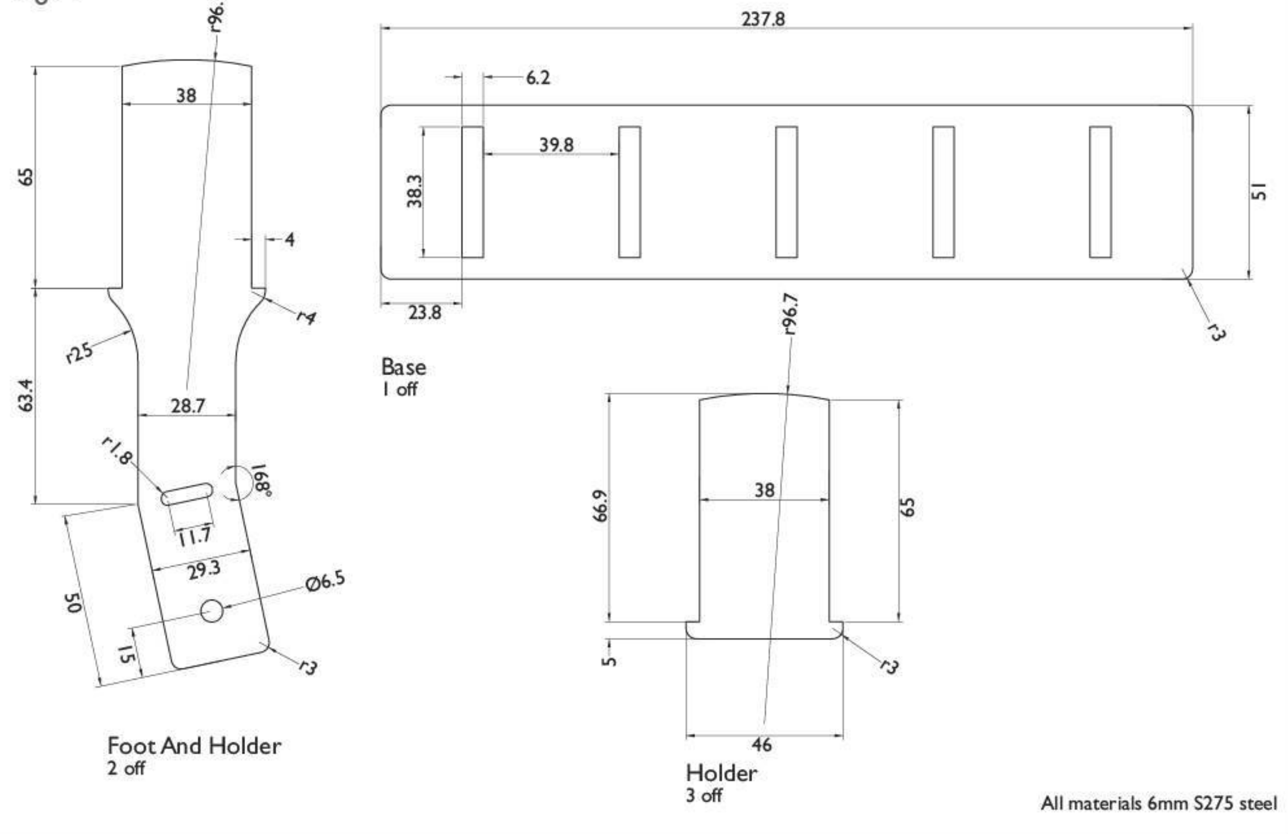
I thought the article on the quick change tool post stand by David Haythornthwaite in *Model Engineer* issue 4404 was a very good idea and certainly gave food for thought. The result of my efforts is shown in **photo 1** and looks very similar to the prototype, except that it is all laser cut and slots together in a few minutes. I must admit I enjoy the challenge of creating a design that ensures the final article is easy to build, accurate and does the job required. In this case it was a relatively simple design; some of the cut parts are shown in **photo 2**.

To build the holder the two stand parts are first bent through 90 degrees. This is made easier by putting a weakening slot in the material. These are then slotted through the base, along with the other 8 tool post holders giving a capacity of 10 holders. I TIG welded my stand together but you could use MIG or even stick if you were careful. Since the holders slot through the base they could be held in with adhesive, the strength comes from the fact they slot through the base. Finally a coat of paint, I will get round to it one day and screw it to the wall.

I have found mine so useful that I made a larger version for my Chester tool posts, same idea only bigger. Drawings of the parts are shown in **fig. 1**. These are really useful pieces of kit that only take 20 minutes to assemble but save hours looking for the one tool post you need which is of course under your nose. Every workshop should have one! ■

Malcolm High's holders in different sizes can be purchased as a kit of parts from Model Engineer's Laser, http://www.modelengineerslaser.co.uk/

Fig. 1



Two Easy Cabinets for the Workshop

Ed Corley describes a useful woodworking project for metalworkers.

The cabinets described in this article can be made with a minimum of woodworking tools and no special woodworking skills. Because they are made to fulfil specific needs, their value is in the job they perform and I sought no bonus points for style. The construction is 'glue and screw' for simplicity and, provided care is taken in spacing the shelves and arranging the storage inside the doors, they are a quick project that has real benefits in a busy workshop.

Milling machine tools in cabinet with storage in doors.

Tools for the job are minimal. Some kind of square for marking out is needed, and although I used a very basic sawtable for the cutting, a circular saw would have been just as effective. I will describe how I did it on the saw table and it should be easy to see how your equipment can be used to get the same results. Assembly requires only a hand-held drill, a screwdriver and glue. I used plywood already in my possession: one cabinet from 12mm shuttering ply, cheap and rough, the other from 12mm interior ply which has far better aesthetic qualities. The dimensions were chosen to suit the material available and the intended location. If you are starting from scratch, the estimated cost to produce both cabinets using interior ply will be around £30 to £40 including hinges and screws; add something for gloss paint and undercoat if you decide to go that route. So, you can treat this as a description of the processes used and ignore my dimensions except where choosing thickness of material for the carcase and shelves and choice of screws.

First things first: why go to the trouble of building cabinets at all? I confess, in my workshop, the clutter was winning. Like many others, I stored tools and other stuff on the workshop wall behind the lathe. Like others, I ignored the dangers of this arrangement until something worked loose while the lathe was running and there was a brief but spectacular moment as the spanner-turned-missile missed me (twice, it bounced off the wall behind and attacked me from the rear). No harm was done, but the lesson was learned. I looked at my shelves and hooks and realised I had outgrown them: It was time to stop tinkering with 'finding room' and start over.

Now, the two cabinets for the workshop, one for holding bits used at the lathe and the other for the milling station, have helped greatly in keeping the work area tidy and orderly. Equally important, by having a dedicated space for DTIs, callipers and other pricey tools, they are safer and last longer.

You will see from the pictures that there are two cabinets (**photos 1 & 2**). The lathe and milling machine have different spindle tapers, so each has its own tooling. We are starting with the larger of the two, which is for the milling machine tooling. Dedicating storage space to items at the place where they are most needed can only be good so, for the mill, the brick wall behind was the obvious place. I measured up how much room was available behind the mill, while leaving access to the motor, and what was left was a 19 inch wide area.

I apologise in advance to any skilled woodworkers who take exception to my chosen techniques. They are appropriate for making a utilitarian basic structure without rebates, dovetails, tongue-and-groove or mitred joints, and are meant to be easily copied by anyone. Also, they work which is, in the end, what counts.

Lathe tooling in cabinet with drop-down shelf.

Making the cabinets is a simple job in two parts: firstly, building the carcase, or the body of the cabinet, and secondly fitting out the storage inside. The first carcase is made as a 'solid' box, that is to say with all six sides glued and screwed together. See **fig. 1**. After this is done, the

12mm ply marked ready for cutting.

front is cut off to make the doors.

Ready? Start by deciding what you want to put in your cabinet which will tell you how to lay out the shelves to avoid frustration later. This could take several cups of tea to get right. It may seem obvious, but bear with me and sketch it out as you go along. The boxes holding my R8 taper tooling were close in height to each other so it was easy to see that a gap between shelves of 3 inch was needed for them. The slip gauges and collets needed a slightly greater height so one shelf with 3.5 inch clearance was drawn. Don't forget to allow for the thickness of the shelf, typically 12mm. I ended up with five shelves, counting the bottom. Five x 18 inch = 72 inch total shelf space and four shelves spaced at 3 inch and one at 3.5 inch. See **fig. 2**. This approach may seem pedantic, but I once built a cabinet that had plenty of space but would have been much more useful if at least one of the shelves had had another ¼ inch clearance. It was simply bad planning, and I learned from the mistake.

As will be seen later, clearance for the items stored in the doors is important so before rushing to the saw, decide how deep the shelves and the storage area in the doors must be to do the job. It is necessary to decide beforehand what depth your shelves will have, to determine where to make the cut that will remove the front of the box. I made three of the shelves four inches deep and one at four and three quarters (the fifth shelf is the bottom piece of the cabinet).

After all that preparation, it's time to start work. Look at fig. 1 and fig. 2 to see how my pieces fit together and make your own sketch, including all dimensions. Mark out the main pieces on 12mm ply: top, bottom, sides, front and back and write names on each. You may be able to get all your shelves out of the same piece: they are exactly the same width as the back piece of the carcase. Try to group your pieces so that all the parts of the same width are laid out together, i.e. if your sides, top and bottom are all 6 inch width, you lay out a long 6 inch line first and then scribe across this to make the individual components (**photo 3**). This gives consistency in dimensions and lends itself to good fitting. If using a circular saw with an adjustable fence, set it to width. A very simple and accurate substitute for a fence is to clamp a straightedge (anything straight will do, such as a piece of flooring or an old shelf) to the workpiece and run the circular saw along it. The trick is to clamp it in the right place. Measure from the edge of the blade (saw unplugged, of course) to the edge of the saw's baseplate. Make a note of the distance, it will be the

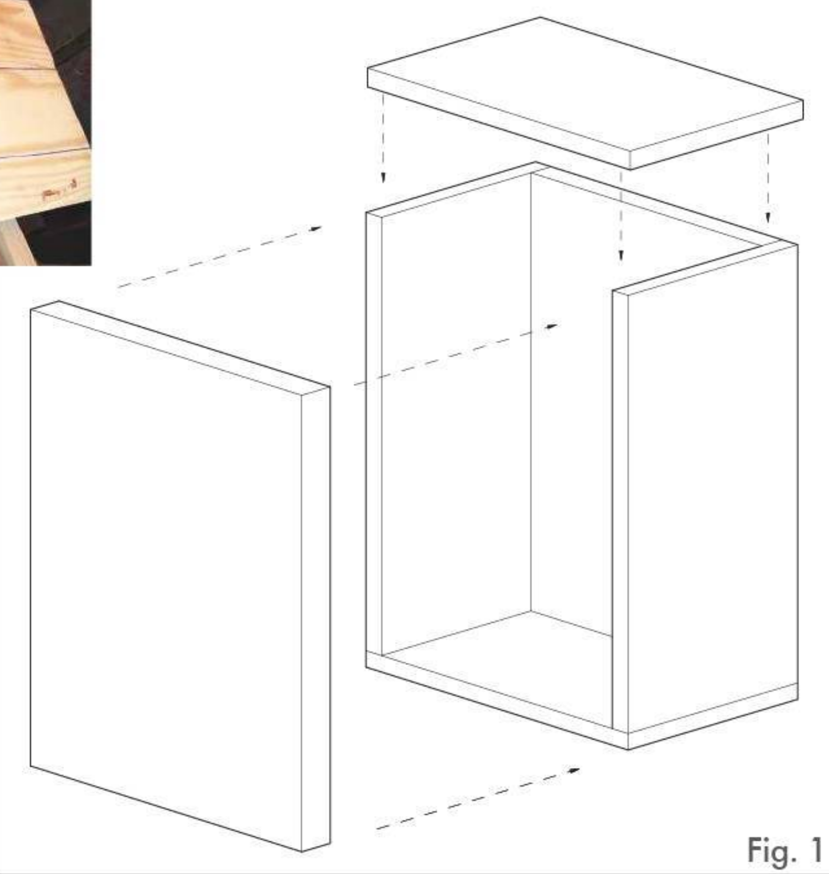


Fig. 1

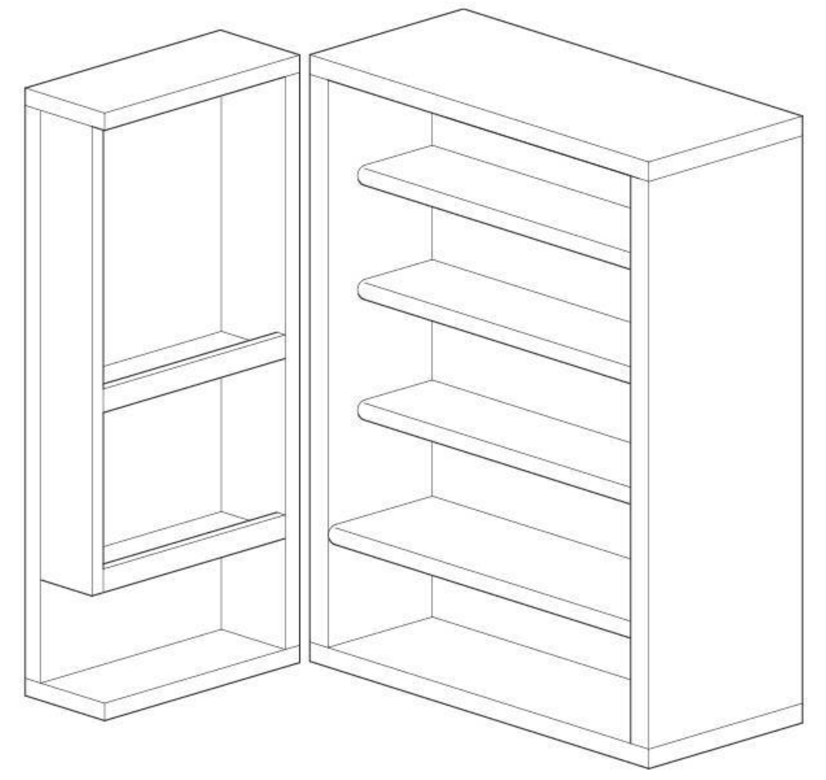


Fig. 2

Improvised fence for cutting panels to size, safety guards removed for photos.

Ready to begin assembly.

Shelf lines marked on the boards.

Attaching first side piece.

same every time. Subtract this figure from whatever width you want to cut to know where to place the improvised fence. It would be a good idea to make a practice cut on some scrap.

If using a saw table as I have, get the same result by clamping something straight across the table surface (visible at the top of **photo 4**). You will run one side of the workpiece along this improvised guide to make your cut. Put the workpiece on the table (saw unplugged) and line up the cut-line you marked earlier with the blade. Bring the straightedge up to the side of the workpiece, take as long as you need to get it parallel, clamp it and leave it in place until all cuts of that dimension are done. Good straight cuts are your target here. Get cutting and be careful.

Once all the pieces are cut (**photo 5**) offer them up to each other for a trial fit. Trim to length if needed and, when satisfied, lay out the back and sides beside each other. Now, all that time you spent planning is going to pay off. With the pieces butted together, edge to edge and corners in line, lay your straightedge across them widthways and mark where the shelves will go (**photo 6**). Use a square to get them level. I know it is obvious but remember to allow for the thickness of the shelf; make two lines 12mm apart if you are using 12mm material for the shelves. Draw an arrow pointing to the top of each piece. By doing all marking in this way at this stage you will have straight, level, correctly spaced shelves without hassle in a few minutes when the parts are assembled.

Its time to put it together. Lay the back flat on the bench with the drawn shelf lines facing up. Offer up the bottom piece on edge, butting up against the back-piece as it will be when finished. Make sure it is centred. Run a generous bead of wood glue along the mating surfaces of the joint and, before it has time to set, drive woodscrews, size 4x25 or 4x30 through the bottom piece into the edge of the back (photo 6 again). Size 3.5 will do instead of 4 if you prefer, but don't go any smaller. This type of joint works well with plywood. Space the screws about three inches apart, it is not critical. A word about doing this the easy way. Use good screws, such as Screwfix Gold or Wickes Ultragold, which do not need pre-drilling, and take care to drive the screw straight so it doesn't break out of the side of the piece you are screwing into. If one does break out, continue with the other screws (you have glue drying) and then back out the offending screw, move along a little bit and re-screw: do not try to drive the screw back into the hole that broke out, it will never work). You should end up with the bottom piece tightly drawn into the back piece. Beads of glue probably oozed out of the joint when it was screwed down, so wipe these off with a damp tissue.

Keep working, don't wait for the glue to dry. Dry-fit one of the sidepieces in position and ensure the shelf lines you drew earlier line up. Turn it over and, starting with the long edge, glue and screw it down tight (**photo 7**) and don't be surprised if it looks like the previously attached bottom piece isn't square. Use a bit of force if needed to align the bottom piece where it meets the lower edge of the side piece, and put your first screw near the front edge. The others will then be in line with no further effort. Do the other side in the same way, then the top.

There is just one thing more to do before we attach the front. Once the front piece is secured in place, we are going to saw off the front section of the box to make the doors so double-check the position of that intended saw-cut to ensure it will clear the shelves. Dry-fit one of the shelves and take the measurement straight off the front edge (**photo 8**). Subtract a bit for clearance and put a matching line or mark on the outside surface of the box at each corner. This line is where you will cut the front off the assembled carcase so it must be clear of the shelves and any edging trim you may add. Once you are happy with everything, go ahead and glue and screw

Checking shelf clearance before securing the front piece.

the front piece solidly in place (**photo 9**). Visualise where the doors will be cut apart and don't put any screws on that line. That is as far as you can go now until the glued joints have cured. Leave it for a day. You're nearly there.

After a decent interval, once the glue has dried thoroughly, cut the doors off the front of the carcase. How to do it? One side at a time, starting with one of the long sides. If using a circular saw, set the fence or clamp another straightedge and adapt the following description to suit. If using a saw table, set a fence as in **photo 10**. The wood in the photo is acting as the fence and will be clamped solidly after the next step. When handling the bulky box you have built on the saw table, be careful; get the saw-cutting lines straight in your mind, ensure the fence is absolutely secure and use caution around the blade. This whole process can be done with a handsaw, but I'm hooked on power tools.

You should have a clearly visible line at each corner of the box where you want the cut. Unplug the saw. Set the box down on the table and line up the blade on the cutting line (**photo 11**). Set the blade cutting depth to a bit more than the thickness of the wood, say 18 to 20mm for cutting 12mm ply. Bring the straightedge fence up to the box and loosely clamp it in place. Make sure it is parallel by picking up the box and repeating the process on the far side of the blade. This is why the line is drawn on all corners around the box: wherever you start, you can check the alignment of your cut before turning on the saw.

When satisfied that the fence is set correctly, tighten it down fully, double check, place the box against the fence a little way from the blade and start the saw. Keeping your hands well clear, snug the box up against the fence and feed the box into the blade. Use a 'push stick' to urge the workpiece along to keep your hands away from the blade. Keep it moving all the way across till the blade appears. 'Kill' the saw. What you have should look like **photo 12**. Turn the box 90 degrees onto one of the short sides and the cut you just made should line up perfectly with the blade. Repeat the process on this short side. Note that the saw cut misses the screws used to secure the top in place. Kill the saw and place the remaining long side face down on the table against the guide, ready for the last cut but don't make it yet. When this last cut is made, the part you have cut off will be free and can move in any direction: not a good idea when in contact with the moving saw blade!

All that is needed to make the box stable during this last cut is to put something in the cuts you have already made to keep the pieces from closing together. The cut made by my saw blade produced a gap (called the 'kerf') about 3.5mm wide so I put a few small screws wedged (not screwed) in the gaps on the three cut sides

Attaching the front after noting location of shelves.

Fence set to correct position for removing front of box.

About to make the first cut to remove the front.

After the first cut.


Using a spacer and clamp to maintain both rigidity and a gap.


The door cut from the main box.


Lid face down, cutting half way through.


Fixit blocks flush with the shelf edge.


It's starting to look like a cabinet.

and clamped it tight (**photo 13**). If you don't have a wide clamp like the one in the photos, then a couple of lengths of masking tape pulled tightly around the assembly to bind it together will do the job. You are ready to carefully make the last cut.

Pass it across the blade like before and kill the saw. You should have something like **photo 14**. Put the main body of the cabinet to one side and concentrate on the 'lid' you just cut off. This is about to become the doors of your cabinet. Measure and mark the line where you want to divide them, which doesn't have to be in the middle. My cabinet for the mill tooling has the left door an inch and a quarter wider than the other, to accommodate the micrometers and other items I had decided to mount inside it. If you are the type of person who has more than one saw, choose the one with the thinnest blade for this cut (or make it with a handsaw). Mark a line where you are going to cut and set the fence. Set the blade for just over half the height of the lid assembly, for reasons that will be clear in a moment. Place the lid face down on the table. Using a push-stick and keeping all your favourite fingers out of the way, make the cut along the length of the door. Supporting the lid carefully, turn it over end for end to ensure that the second cut is in line with the first, remembering that the lid is now held together only by what remains of the two pieces at each end, (**photo 15**). Make the last cut through those two joining sections exactly as you made the others, using the fence and a push stick (or cut it apart with a handsaw). You now have your doors. Put the pieces to one side and return to the main body; it's time for the shelves.

The shelves are the same exact width as the back so offcuts from the piece of ply used for the case provided all my shelves. Use at least 12mm material if the shelves are going to carry a load of metal. You may have other material for your shelves, but do not rely on chipboard or MDF. Try to get a snug fit inside the case as this gives a lot of strength to the finished assembly. One of my shelves was the maximum depth to just clear the closed doors and the others were set back a bit, so set up a cutting fence, as you did before, for whatever depth (front to back) you have settled on. If you intend to face the exposed edges of the shelves with hardwood trim, which I recommend, allow for the thickness of the edging material. Once cut, test fit them and sort out if one or another is a better fit in a particular position.

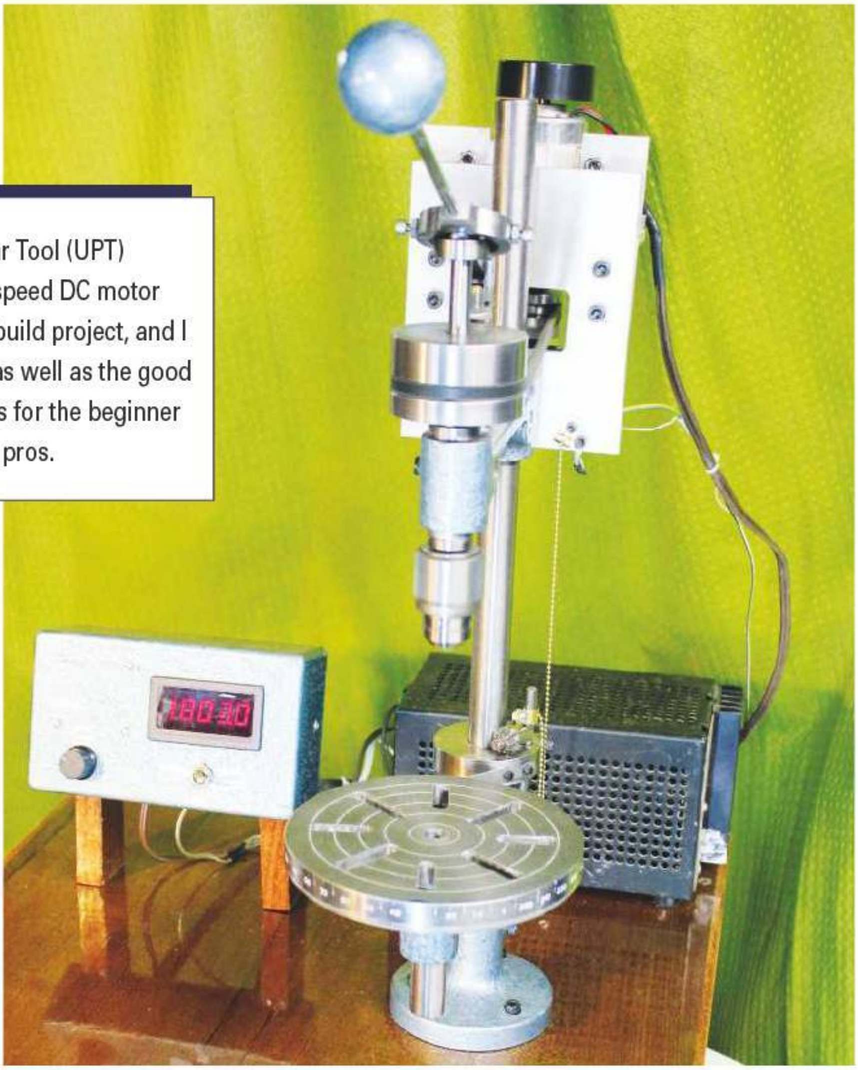
Because of the 18 inch length of the shelves on mine and the weight of the tooling, they need a lot of support. I chose the simplest, quickest way to fix the shelves. 'Fixit Blocks', the plastic blocks that hold together kitchen base units, are available from most DIY shops and are deceptively strong. A typical fixit block has three countersunk holes for screws in two directions: two holes for the surface against the case and one hole to screw into the bottom of the shelf. Mine came from Wickes and were very good value, available in packs of 25 or 100. Use three per shelf: one at each end and one in the middle (**photo 16**). If your shelves are short you can skip the one in the middle, if they are longer, use two. Lay the shelf upside down on the workbench, line the block up flush with an edge and screw them in place on each shelf. Starting from the top, offer the shelf up to the case using the lines you drew earlier and drive screws though the holes in the blocks into the case. Carry on and attach the others, working down. Stand back and admire your work (**photo 17**).

To be continued...

Updating the Universal Pillar Tool

David Graves brings George Thomas' classic design into the 21st Century.

My modern update of the Universal Pillar Tool (UPT) includes better bearings and a variable-speed DC motor drive. This was largely a design-as-you-build project, and I have detailed all the things I did wrong as well as the good decisions. There are some useful lessons for the beginner here and perhaps even some for the old pros.



There was one more step necessary to complete the disc. As mentioned in the last part, a driving tooth engages the slot in the shaft to transmit power from the pulley to the shaft. I originally considered simply filing out a non-circular opening in the center of the disc, but eventually decided to bore the hole (as described above) and silver solder in the tooth (as Thomas did). I used a 3/32 inch milling cutter to cut a slot out from this center hole for a distance of ¼ inch. The depth was 0.100 inch rather than going through the entire 0.125 inch depth of the disc. This provided both a shelf to set the tooth on and additional surface area for the silver solder (added strength). The tooth blank was cut from a piece of 3/32 inch gauge plate after rounding the edge to fit the rear of the milled slot. I made no attempt to cut the exact tooth shape at this time. Instead, the height was about 0.110 inches and the width 3/32 inch for the whole (longer than needed) length.

9

The disc after silver soldering the tooth.

After I applied flux and a flattened piece of silver solder (it doesn't roll around as the flame hits it when flattened) the blank was soldered in place. **Photograph 9** shows what it looked like after a bit of work with some abrasive paper to clean off the flame oxidation. **Photograph 10** shows the tooth after additional work with a needle file to fit it to the shaft slot. (Obviously the shaft has to have been finished in the mean time to give a slot to fit it to.) I was pleasantly surprised to find how easy this whole operation was. I was expecting difficulty with the soldering and/or filing, but all went well. I trust that this tooth will have adequate strength. If necessary, I could easily have made it higher (say 0.2 inch) and just had the excess sticking up from the surface. As it is, there is a bit of excess height as seen in this last photo. Although it would have looked smoother if I had ground it flush, it would not have been as strong. Practicality won out over aesthetics this time.

10

The tidied up tooth engaged in its slot.


11
Grinding the shaft to size.


12
Using a cutoff disc to groove the shaft.

The Drive Shaft

I was also pretty worried about working with the casehardened shaft. Clearly the case would have to be removed by grinding rather than by using lathe tools. It was easy to center-drill the end after using a grinding wheel in the Quorn to cut the shaft to length. I then made a slotted aluminum bushing to adapt my ⅝ inch collet to the 10 mm shaft material. I had decided to use my Foredom flexible shaft tool in the lathe to do the grinding. Something like a Dremel tool with flexible shaft would probably work, but would have a lot less power than the Foredom. If you do any such grinding, be sure to protect everything, especially the lathe ways, from the grinding dust if you don't want to bring your lathe to an early death. Also, clean everything thoroughly after doing any grinding. First, I used a stubby grinding tool to reduce the end of the shaft to fit the top ball bearing unit. This is shown in **photo 11**. The lathe was rotating counter to the grinding tool (backwards). Next, I mounted a 1.5 inch diameter Dremel *flex-lock* cutting disc and used a pair of large wooden hand screw clamps on the collet chuck. These clamps are the Jorgensen type, one in front and one behind bearing against the ways. They are familiar to woodworkers and look like machinist's clamps on a large scale. This prevented the lathe from rotating the slightest bit while the grinding disc mounted on the lathe carriage was traversed back and forth along the shaft to cut the groove. **Photograph 12** shows the setup. I decided that a 1½ inch slot (Thomas design) looked too short, so I made mine 2½ inch long. The shaft itself was 6⅛ inch long, by the way, also longer than Thomas specifies. This I hoped would provide more drilling depth than the original design (it didn't, as I will explain later).

It was interesting to hear the wheel cutting. The first fraction of a second produced a particular 'zing' that differed from that heard during the remainder of the cut at a given manual incremental advance of the lathe carriage. I am fairly sure this represented the case being cut through and the remainder of the sound the cut through the underlying metal. I cut the slot approximately 0.062 inch wide (by moving the cross-slide for two parallel cuts) and about 0.090 inch deep. This approximates what Thomas used (0.080 inch deep). However, the flexibility of the wheel resulted in a trapezoidal slot that was slightly narrower at the bottom than at the top. This may be seen in the matching tooth profile shown in photo 10. An alternative worth considering is to stack two abrasive discs on the shaft to cut the entire slot width at once. This might stiffen the discs enough that the trapezoidal slot shape (due to flexing of the cutting disc) could be avoided.

Be sure to feel the temperature of the shaft during the slot cutting process. You do not want to reduce the surface hardness by letting it get too hot! Cutting the slot was somewhat tedious (especially because of frequent stops to permit cooling), but the result was almost as good as I had hoped. The tedium was almost enough to convince me to use coolant. The top edge of the slot was stoned to remove the burr produced during the cut. As expected, the needle bearing rotated smoothly on the shaft with no evidence of any catching of needles on the slot. There is a cage supporting the needles, of course; they are not loose as in some automotive uses. If one thinks about how a D cutter works when it is only slightly more than a half cylinder in width, this should be quite understandable. The shaft cannot move off centre for the slot edge to dig into a needle.

The bottom end of the shaft was prepared as follows. First, after centre drilling and supporting the end, about 0.020 inch was taken off the diameter in the lathe (by grinding, of course) for a total length of about ¾ inch. This creates a shoulder for the bottom stop disc and the hole in this latter piece should be made to match. My plan was to turn the bottom taper for the drill chuck with a regular lathe tool. However, I found that the shaft was still rather hard in places; apparently some of the case was still present. So I went back to the grinding wheel on the flexible shaft tool. This worked fine and probably gave a better finish than turning would have. This time I used a thin disc grinding stone with better control than the stubby wheel I used previously (sorry, no photo shown). I prepared the shaft for a Rohm chuck with Jacobs #1 taper, again different to Thomas' specified #0 taper. The half-angle for mine (compound slide setting) was about 2.2 degrees and the length of the taper was about ⅝ inch.

While the shaft was still in the lathe, I used 300 grit abrasive in oil to lap the shaft and chuck together. After lapping, I noted a small bright band on the shaft and there was a barely perceptible wobble in the chuck upon assembly (I did this while the shaft was still in the lathe and ran it at low speed to look for a wobble). Looking carefully in the chuck, I could see a small bright spot in the taper that stood out against the darker abrasive layer.

Be sure to feel the temperature of the shaft during the slot cutting process. You do not want to reduce the surface hardness by letting it get too hot!

Apparently a small metal particle was imbedded along the wall. Whether this was a left over from manufacturing the chuck or was a bit of contaminant that I had introduced I will never know. But I never would have known about it without the lapping. In any case, a bit of careful scraping with a triangular hand tool removed the particle and gave as good a rubout for the chuck as could be expected. The taper is tight enough that I expect never to need Loctite to hold the chuck in place. The stop disc (no drawing shown; see the book) is loctited on the shaft. A screwdriver or wedge can be used between chuck and disc to remove the chuck if necessary. Be sure to put a shallow taper on the bottom of the stop disc (look ahead, it is visible in photo 18) to permit this to be done.

This is a note added after the whole assembly was completed. I was disappointed to find that the overall travel of the shaft was about 1½ inch rather than the 2½ inch I had anticipated. Even though I had made the shaft and slot about 1 inch longer than that specified in Thomas's book, the creep in my dimensions (top

Roughing the support column.

Holding a second chuck using a stub shaft.

flange in second spindle piece, height of pulley, length of bearing spacer, etc.) had eaten up enough space that the extra inch of slot could never be accessed. I now recommend at least 7¼ inch as the total length for the shaft rather than the 6⅛ inch given above if you want more travel. See **fig. 6** for specific dimensions of my original design. However, I think my idea of a 2½ inch travel was probably too ambitious for this drill. The linkage from the operating handle to the top bearing holder certainly would not allow as much front-to-back movement as would be required for this much vertical travel.

The Bearings

Table 1 gives a list of the bearings and shaft material that I used. If you follow my design, it may be helpful.

The shaft length given in this table is almost 15 inches and only about half that length is actually needed. I was not sure if I could do the slot grinding successfully on the first try, which is why the extra length was ordered. If I get ambitious enough to do a second longer shaft, the leftover will be useful. I have not given the source for these parts because I am not particularly happy with the supplier. The items cost about $45, but shipping and handling was more than ⅔ of this price! And when I wrote to complain, they never even answered my letter. If the supplier fails to list the shipping cost before you place the order (as this one did), beware.

Top Bearing Holder

The only thing to be said about this item (no drawing shown) is that obviously it has to be larger than the original ⅞ inch design diameter since the OD of my bearing is almost the same as this. I made it 1 inch OD but cut the groove for the drive pins in to the same inner diameter as Thomas specified (⅝ inch). The extra groove depth will provide some additional front-to-back movement range if I do ever make a longer shaft.

Support Column

The support column (the item that provides the pivot point for the operating handle) is pretty much the same as that shown in the book. My stock was 4.5 inch long, as in the Thomas design, so I used that. It should have been longer, as will be apparent below. If you deviate, I suggest that you make it a height such that when the drill shaft is at the midway travel point, the handle will be horizontal in this support. I was off by about ⅛ inch (again due to the dimension creep I mentioned earlier). This means that the effective front-to-back movement of the spindle relative to the operating handle will be different above horizontal than below horizontal. And this in turn means that the circular opening in the operating handle will need to be larger than it would if the above and below angles were equalised. **Photograph 13** shows an initial rough cut making the cylindrical part with the square end held in a small 4-jaw chuck (originally from a Unimat). **Photograph 14** illustrates how I hold this chuck with a stub shaft in a larger collet chuck. I find this trick of holding one chuck in another useful at times; in this case, it is much safer to hold a round file against the transition area from round to flat than it would be if my 8 inch 4-jaw were used. After tracing a rough outline for the curved top of this piece through some bluing, I shaped it by hand, holding it against a belt sander and then smoothing with a self-made filing machine. The slot for the operating handle was not completed at this time. It is better to wait until the handle itself is finished.

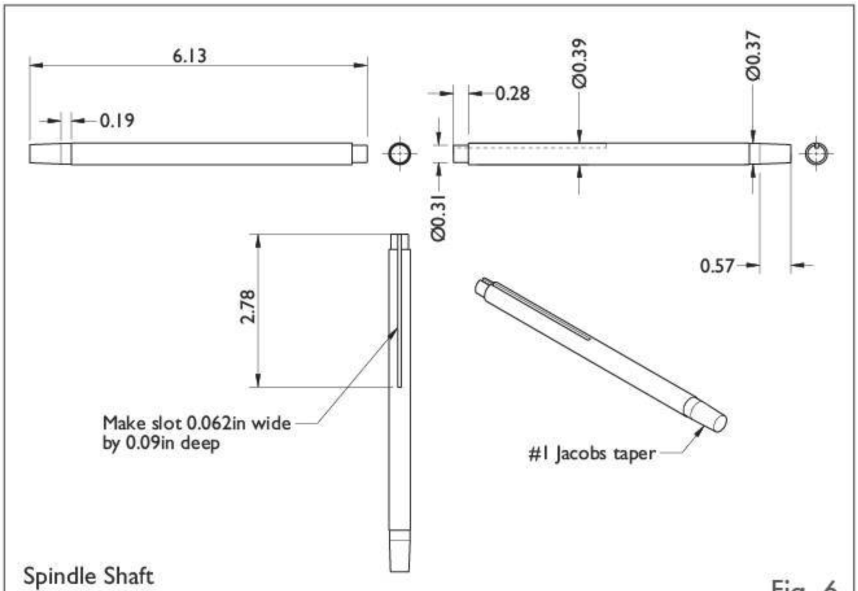


Fig. 6

Table 1: bearing and shaft dimensions

Diameter or ID	OD	Width	Description
8mm (0.315 inch)	22mm (0.866 inch)	7mm (0.2756 inch)	Top bearing
17mm (0.6693 inch)	40mm (1.5848 inch)	12mm (0.4724 inch)	Pulley bearings (2)
10mm (0.3937 inch)	14mm (0.5512 inch)	10mm (0.3937 inch)	Needle bearings (2)
10mm (0.3937 inch)	Shaft (375 mm long)	–	Case-hardened
Ground Carbon steel			


15

Now you know what a sex bolt looks like.

I made the ¼ inch diameter end section at the lower end 1⅜ inch long as per the book. Since I had made the support arms thicker than specified, I was surprised (but should not have been) that it was too short to pass entirely through the hole in the arm. Rather than starting over, I decided to make a 'Chicago bolt', sometimes also called a 'sex bolt', to secure the column on the bottom end. This has a hex head on the end, a smooth exterior and a threaded hole inside the bolt section. See **photo 15.** I made mine with a 5⁄16 inch exterior diameter, which works well for a ¼ inch threaded end on the support column. I seem to keep making problems for myself with my partial on the fly re-design of the UPT but then find a way out of them.

I suggest drilling and reaming for the pivot pin now even though the slot for the operating handle has not been cut. It is easier to cut the slot to fit the handle rather than vice-versa, and a close fit will avoid any possible side-to-side movement of the handle during operation.

Operating Handle

This was one of the stranger-shaped pieces. I started with a piece of steel 1¾ x 4½ x ½ inch (extra length at the rear end was adjusted later). This was clamped in a milling vice and the centre hole drilled and bored to 1 3⁄16 inch diameter (to clear my larger top bearing holder or drive ring). Note to self: next time, remember that the rotating drill swarf will scour off bluing and hide any lines previously made on the work piece. My outer ring diameter was 1¾ inch. Thomas left a gap of roughly ⅛ inch between the top bearing holder and the handle, since as the shaft goes up and down, the distance from the handle pivot to the bearing holder will change. The spindle moves vertically, and the handle swings radially about a centre pivot. I think ideally, when the handle is horizontal, the drive ring should be well forward of the bearing centre. Then as the handle is either raised or lowered, the pivot to bearing distance will be increased and the bearing will be forward of centre in the drive ring. If I had made things correctly, the handle would be horizontal at mid-stroke. In any case, I laid out the pattern on the bar stock and after creating the hole, used a ¼ inch end mill to cut the two long lengthwise slots to form the handle. **Photograph 16** shows this operation with one slot finished and work on the second one proceeding. The machinist's clamp is there to prevent vibration of the fairly thin handle section.

Yes, there is a goof here. I was watching the digital readout rather than the cutter and forgot I was aiming to stop at a reading of 1.0 inch rather than 0.0 inch on the first cut. However, this did not matter because I had planned to thin the whole handle anyway. I took 0.04 inch off both top and bottom so that the total thickness in the ring region was about 0.42 inch (Thomas had a total thickness of ⅜ inch). The advantage of a thinner handle is that with the handle tilted, there should be less chance that the bearing holder interferes with the handle ring. I later found that my clearance was still a bit too low. Next, the stock was mounted on a rotary table to cut the outer radius. I centred the rotary table on the spindle and zeroed the digital readout. Then I centred the work piece on the spindle and clamped it down for work. Thus, it is automatically centred on the rotary table. **Photograph 17** shows one side completed. The ring thickness has already been reduced on one side as can be seen. However, note that the front end, which will be threaded to take the front portion of the handle, temporarily has been left at full thickness. This permitted clamping without sagging and added a bit of extra thickness to this area in case I needed to do some more thinning of the ring later. Eventually, I decided to thin the whole thing since it looked funny with the step in thickness in the ring area. To avoid extra work, add new clamps for working on the second side before removing the first clamps. This avoids having to re-centre the work piece. No drawing is given, but the only differences from the original are the inner and outer diameters of the ring portion.

The rest of the work was pretty straightforward. The ½ inch deep hole for the front handle was drilled, as were the through holes for the drive pins, and all were threaded. I chose to use standard 8-32 SHCS (socket head cap screws) for the drive pins, grinding down the ends to provide the driving pin sections. A split-threaded collar was made to secure them in a collet on the Quorn for this operation. Purists may wish to use a slightly larger screw such as 10-32. When I had taken the diameter down to the required 0.125 inch, there was still a bit of thread showing, so I reduced the diameter to 0.120 inch. This tiny bit of slop in fit between pin and bearing holder is not significant. If it had been, I could always have drilled out and threaded for the larger diameter cap screws. Incidentally, I left enough extra length and thread on the screws that I could include jam-nuts to lock them in place at the correct depth. I considered just jamming the screw head itself against the handle piece and grinding to the correct length but then did it this way for a bit of added flexibility.

At this point, with the exact width of the rear portion of the handle determined, the slot in the support column to accommodate the handle can be cut. Here is what I consider an important step: assemble everything with the handle sliding in the support column slot and move the handle through its full range of movement. I found that the inner diameter of the ring portion was not large enough to permit full motion without altering the proposed position for the pivot pin during a stroke. The bearing holder fouled against the ring with a fixed pivot point. I had to go back to the milling machine and use the boring head to change the circular opening to an oval (long dimension front-to-back, of course). Instead of 1 3⁄16 inch, I made it almost 1⅜ inch long. It turned out that this was overkill and 1 5⁄16 inch would have been adequate, but you should check clearance between ring and bearing holder before drilling and boring that pivot hole in the handle.

With the newly elongated opening, I assembled again and when I had found the best apparent pivot point, used a prick punch through the hole in the support column to mark the handle. Again, exercise the handle through its full range, being sure that you can keep the punch mark centred in the pivot opening. Now one can drill and ream that pivot hole in the handle with confidence that everything will work as desired. **Photograph 18** shows this testing in

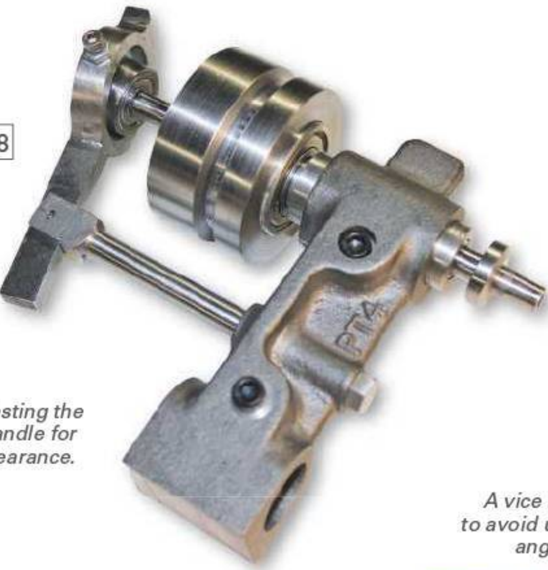

16

Slotting the operating handle.


17

Profiling the work on the rotary table.

18



Testing the handle for clearance.

19

A vice in a vice to avoid using an angle plate.

progress. Next, the handle can be cut to length, slotted, drilled, and shaped for the spring-mounting pin and finished off. I mentioned above how I sometimes use a chuck mounted in a chuck to advantage. **Photograph 19** shows a similar trick, a vice held in a vice, to mill longer vertical pieces that otherwise would require clamping against a right angle plate.

Out of curiosity, I calculated the handle-hole to bearing-holder values in Thomas' design and my own using a bit of trig. His ring I.D. to holder clearance was 0.2188 inch and the required movement (assuming 0.75 inch elevation above and below horizontal) was 0.1435, inch which works. My required clearance for an upward movement of $\frac{7}{8}$ inch (downward was less because the support post should have been a bit longer for a horizontal midpoint) was 0.1981 inch. With my original 1$\frac{3}{16}$ inch I.D., clearance was 0.1875 inch (not enough). With a 1$\frac{5}{16}$ inch I.D., clearance would have been 0.3125 inch (plenty). **Photographs 20** and **21** show a top view of the bearing holder with the handle raised and horizontal respectively. Note where the pins engage the bearing holder in the two photos. I should mention that my simple trig calculations assume a zero thickness for the operating handle, so the actual required clearance will be somewhat larger than given here. I'm sure my 3-D design program would have done a better job of finding clearances on an assembly drawing, but I am happier simply making things in the shop than clicking a computer mouse.

There is not much to say about the handle extension. I made it 6 inch long out of ¼ inch drill rod with a wooden ball handle. I did not create a larger diameter collar region where it joins the main handle piece as Thomas did. If I did it again, I would try to find a somewhat smaller ball and would make it only 5 inch long.

20

Bearing holder with handle raised.

21

The holder with the handle horizontal.

Lower Spring Holder and Depth Stop

These two items slide and lock on the $\frac{3}{8}$ inch portion of the support column. The book also shows a stop ring that locks on the spindle itself, but this seems inappropriate and redundant to me. It would limit the travel of the spindle if left in place and would require disassembly to add or remove it. If the support column has been made an accurate 0.375 inch in diameter, a spring holder and depth stop mounted on it should be sufficient to adjust spring tension and limit spindle movement. There is no difficult machining here, so I will not say too much about them.

My pulley was rather big and bulky, so some small redesign of the depth stop was needed to avoid interfering with it. In addition to making the depth stop shorter to avoid that large pulley, I did not feel that the extra split in the depth stop piece and the lock screw to prevent the main screw from rotating was necessary. The ¼ inch x 40 tpi thread of the depth stop screw was slightly larger in diameter than Thomas's and was slightly longer than one inch. I added a $\frac{3}{16}$ inch brass tip both for elegance and to fill the centre-drilled hole made for tailstock centre support, **photo 22**. The threads were tight enough that vibration rotation was not a big concern. However, I did add a threaded locking ring anyway, as can be seen in **photo 23**. What is not apparent in this photo is that the locking ring is largely hollow so that the depth adjustment screw knob can telescope inside it. I did this so that there would be enough of a ring to grip without difficulty. With its additional length and proximity to the support column, the depth stop screw can cover the full range of possible spindle travel distances without relocating the depth stop along the column. The photos give a good visual representation of the design. It is simple enough that no formal drawing has been given. It would probably be better to use still longer a screw to avoid having the telescoping adjustment knob and locking ring.

22

The brass-tipped depth stop.

23

The depth stop locking ring.

To be continued...

Stepperhead Lathe Construction
Part 19

Alan Jackson continues his description of the Lever Locking Topslide commenced in MEW issue 210, December 2013.

This series details construction of my Stepperhead lathe although many aspects of the design could be incorporated into other lathes if so desired. The whole design is a series of modules or building blocks that can be adapted and used on other lathes.

The finished Stepperhead CNC lathe.

Lower Slide (Drawing 45)

(Machine all faces of the rectangular block, for the lower slide, square and slightly oversize, say 30 thou, althouTgh the length can be the finished size. The excess material each side of the v-slide should also be removed, leaving a raised square sided centre section.)

Pack it to the correct height on the cross slide with the feed screw nut end facing the chuck. Bore the hole for the feedscrew through the block ensuring that the hole does not break through the front face. Drill through and bore the nut recess to size and depth. The tapped holes that retain the nut should be made with the nut in position and the slits in the nut orientated vertically so that the retaining screws can compress the slits. To do this you will need the nut before making these holes. The hole for the locking spindle should be bored next. Rotate the block so that the counterbore faces the headstock; pack it to the correct height. Drill then ream the bore to size and finally machine the counterbore for the retaining screw. The holes for the stirrup lever pivots should also be drilled slightly undersize at this stage because it will be difficult to do this into the sloped v-slide surface.

Stirrup Lever (Drawing 49)

Partially make the stirrup lever, just the top section, making the vertical arms (undrilled) to the overall largest section and parallel and the lower contact face area oversize to allow for machining. The radius ends and reduced arm section will be completed later. The plan is to machine the annulus recess with the stirrup lever in situ. This will ensure that the contact face of the stirrup lever is correctly shaped. End mill a rectangular recess in the lower slide contact face so that the stirrup lever can be fitted tightly into its position. Drill and file the vertical rectangular section holes to a close fit for the stirrup arms. Fit the stirrup lever fully in position and drill and ream the holes for the stirrup lever pivots using the lower slide body as a drilling jig. Remove the stirrup lever for the next operation, which is to mill the raised V-slide on a vertical mill parallel to the feed screw hole.

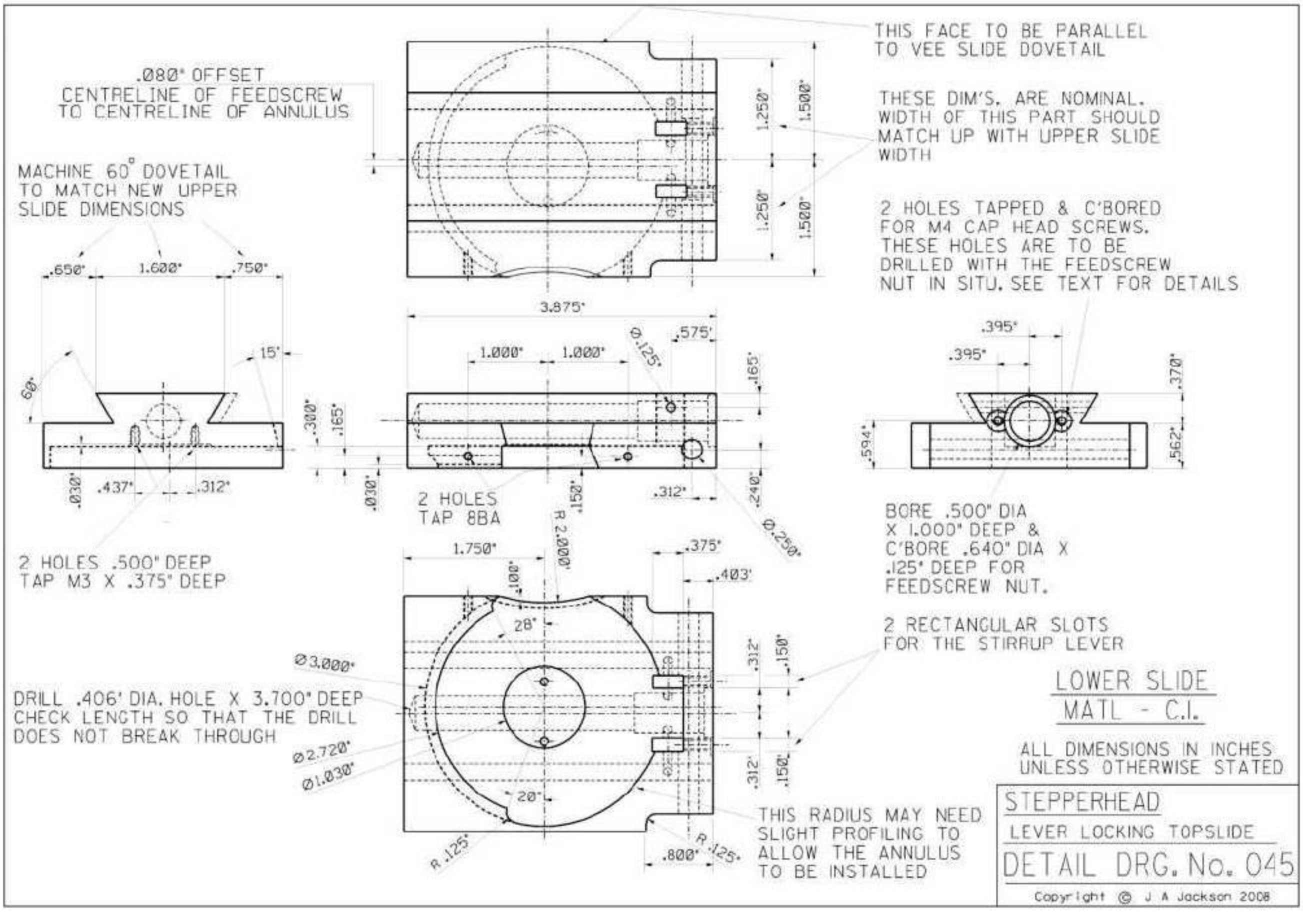
The next operation is to machine the recess for the annulus so it would be handy to have the annulus available as a gauge. It does not need to be completely finished, just the outer diameter, chamfer and thickness. Refit the stirrup lever and retain it with its pivots. This assembly can now be mounted in the lathe using a faceplate or 4 jaw chuck with the annulus recess on centre. Skim the contact face fully. Before completing the 45 degree undercut to the recess a piece of scrap packing should be placed between the chuck jaw and the body face that will be machined through the surface where the annulus will project outside the body of the lower slide. The machining process will cut into this packing when making the undercut. Machine the annulus recess to the final dimensions with a smooth finish to the annulus contact face. The location recess for the centre pad should also be completed at this stage.

Remove the stirrup lever carefully so as not to disturb the mounted position of the block in the chuck. The next operation is to remove half of the recess to allow the annulus to be inserted in position. This can be done in many ways. While it is in the lathe chuck you could use a topslide milling spindle if you have one. Carefully manually rotating the lathe mandrel against the cutter for the required rotation. It can also be done by rotating the chuck 180 degrees by hand taking small cuts with the top slide. It would be good if stops can be arranged against the chuck jaws to prevent rotating overshoot. This is slightly more difficult with the annulus offset because there is no aperture available for the cutting tool to finish in. The removed area does not have to be accurate it only has to provide sufficient clearance so that the annulus can be inserted. Alternatively and much easier; this operation can be carried out on a vertical mill and a rotary table if you have one.

Annulus (Drawing 47)

A disc cut from a bar or plate of mild steel should be adequate. Bore the centre first and skim the top face then mount via the bore and machine the other face, O/D and chamfered periphery.

Two tee bars, one should be an easy sliding fit in say the tee slot closest to the chuck, the other should fit a bit freer to avoid jamming. The tee bars can be made separately and attached to the annulus by cap screws or the annulus can be made with milled raised guide bars. A flat strip can be attached with countersunk screws to form the tee bar. This second method provides longer screw thread and integral guide bars. An identifying punch dot should be made on the upper surface at the end of the locating tee bar. This is so that the top slide can be replaced with the tee bars in their correct slots after it has been removed. The starting point for the



THIS FACE TO BE PARALLEL TO VEE SLIDE DOVETAIL
.080" OFFSET CENTRELINE OF FEEDSCREW TO CENTRELINE OF ANNULUS
MACHINE 60° DOVETAIL TO MATCH NEW UPPER SLIDE DIMENSIONS
THESE DIM'S. ARE NOMINAL. WIDTH OF THIS PART SHOULD MATCH UP WITH UPPER SLIDE WIDTH
2 HOLES TAPPED & C'BORED FOR M4 CAP HEAD SCREWS. THESE HOLES ARE TO BE DRILLED WITH THE FEEDSCREW NUT IN SITU. SEE TEXT FOR DETAILS
2 HOLES TAP 8BA
2 HOLES .500" DEEP TAP M3 X .375" DEEP
BORE .500" DIA X 1.000" DEEP & C'BORE .640" DIA X .125" DEEP FOR FEEDSCREW NUT.
2 RECTANGULAR SLOTS FOR THE STIRRUP LEVER
DRILL .406" DIA. HOLE X 3.700" DEEP CHECK LENGTH SO THAT THE DRILL DOES NOT BREAK THROUGH
THIS RADIUS MAY NEED SLIGHT PROFILING TO ALLOW THE ANNULUS TO BE INSTALLED
LOWER SLIDE
MATL - C.I.
ALL DIMENSIONS IN INCHES UNLESS OTHERWISE STATED
STEPPERHEAD
LEVER LOCKING TOPSLIDE
DETAIL DRG. No. 045
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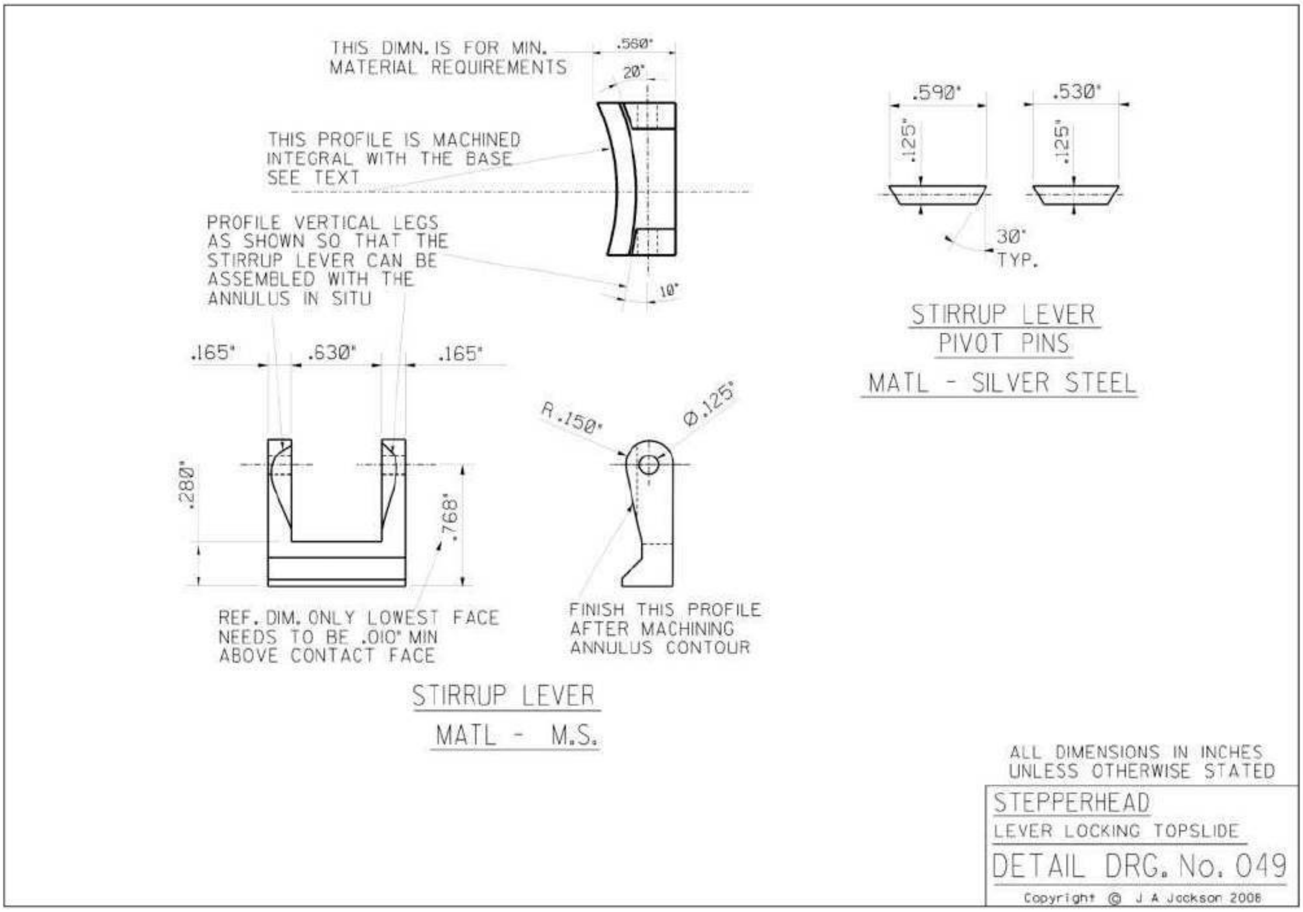

THIS DIMN. IS FOR MIN. MATERIAL REQUIREMENTS
THIS PROFILE IS MACHINED INTEGRAL WITH THE BASE SEE TEXT
PROFILE VERTICAL LEGS AS SHOWN SO THAT THE STIRRUP LEVER CAN BE ASSEMBLED WITH THE ANNULUS IN SITU
REF. DIM. ONLY LOWEST FACE NEEDS TO BE .010" MIN ABOVE CONTACT FACE
FINISH THIS PROFILE AFTER MACHINING ANNULUS CONTOUR
STIRRUP LEVER
MATL - M.S.
30° TYP.
STIRRUP LEVER PIVOT PINS
MATL - SILVER STEEL
ALL DIMENSIONS IN INCHES UNLESS OTHERWISE STATED
STEPPERHEAD
LEVER LOCKING TOPSLIDE
DETAIL DRG. No. 049
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graduations can be a bit tricky. I positioned the disc by locating from the tee bar and using a square to line up the zero point. Graduate the periphery every degree and stamp 1⁄16 inch numbers every 10 degrees. I used 0 to 90 four times. The portion of tee bar that protrudes outside of the annulus must be reduced to be below the surface of the cross slide when it is in its uppermost position by say .020 inch.) If this is not done the top of the tee bars will contact the underside of the top slide and prevent the top slide from locking to the cross slide when the top slide is set at an angle. This will only apply if you make tee bars rather than integral bars and a flat strip on the annulus.

Annulus centre pad (Drawing 47)

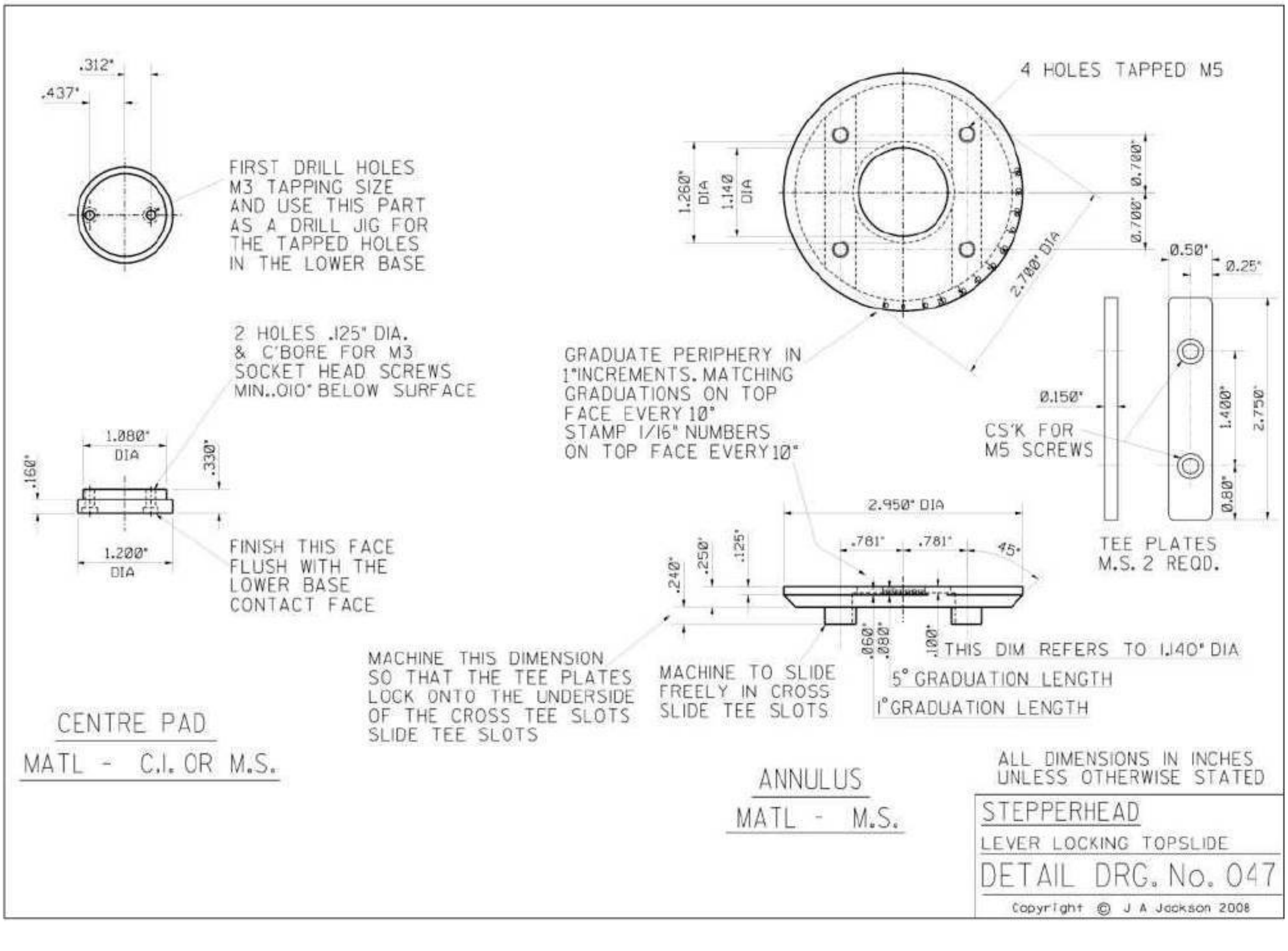
This component is secured in position after fitting the annulus. It is also used to slightly lift the annulus above the cross slide surface. The advantage of this is that the underside of the annulus will not rub over the cross slide surface when the top slide is re-positioned; this avoids scuffing the cross slide surface. So a stepped recess is made in the annulus and a collar added to the centre pad that holds the underside of the annulus about 0.010 to 0.020 inch above the cross slide when assembled. The diameters of the recess and collar should have sufficient clearance so that it does not impede the locking movement of the top slide. The holes in the centre pad should be first drilled to the tapping size. It can then be used as a drill jig for the lower slide. Open up the holes afterwards.

The surface of this pad should make contact with the cross slide surface. The assembly of the pad and body should be blued and scraped flat (or surface ground) to fit the cross slide surface in the locked position. This is to avoid distortion of the top slide when locked.

Stirrup lever and eccentric (Detail Drawings. No.047 & 048)

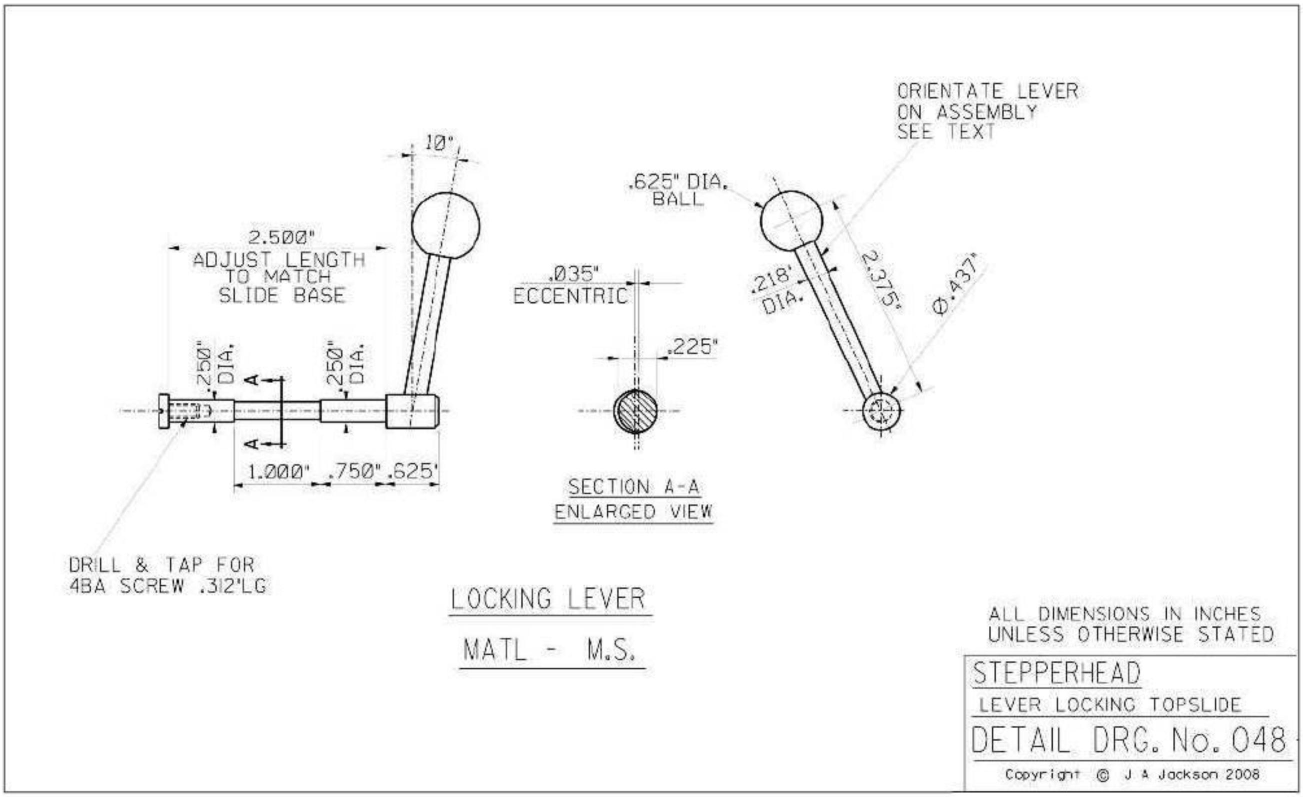
The rear face of the stirrup lever and the contour of the eccentric need careful fitting to ensure good operation. I suggest finishing the stirrup lever first. Profile the vertical arms to the final shape so that it has sufficient movement when installed and can contact and clear the annulus. The underside foot of the stirrup lever should be filed away so that it is above the contact face of the lower slide by say .010 inch. The eccentric contact face of the stirrup lever is carefully filed or milled away so that the eccentric can move the stirrup lever to lock and unlock the lower section of the top slide to the cross slide. In order to install the eccentric spindle, the stirrup lever pivots have to be removed and the stirrup lever lowered so that it can be moved towards the annulus to give sufficient clearance to clear the full diameter of the eccentric spindle. For the fitting process it is simpler to use a longer piece of 0.125 inch dia rod pushed through both pivot bores without the feedscrew nut in position. This is a trial and no error process of fitting, the top slide lower body assembly to the cross slide, so that it locks and unlocks and operates smoothly. The hole for the locking arm is best positioned when the eccentric is finished.

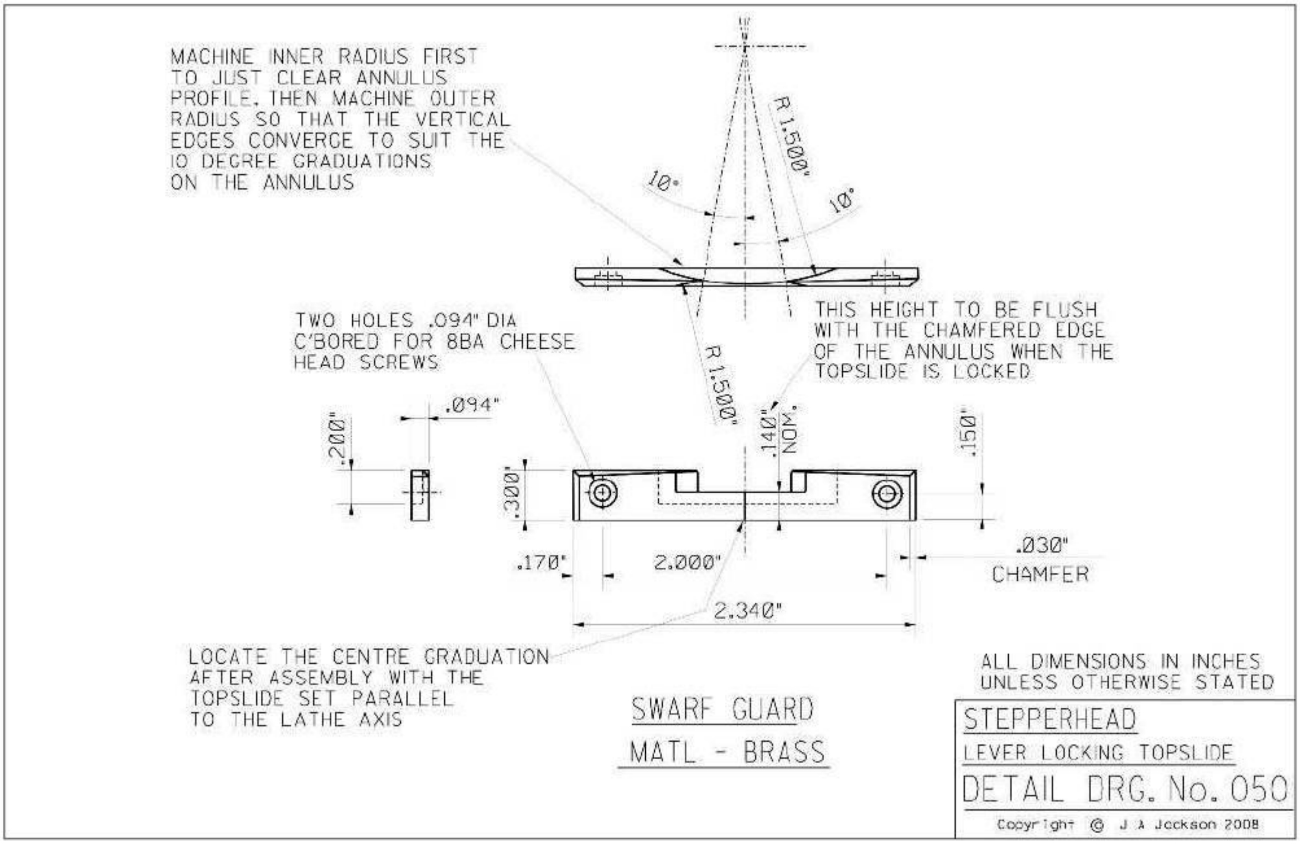
The largest diameter of the eccentric spindle should be left oversize; it can then be gripped by pliers to rotate the eccentric during fitting. The bruised area can be turned off after drilling the hole for the locking lever. Position the locking lever so that it is free in the vertical and locks at about 45 degrees from vertical. To install the feedscrew nut it is best to use the feedscrew inserted fully into the nut to push the nut into position, this avoids compressing the slits cut into the nut. If the nut is to be removed it is also best to insert the feedscrew fully into the nut in order to pull the nut out. This will prevent the nut being broken through one of the nut slits. The stirrup lever pivots should be adjusted for length so that they just touch the nut on the inner ends and just below the dovetails faces on the outer ends. When the feedscrew nut is fitted fully into its bore, ensure that the slits in the nut are positioned so that the retaining screws can compress the slits, then a 0.250 inch reamer will be required to remove a small part of the nut obscuring the eccentric spindle bore. Drill and tap for the M4 screws that retain the feedscrew nut with the nut in position and a 0.250 inch piece of rod inserted into the eccentric pivot bore to prevent the nut from rotating while the counter bored notches are cut into the nut so that the screw heads are flush with the top surface of the nut. (Using a suitably sized endmill?). Then remove the rod in the eccentric spindle bore, remove the nut using the feedscrew as describe above.



The M4 counter bores can then be made about 0.030 inch deep into the lower slide so that the M4 screw heads will retain the nut and can be also used to slightly compress the nut to reduce the backlash between the nut and feedscrew to a minimum. Before the nut is finally inserted back in its bore the small radiused notch in its outer diameter created by the reamer should be filed a bit larger to allow the nut slits to be compressed by the M4 retaining screws. If the stirrup lever is to be removed for any reason (this will not normally be required) the pivots can only be removed by removing the nut first (using the feedscrew fully inserted to pull the nut out) then a suitably sized Allen key can be inserted into the nut bore to push out the pivots.

To be continued...





A Siege Machine

Martin Berry takes an unusual approach to completing a workshop refurb.

After many years of collecting (hoarding) machine tools and other useful objects which will 'come in handy one day', the realisation that my existing workshop was too small became obvious when there was no way any work was going to get done as there was nowhere to stand. Furthermore, my expectation of collecting for my retirement was starting to be overtaken by the realisation that retirement was, in relative terms, not that many years away and I'd better get on with my hobby instead of dreaming about it.

Siege machine ready for action.

Fortunately, I have a reasonable size garden by modern standards and, after protracted negotiations with domestic management, an agreement was reached to build a new workshop at the bottom of it in exchange for a kitchen extension. The workshop would be about 50% bigger than my existing garage from which 90% of the content would be relocated.

Various options were considered including; timber, sectional concrete and brick. It was clear that a proper brick building, much as I would have loved one, was going to stretch funds well beyond my budget and a cheaper timber building might result in a noise issue with the neighbours. Therefore concrete was selected as the best solution. Being fairly tall, I chose a building with a 2.6m eaves height giving me plenty of head-room and extra space for storage. Unfortunately, the company concerned went bust and took some of my money with it. After recovering from the shock, I selected an alternative supplier who could offer 2.1m eaves height and, by adding a 300mm skirt, increase the height to 2.4m. Unlike other suppliers who wanted all their money up-front before delivery, this supplier was happy to take 20% deposit with payment of the balance on completion.

Prior to delivery the base was laid with 50mm of Celotex insulation beneath to reduce heat loss through the floor. The building was to be internally insulated with 150mm of mineral wool loft insulation in the ceiling and 100 mm of cavity mineral wool insulation in the walls.

The whole was lined with plasterboard and two layers were used on both walls and ceiling to give maximum sound attenuation. One of these layers was an acoustic board, which is more dense than standard plasterboard and weighed in at 30kg/sheet whereas a standard plasterboard sheet weighs around 18kg.

Here came the problem, how to get 30kg plasterboard sheets placed on the ceiling. Being short on volunteers (none), and myself not having the physique of Arnold Schwatzenegger, this was going to be very difficult. So after a few days of pondering, the concept of my siege machine was born (**photo 1**).

The base was made from an old bench table frame with a couple of uprights G-cramped on. Onto these a simple table frame, narrower than the plasterboard, was hinged using 12mm bolts. The table is held in the horizontal position by a hinged support and some supports, nailed to the end, hold the bottom of the board in position when loading. I had some table roller balls which were screwed to the table and made moving the board on the table significantly easier. The unit is moved around and elevated using a pallet truck. I bought the pallet truck for another project and it seemed the obvious choice for this. Large castor wheels fitted with brakes and screw jacks on the table were considered as an alternative option.

In use, a plasterboard sheet is lifted onto the table while in the inclined position. The table is lifted into the horizontal and the support pulled up. The whole unit is then rolled into position and lifted to within 10-20 mm of the ceiling. Final positional adjustment is made by sliding the board before the final lift into place (**photo 2**). Then a few plasterboard screws are put in to hold the board and the unit dropped and pulled away before installing the remaining screws.

With all ceiling boards up (**photo 3**), the campaign was a success. Next, the attack on the walls! My siege machine is no more, with all bits recycled to other duties or back into the stock box. The only cost was a few nails which, I can honestly say, I had no desire to reclaim. ■

Plaster board raised ready to fix.

Boarding all finished.

A beginners' guide to Home Metalworking

Part 8

David Clark completes his survey of milling tools and starts on some practical exercises.

As well as working in engineering, David Clark has set up and operated several home workshops. This regular series offers much sage advice for the beginner.

A 90 degree engraving cutter.

A 60 degree engraving cutter.

This is a very good face mill...

...that uses 8 sided tips.

This selection of cutters from Warco comes in a wooden box.

This useful cutter rack is from Machine DRO.

Another useful tool in the milling machine, is an engraving cutter **(photos 25 and 26)**, these are readily available on eBay. You can get these in quite small sizes such as 3mm shanks and they are often made in tungsten carbide for long life. These engraving cutters are very useful as an alternative to the centre drill especially when a centre is required to be drilled on an angle. I have used these engraving cutters in production where they were very effective in centring holes at a 30 degree angle.

These engraving cutters are available in various sizes and various angles from very acute angles right up to where the cutter is parallel and can be used like an ordinary milling cutter on its side.

If you have a larger milling machine you can use one of the large face mills that take inserted tips **(photo 27)**. There are various types and makes of face mill and also various shapes of tip. Some tips only give you 2 cutting edges while others will give you 8 cutting edges which make the cost of a tip quite economical **(photo 28)**. You can even get round tips that you can rotate just enough so that the wear does not become a problem.

When you first start out with your nice shiny new milling machine it would pay you to buy a box of cutters of various sizes **(photo 29)**. You will find this is more economical than buying individual sizes and the wooden box is useful for keeping the cutters safe and protected. As you wear the cutters out all you have to do is replace the cutter you that is worn out to keep the set complete.

Cutters should either be stored in their original plastic boxes or you can buy little trays to store your cutters on to stop their sharp edges knocking together **(photo 30)**.

Now we have sorted all our cutters out, we need to be able to clamp the vice or other fixture onto the milling machine. For this we use clamps **(photo 31)**. Clamps are available in various sizes and thicknesses and you can also make your own clamps if you wish. There are various types of clamps, the basic plain flat clamp, and a swan necked clamp (**photo 32**) which has one end directly onto the table or a bit of packing and the other end on the vice or fixture. These clamps are very useful because you don't have to mess around with packing to get the height correct.

You need to use proper Tee nuts for the milling machine (**photo 33**). If you try to use say a standard hexagon head bolt or similar you may ruin the Tee slot and even the table. Tee nuts are readily available from your engineering supplier but they are also very easy to make and you should make several to get you going. To go with the Tee nuts you should have some nuts, preferably top hat nuts with shoulders on to spread the load and you should also use washers under the nuts. For studs you can buy what is called studding or it is also known as all thread. You buy this by the meter and you cut it to the length to suit the job in hand. A few weeks using your milling machine and you will probably have all the different lengths of studding that you will ever need.

Another type of clamp that is very useful is a clamp with a milled angular profile on it. By the use of these angles you can set the height of the clamp to suit the job by simply moving the clamp up a step in small increments. You can buy sets of these clamps from your engineering supplier; they are very useful and will do most of the things that you require a clamp to do. A bonus is that the blocks can be interlocked with each other to increase the height of packing in fine adjustments (**photo 34**).

31

A selection of clamps should be available.

32

These swan neck clamps are very useful.

33

Tee nuts, top hat nuts and washers are required to clamp work and vices down.

34

This is a stepped block from a clamping set.

1

Castings and materials for a Stuart 10V.

2

The box bed casting.

3

Machining under the box bed.

Now we know the basics of milling cutters and clamps etc. it is time to look at how we machine various components. I will start with a common item in many model engineers' workshops, a Stuart stationary steam engine. Many model engineers over the years have started out in this hobby by building a Stuart No 10 vertical engine (**photo 1**).

For many years Stuart Models (**ref 1**) has been selling kits to make steam engines. Recently the engine kits have been supplied from the foundry in Bridport in Dorset after many years from being supplied from Jersey.

I won't go into how to build the complete kit but rather give some advice on how to machine individual items. Photos may show the horizontal engine (10H) or the vertical engine (10V) components.

The first item we will look at is the box bed (**photo 2**). This is a rectangular box shaped casting with thin walls. The casting needs cleaning up all over to leave a good surface for the paint to adhere to. This can be done with files and emery cloth. The top and bottom of the casting needs to be flat and parallel to each other. You can either machine the bottom surface on the lathe (hold in the four-jaw chuck) or on the milling machine (**photo 3**). Note the packing to stop the casting from rocking. Take off the minimum amount of material to clean up the surface. If turning, the lathe tool should ideally have a tungsten carbide tipped cutting edge. Use a diamond lap (**photo 4**) to put a 45 degree x 1mm chamfer on the corner of the tool to help to get under the casting's skin. If milling the surface, a standard end mill will do but if

A diamond lap. fitted with a handle.

Comparing the horizontal and vertical box beds.

Box bed clamped to the mill.

The vertical baseplate casting.

Underside of the baseplate.

you have an old one, you can also put a 45 degree x 1mm chamfer on the corners.

Put a sheet of wet and dry paper onto a flat surface (a granite chopping board should be flat enough) and rub the machined surface on the wet and dry paper. You should have an even finish right across the machined surface and the component should not rock. **Photograph 5** shows the finished undersurfaces of a horizontal and vertical box bed.

Now you can clamp the casting onto the lathe's faceplate or flat down onto the mill's bed using the casting's mounting lugs (**photo 6**) and take a very light cut across the top. Again, rub the machined top surface onto the wet and dry paper. Aim for a smooth finish with no hollows and no rock.

Next we will tackle the bedplate (**photo 7**). The bedplate casting will have a lump on the underside where the molten metal entered the mould (**photo 8**). You should file this lump off before machining the underside. Again, you can do this in the lathe (**photo 9**) or by clamping it down to the mill's bed.

Clamp the casting onto the mill's table to machine the top surface with a clamp at each side (**photo 10**). Mille the top of the column mounting faces flat. The size is not critical, just make sure the surface cleans up.

Turn the bedplate 90 degrees and clamp down using the clamps on the surface we have just machined (**photo 11**). Machine the tops of the bearing mounts to the same height as the column mounting faces. You are only taking a minimum amount of material off so you should not need to alter the cutter's height. Finally rub the finished surfaces on a bit of wet and dry paper to ensure they are flat and parallel.

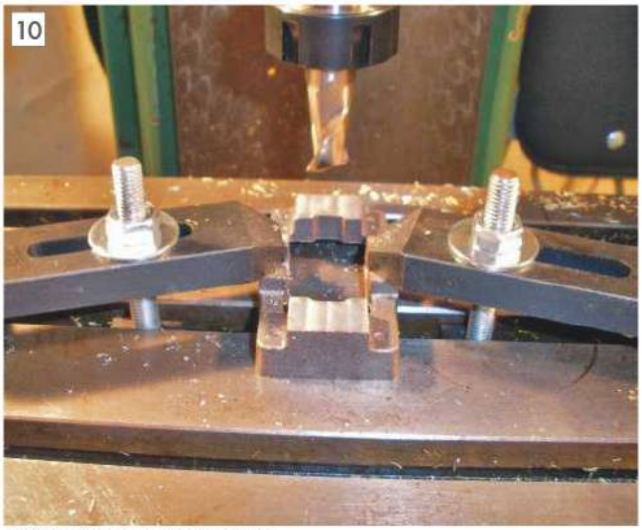
We now have a pair of flat and parallel castings that just need drilling. The box bed needs two mounting holes in it. The drawing does not give the size or position of the mounting holes but the casting has two dimples where the holes need to be drilled. However, these two holes need to be either spot faced or countersunk to take a screw or bolt head.

We will use a commercial counterbore to do the spot-facing. A counterbore is the same as a spot-face but the counterbore will normally be taken deeper so the screw is sunk below the top of the component. Most commercial counterbores have a pilot hole far too big for the diameter of the bolt so drill the casting for the pilot of the counterbore that will give the best size for the bolt head. When you have spot-faced the two holes, you can open up the holes to a nice snug fit on the bolts.

Alternatively you can countersink the holes to take a standard woodworking screw if you wish.

Now we need to drill the tapping and clearance holes in the box bed and bedplate. Clamp the two components

A lathe can be used to machine flat surfaces.



Milling the standard mounts.

down making sure the bedplate is square to the box bed and is set equally in the centre (**photo 12**).

Pitching out holes using co-ordinate drilling

Figure 1 shows all of the dimensions for the hole positions for a bedplate casting. They are in the same positions as given in the Stuart drawing but are redrawn from the datum point at the top left. It is always advisable to redraw any co-ordinates using the top left corner of the component as a datum point when pitching out holes. It is still useful if you have a digital readout.

The datum for the machining is the top left theoretical intersection of the two datum lines where all the dimensions are taken from. I have added letters to all of the hole centres to show the drilling sequence I used.

First wobble off the back face of the top casting and then the left-hand end of the casting in turn. Find the edge of the back face first, move the table towards the edge finder until the edge finder rolls off or along the edge of the casting. Raise the quill and move the table away from you by half the diameter of the edge finder. Zero the dial if it is zeroable (or write down the reading if not). The centre of the edge finder should be directly over the edge of the component.

Move the table another turn or two so that the wobbler is right over the job, the amount of movement is not important. Now you need to use the edge finder on the left-hand edge, zero and move the table half the wobbler diameter. Zero the dial for the axis you have just wobbled from. Wind back in the first axis you just set so the wobbler is a turn or two away from the job. Wind back to zero so the centre of the spindle is over the datum point again. This is the theoretical intersection at the top left-hand corner of the component.

Right, let's pitch out the holes. Move the table along the x axis to 0.225in. Now we are in line with the row of four holes at the left-hand side of the job. Move over in the y direction by 0.2 inches and centre drill the first hole. This hole may wander slightly as it has already got a dimple from the casting process. If you can, use a CNC 90 degree centre drill. Move in the y axis to 0.5 inches and centre drill the next hole. Move to the 1 inch position and again centre drill the hole. Move to the 1.3 inches position and centre the last hole in this row. Move to the 1.375 inches position and then move to the 1.037 inches position in the x direction and centre drill the hole. Finally move to the 1.633 inches position and drill this hole. We now have holes A, B, C, D, E and F centre drilled. Now we go back to the datum point at the top left of the component.

Move over to the 0.125 inches position and move along to the 1.037 inches position. Centre drill the hole then move along to the 1.633 inches hole and centre drill again. Now you can move over to the 0.2 inch in the y axis and to 2.475 in the x axis. Centre drill the I hole and move over in the y axis to centre drill holes J, K and L. You now have 12 drilled holes in the correct position and without any errors from backlash in the feed screws.

If you did wind past the required hole position accidentally, just wind back a turn or two and then move up to the hole again.

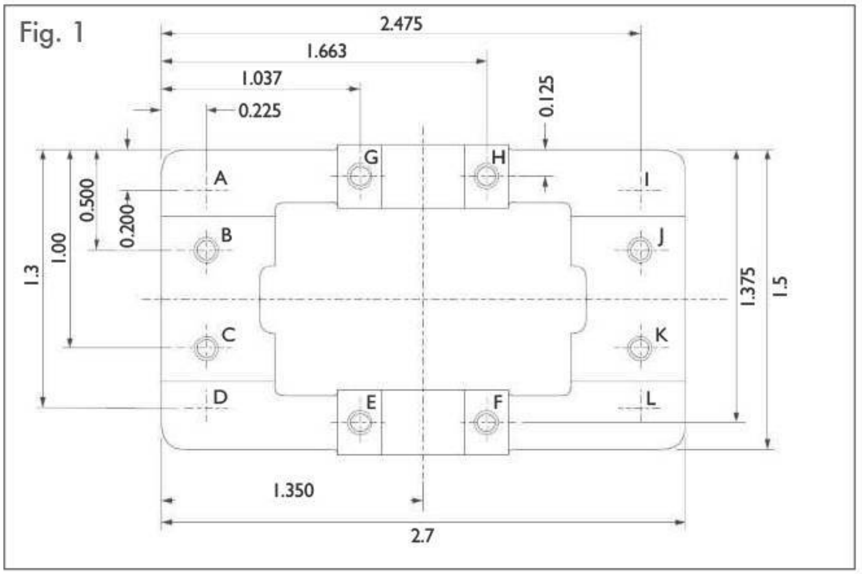
By going back a couple of turns, and then moving forward again, you are taking the backlash out of the equation.

I hope this is clear; if not read it through again doing the moves in your mind using the drawing. The principle will work for any component you care to machine. Yes, you might have to sketch it out differently or re dimension it but it will save you time and save you scrapping work. Do double check your dimensions carefully if re drawing though. This method is not only relevant to machines without a digital readout. I have used the same principle on a worn out CNC machine to reduce errors to within drawing limits.

Now you can change the centre drill for a tapping drill and drill all the holes in both castings. Do not be tempted to drill clearance size holes in the top component while the bottom component is still in place. You may drill one or more of the box bed holes clearance size right through. Now how do I know that?

To be continued...

Fig. 1



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1. STUART MODELS, Grove Works, West Road, Bridport, Dorset DT6 5JT
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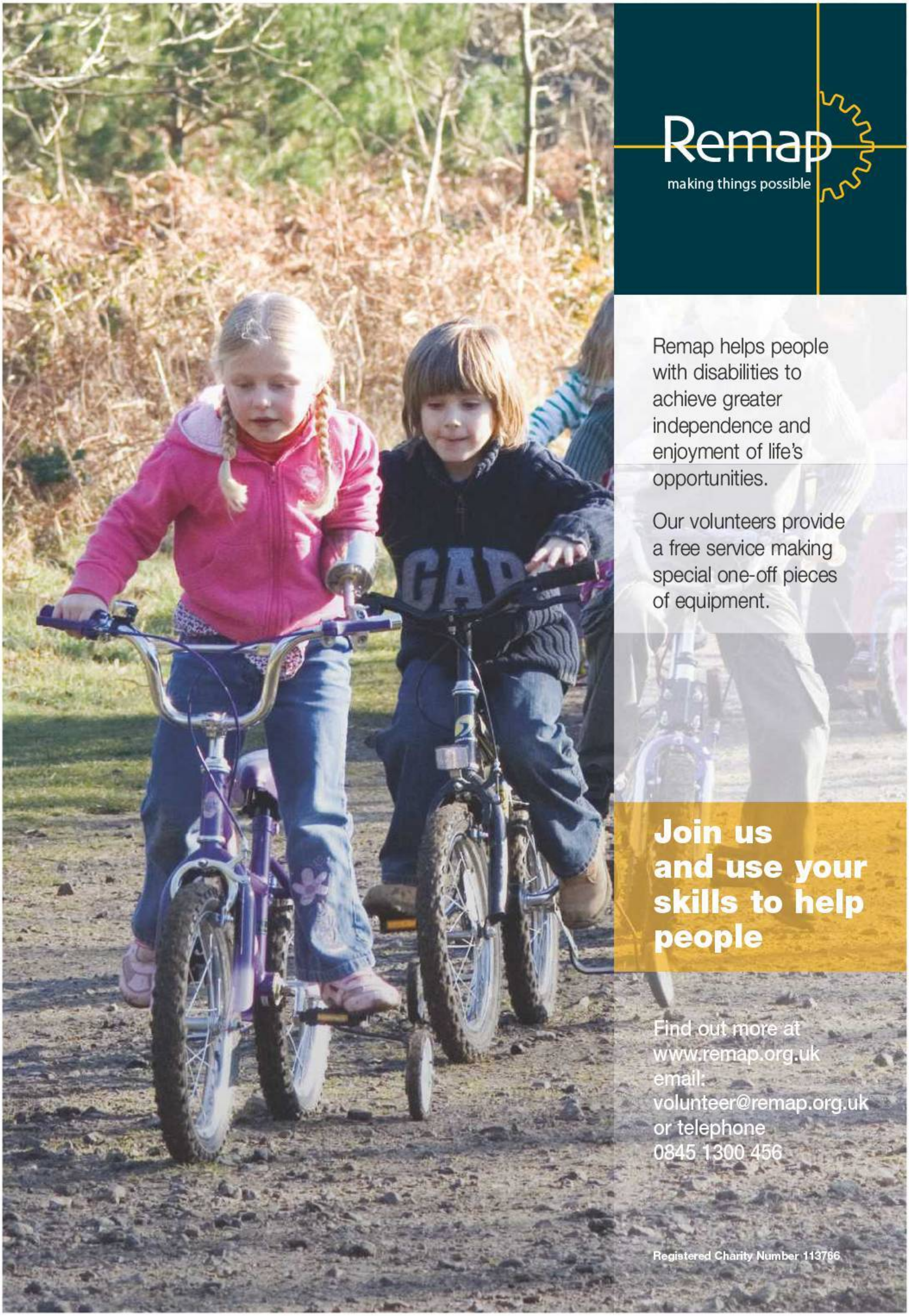
Milling the top of the bearing housings.

Drilling the holes.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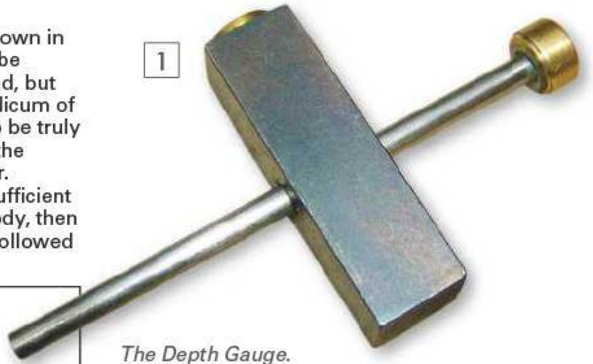
Stub Mandrel's Short End
A Depth Gauge

Stub Mandrel's aim is to never let anything long enough to hold in the chuck go to waste.

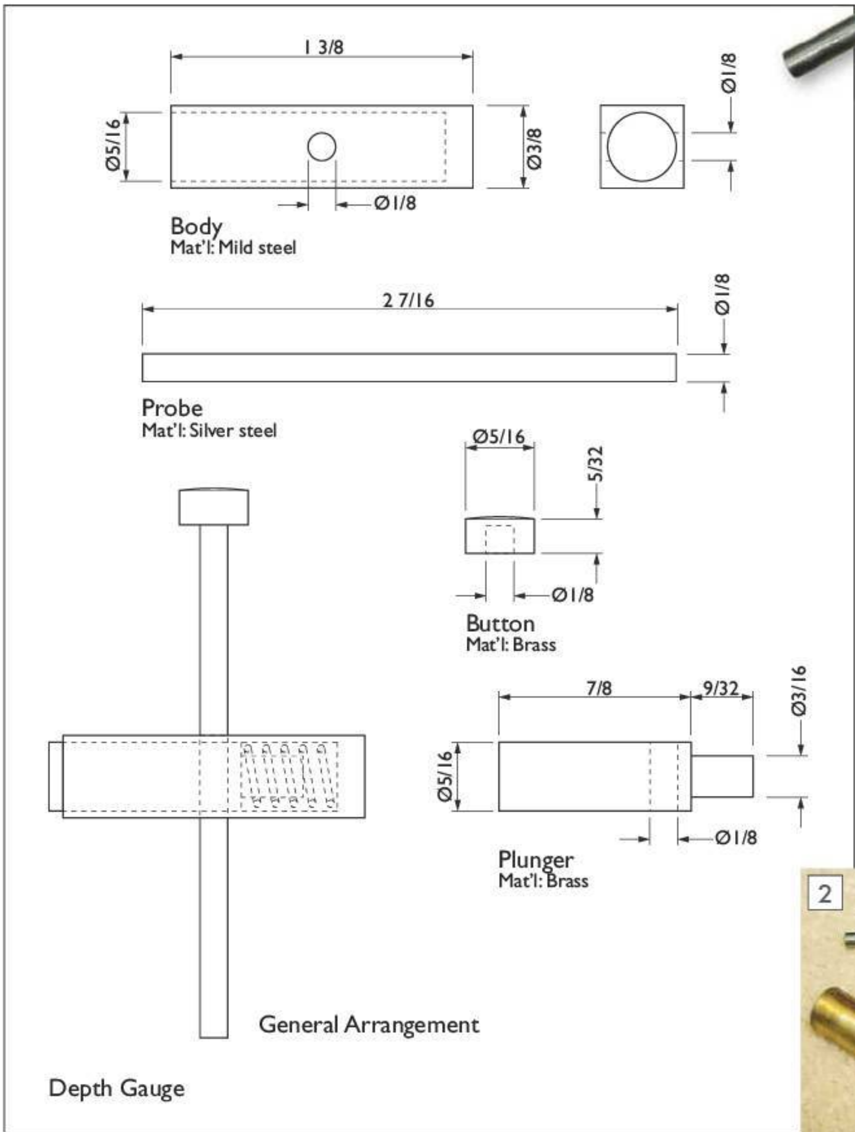
A small depth gauge that can reliably hold its setting is an invaluable asset. My original small depth gauge followed some advice given in ME, and was a rod of silver steel inside a plastic 'spring toggle'. To be honest, I found the round toggle an awkward shape, so I salvaged the spring and the depth rod, and remade the toggle in brass and steel. If ever there was a good use for a few pieces of scrap, this is it.

The construction is simple, as shown in the drawing. The dimensions can be adjusted to suit whatever is at hand, but one or two operations need a modicum of care. The hole for the rod needs to be truly perpendicular, and to go through the centre of the body and the plunger. Accurate marking out should be sufficient for this job. Start by drilling the body, then pop in a short piece of brass bar, followed by the plunger, and clamp it firmly in the body. Now drill the central hole through both parts either in the lathe or a mill, for maximum accuracy. Drill the hole to nominal size, the slight oversize of a normal twist drill is just sufficient to give a good sliding fit. I like the slop-free fit that this gives for the rod in the plunger. The second item needing care is facing the end of the plunger very neatly, so it is a true, flat face. The brass button on the other end of the plunger may be held on by a retainer such as loctite. If you would like pressing the plunger to give a greater degree of freedom for the rod to move, enlarge the hole in the plunger by 1/64 inch.

Two easy ways of putting a nice finish on the body of the tool are oil blacking and bluing. I blued mine, simply by papering it to a good finish and heating it slowly with a small torch. The knack is to stop heating at just the right moment. Some steels don't seem to blue as well as others and for these oil blacking is a more robust finish. For a small component like this I would heat it to a dull red heat, and drop it into a golden syrup can half full of old cooking oil. I have never managed to ignite the oil doing this, but it does make a lot of smoke, so please do such work out of doors! ■



The Depth Gauge.



The components of the depth gauge.

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Drop us a line and share your advice, questions and opinions with other readers.

HAMMER TO FALL

Dear Neil, The cover photograph of issue 217 shows, I believe, a Blacker hammer. Just to let you know there is one working at Wortley Top Forge at Thurgoland, to the Northwest of Sheffield. Good luck to your excellent mag.

Ken Preston

UNIVERSAL PILLAR TOOL BEARINGS

Dear Neil, I think David Graves is referring to a Drawn Cup Needle Roller Bearing (D.C.N.R.B) HK1010 - which is a metric bearing - 10mm x 14mm x 10mm. if so, many people make the mistake of measuring the OD of such bearings and opening up the housing to accommodate.

1) A D.C.N.R.B. gets its support from the housing in which it sits. As is, before fitting, the outside diameter is likely to be greater than 14mm. This type of bearing has to be press fit into a housing, using an appropriate mandrel. The housing diameter has to be between half a thou to a thou smaller than the outside diameter of the D.C.N.R.B., depending on how hard or soft the housing material is.

2) To prove point 1, take the bearing and put it onto a 10mm shaft, and you will see/feel it rattle. You make a 10mm diameter mandrel T shape/top hat to suit hole diameter, for the purpose of press fitting. When you press fit the bearing into the housing, the needles will 'compress' onto the shaft of the mandrel, to get correct fit. After the D.C.N.R.bearing is fitted correctly into the housing, you will find that a 10mm shaft will go through it with a perfect fit.

3) One should not open up the housing to the outside diameter of a D.C.N.R type bearing or use loctite for fitting these specific type of bearings - unless it is a 'bodge'.

4) All good D.C.N.R.bearings and one way clutch D.C.N.R.bearings are stamped with a bearing number. When inserting such bearings into a housing, the 'pressing' should be done on the side which has the bearing number marked, as this 'end' of the drawn cup 'plate' is hardened, specifically for the purpose of 'press' fitting.

I have often come across this problem, especially with lubricators where one way D.C.N.R.clutch bearings are used, and the user complains of 'slippage' over time.

Hope the above information helps.

Ketan Swali, ARC. Euro Trade, Leicester

David Graves replies:
Being an engineer of the chemical rather than mechanical variety and only self-taught in machining, I was unaware of this information and appreciate the advice. I hope readers will heed the recommendations of an expert in bearing use.

With that said, I would like to offer a couple of empirical observations. When I first bored out the spindle to the specified (correct) diameter, I found that about ¼ to ⅓ of each end of the bearing could be inserted into the housing without pressing it in. This suggests that the bearing cup was cylindrical with a slightly barrel-shaped center portion, and I assumed that this was to accommodate any axial misalignment. There was never any discernible play between shaft and bearing before or after installation and certainly no 'rattle' in my case even after I enlarged the bore a bit.

Out of curiosity, I placed a DTI against the drill chuck and manually applied a substantial positive and negative radial load. The maximum deflection produced was 0.001 inch and the deflection was directly proportional to pressure (no detectable sudden jumps). To me, this indicates bending of the shaft rather than slop in the bearing-to-shaft fit. Probably my method worked because the needles are supported well at each end by the bearing cup itself. How long the bearings will last with my modest side loading only time will tell. I wonder how many import drill presses would show as good a result?

If I were doing this again, I would adopt the following procedure: Bore at least three holes in a scrap of ½in. thick steel, e.g. 13.98, 14.00 and 14.02mm in diameter. Press the bearing in largest hole and check shaft fit. If any play is detected, continue to press in same direction to remove bearing and try the next smaller hole. Continue until a size is found that will not accommodate the shaft and then back up one size when making the spindle. If I were being picky, I would use a separate test bearing for fitting rather than one I intended to use in the spindle.

David Graves, Devon, Pennsylvania

MYFORD ANTI-RUST

Dear Neil, I really did find the rust article very useful and will, eventually, get round to trying the electrolytic method. The photo No. 5 on p30 of issue 216 shows products that Myford once sold: Rust Ban 393 from Exxon Mobil and Calpreve 91 from Calder Oils. The article states that these products are no longer available from Myford Ltd but doesn't mention the anti - rust products that Myford do sell - and use in house in connection with their own business for spare parts and new machines: Mobil Arma LT ref 1771 for Long Term use and Mobil Arma MT ref 1772, a lighter oil for Medium Term protection.

Both come in 1 litre packs costing £19 plus VAT per litre and are available in UK only including on line

I bought my first Myford on HP in the 1950's - a Super Seven after seeing the first one in Leeds at Smiths in the Headrow. Cost for the basic lathe was £57 - 17s - 6d, serial number 47. The chucks and many extras came to nearly as much again. The swivelling milling slide was £5. By the time the HP was cleared everything had gone up in price substantially and there were waiting lists.

My S7 has been updated as improvements came along and is still a favourite in regular use. It's good to know that Myford has been rejuvenated and will continue to serve us well.

Colin Murdoch, Leeds

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Spade Drills

Henry Hicks revisits an old technology with a contemporary application.

Anyone who has tried to drill sheet brass will know that this is an exercise fraught with danger. As soon as the drill starts to cut the brass sheet tries to run up the drill flutes causing all sorts of mayhem. Even if the sheet is clamped to the drilling table this 'run-up' effect still gives trouble. The standard way of dealing with this is to grind a small flat on each cutting lip so that the drill scrapes rather than cuts. This method certainly works, but it means damaging a drill to cut brass and then re-grinding to cut steel afterwards. I am not keen on either of these operations. In order to bypass this difficulty I decided to use spade drills, which have no flutes and which can be used on brass sheet directly.

Tapering the end of a silver steel rod.

My first thoughts were to find a supplier of these drills, and in this quest I spent some time on searching the web for answers. Finding spade drills for cutting wood is no problem. Similarly drill bits of 1 inch and over are fairly common. Finding such drills as small as ⅛ or less was much more difficult. I did find a supplier of such drills made from solid carbide, starting price about £12 each, which is not excessive for solid carbide, but still expensive. A set of 10 costs about £100. There must be an easier way. Also note that carbide behaves like glass – the drill will shatter if it is misused in any way whatsoever. When drilling brass sheet the most difficult time is at breakthrough, when the smallest rag can cause just such a breakage.

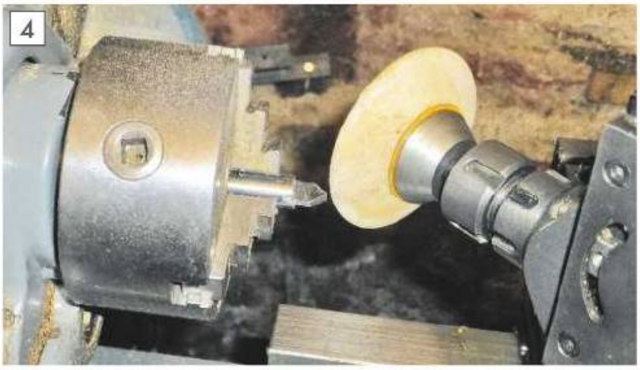
In the end I decided I could make my own from silver steel and trade workshop time against cash. I have now made several such drills, adding one to the set as needed.

It turns out that spade drills are not difficult to make, but they do take up a little time. Since I am firmly wedded to the Imperial system of units I normally start with a silver steel rod of the diameter wanted, such material being readily available.

I start by turning a taper on the end of the rod (**photo 1**) and then mill flats on

The dividing head at the back of the lathe mandrel.

Shaping the tip of the drill.



Grinding the cutting edges.

A selection of spade drills made by the author.

opposite sides. The included angle of the taper is not critical, I have used anything from 60 to 90 degrees. In the case of the ½ inch cutter, illustrated here, I cut slots with a slitting saw and then sawed off the 'wings'. The dividing head is used attached to the rear of the mandrel (**photo 2**) in order to ensure that the slots cut were exactly parallel to each other. After attaching the dividing head I advance it a couple of turns to take up any slack before any machining is done. Then take a cut one side, advance the spade drill by 180 degrees and take a cut on the other side (**photo 3**). Continue until both cuts are deep enough. When happy with the result advance the spade drill by 90º plus one turn to leave it horizontal instead of vertical. (See later).

Now the milling attachment is equipped with a cup shaped grindstone, as in **photo 4**, with its centre coincident with the lathe centre, and the narrow faces of the cutter are ground flat. Note that the embryonic drill was advanced an extra turn of the dividing head before being ground in order to create some relief behind the cutting edge. Now both sides can be ground, one after the other, with the top-slide at the same angle as before, until the cutting edges are fully formed. This technique should result in two cutting surfaces linked by a third edge in the middle. This third edge will cut, albeit slowly, but I have found it better in use to drill a pilot hole of diameter equal to the length of this edge. The pilot hole will be so small in diameter compared with that of the drill just made that there should be no trouble with 'run-up' effects.

The shank of the spade drill is then tapered, only 1 or 2 degrees, so that there is clearance behind the cutting edges.

The resultant drill is then hardened and tempered. Heat the cutting edges to cherry red and quench, then polish one face with emery so that the silver colour shows through, then heat to light straw and quench. I suggest you test the drill with a file to make sure it is hard before trying to temper it. If the file cuts, then the drill was not properly hardened. The file should skate off the surface like trying to file glass. When heating to temper do not heat the drill point, but the shank so that the colours can be seen running up the drill to the tip. Quench when you reach the desired colour at the point, normally light straw for a cutting tool. This should leave the drill shank soft so the drill chuck can get a good grip.

Photograph 5 shows a selection of drills, all slightly different in style, which I made that way in order to try out various settings. You can see that some of them might be a little soft, the final colour being nearer blue than straw. In spite of this they all cut more or less the same. About the only common feature is that they are mostly made out of ½ inch silver steel. What you can't see is that they have their cutting size stamped on the bottom. ■

In our Next Issue

Coming up in issue 219

On Sale 1st August 2014

« Terry Gorin describes the gear train addition to his Unimat SL

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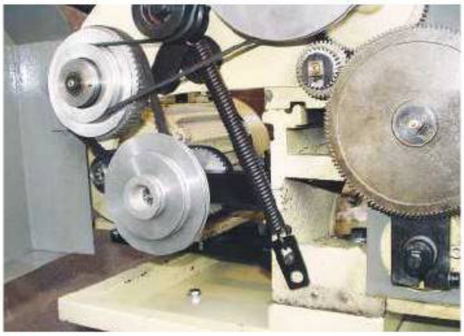

Tony Weale uses toothed belts to slow down an Asian 9x20 lathe

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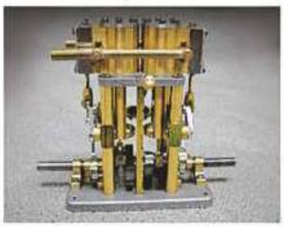

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