

No.256

THE MAGAZINE FOR MAKERS AND HOBBY ENGINEERS

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JULY 2017

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- Making Division Plates
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- Gear Cutter - An Update

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On the Editor's Bench

Getting things in focus

One particularly useful application of 3D printing that links to my other hobby of astrophotography was printing a series of Bahtinov Masks, these are simple but effective devices that use a pattern of large slits to create diffraction patterns from bright stars. These aid the focusing of telescopes and lenses, as all you have to do is turn the focus knob until three bright lines all cross at the same point.

Another focusing issue was a visit to the optician, which resulted in three! new pairs of glasses for distance, intermediate and close-up work. I lost my intermediates a few years ago and have been 'getting by' – it's a real boon for workshop work, as well as the computer to have something

that let me focus between a foot and a yard without difficulty. This also led me to get around to completing a planned aid to benchwork. I had a good quality 100mm acrylic lens and a circular LED 'cupboard light' and had been planning to make a bench magnifier. With the centre cut out of the lamp with a fretsaw and tidied up the lens was a good fit and easily epoxied in place.

The big challenge was accurately making lots of metal arms with accurately spaced holes to give a double parallel motion, like an anglepoise lamp. Inspiration struck and instead of spending an age cutting metal, I spent an hour or two with TurboCAD and then printed out a selection of parts. Metalworking was confined to bandsawing a suitable chunk of steel to shape for a base, tidying it up on the lathe and drilling and tapping an M6 hole. I was also able to make a very neat cover for the back of the LED/lens assembly. A tactically positioned battery box with a lithium battery and its control/charger board supplies power and aids stability. I will be putting the STL files for the lamp on the web at www.model-engineer.co.uk/lamp.

The whole thing works perfectly, aside from one minor oversight – I forgot to include an on-off switch, so I will be printing a more elegant battery box – with a place for a switch!

Finally, my apologies to Eric Clark for spelling his surname incorrectly on his article "Making the Most of an old Chuck" in MEW 255.

Neil Wyatt



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Coming up...

in our next issue

Coming up in our next issue, MEW 257 will be another rewarding read.



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Drill sharpening With A Cutter Grinder



Will Dogget makes a useful pair of accessories to aid drill sharpening using his cutter grinder.

After making a cutter grinder for reconditioning end mills and slot drills. I thought it might be possible to sharpen drills on the grinder with this method as well. As I do not like grinding on the side of grinding wheels (grinding wheels are not designed for side load and dressing them is difficult as well) this is why all the tools I make use the front face of the grinding wheel.

My initial thought was to make sleeves with holes the size of the drills and hold them on the drills with small screws these in turn would be held in the Morse collets that are used to hold the milling cutters. But this meant making one holder for each of the different drill sizes that I have, this would mean making about 30 sleeves. This was an awful lot of machining for not a lot of gain.

The other consideration was length of the larger drills would be a problem in these Morse collets, as there would not be enough length in the collets for the drill at the back of the collet. The collets use a screw thread to tighten them into the holder so this would be in the way.

The flexibility of the ER collet system i.e. covers a range of sizes with one collet, got me thinking that this would cover the range of the smaller sizes of both imperial and metric drills that I have. The fact that the ER systems use a nut on the front of the holder means there is clearance behind the collet for the drill.



Finished ER 25 holder



Cutting bar stock



Starting to face bar

Additionally, with a collet chuck holder for the mill I could use some odd sized milling cutters that I have in the mill as a bonus.

All that was required was some form of support for the ER collets to present the drill to the grinding wheel at the correct angle.

The first thing to do was get some collets and a collet chuck holder, I found some bay at a good price even with post and packing. So the order was placed for 15 ER 25 collets sizes from 2mm to 16mm and a number 3 Morse chuck holder. I also ordered an extra ER 25 nut to use with the collet holder that I was going to make. After the order arrived, just over a week later I gave the parts a thorough check over and to my relief the collets, chuck holder and nut were of excellent quality.

ER 25 Drill holder Collet holder, photo 1

The first part to be made was the collet holder shaft. For this I used some mild steel 40mm dia x 125mm long **photo 2** shows this being cut to length.

I then put the blank into the lathe and faced the blank both ends and then centre drilled it **Photos 3** and **4** show this. Next I drilled a 16.5mm hole all the way through the bar this hole is for the back of the drills to go into when they are being ground on the front faces.

The end was then turned to size for the thread, this is 32 mm dia and 1.5 pitch for an ER 25 collet nut **photos 5** and **6**.

The lathe is then set up to cut the thread, **photo 7** shows the second pass just starting. The new ER nut was used to check the thread at the later stages of the thread cutting.

After the thread was cut I then cut the taper for the collets, the top slide was set to 8 deg for this although it was a bit trial and error to get the collet to fit. Taking light cuts and checking the fit before too much was removed did the trick, I used a collet that I had bought for the dimensions and fit.

The shaft was then reversed in the lathe chuck and the rear diameter was turned to size, **photos 8** and **9**, the finished collet



Centre drilling



Starting to machine to diameter



Finished at size for thread



Starting the thread



Starting to size barrel part



Finishing barrel

holder shaft is shown in **photo 10**. The dimensions for the collet holder are shown in **fig. 1**.

Collet holder support

To support the collet holder and allow it to rotate for indexing a support body was required. This was made from a piece of 1 1/4 diameter pipe as this cut out a lot of boring I made this a finished length of 80 mm long. By holding it in the lathe chuck and facing one end and then the other to size before moving on. To hold the collet holder support in place on the angle support a piece of 10mm x 20mm is welded on down the centre of the tube and another piece of the same material is welded at right angle to the first. This second piece is for the support for the indexing arm, as in fig. 1, the centre piece has two holes that are drilled and tapped M6 at 60mm centres. The second piece has one hole drilled and tapped M6 at the outer end for the index arm support stud.

Above the index support arm a piece of 15mm diameter 20mm long was also welded to the side this is the clamp nut.

The 15mm diameter section for the clamp nut is drilled and tapped M8 in the lower part and 8mm clearing on the upper part this machining was done before it was welded to the side. After it was welded on, the thread and the clear holes were cleaned up.

After the welding drilling and tapping



The finished barrel

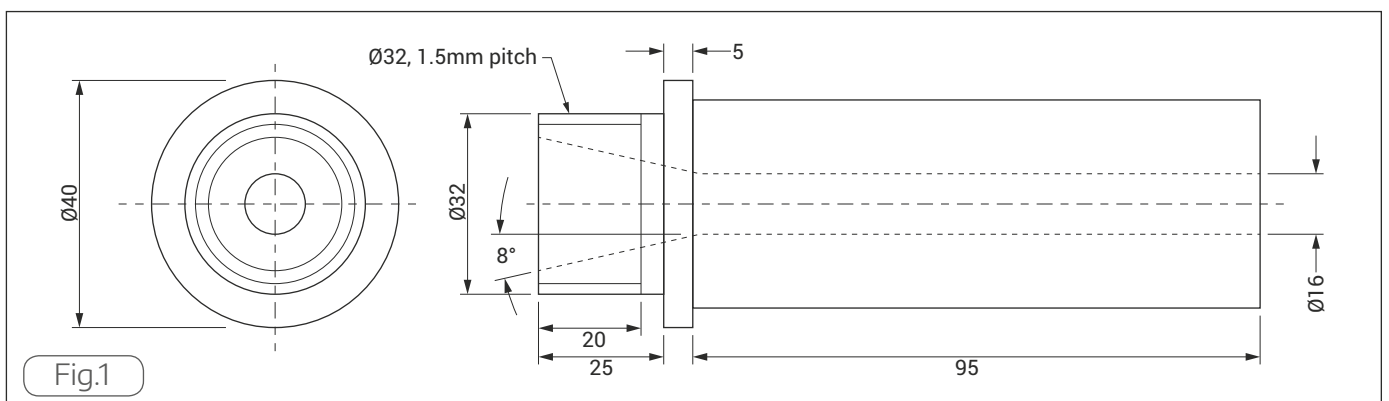
were done the holder was put in the lathe and the bore was machined to the holder size, **photo 11** shows the boring in operation.

For the clamping action to work two slots are cut with a slotting saw one between the tapped part and the clearance part, this was a 5mm cutter, and the other extending above the first for 25mm, This was a 3mm slot. The slots were cut on the milling machine the position can be seen in **fig. 2**

The dimensions for the holder support are shown in fig 4. **Photographs 12 and 13** show the part with all the machining done and some filler to tidy it up and only the painting to be done.

Index ring and finger

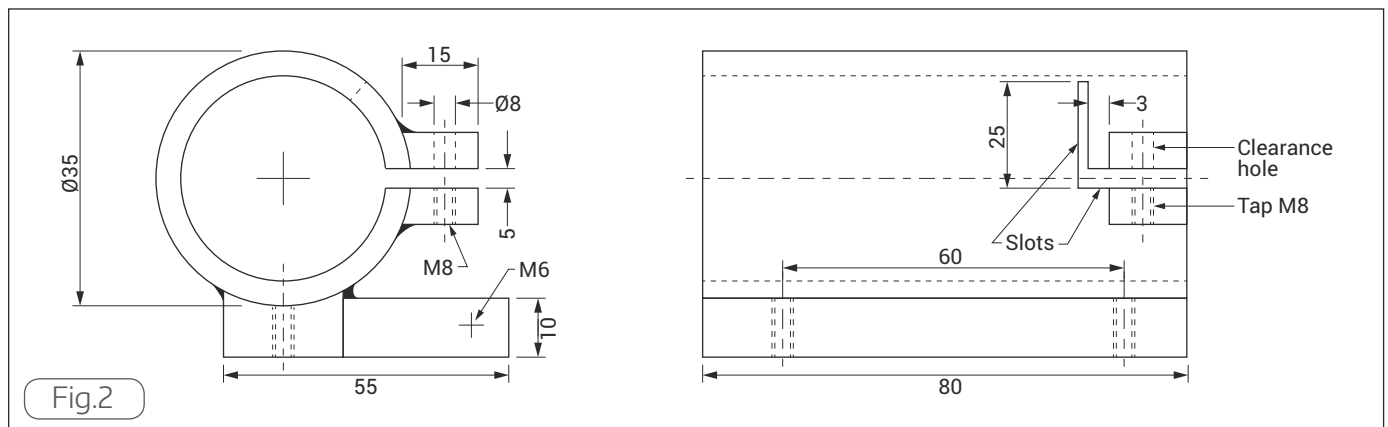
The indexing ring was made from some 50mm diameter steel turned to 48mm and bored to fit the collet holder rear shaft and finished at 12mm wide. It was then put in a



11



Boring the holder



small chuck that was fitted to an indexing head that was bolted on the milling machine table. Then two steps were cut with a small milling cutter at 180 deg on the outer diameter of the ring **photo 14** shows this being done.

After the milling operation, a hole was marked out between the steps and taped 2 BA for a socket head grub screw to secure the ring to the shaft the dimension are shown in **fig 3**.

The finger was made from some 12mm square steel drilled at 6mm at the bottom and tapered towards the top to fit in the steps on the index ring. **Photograph 15** shows the taper being cut **fig. 5** shows the dimensions for this.

The clamp screw

This was made from 15mm steel with a finished length of 45mm long as fig 4 the

12

Holder near completion



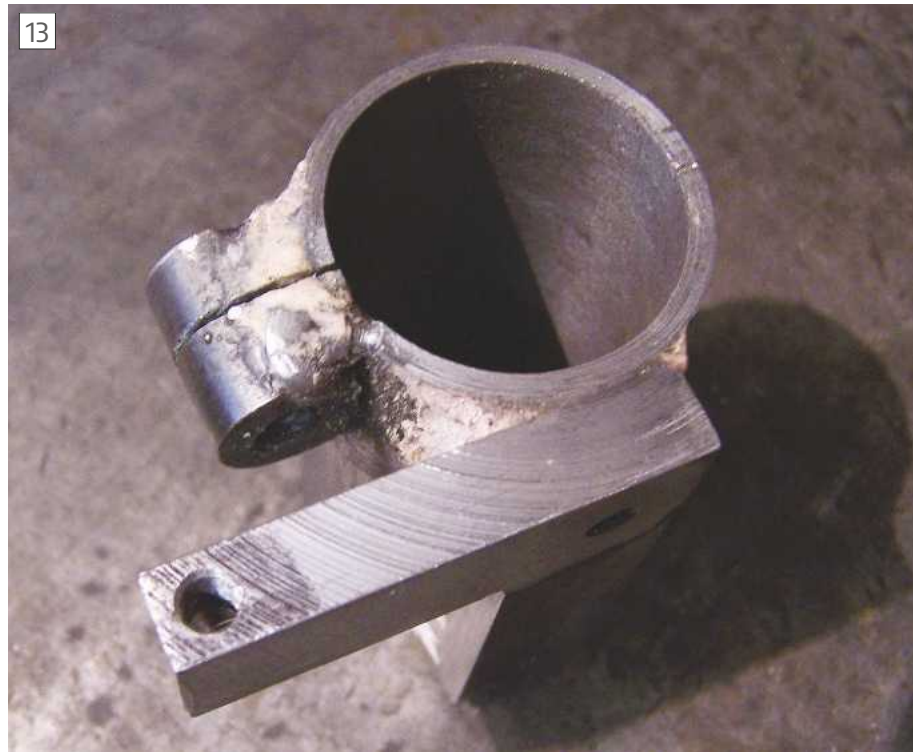
handle was 8mm steel 95 long screwed to the clamp piece. To position the handle in the correct place so that it is not in the way of the grinding wheel. The clamp screw was put in place and done up to so that the handle position could be marked it was then drilled and tapped. The clamp can be seen in photo 16 along with the other semi finished parts that makeup the collet holder and collet holder support.

Tool holder angle support

The tool holder angle support is made on the same lines as the support I made for the milling cutter holder, this is from some 60 x 60 x 10 angle that starts as two pieces of angle that are 100mm long. One is cut at 45 degrees on both sides and 50mm high the other is also 50mm high but the sides are cut at 30 degrees. The dimensions for these are shown in **fig 6**. To cut the angles I used Mike Haughton's jig, which I made just after it was published in Model Engineers Workshop No.179 this jig gets used a lot of in my workshop as it saves wasting material that is to short to cut in the normal bandsaw vice.

Photograph 17 shows the base of one of the angles being machined flat, **photo 18** shows the 6mm slots being cut.

Hole A in the lower part is reamed 8mm this is to keep the accuracy when the tool is moved to a new angle, hole B in the upper part is taped M8 for the socket head pivoting bolt. The slot at D is for positioning the support on the base

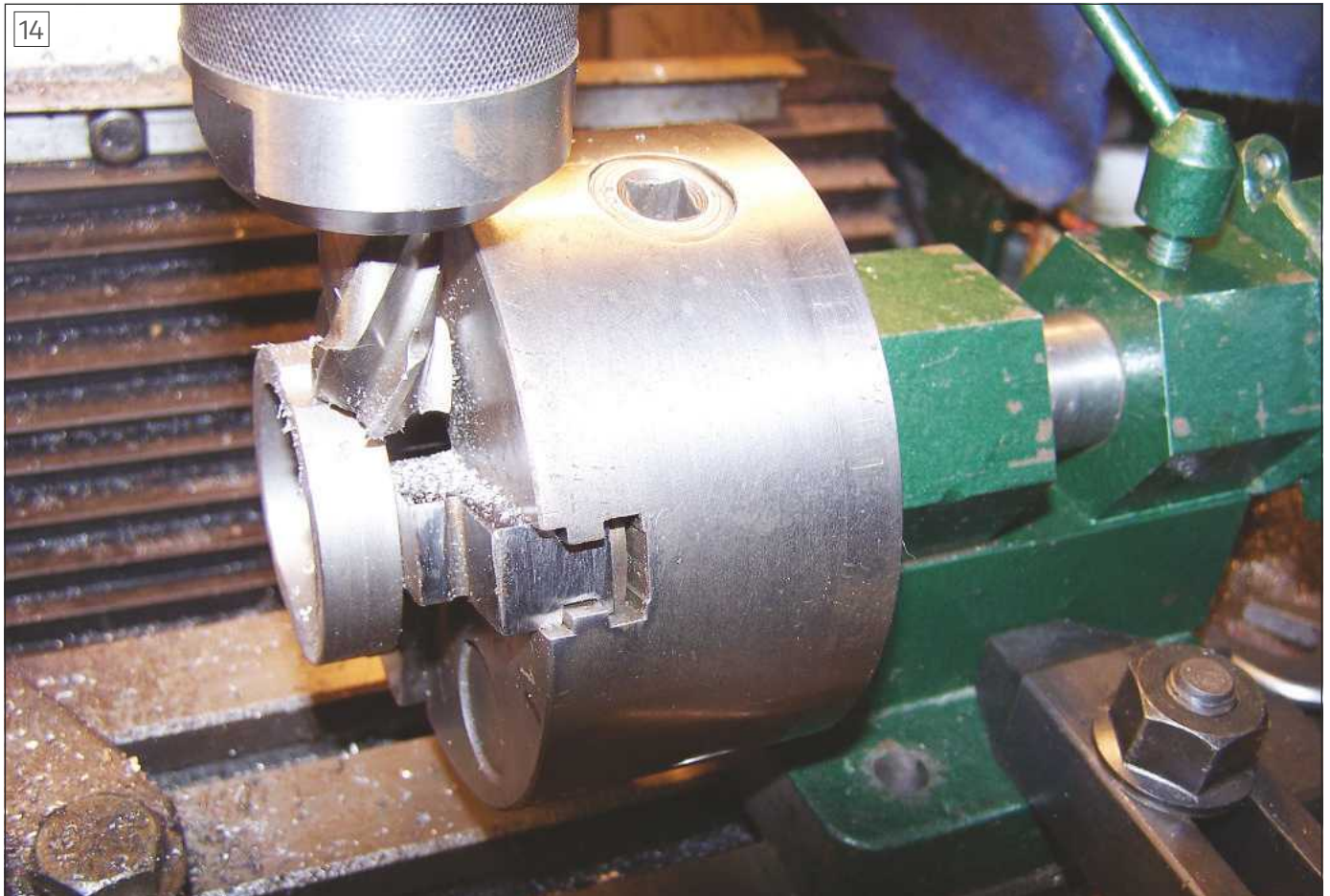


The machined end of the holder

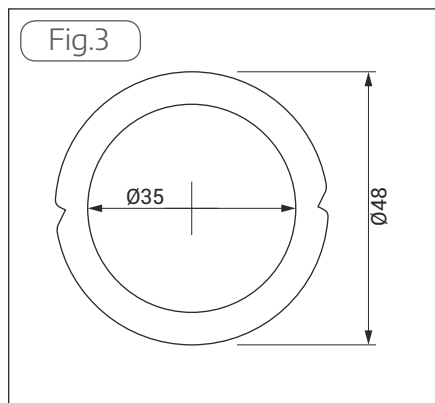
carriage. Slots C are for holding the tool holder to the support, they are 40mm long. I have added a pointer to the top of the lower part to line up with degree marks on the top part. **Photograph 19** shows

the parts after machining and ready for finishing.

To finish the collet holder support and the tool holder support were painted, the clamp the indexing ring, the indexing finger



Machining the index ring



and the collet holder were all chemical blackened as can be seen in photo 1. The finished parts ready for assembly are shown in **photo 20**. **Photograph 21** shows a 13mm drill in position ready for sharpening.

The last thing to make was a spanner to fit the ER nut. There was one sent with the chuck holder but I wanted one just for the drill holder as this is away from the milling machine.

The original spanner and the shop made

one are shown in **photo 22**. I made the spanner from 25mm x 6mm flat mild steel. I marked it out from the original. I then chain drilled around the inside radius and then chiselled the waste away. Then I cut the handle to a taper with a hacksaw and finished the taper on the mill. The final shaping and cleaning was done with a file, when it was finished it was also chemical blackened. Although I used mild steel I haven't done anything to it as it works fine as it is.

Having made the ER drill holder, it is now possible to use this to sharpen milling cutters as well as drills.

To use the ER collet

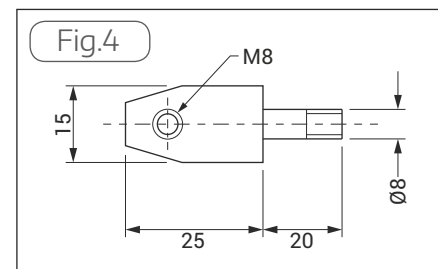
The ER collet is used in a similar way as the milling cutter holder, is that is by plunging the cutter/drill onto the grinding wheel face, the only real difference is the angles that are used.

All the setting up is done with the grinder switched OFF.

The drill is put in the holder with the right collet for the drill and the drill about 25mm out from the collet. The index is set with the finger in one of the cut outs and the clamp

is tightened. After this the drill is set with the cutting edge horizontally, this is the edge to the left looking down on it and the collet nut is tightened.

The holder and grinding wheel are set to the required angles, both the point angle, that is the angle sloping away from the point of the drill, this angle is normally 59 deg to give an inclusive angle of 118 deg. The other angle is what is known as the lip clearance, this is the one that slopes away from the cutting edge to the back of the drill, this normally 10 to 12 deg. The drill is then set-up to just touch the grinding wheel face then the carriage stop is positioned against the carriage and locked there.



Machining the indexing finger



The nearly finished parts



Machining the angle base



Machining the slots in the angle base



The angle base parts



Finished parts



Drill in position for sharpening



Original and shop made ER spanners

To be continued

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Making a Division Plate from Scratch



Paul Murray shows a method for making a division plate using a milling machine and easily worked low cost material to make a master which is then used to produce a division plate of the required size in a material of your choice.



A division plate can, in principle, be produced by setting up a sequence of x and y co-ordinates in order to produce the required number of divisions. Such a method is subject to errors due to the incorrect setting of one or more co-ordinates and backlash. A method is proposed in which the angular settings and the final radius settings are separated. This method does not require high precision marking out or setting out as any error is measured and eliminated during the manufacturing procedure. The procedure below demonstrates the method for a division plate with 17 holes, but can be used

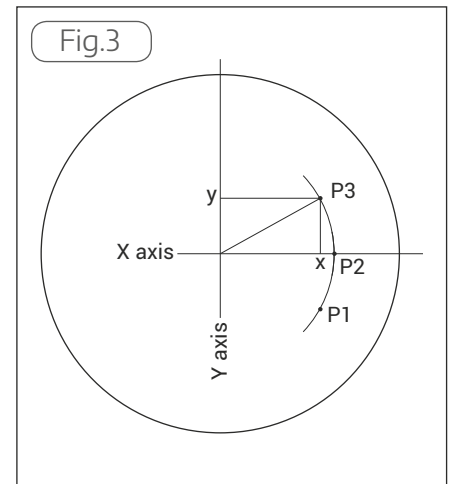
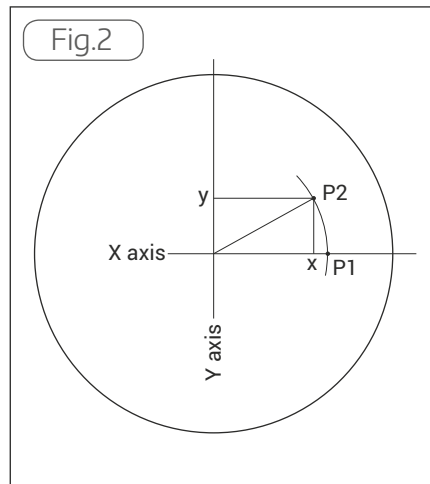
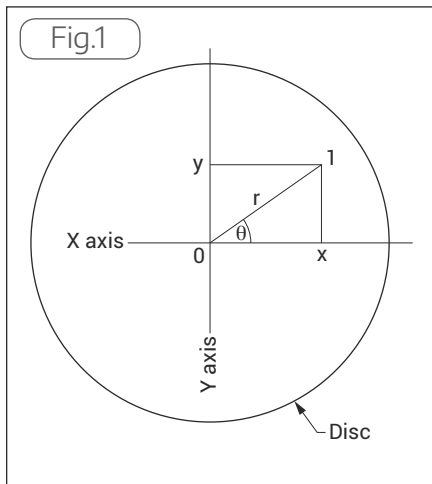
to produce a wide range of odd and even numbered plates. The procedure enables anyone to make division plates, including prime number division plates, without the need for access to a dividing head or dividing head with a micro-attachment. **Photograph 1** shows a sample division plate produced from a piece of scrap to evaluate the method.

An article in MEW 198 described a useful indexing head¹, the build description of which used a Versatile Dividing Head² or rotary table to produce the index wheel. Having an interest in producing a 17 tooth gear wheel, and not possessing either

a Versatile Dividing Head or a rotary table, I considered how an index wheel or division plate might be produced with the machinery available, namely a lathe and a small mill. The procedure, which is quite straightforward, is in two parts: firstly, the generation of the correct angles, and secondly, transferring these angles to a metal disc at the required radius.

Theory

If a division plate is required to have N holes then Θ , the angle subtended at the point of rotation between adjacent holes, is given by $\Theta = 360/N$ degrees, from which N



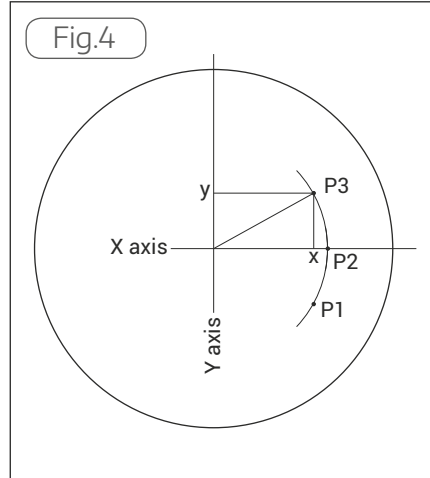
times $\theta = 360$ degrees. Now an angle can be determined by the x and y co-ordinates, as shown in **fig. 1**, where O is the centre of rotation. In terms of defining the angle θ the absolute values of x and y are not important: it is the ratio of y to x which is important ($\tan \theta = y/x$). Point P1 at co-ordinates x, y defines the centre of Hole 1 on the disc (or division plate) at distance r from the origin O.

Now, if the disc is rotated clockwise by the angle θ then the situation shown in **fig. 2** obtains. Point P1 is now on the x axis at $x = r$ and point P2 has co-ordinates x and y. Point P2 corresponds with the centre of Hole 2 on the disc.

Rotating the disc by angle θ again produces the situation shown in **fig. 3**. Point P1 is now at angle θ below the x axis, point P2 is now on the x axis, and Point P3 is now at position x, y.

If the disc is rotated through angle θ N times in total then N Points will be defined and the disc will have rotated 360 degrees. Rotate the disc by θ once more and Point 1 should now be back as shown in fig. 1.

If either x or y (or both) are incorrect then



θ will be the wrong value and the points will not be uniformly spaced around the disc, as shown in **fig. 4** for the case where the ratio of y to x is too small. In this case the distance between the last point and the first point is greater than the distance between any other pair of adjacent points.

Now, since we are only interested in

getting the angles correct at this stage, we can assume either x or y is correct. We will assume x is correct. Since the value of y/x is too small, the correct value of y, denoted y_c , is given by $y_c = y + h$. Each time we marked a point (or drilled a hole) the y value was short by h. Since we marked N points the total accumulated error is N times h. Thus, if we measure the excess distance between points PN and P1 and divide this value by N we have the correction which must be added to the y axis in order to correct the error in the angles. The angular division can then be repeated. In the event that an error still exists then the correction procedure can be repeated until the required angular precision has been reached.

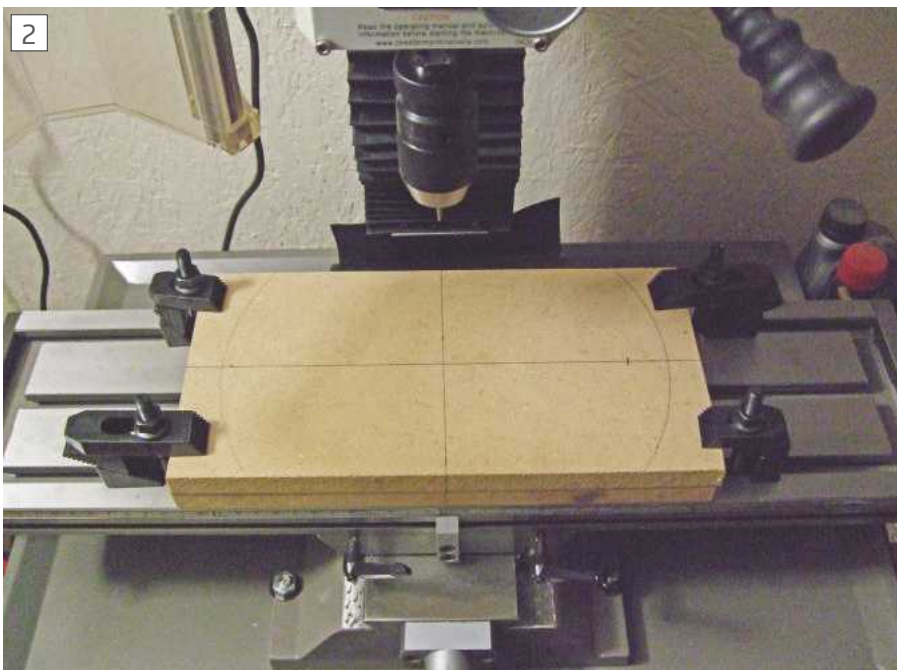
Practice

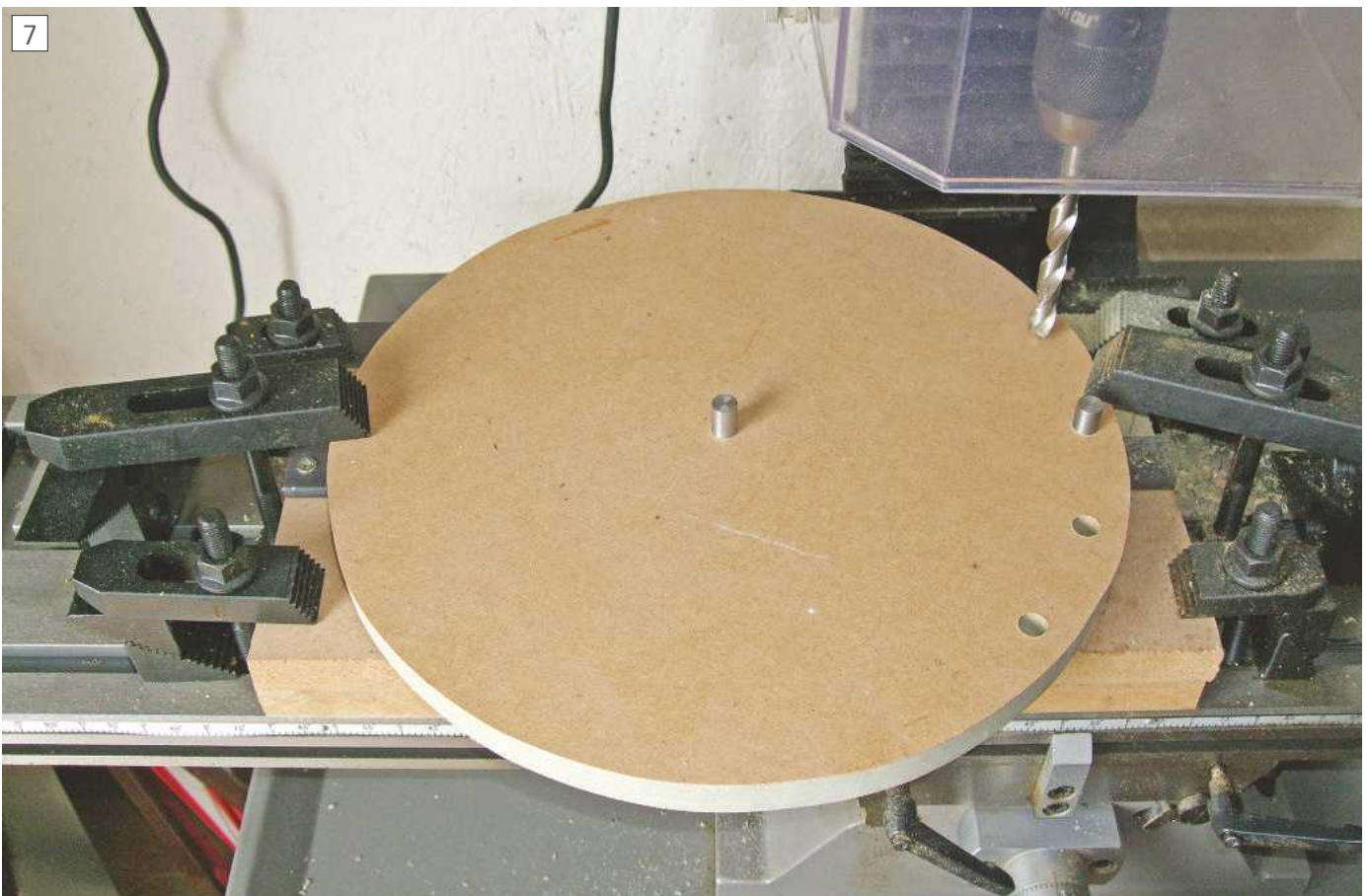
A circular disc will be mounted on the mill and used to produce the required angular divisions by drilling holes centred on the points described above. These angles will then be copied on to a metal division plate at the required radius. Production of the required angles can be achieved using an easily worked material, such as MDF.

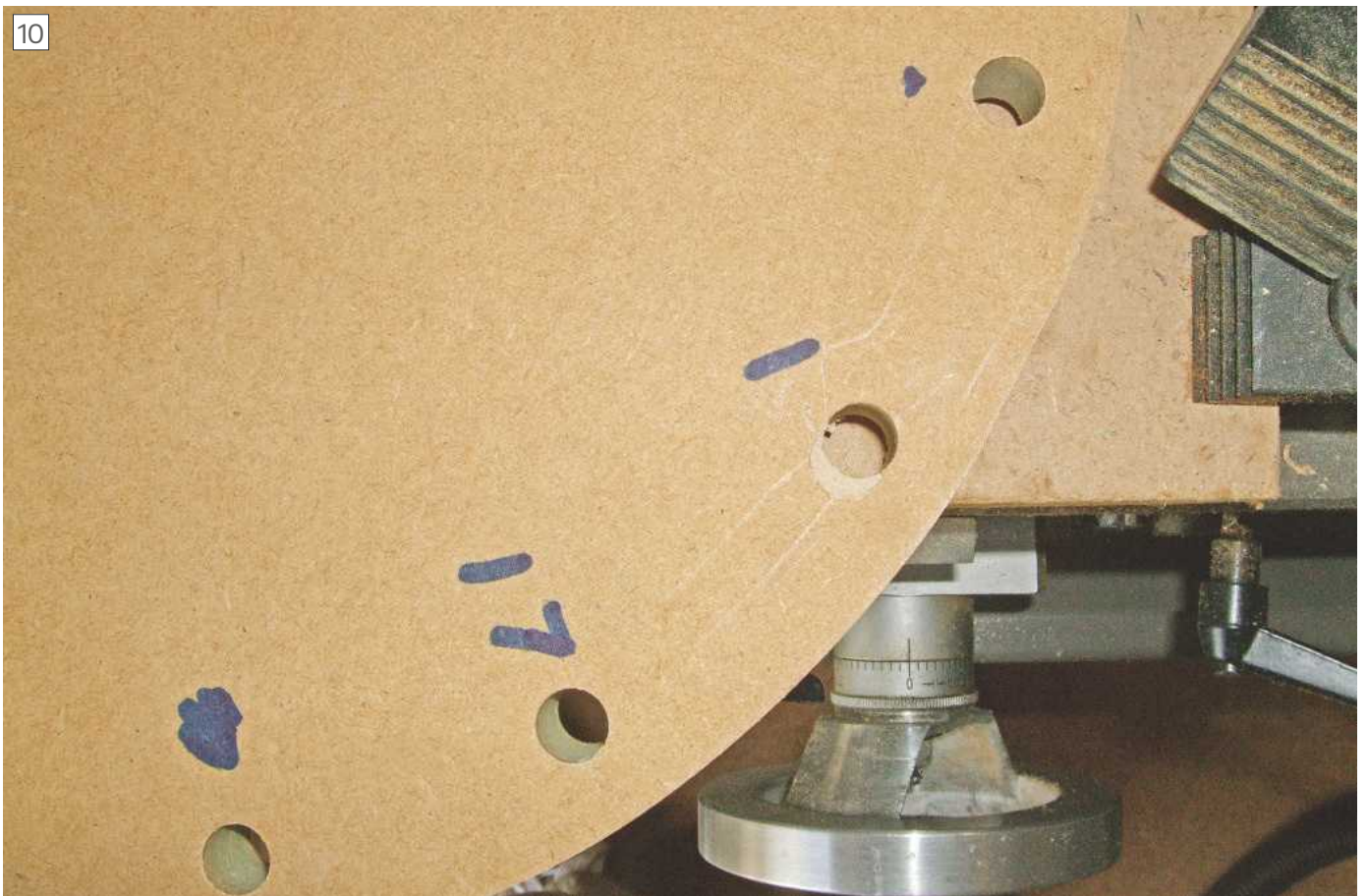
Photograph 2 shows the mill with a double layer of MDF clamped to the table at about the centre on both axes. A double layer was used in order to protect the mill table from inadvertent drilling. A circular piece of MDF will be clamped on top of this to set up the required angular division. In order to minimise errors 'hardened' pivot point and indexing points were provided by attaching a piece of iron bar, from the scrap box, along the x-axis, with a matching supporting piece along the furthestmost edge. I also considered it important to make the disc as large as possible to minimise errors.

Note that the table will be moved towards the operator and to the left, so take up the slack accordingly before following the clamping, milling and drilling instructions below.

My mill will just accommodate a 12 inch diameter disc, so, with the y-axis clamped and the dial set to zero, a slot was milled along the x-axis between 5 and 6 inches from the centre. A slot was used since the exact radius is unknown. I chose 10 mm









for the slot drill but this dimension is not critical. The table is then centred in x, the dial set to zero, clamped and the centre or origin hole drilled, as shown in **photo 3**. Again I chose 10mm.

An MDF disc of 12 inches diameter was marked out with a simple beam compass and cut out with a jig saw, as shown in **photo 4**. A high degree of circularity is not required as it only needs to be swung round on the mill table. Since it is probable that a second set of holes will need to be drilled it is convenient to make a second MDF disc at this stage. A second set of holes can be drilled into one disc but it is more than likely that interference between the two sets will occur so a second disc is easier.

Since the slot was milled between 5 and 6 inches offset the aim is to put the holes at about 5.5 inches radius. For a 17 hole division disc the angle between adjacent holes is given by $360/17$ degrees. If the radius is 5.5 inches, then

$$x = 5.5 \cos 360/17 = 5.129$$

and

$$y = 5.5 \sin 360/17 = 1.987$$

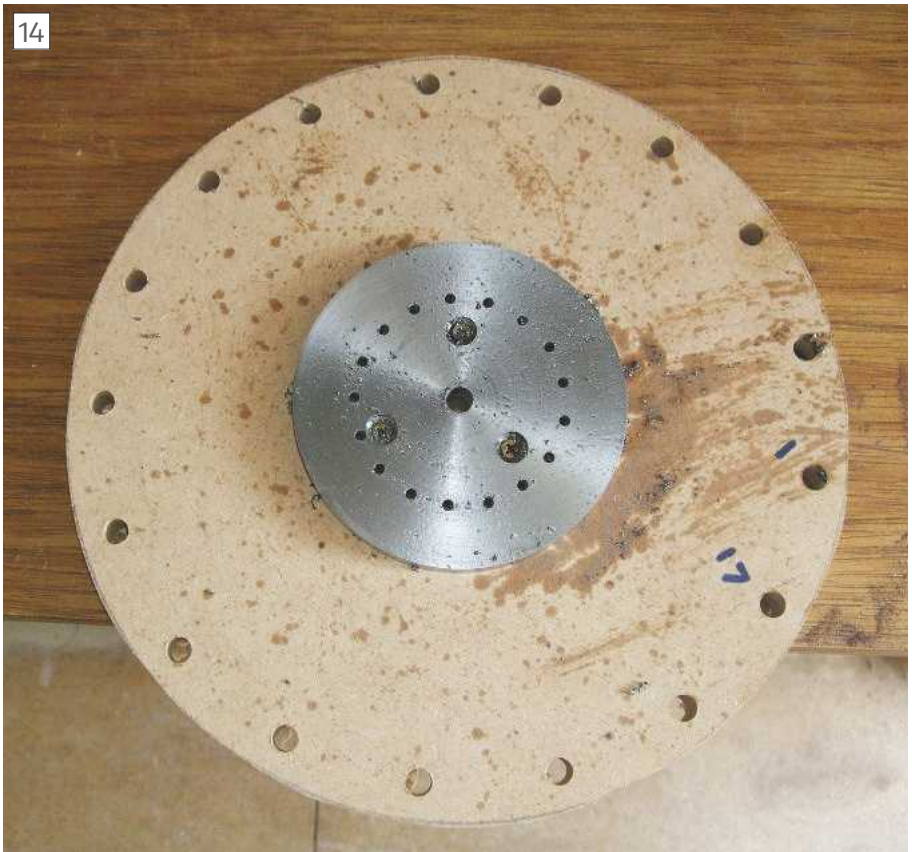
Now, for convenience of setting and to demonstrate the method

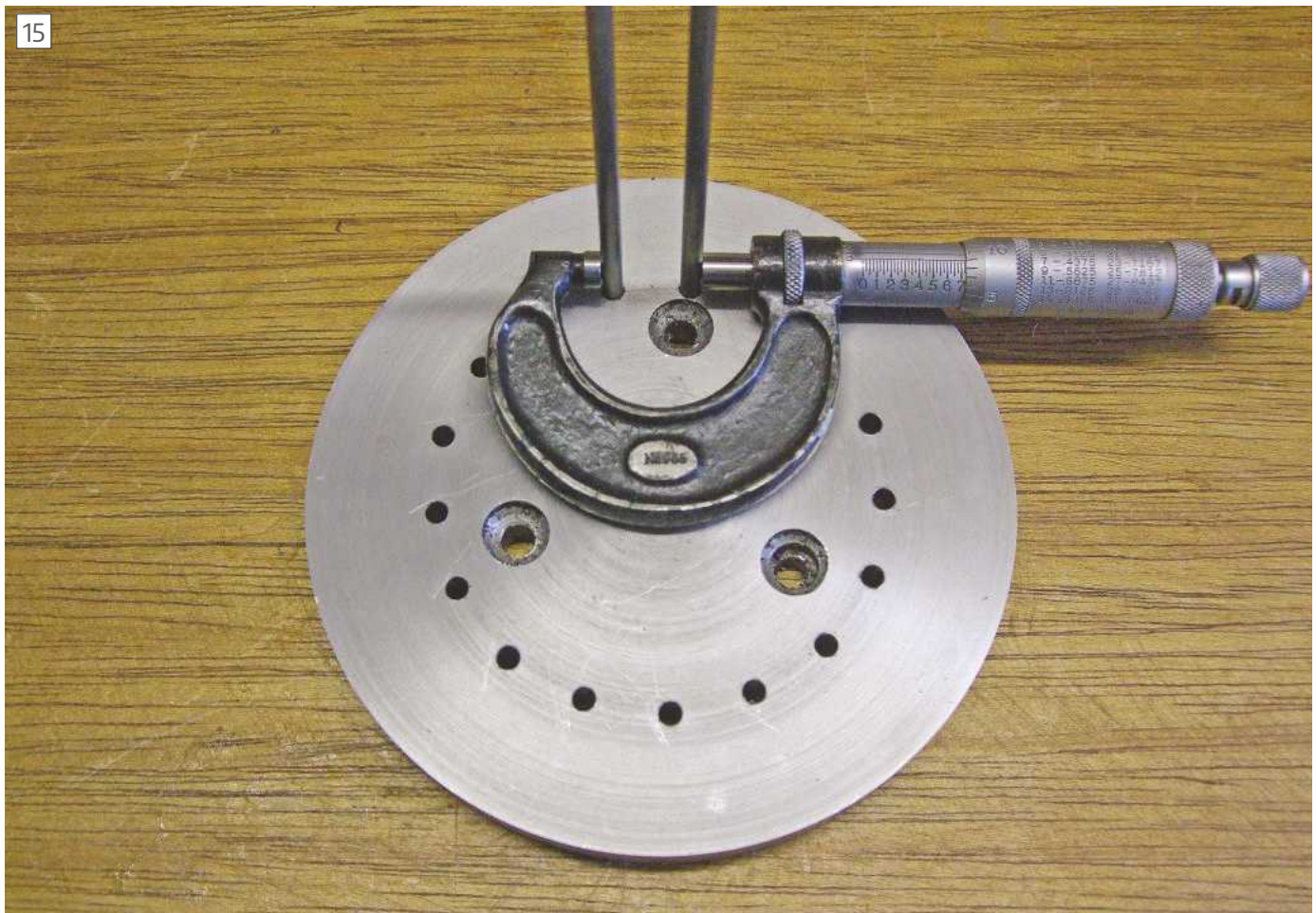
y is set at 2.000

and

x is set at 5.200

thus, the angle is actually 21.0375 and





rotating the 'full' circle will only use 357.64 degrees.

The disc is mounted with a 10mm pin in the centre and clamped. The table is then offset in x and y as shown in **photo 5** and Hole 1 drilled to coincide with point P1. The disc is then unclamped, rotated so that Hole 1 is on the x-axis, with a 10mm pin through the MDF into the steel bar below, and Hole 2 drilled, as shown in fig. 2 and **photo 6**. This process is repeated, **photo 7**, until all 17 holes have been drilled, **photo 8**. The disc is indexed one more time so that Hole 17 is over the slot. **Photographs 9 and 10** show that, as calculated, the drill

has not quite reached Hole 1. The error can be measured, as shown in **photo 11**, by measuring the distance between Holes 16 – 17 and Hole 17 – 1 and taking the difference. The measured difference was 0.26 inches. This is divided by the number of holes (17) to give a correction of 0.015 inches in the y axis. Since the initial set angle was too small the 15 thou is added to the y displacement.

A new MDF disc was mounted and the drilling and indexing process repeated. **photo 12** shows Hole 17 at the index slot and stationary drill passing smoothly through Hole 1.

At this stage a steel disc was attached to the MDF and the angularity of the holes copied at the desired radius, **photos 13 and 14**, the new holes being 5/32 diameter on a 1.6 inch radius to approximate the requirement of the indexing head1. The copying was done by 'plunge' drilling using a standard jobber's drill.

Does it work?

After completing the steel disc both the MDF disc and the steel disc were measured for angularity. Pins were placed in adjacent holes, a measurement taken across them and the pin diameter subtracted to give



the hole centre spacing. For the metal disc two 5/32 silver steel rods were placed in adjacent holes and a measurement taken as shown in **photo 15**. The rods were then removed and replaced, spun round in their respective holes and swapped over, a reading being taken at each stage. There was 1 thou variation over the four readings, thus giving confidence in the method.

The results, for both discs, are shown in Table 1 under the headings MDF and Steel.

The sum of the hole spacings represents 360 degrees in each case and this was used to calculate the error from the mean angular spacing for each pair of holes, expressed in minutes of arc.

Considering that, for the 17 hole division plate used as a demonstration, the mean angular spacing should be $21^{\circ}10.6'$ the results for the MDF disc are very good, the maximum error being about 0.24%. The results for the steel disc are not so good, the maximum error being about 3%, and do not show any correlation to the errors in the initial MDF disc. It is concluded that this is due to plunging into the steel with a 5/32 drill as shown in photo 13 and it is recommended that a more easily machined material is used to make the division plate and that the holes are spotted before drilling to reduce drill wander.

A lump of cast iron which had been purchased some time ago was therefore faced both sides and pinned to the MDF, **photo 16**. The MDF plate was then indexed and holes spotted in the cast iron blank using a centre drill, **photo 17**. The holes were then opened up to 5/32 by indexing again, **photo 18**, to give a finished division plate, **photo 19**. The holes were only drilled $\frac{1}{4}$ inch deep as this was just an evaluation exercise. The hole spacing was then measured using a vernier gauge in a similar manner to that shown in photo 11, the results being tabulated in **Table 1** under the heading 'Cast Iron'.

Conclusions

It is possible, with a little care, to make a division plate, even for a prime number of divisions, to be used with a simple indexing head when the cost of a versatile dividing



head cannot be justified. An additional benefit is that the principal errors are eliminated whilst using a low cost material so that there is no risk of incrementing a dividing head by the wrong amount whilst cutting a gear. ■

References

1. Indexing Head, Roger Vane, MEW198 et seq.
2. Versatile Dividing Head, George Thomas.

Table 1

MDF Disc				
	Across Pins	Centres Inches	Error Inches	Error Min of arc
1-2	2.414	2.020	-0.003	-2
2-3	2.422	2.028	0.005	3
3-4	2.418	2.024	0.001	1
4-5	2.420	2.026	0.003	2
5-6	2.418	2.024	0.001	1
6-7	2.417	2.023	0.000	0
7-8	2.412	2.018	-0.005	-3
8-9	2.420	2.026	0.003	2
9-10	2.415	2.021	-0.002	-1
10-11	2.420	2.026	0.003	2
11-12	2.413	2.019	-0.004	-3
12-13	2.415	2.021	-0.002	-1
13-14	2.414	2.020	-0.003	-2
14-15	2.417	2.023	0.000	0
15-16	2.412	2.018	-0.005	-3
16-17	2.422	2.028	0.005	3
17-1	2.419	2.025	0.002	1
Total		34.390	0.000	
Average		2.023		
Note: Total corresponds to 360 degrees at each radius.				
1 thou is $0.001 \times 360 \times 60 / 34.39 = 0.628089561$ minutes of arc				

On the **Wire** **NEWS** from the World of **Hobby Engineering**

We visit the Doncaster Show

This was the twenty-fourth year of the National Model Engineering and Modelling Exhibition and the second time at its new home of Doncaster Racecourse. Once again, we had a stand near the main entrance with back issues and binders for Model Engineer and Model Engineers' Workshop on sale, where I was to be found chatting to readers for most of the Sunday. Nonetheless, I found

time to get around most of the exhibition and meet both familiar faces and new ones. As seems usual at any model engineering show, the vast majority of exhibits were models and but nonetheless some very creditable workshop tooling and accessories were on display on the Club stands.

I will let the captioned photos speak for themselves, this is only a selection

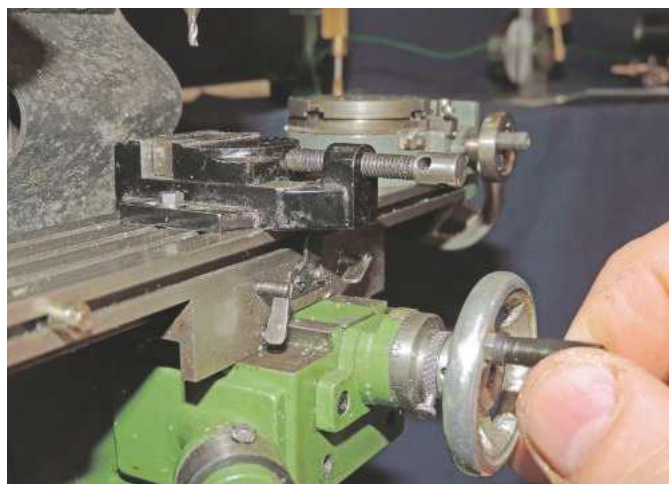
of the tooling on show – I felt there was rather more here than at most shows. The show was well attended with a good diversity of clubs and interests present, as well as a good showing from the trade. Congratulations to Gavin Rex and his team for another fine show – see you in 2018!

Neil Wyatt

To be concluded



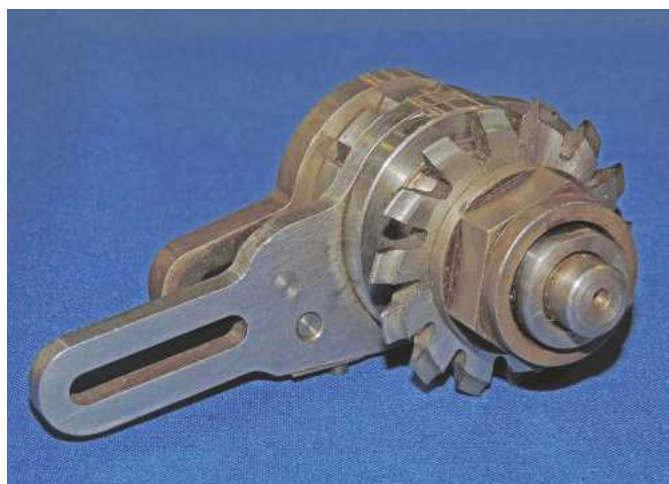
Excellent pattern making by J. Barraclough for this AM35 engine.



The incredible detail of J. Brittan's quarter-scale Warco milling machine, as featured on our cover.



Myford taper turning attachment by Steve Tracey, who also exhibited several other beautifully finished tools, including a mirror-polished cast iron boring head.



A Eureka backing off device by Tony Phillips of the SMEE

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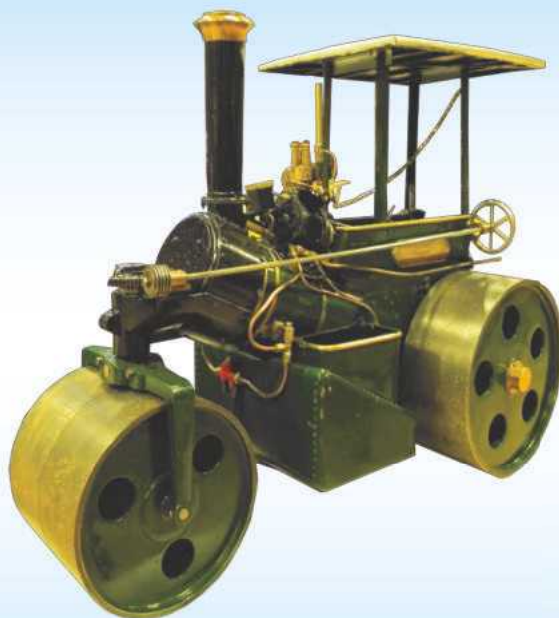


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One Man and his Lathe

Trevor Winter and his sixty-year-old Zyto Lathe

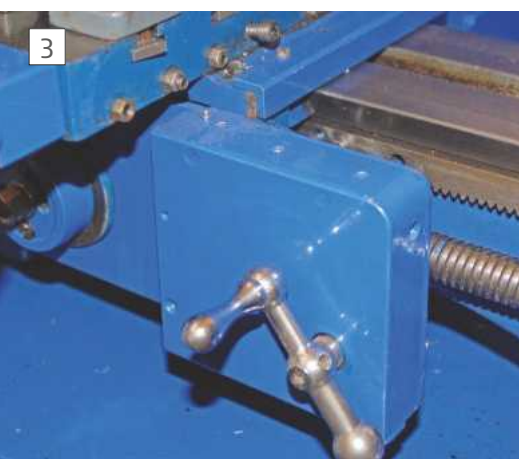
I have owned my Zyto lathe for 60 years and purchased it when I was 18, a craft apprentice at the Marconi Wireless Telegraph Company. It took me a year to save up for it as I only earned £4 per week and gave my mother half towards my keep; credit was not available in the 1950s and even if it was it would not have been approved of by my father. It cost £33-00 for the lathe and £5-00 for the countershaft, I would have liked a Myford ML7 but it was very considerably more expensive and was completely out of reach. Over the years, it has repaid its purchase cost many times over and has given me great pleasure; of course it was a budget model without the sophistication of more expensive lathes but adding modifications and improvement has given me considerable satisfaction, **photo 1**.

History of the Zyto

The Zyto brand lathe was retailed by S. Tyzack & Son of Old Street, London, a firm of tool merchants who had been marketing this brand since the late 1920s having purchased the Billing Tool Company of Clerkenwell Road, London in 1927 and rebranded their lathe as the Zyto. There followed a number of design variants and some outsourcing from the Portass Company but the model I have began life in 1937 and continued with minor modifications through to 1959 with an interruption due to the war. A very detailed history can be found on the website www.lathes.co.uk where extensive information about almost every brand of lathe and milling machine is to be found, also copies of manuals, instruction books, some spares



Zyto Lathe



Carriage gearbox

2

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Height from Saddle	2 in.	Overall length of Lathe	30 in.
Guide Screw	8 T.P.I.	Change Wheels :	20, 25, 30, 35, 40, 45, 50, 55, 60, 65
Headstock Mandrel Admit	1 in.		

Back Geared Guards and Change Wheels, together with Catch Plate and Finished Back Plate for Chuck are all included.

1953 Zyto advertisement

together with second hand lathes etc. for sale. This is a splendid website which I thoroughly recommend.

Photograph 2 is the 1953 advertisement which includes the specification, it is the

same as mine but without the guards which were added by the time I bought it in 1956.

Setting up the lathe

The lathe was delivered and now had to be

4



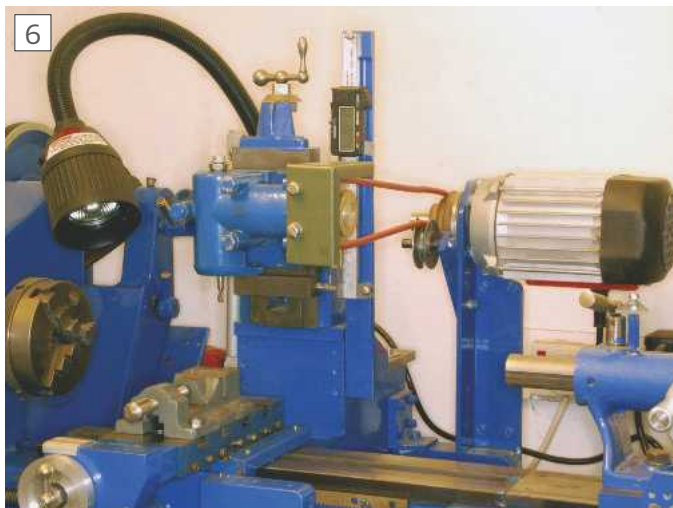
Topslide scale and gearbox

5



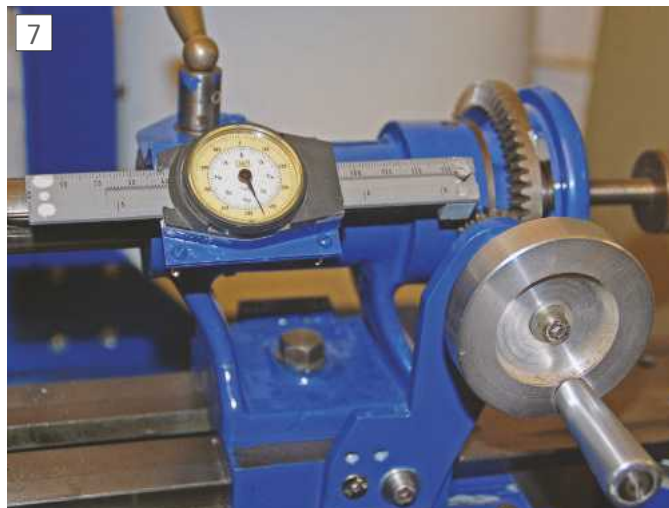
Variable drive

6



Milling head

7



Tailstock drive

set up, it needed a stand so I constructed one for it, a wooden facsimile of a Myford type made by recycling - it wasn't called recycling then it was known as 'make do and mend' during and just after the war - my mother's kitchen dresser which had just been replaced with a modern Kitchen Cabinet. There was sufficient good sound wood to complete the job. Fully assembled, complete with a second-hand ex washing machine motor, the lathe bolted in place and was switched on - then huge disappointment, incredible vibration! the whole assembly tried escaping from the shed. What was wrong? I didn't know, my father said he knew someone who

would. He had a friend who was Workshop Superintendent at the firm where he worked and would ask him for advice. This kindly man visited the next day and said the problem was that as the countershaft was separate from the lathe and that they were mounted on the wooden bench top which was flexing but he knew how to solve the problem, he took some measurements and left. Two days later he reappeared with a large piece of 1/4 mild steel plate and three pieces of heavy channel ready drilled. He reassembled the lathe on the plate, bolted it to the stand and switched on. Result vibration now at entirely acceptable levels, He would accept no payment saying to my father he was very pleased to see the lad was so keen on engineering. My gratitude was very great as I thought I had spent all my money on something that would not work.

The lathe was housed in an 8 by 6 foot shed made from plans in the Woodworker magazine. All was well at first and I really enjoyed using it, materials were not a problem as employees were allowed purchase, for entirely nominal amounts of money, material from the workshop scrap bin; a fringe benefit I valued all the years I worked there. Everything was fine right through the summer and early Autumn but then there was period of very cold weather quickly followed by warm damp days. this caused a coating of red rust to develop on bed of the lathe. This was always going to be a problem with an unheated workshop.

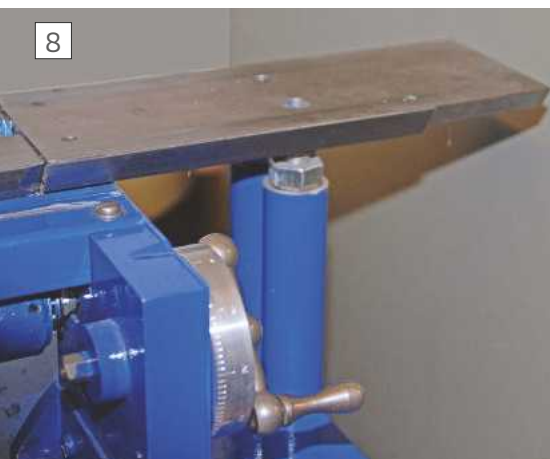
I tried Three in One Oil which worked fine on saws and chisels etc. but on the lathe droplets of water sat on the lathe bed and displaced the light oil. My solution was to coat the surfaces with grease which was fine if the lathe was not required for some time but a real pain to clean off every time it was used. It was some time before I found a light rust preventing oil that was ideal for the job. The real solution only came 25 years later when I graduated to an indoor workshop with a radiator connected to the house central heating system- the luxury, all year round comfort and freedom from rust.

The first modifications, to overcome some of the lathes shortcomings

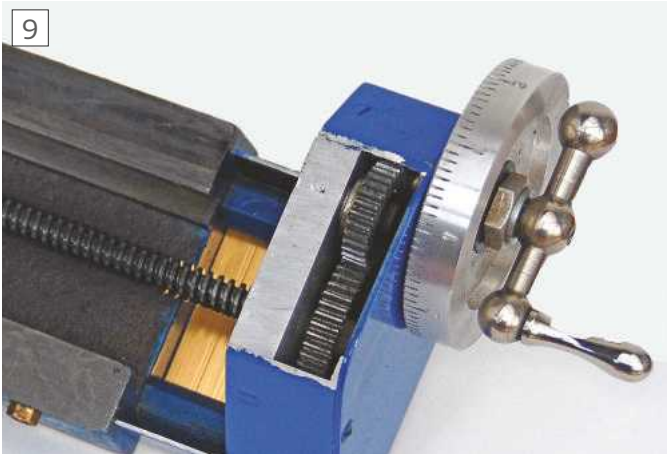
The carriage hand wheel which operated via a small gear mating on the rack bolted to the front of the lathe bed made the movement of the carriage very fast but also meant that the hand wheel rotated counter intuitively, clockwise when the saddle moved towards the headstock which I found very disconcerting. To overcome this problem I removed the hand wheel, fabricated a gearbox using 3 to 1 ratio gears from a wind up gramophone, **photo 3**.

The top slide was simply attached to the cross slide with a lug and a bolt without any form of angular calibration, luckily I found an old broken top slide in the scrap bin at work, part of which, with a bit of ingenuity could be used to rectify the problem, **photo 4**.

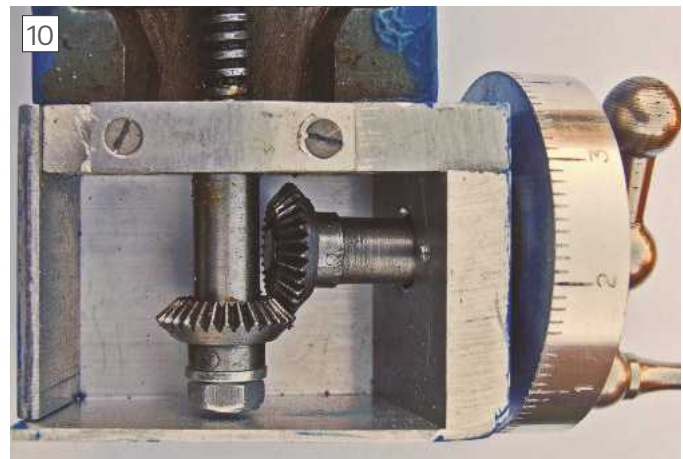
8



Bed extension



Cross-slide gearbox



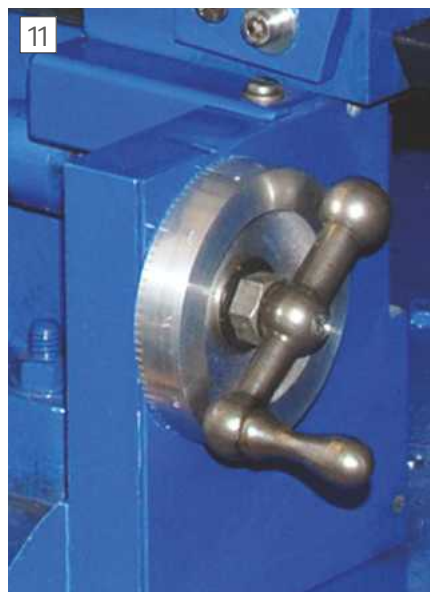
Topslide gearbox

The tool post was of the most rudimentary kind, just a clamp on the top of the top slide. A four tool indexing turret was the answer and I fabricated one out of some scrap pieces of mild steel. The indexing was very simple, just a pin positioned to touch each of the four corners of the turret in turn. This was used for many years until my wife bought me a quick-change tool post for a birthday present. What a joy it is to use.

As delivered the drive was provided by a flat belt from the countershaft to the headstock giving only 3 speeds and three very slow ones using the back gear. At first I thought the flat belt drive, which slipped under quite moderate load was a disadvantage and I considered modifying the pulleys to take V belts but there was not enough meat on the pulley castings to do this and poly-vee belts were not available in the 50s. Subsequently I found a positive advantage of the flat belt drive as I have never broken a tool and as production work is not undertaken, working a little slower with lighter cuts has not proved a problem. I had the good fortune to obtain a Picador spring loaded adjustable pulley second hand for £1. By using this on the motor, which I remounted to pivot on the countershaft and with a long screw and pivoting nut to adjust the position of the motor I was able to get approximately 2 to 1 variable speed drive. This has added a lot of flexibility and proved invaluable as quick way of decreasing speed for parting off etc., **photo 5**.

SA simple adjustable carriage stop was added, which with the top slide enables axial precision; a device so useful I wonder why manufacturers do not fit it as standard. I have considered making a turret version for use when making a number of similar parts but somehow have never got round to it.

For the next few years I just used the lathe for model engineering, making toys for my sons and for making spare parts and repairs for family and friends on the understanding that when their domestic appliances were replaced, I could have the old ones to cannibalise. Such a wealth of useful stuff in washing machines etc. motors, pulleys, bearings, belts etc. Sadly, by the 90s things were changing, induction motors and series motors were



Leadscrew gearbox

being replaced in appliances with fancy motors with circuit boards and microchips and a degree in electronics was required understand them. There were fewer pulleys etc. and more things were riveted and welded rather than bolted together - the throw away society had arrived.

Moving house brought the luxury of an indoor workshop, in the garage, with a radiator which banished rust and shivering - such joy.

A few years later, a dramatic change in fortunes, caused by redundancy from my job as a mechanical designer, in my fifties and with little prospect of obtaining a similar position, as manufacturing industry had been decimated in the 80s, I decided to turn a hobby of Cabinet Making into a self-employed occupation.

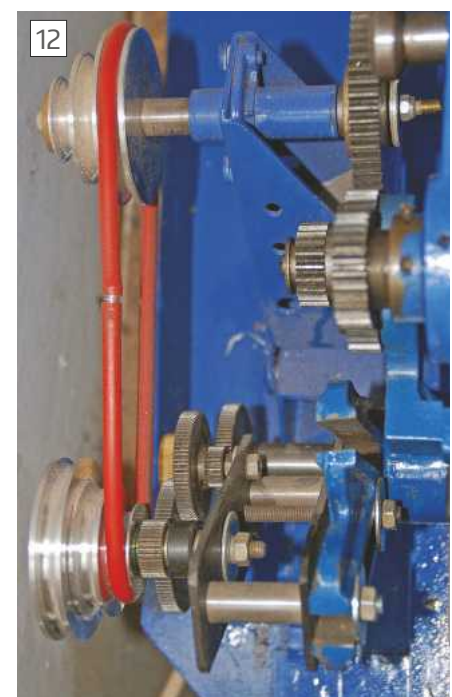
The Zyto proved invaluable for modifying and improving my woodworking machines, also for making jigs and fixtures to enhance my woodworking productivity. This, perhaps the most enjoyable part of my working life, was cut short by a health problem which necessitated my retirement after seven years. A correct diagnosis and corrective surgery took several years and by that time it was too late to resurrect my business .

Retirement brought more time to use the lathe and to make all the modifications and improvements which had been swirling round in my mind for many years.

Modifications and Accessories to improve performance

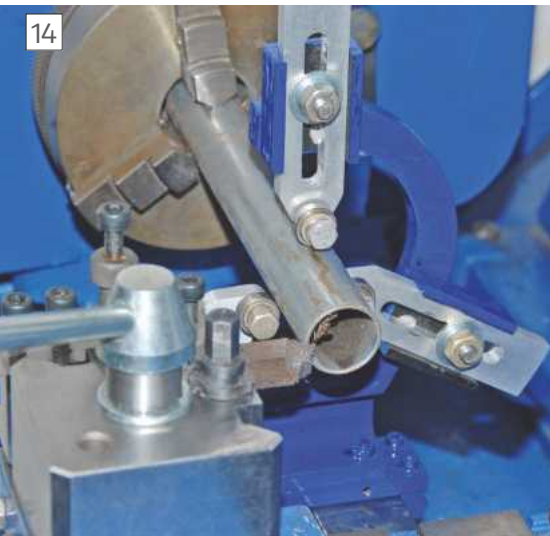
Milling Head

I had lacked milling facilities, other than using a vertical slide mounted on the cross slide. Catalogues showing lathes with a milling attachment mounted at the rear of the bed gave me the idea for a solution. I possessed a Myford vertical slide, a second-hand small induction motor, and an Angel Gear right angle gearbox which could be modified to make the milling head, **photo 6**. It was just a matter of joining them together and bolting them to the back of the lathe! But there was more than a little head scratching before it was fully working. A really stiff box was fabricated from aluminium alloy plate, angle and channel to support the vertical slide and this was fixed to



Fine feed drive

the back of the lathe and to a piece of channel which was bolted to the steel base plate base. It was important that the top face of this box where the vertical slide was fitted was parallel to the lathe bed in both planes, achieving this was tricky as the back of the lathe was as cast and base plate just as rolled black MS plate. The technique used in civil engineering and by millwrights to level machines on uneven floors is by using pushing and pulling jack screws to precisely position and filling the

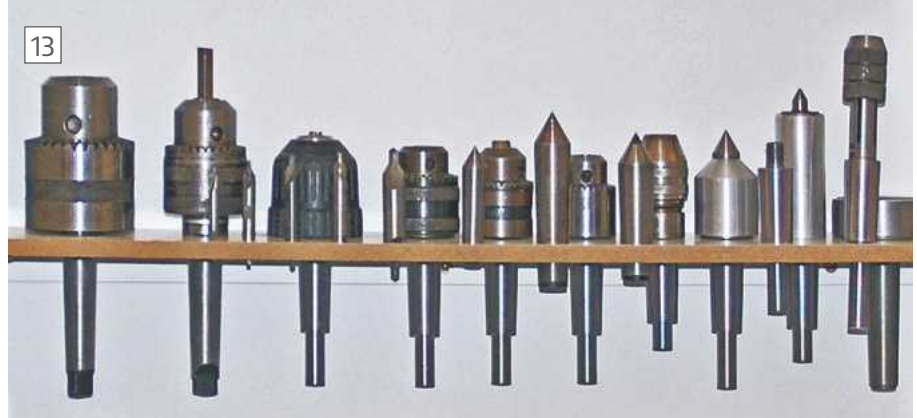


Fixed steady

gap between faces with grout. This is the method used with two-part polyester resin putty as the grout. The alignment accuracy was obtained using a clock gauge attached to the cross slide. The spindle in the gearbox was modified to accept both a 1/4 inch drawbar collet and a shaft with a 14 x 1mm pitch thread for attaching Unimat chucks. An inexpensive digital calliper was modified and fitted to give backlash free measuring to the vertical slide. To avoid the necessity of perfect alignment of the gauge to the vertical slide which would have been difficult with un-machined surfaces the moving part was attached with a piece of piano wire which allowed slight lateral movement. A recent addition is a gas strut, of the type sold to balance kitchen cupboard doors, to work against the backlash inducing effects of gravity. Although only suitable for light work the milling attachment has proved very useful and well worth the time and effort to make it.

Tailstock Improvements

The design of the Zyto tailstock does not follow the conventional pattern but has a threaded barrel with a smooth hand wheel/nut held in place with a split ring. This has two disadvantages, it is very fatiguing when drilling large diameters is being undertaken and chucks are not automatically ejected when fully retracting the barrel. To overcome the first problem, I salvaged the approximately 3 to 1 ratio gears from an unwanted Stanley hand brace. I machined the larger wheel to be a push fit on to a machined register on the hand wheel. A bracket fitted to the tailstock body and a



Quick change tailstock tooling



Rear toolpost

hand wheel/spindle fitted to the smaller gear completed the job, **photo 7**. The second problem was solved by using Loctite to secure a tapped plug in the end of the barrel. A knurled headed screw ejects the chucks.

Jacking screws and a stop screw were fitted to enable accurate set over adjustment and precise re-alignment of the tailstock when taper turning. The final modification was fitting a dial calliper to enable accurate drilling depths.

Increasing Bed length

The Zyto is only 12 inches between centres and the tailstock often gets in the way, especially when using the milling head. Somewhere to park it was required and the solution was to extend the bed, **photo 8**. I hacksawed and filed an extension out of a piece of mild steel plate using the tailstock as a filing gauge. Hacksawing and filing are superb upper body exercises - much cheaper than Gym membership. A bracket was used to attach to the end of the lathe bed and a pillar with shims to fix to the baseplate, resulting in quite surprising accuracy. It was never intended to be more than a parking place but has been used very satisfactorily as a bed extension to machine an over length shaft - a real bonus.

Accuracy and convenience - calibrated dial and gearboxes

The dials as fitted were very rudimentary, they were small, not adjustable and poorly made. The cross slide travel was limited, noticeable when facing large diameters. Myford's solution was an extension bracket,

my unashamed copy was to use spacers to extend the travel. The dials were replaced with larger friction grip adjustable ones made from an off-cut of free machining aluminium alloy, **photo 9**. When turning, every thou the cross-slide advances takes two off the dia. Looking through my box of assorted gears I found two suitable with a ratio of 2 to 1 and a third to mesh with it to maintain rotation direction, which incidentally makes the gearbox easy to make as gears do not have to be accurately centred as the third gear can be adjustable to give a perfect mesh.

Top slide improvement

The success of the cross-slide gearbox made me think about the top-slide, which when turning between centres, can be difficult to turn the handle. So looking through the box of gears two identical bevel gears were spotted and the idea for a right angle gearbox formed in my mind. Some bits and pieces of aluminium alloy, a couple of sealed ball races and a new friction grip dial was all that was required. The result much greater convenience in use, **photo 10**.

Lead screw calibration

Only the lead-screw now required attention, it is 8TPI and therefore the hand-wheel is calibrated with 125 divisions, not very convenient with multiple turns being required when milling.

The answer was a 4 to 5 ratio gearbox, with the box of gears plundered again, with scrap aluminium alloy, sealed ball races, and a similar friction grip dial, **photo 11**.

Fine Feed gearbox

The change wheels provided with the lathe



Dividing on the headstock

could not provide a ratio to produce a satisfactory fine feed. 1, 2 & 4 thou per rev. seemed desirable. Some head scratching followed, luck intervened when a friend donated two broken electric drills that were quickly salvaged for the gears which proved just right. Two three step pulleys, gearbox side plates, brackets and pillars were made and assembled. Polyurethane belting purchased and the device tried out and found to work well, **photo 12**. One drawback is it has to be completely removed when screw-cutting is required, removal and replacement take about 10 minutes but as this does not happen often so it is acceptable.

Quick Change Tailstock Tooling

I made a tailstock turret, but was disappointed with it as it seemed awkward to use on the short bed of the Zyto and tended to foul the milling attachment. My very impressive Quick change tool post gave me the idea for quick change tooling for the tailstock. What would be required would be a number of chucks and tool holders with tooling semi-permanently fitted, which could be quickly fitted and removed from the tail stock. The tailstock of the Zyto is bored with a No 2 Morse taper so the first task was to make a number of tapered adaptors to which chucks and other tooling such as die holders, tap holders, wobblers etc. could be attached. Pieces of free cutting mild steel a little over twice the length of the adaptors were centred at both ends to make two adaptors. The top slide was set to the correct angle using an existing centre and a clock gauge. A 'production run' of adaptors were taper turned two at a time. Individual adaptor ends were machined to suit the chucks and then the adaptors were separated. Buying chucks is expensive but in our throwaway society I found another source; in the DIY market: battery drills are sold at quite low prices but purchasers find that when the battery fails the manufacturers charge almost as much for a replacement battery as for a new drill so they discard the drill and buy a new one. All my chucks, of various types and sizes have been obtained second hand. In practice this is a very efficient way to use the tailstock, **photo 13**. The other quick change tools I have made include running centres, die holders, tap holders, a centre finder, a tailstock drilling pad with V groove for centre drilling and a device similar to a running centre but with a 3/8 UNF thread instead of a centre for attaching a drill chuck - very useful for working on shafts without a drilled centre, for example truing the commutator on electric motors.

Limited headstock bore

The most unfortunate feature of the lathe and one that cannot be improved is the small diameter of the headstock bore of only 3/8 of an inch, which is somewhat limiting. There was no practical solution so a 'work around' was required, the most obvious was a Fixed Steady, **photo 14**,

which could be easily fitted and removed. This again was made from scrap aluminium alloy with sealed ball races used to contact the work to avoid marking it.

Rear Tool Post

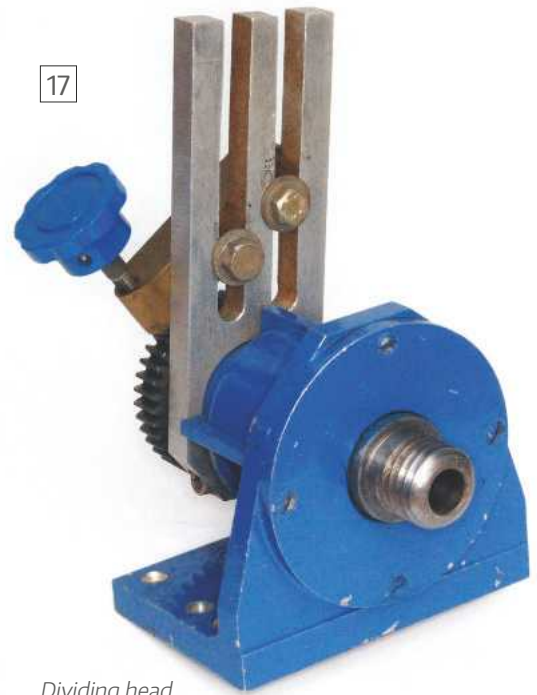
The Zyto is quite lightly built with the result that when parting off chattering can occur but this problem can be somewhat ameliorated using a rear tool post, **photo 15**, but this needs to be easily fitted and removed. I liked the design of the old Drummond tool post, easy to make, quite sturdy, it is easy to fit and requires no packing to obtain centre height.

Dividing on the Lathe

I made three dividing devices, the first a very simple arrangement on the lathe headstock, was copied from an article saw in The Model Engineer 50 years ago. The bore at the remote end of the spindle was tapped and an adaptor machined to accept a change wheel. A bracket was attached to the head stock with a screw in detent, **photo 16**.

The second was a dividing head made using the bearing housing and bearings from an automatic washing machine fixed to a piece of alloy angle with a mild steel spindle turned with a nose identical to the lathe. when mounted on the cross slide the centre height of the spindle is the same as the lathe. This again used a change wheel and screw in detent as the dividing device, **photo 17**.

The third is a small rotary table. I found a video on You Tube showing how to make a worm wheel using a tap. and following the instructions, the 120-tooth worm wheel. was tuned from a piece of mild steel and bored to take a pair of thin section ball races which were press fitted in. This was then bolted onto the top slide to freely rotate at centre height, with a tap held in the chuck and supported with a running centre. The lathe was set about 150 rpm and the cross slide advanced slowly until the worm wheel was cut to depth. The worm was screw cut. The gearbox was fabricated from aluminium



Dividing head

alloy with two small ball races supporting the worm and an alloy hand wheel. A mounting plate was bolted to the top of the worm wheel with a pattern of M6 tapped holes for mounting work and a M14 x1mm tapped hole in the centre for fixing Emco Unimat chucks. Using the dividing head shown in photo 17, the mounting plate was divided into 120 divisions and the hand wheel into 60 divisions equal to 3 minutes of arc. A compound train was necessary for the 120 divisions as the largest change wheel supplied with The Zyto has 60 teeth. This is not a heavy duty device but has proved very useful, **photo 18**.

The Zyto lathe has been a constant companion for 60 years, it has been very useful, saved me a small fortune over the years, given me great pleasure modifying and improving it and is now better and more accurate than when I bought it. Making something out of nothing was a necessity when I was young but is now a source of pleasure and achievement. ■



Rotary table

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Readers' Tips



Hanging Around



TIP OF
THE MONTH
WINNER!

David Godley wins this month's Chester Vouchers with an easy tip for better QCTP storage.

Always with an eye on cheap but effective solutions to issues that arise, having used and proved this tip, I offer it to anyone who like me, needs to rack their lathe tools conveniently and securely, with a minimum of effort.

In my collection of "it may come in useful one day", I had a small one of those pressed out storage racks which are fixed to a wall; and on

which you hang plastic trays/boxes in which items are stored. I cut a strip of these off and cut that into individual pieces. These were drilled and screwed to my mounting board which is placed behind my lathe on which other items such as chuck keys, spanners, etc. are also mounted.

As they say a picture paints a thousand words, and I am sure readers will understand far easier my arrangement when viewing the attached, rather than my attempt at describing it. I did find that without cutting into individual pieces, the tools were too close to each other.

Revive a Drill

Runner up Lloyd le Gresley says its easy to bring old battery drills back to life!

Eric Clarke's article in the June M.E. Workshop, and his remarks about integral batteries failing in first generation battery drills, reminded me of a recent problem I'd had with drill battery packs.

After some research, I realised that it would be impossible to find four 9.6v nicad battery packs for my two early generation battery drills. My last battery had just failed, but the two drills were still working well (not ready for the bin just yet I thought!)

Using my Dremel drill fitted with a narrow cutting disc, I carefully cut away the battery case to reveal the stack of 8 tagged 1.2V 2000m AH Sub C type NiCd cells wired- in series.

Searching the 'net' I was pleased to find that "Batteries Plus" of Hartley in Kent, had these items in stock at a very reasonable price. 24 tagged 1.2v NiCd cells were ordered and quickly received with a note saying that the 2000 mAH had been replaced by a 2400 mAH - even better - more power!

I spent one afternoon re-building four battery stacks, adding insulation and linking wires where required. To complete the task, a hot glue gun was used to re-assemble the four battery pack cases



and their new contents. If you do attempt this, the new cells come fully charged, do not short them out!

I now have two first generation battery drills back in full working order, with two battery packs for each, and even better, more powerful than before!

The photo shows one of the drills with two rebuilt battery packs and one of the original stacks of 8 Sub C 1.2V cells.

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. **Don't forget to include your address!** Every month I'll 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.chestershobbystore.com to plan how to spend yours!

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Making a Valve Rod Coupler



Andrew Johnston describes some tricky machining.

The four-inch scale traction engines I am building are based on the Burrell single crank compound (SCC) design. The engine is, naturally, a compound with high pressure (HP) and low pressure (LP) cylinders. However, unlike a conventional compound engine where each cylinder connects to its own crank, in the SCC both HP and LP pistons are connected to a common crosshead and thus to a single connecting rod and crank. Similarly, each cylinder has its own slide valve and ports, but external to the cylinder both valve rods are coupled together and are driven by a single set of valve gear. This article describes the manufacture of the valve rod coupler ensuring that the important geometric constraints are met while making



Valve Rod Coupler – 3D CAD Model

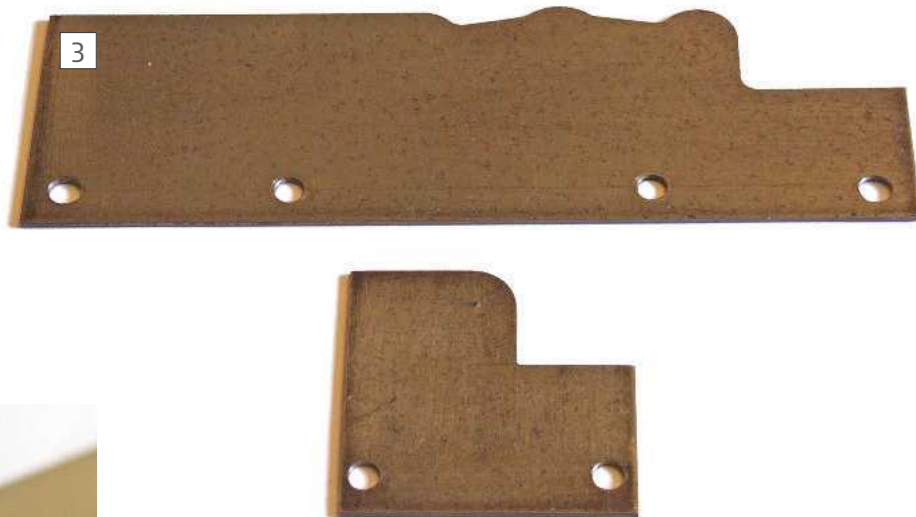


Hydraulic Copy Unit

the result look pleasing to the eye.

Design

A 3D CAD model of the valve rod coupler is shown in **photo 1**. The central hole attaches to a shaft connected to the expansion link of the valve gear while the two outer holes drive the two valve rods. These holes form an important geometric constraint on the coupler. The three hole axes need to lie in the same plane, and be parallel. In addition,



Profile Templates

the two outer holes need to be symmetric around, and the correct distance from, the centre hole. The two flat sides also need to be parallel to each other and perpendicular to the hole axes. The profile of the coupler is unimportant regarding function, but is important visually as the coupler is prominent on the engine. The drawings show the junction between the tapered portions and the balls as sharp. I do not have a radius turning attachment for my lathe so that would be

difficult to achieve. I added fillets instead, which are in keeping with the full-size SCC engine in the Burrell museum.

The drawings show the distance between the outer holes as 2.59", equally spaced around the central hole. To catch errors in the drawings, and compensate for some imperial material sizes that are no longer available, I am modelling all parts of the engine in 3D CAD. My CAD assembly of the motion gear shows that the 2.59" dimension should actually be 2.5898". While the difference is minimal, one might as well eliminate a possible source of error.

The key point when planning the manufacture of the coupler is ensuring that the geometric constraints for the holes and



Korloy KGT Holder and Insert



Cutting the First Profile

flat sides are met. It would be possible to form the complete profile on the lathe first, but then holding the coupler to mill the flats and drill the holes would require some intricate jiggling.

Manufacturing Sequence

The manufacturing sequence that has been worked out allows the holes and flats to be machined in such a way as to ensure that the geometric constraints are met. While I don't have a radius turning attachment I do have a hydraulic copy unit for my lathe. This is a unit that bolts on the back of the cross slide and has a toolholder driven by a hydraulic cylinder. The position of the cylinder is controlled by a stylus that follows a template held on supports on the back of the lathe bed. A general view of the hydraulic copy unit is shown in **photo 2**. Visible behind the lathe bed are the stylus and the template supports. Not visible are the support bar bolted onto the back of the lathe bed and the hydraulic oil reservoir and pump that provides the hydraulic pressure



Close up of Profiling Operation



Embryo Couplers



Drilling Hole

(350psi). A more detailed description of the hydraulic copy unit has appeared in a past issue of MEW (ref. 1).

The first operation is to form almost the complete profile, leaving the ball at one end partially formed. To form the profile, we first need a template. The template that the hydraulic copy unit stylus follows can either be a flat sheet or an example of the part to be made. The latter method is chicken and egg in this instance, so I used a flat template. Due to the fairly complex profile I chose to make the template on the CNC mill. A piece of sheet steel was marked out and filed to get three sides straight and square and the holes drilled to fit the template supports. The G-code to create the profile was then generated in my CAM program. The profile took 4 minutes to mill with a 3mm cutter, and rather longer to program. The templates used for making the coupler are shown in **photo 3**, the template being discussed is the upper one of the two.

To machine the profile, I used a Korloy KGT toolholder and a copy profile insert.

The insert is similar to a parting off insert but has a 3mm partial diameter at the end, **photo 4**. The stylus on the hydraulic copy unit should match the shape of the tool to ensure faithful reproduction of the template. In this case, it is simply a 3mm diameter spigot. A general view of the hydraulic copy unit cutting the profile is shown in **photo 5**. At the outer end the template is perpendicular to the lathe axis, corresponding to the maximum extent of the outer ball. Due to the geometry of the stylus control arm I found that the unit was happier following the template when traversing from the chuck outwards rather than towards the chuck. A close up of the profiling operation is shown in **photo 6**. Despite the slender nature of the toolholder there were no chatter problems running at 800rpm, with a roughing depth of cut of 30 thou and a feedrate of 6 thou/rev. The swarf is coming off a nice blue colour. Another design feature to avoid chatter is that the fillets are of a diameter slightly larger than 3mm. This prevents the length of cut on the insert changing rapidly as it

encounters, and then leaves, a fillet.

Note that the tool is upside down. The tool is behind the work so if it is the normal way up the lathe needs to be run in reverse. The lathe has a D1-4 Camlock spindle fitting so there is no chance of the



Split Sleeve



Close up of Coupler in Split Sleeve



Finished Valve Rod Couplers

chuck unscrewing when running in reverse. However, running the spindle in reverse also means that all the feed directions are reversed. I prefer to run with the tool inverted and keep the feed directions as one is used to with normal turning. Another advantage of running with the tool inverted is that normal right hand tools can be used to get close to the chuck, obviating the need to purchase left hand tooling.

The key to being able to mill one side flat and drill and ream the holes in the correct orientation is to profile two embryo valve rod couplers on each end of a bar (I am building two identical engines), **photo 7**. Of the four couplers shown one is scrap due to a machining error, one is a spare and two are for the engines. The unmachined length of bar in the middle can be located in the T-slot of the milling machine ensuring alignment with the table. This setup allows one side to be milled flat and the holes drilled and reamed without moving the coupler, **photo 8**. The location of the central hole was set mid-way across the axis of the coupler using the 1/2 function on the DRO. Along the axis, it was centred by eye. The distance from centre hole to

each outer hole was set using the DRO. A micrometer conveniently fits in the T-slot to allow measurement of the thickness when milling the flats.

Having drilled and reamed the holes the next operation is to separate the couplers from the parent bar and finish the profile on the partially formed ball. This requires a new template for the hydraulic copy unit, and a means of holding the embryo coupler firmly to resist the cutting forces without damaging the existing finish and ensuring concentricity to maintain the profile.

The template to form the end of the second ball is the lower of the two shown in **photo 3**. Since this is a simple radius the template was marked out and filed to shape by hand.

A simple way to hold the coupler uses a split sleeve, **photo 9**. This is made from aluminium alloy so as not to damage the finish on the coupler. To make the sleeve it is drilled through with a 10mm drill. The hole is then opened up to 3/4" to a suitable depth to fit the smaller ball. The larger ball is nominally 7/8" but measures slightly oversize, so the sleeve was bored out to be a snug fit. Finally, the sleeve is split using a hacksaw. A close up of the coupler

in the split sleeve is shown in **photo 10**. Concentricity wasn't measured, but the finishing cuts blended in with no evidence of misalignment, so probably within a few thou. The sleeve left a slight witness mark on the coupler but this was easily removed with a couple of strokes of 800 grade wet and dry.

Once the profiling is finished it is simple to clamp the coupler onto the mill table and mill the second side flat, moving the clamps as required and machining to the vertical knee dial once it is set to zero at the appropriate thickness. The two finished couplers are shown in **photo 11**.

Conclusion

This has been an interesting exercise in machining and holding a deceptively simple part that nevertheless has some important geometric constraints, and has to look right as it is prominent on the engine. I have also learnt a lot more about using the hydraulic copy unit. ■

References

Ref. 1: Fitting and Using a Hydraulic Copying Unit - MEW No.167 September 2010

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- ENV Aero Engine
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Modern Flute Making in a Small Workshop



In an interesting diversion for MEW, Stephen Wessel describes the philosophy and techniques he applies to a challenging craft, with many lessons for those of us who aspire to achieve the best from our workshops.

Introduction

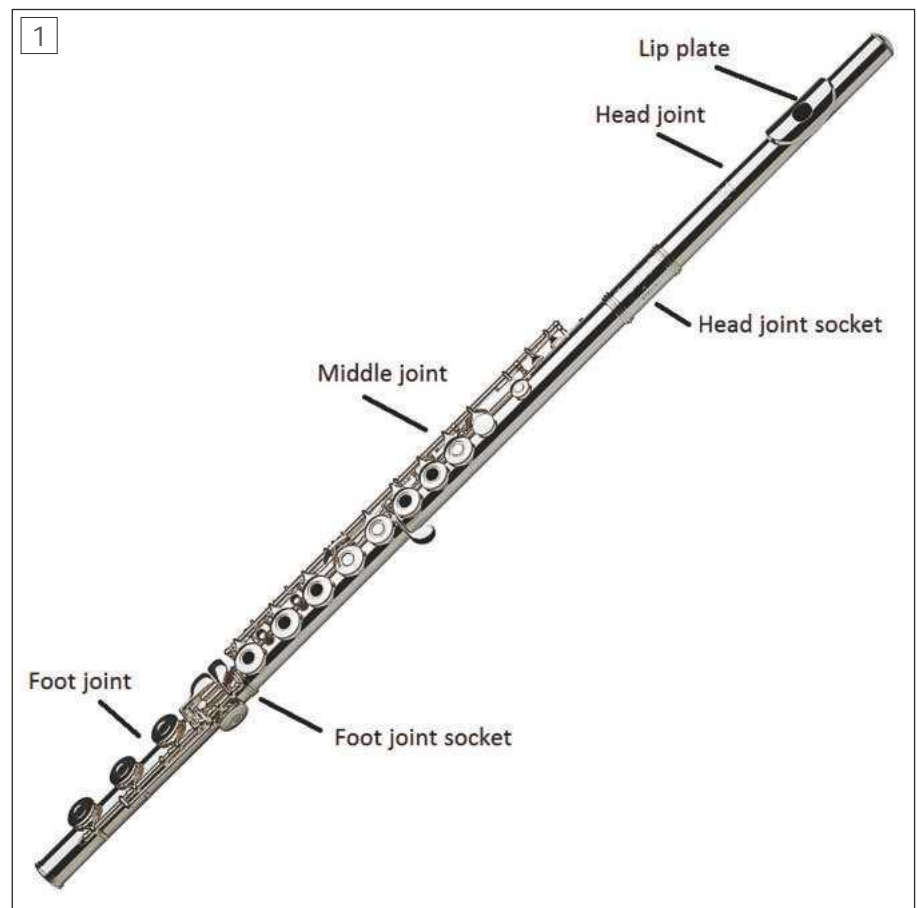
I am one of a small number of artisan makers of modern musical instruments. Collectively we keep alive the traditional hand-working methods that were common until the 1960s but which are now in serious decline. We offer a truly bespoke service, a fastidious attention to excellence and listen closely to our customers. We share the same enthusiasm for our work as do the craft makers of everything from bicycles to beer. It is probably true to say that many of the very best instruments are still made entirely by hand, often, as in my case, by one person.

In this three part article I am going to outline some of the processes involved in making a flute and while not forgetting that my readers may have more interest in tools and techniques I shall also have to explain my design philosophy as determined by musical requirements and how it may differ from that which governs the mass production of the flute in factories around the world. The processes and materials are not necessarily those used by other makers. Part 1 will form an introduction to the subject and go on to describe the tube making.

Part 2 will cover the key making or "engineering".

Part 3 will talk about finishing and maintenance.

The word 'flute' describes a large family of instruments but not withstanding the accomplishments of your Editor on several of the more primitive sort, I am limiting the discussion to the modern orchestral flute made nowadays mainly in metal.



Schematic of the modern Boehm flute

I did not take a course in "flute making" for back in the 1980s there was no means of doing so, at least not in the UK. I was

however married to an accomplished professional flute player, had a degree in engineering, played the clarinet a good



Wessel flute fitted with Sheridan head joint

2a



Another flute with an alternative key arrangement for G & G# at centre

3



The three joints shown separately

deal and was currently self-employed as a harpsichord builder. Model engineering was in the mix too. When she announced that she needed a better instrument we consulted a friend, the well-known silversmith John Webb, and to cut a long story short, he and I set up to make her a new flute! At this point a technical clarification is needed. The flute comprises three main parts, or 'joints': the middle and foot joints that carry all the tone holes and keys, and the head joint. The latter could be described broadly as the mouthpiece. It is a short tapered tube carrying only the 'lip plate' in which is cut the embouchure hole, **photo 1**. Naturally it is of crucial acoustic importance but is usually thought of as a separate entity, so much so that there are specialist makers of them around the world who do nothing else. John, at the time I met him, was one of these and had begun to find a market.

Photograph 2 shows a complete flute with all three joints connected. **Photograph 2a** gives a closer view of the body. Although a perfectly standard Boehm flute (the fundamental layout having changed little since Boehm's day, c.1847) this one has several new features explained in the text. **Photograph 3** shows the bare tubes.

The Early Business

Flute production at that time was, and still is, dominated by American and Japanese makers. In earlier times the better instruments came from Germany or France while English makers and players followed a long tradition of using wood rather than metal. Fashion for the all-silver "French style" swept all before it during the 1960s and the English makers began to disappear.

Meanwhile, many of the leading London players had developed a passion for rebuilt 19thC Parisian flutes, claiming them to have a far more beautiful sound than anything coming out of American or Asian factories. The trouble was that these old flutes had been around a bit and were very delicate, having thin tubes and notoriously unreliable mechanism. So it seemed to us neophytes that here was our starting point: we would try to emulate these expressive instruments but improve their mechanicals with the help of some modern materials. Lots of necks sticking out here for the simple reason that you don't "copy" something by altering its fundamental composition! But unless you do, nothing much will be learnt.

To avoid having to delve into the history of the flute, for that is well beyond the scope of this article, I will simply state that we decided to keep to a relatively thin silver tube, around 0.013" wall, and try stainless steel for the keywork instead of the usual silver or nickel silver. Steel would be lighter and stiffer than the traditional metals and we planned to inlay some of it with polished black plastic to lighten it further. We had several other ideas, some of which were tried out in prototypes and test rigs but the design soon settled down to a broadly conventional flute with a highly responsive action that did in fact sound quite like those Paris flutes.

My role in all this was to make the keywork and fit it to the handmade tubes supplied somewhat erratically by John. I also did all the finishing work and got them to play properly under my wife's guidance. Thirty years later I am doing the whole thing with the exception of head

joints, which as mentioned earlier are better bought from specialists. Most of my customers already own a good head joint that they want to carry on using in a new flute so it makes good commercial sense to do it this way.

The requirement

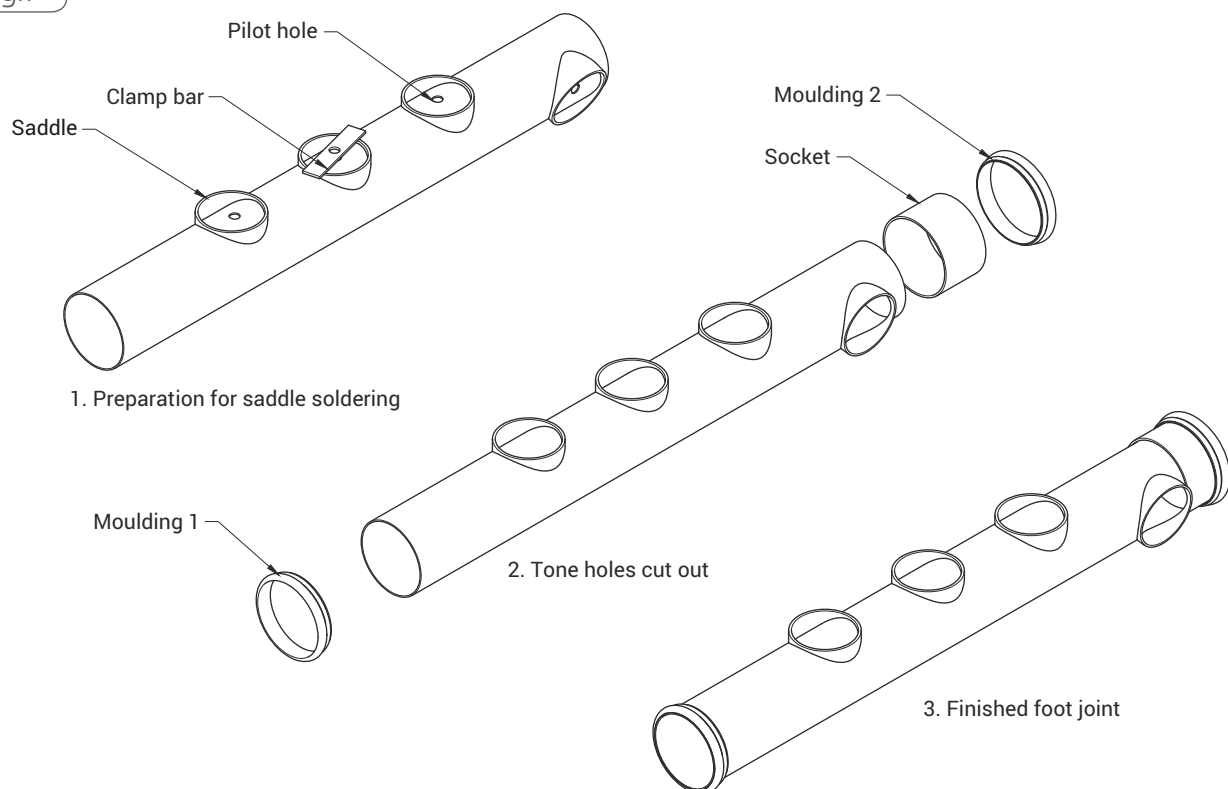
What makes a flute good enough for a fine player? This question has of course dogged the lives of every instrument builder since the beginning of written music. Musical performance of every sort is a highly competitive and emotionally charged business. There are always many more musicians than available jobs and only the best will earn a living by playing alone. So their instruments are of vital importance in giving them the edge. Here is a list of the basic qualities of any wind instrument: It must:

1. play in tune
2. have a highly reliable mechanism (usually referred to as "keywork")
3. be responsive to the tonal needs of the player
4. have a focussed, resonant sound that projects well
5. play evenly from bottom to top

Taking these points in turn,

1. The tuning of any wind instrument is a compromise. You are trying to get all 12 notes in each of three octaves as near to "equal temperament" (as a piano keyboard) as possible. This is theoretically impossible but every generation of makers and players sees an improvement. The exact position and diameter of every tone hole is determined by a mixture of maths and playing experience. The idea is to make playing "in tune" as easy as possible with

Fig.1



Footjoint Construction Steps

the minimum of embouchure change. Nowadays we have got pretty near.

2. Properly engineered keywork is vital. All the holes on a flute are covered by thin cups or keys, each containing a soft pad to make an airtight seal. With only 9 active fingers (the right hand thumb is used for support only) some of the keys are closed automatically by others, involving a number of clutch mechanisms. Each pad must close off its tone hole completely and positively with the absolute minimum of finger pressure. If there is a small leak the flute will not play properly; it will lack power and resonance. So keywork has to be precise, light in weight and hard-wearing enough to withstand the rigours of daily practice, travel and changing atmospheres. And, of course, comfortable. Rather like a satellite, once it leaves the workshop, the flute is on its own out there, receiving little attention and sometimes no maintenance for years.

3,4 & 5. Flute sound should be anything but bland and monotonic. A good player will expect to produce a whole palette of colour and dynamic according to the demands of the music. Nobody knows exactly how this is achieved, some instruments enabling these variations more easily than others. American flutes tend to be heavy and thick-walled. This gives them raw power but often at the expense of expressiveness. They have a tendency to limit the colour spectrum and impose their own idea of flute sound upon the player. I am convinced

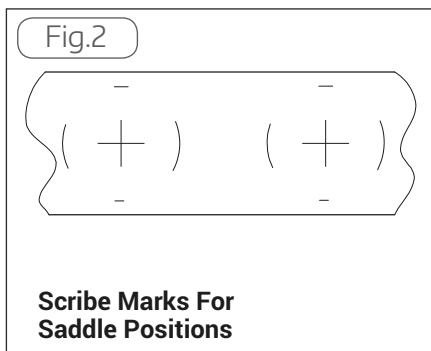
that too much weight in the keywork has a bad effect: a sort of deadening. Different players can get a different response from the same instrument, partly because the acoustic system includes the oral cavity; everyone's embouchure, and of course skill level, is unique too. Players know instinctively what they want from their instrument and it is the maker's job to interpret this as best he can; he is a "tool maker" and intuition is often a better guide than physics.

Another major consideration is that most flutes will form part of the orchestral

woodwind section where they have to blend. The standard repertoire comprises a vast amount written in previous centuries as well as our own by composers familiar with earlier, sometimes more primitive, versions of the modern instruments we know. You cannot therefore introduce a radically new sound into the mix. The musical profession is a conservative world that tolerates only minute incremental changes. Anything the maker can introduce that improves the ease and flexibility of the playing experience is good because the player is then able to concentrate solely



Marking out tone hole positions. The disc shows all the angular data and the piece of angle clamped to the lathe bed carries an index mark.



on the music without worrying about the instrument. He wants the best tool for the job. This should be the maker's goal, pure and simple.

The tube

This is the acoustic heart of every wind instrument, containing the air column which is set in vibration by a rapid alternation of eddy currents around the embouchure hole. (Or in the case of the oboe, clarinet and bassoon by the reed vibration) The body tube of a flute is cylindrical and has a bore of 19mm and a wall thickness (varying between makers) of 0.012" to 0.018". (The two units of measurement may be characteristic of our times, the original work on the "modern" flute having been done chiefly by Theobald Boehm in Germany during the mid 19thC while later developments were mostly English or American). The default material is silver. This is far too expensive for the millions of factory produced instruments so nickel silver (a copper/nickel alloy) is used instead for the cheaper instruments and then silver plated. Gold is also used for some high end flutes and occasionally platinum. Other exotic materials such as pure tin, glass, even rock crystal, have been tried too but usually end up in museums. The tube material does have an important secondary effect on the sound but practicality and hygiene considerations have a part to play – precious metals are less reactive to the kind of stuff likely to be deposited on them.

I use silver exclusively and the seamless tubing is manufactured especially for me in Birmingham. I discovered recently on a visit to the works that, in place of the sophisticated CNC plant that I had always imagined necessary for the high quality production of such tube, it is actually made more or less by hand by the same fellow who has been doing it for nearly 30 years! He has become better and better at getting it perfectly round and within tolerance and it was nice to be able to compliment him personally. The tube starts life as a thick-walled tubular casting. It is then drawn down progressively through steel die plates on to a series of steel mandrels until it is several metres long. Constant annealing is required and scrupulous cleanliness to prevent pits and scars. Various other diameters are also needed for tone hole saddles and sockets (see **fig. 1** for explanation of terms).



All saddles clamped in place ready for soldering. Two foot joints are shown (see text) and a head socket.



Cutting the tone holes out.

Silver is a delightful metal to work with, somewhat like copper in that it rapidly work hardens; very sharp tools are needed, particularly for turned work. In the annealed state it is fairly soft so great care is needed to prevent damage such as dents. These can however be removed with almost no trace, a job often needed during servicing or repair work.

In the early years we made our own tubes individually by wrapping a silver sheet into a tube, soldering a butt joint and then drawing it down on a hand operated draw bench. The whole process was extremely difficult; every tube would come out slightly different from the last and the scrap rate was about 50%. Thinking about all that now makes my hair stand on end.

I deliberately order the tube slightly undersize on bore with a wall about 0.001" too thick. This gives me the freedom to get both exactly right on my own mandrels as well as straighten it when necessary. This work is done chiefly by very light burnishing using a piece of polished 3/4" steel rod. Uniform strokes up and down all the way will gradually enlarge the bore while if they are confined to the concave side only, the tube will curve in the opposite direction.

The tube is then annealed and checked

again for straightness. Laying out the hole positions is done on the lathe using the lead screw, **photo 4**. A small cross is scribed at each centre and a tiny mark representing the edge of each hole. This work needs to be done with great accuracy working to about 0.002". Some of the holes are in line with each other but several are placed at various angles around the tube. This information is carried on a large disc temporarily attached to the mandrel supporting the tube.

The distances between each hole and from the end of the tube form what is known as the "scale". Many different scales have been devised since Boehm's day and overall pitch has also varied. This has now settled at about A-442 in most countries. The scale I use is best described as "work in progress" by William Bennett (known to all as Wibb), one of our top players and professors of music teaching who has done more to further the modern flute than anyone. I am fortunate to have received his support throughout my career. His latest scale is as good as it gets.

When all hole positions have been checked, a pair of fine dividers is set on each cross and used to scribe arcs representing the outer edge of the saddle. See **fig. 2**. These marks are vital because a pilot hole

will be drilled through the cross and if that drill decides to wander off course, which it usually will, the centre is immediately lost. The purpose of this hole can be seen in fig. 1 and **photo 5**. A small clamp bar is needed to hold each saddle secure during soldering. A 10BA screw passes through it into a similar bar placed inside the tube. This photo shows two alternative foot joints of different lengths, the longer one provides not only an extra low note B but also a different colour or timbre to the sound of the entire compass. Players can choose which they prefer and often have both.

My flutes are unique in having silver-soldered saddles. Nearly all production instruments have so-called "drawn" tone holes whereby some of the tube material is drawn and stretched up to form the "saddle", no additional material being required. This is a process that can be done by hand using a special tool but the tube wall around each hole is then inevitably thinned and highly stressed. This locked-in stress runs counter to my philosophy that the tube should be stress-free and homogenous; it should leave the workshop in the fully annealed state. It will gradually harden with age and playing but in a way defined only by the acoustic vibrational patterns set up within it. Unrelieved stress caused by manufacturing processes could be one reason why many mass produced flutes play unevenly. Some upmarket flutes do have "soldered" tone holes but invariably this is carried out with soft solder which, in the old days, would have contained lead. Now lead is the great enemy of silver: at room temperature any lead solder on silver will gradually become porous as the two metals eat one another; at red heat an instantaneous reaction takes place resulting in a hole in the silver! I learnt this to my cost many years ago when a tiny spot of lead solder, unseen on the hearth, somehow got itself on to the piece of silver I was heating. I didn't realise until later I found a mysterious little hole.

The saddles are made from five different diameters of seamless tubing and are profiled accurately to fit the body tube. This is done by offering up a length of tube to a drum sander of the same diameter as the body tube running in an old lathe. After sanding, the saddle is parted off to the correct length plus a finishing allowance of a few thou.

Soldering on the saddles is a job to be done on a quiet day – no radio, no storms and floods, phones off the hook and no likelihood of unannounced visitors or postmen wanting signatures. Utmost concentration with a completely relaxed state of mind is what's needed here; the tube is supported on an old bow saw blade with the teeth ground off. This keeps it straight without taking away heat. Just enough solder is introduced on the inside of each saddle and is seen to flash around making a neat and strong bond. I use only the silversmiths' hall-marking solders, Easy, Extra Easy, Medium and Hard. Each contains



Finished tube.

a minimum of 66.7% silver and all are free flowing and delightful to use, melting at different temperatures. The work is liberally fluxed with Argotect rather than Easyflo; this prevents the formation of "fire stain" leading to less cleaning up. Standard silver is 92.5%, the remainder being mostly copper. At high temperatures silver is porous to oxygen allowing the copper to become oxidised to cuprous oxide which is pinkish. The longer it remains in the fire the deeper is this oxidation and it cannot be removed by the pickle. You are left with faint pink blotches that can only be removed by abrading. Curiously, if the staining is uniform all over the piece it is quite pleasing but you don't want it on a flute.

Mouldings and sockets

These are the stiffening rings placed at the end of the main tube sections and also form part of the sockets that connect the body tube to the head joint and foot joint. The rings have a decorative section based on the classical moulding shapes such as the cyma, torus, etc and are made from rectangular silver strip that has been formed into a circle, hard soldered and turned using a form tool. Between soldering and turning the bare ring is jammed on to a tapered mandrel and hammered all round until it perfectly fits over the relevant tube.

After turning the ring is annealed and pickled before fitting to the tube. If it is a little loose on the tube, a graver is used to raise a number of tabs on the tube surface that will grip the inside of the ring during soldering.

The sockets themselves start out as short lengths of a larger size tubing that closely fits over the body tube. Socket tube is burnished as described above until it fits smoothly. Silver is a slippery metal so sliding one tube into another relies on a good fit, absolute roundness and no trace of oil or dirt.

Cutting the tone holes

Once all the soldering is complete the material inside each saddle must be cut out to form the tone holes, **photo 6**. This is

undoubtedly the most hazardous process involved in making a flute by hand.

The problem is the tube is very fragile and cannot be supported on any machine other than by a mandrel passing down the inside. So milling them out is really out of the question and in any case would take far too long; I use a tiny burr running at top speed in a hand held drive unit to rough out each hole, continue with a larger burr followed by fine sanding drums. Once again, complete concentration, a relaxed but very firm grip and total confidence in the tool is the order of the day. A tentative approach will lead to disaster when the tool kicks violently, jumps out of its path probably nicking either the saddle or the tube outside. The scrap-box may then receive a large donation while misery reigns. The main cause of this trouble is either a blunt burr or more likely a worn nose bearing in the appliance. Given that accidents and errors do occasionally occur I learned a long time ago that almost never is it worth the time spent trying to correct large ones. Much better start again, despite the loss of precious metal. This is Rule 1. Rule 2 is that every customer is equal. Never ever should one be tempted into thinking that a young student or beginner is less important than a top professional and might not notice some tiny defect. Next thing you know she is having a public master class with that same pro!

The final job is to clean up. A scraper run around the bottom of each hole will ensure a smooth rounded junction. The traditional undercutting in this area applied to wooden instruments such as clarinets and oboes isn't necessary or possible on a metal flute that is so thin walled. Assuming the tube has been pickled to remove most of the oxides, there may be small and very thin patches of fire stain despite the special flux. Very fine Scotchbrite mops can be used around the holes but generally a wet & dry paper of 1500 grit is sufficient followed by 2500 and finally 4000 cloth. Ultimately it will be polished with rouge but that can now wait until the instrument is almost finished, **photo 7**. ■

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Lehman Archer and B.A. Taps



Following a letter from a reader and my comments in Editor's Bench, I received many emails and even phone calls about their taps. Particularly interesting was material that Eric Clark sent me with the accompanying note:

Dear Neil,

I have just read the latest *On the Editor's Bench* (Issue 253) about Lehman Archer Lane (LAL).

Whilst on holiday in Yorkshire a few years ago I purchased a 1929 copy of the *Lehman Archer catalogue* from a second-hand bookshop in Sedbergh which is a small town with lots of bookshops a bit like a miniature Hay on Wye.

It is a most interesting book of 164 pages giving details of all LA's products together with lots of other tools from various manufactures including the rather quirky Wade lathes. Your number 37 set would have cost your Grandfather 29 shillings in 1929!

Most interesting, at the start of the book, is an account of LA's involvement with the inception of the BA thread system. Attached is a pdf copy for your perusal.

In addition to the usual sets of standard threading tackle LA list special sets for some common motor cars of the day e.g. "The Morris Outfit" No 113 costing £10 containing taps and dies for every component listing details of thread

THE BRITISH ASSOCIATION (B.A.) TAP



diameter and pitch. Similar sets were made for Ford cars and for magnetos.

This book is in wonderful condition for its age and was a truly wonderful find and only cost me £2.

I hope this of interest.

Best regards

Eric

Here's the section about BA taps from Eric's leaflet:

It may be a bald statement to say we made the first tap—but it is a fact that the late Mr. T. Lehmann, the founder of the business now known throughout the world as Lehmann, Archer & Co. Ltd., London, actually originated and manufactured the first British Association (B.A.) tap and die.

This incident is quite historical, and to the engineering world is of intense interest. It was about the year 1881 when a number of scientific men having a thorough knowledge of scientific instrument manufacture, under the aegis of the British

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BEST ENGINEERS' STOCKS AND DIES.
WHITWORTH STANDARD THREAD.
(CIRCULAR PATTERN).

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1	1/4"	1 1/2"	28/-	40/-	44/-
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4	7/16"	1 1/4"	36/6	58/-	67/-
5	1/2"	1 1/4"	36/-	65/6	75/-
6	9/16"	1 1/4"	38/6	67/6	76/-
7	5/8"	1 1/4"	42/-	77/-	84/-
8	3/4"	1 1/4"	42/6	72/-	84/-
9	7/8"	1 1/4"	48/-	78/6	91/6
10	1"	1 1/2"	47/6	87/6	102/-
11	1 1/8"	2"	96/-	145/-	165/-
12	1 1/4"	2 1/4"	99/-	143/-	163/-
13	1 1/2"	2 1/2"	105/-	159/-	180/-
14	1 3/4"	2 3/4"	126/-	180/-	202/-
15	2"	3"	127/-	185/-	214/-

These ranges of Stocks and Dies can be made up in B.S.F., Brass Gas, Iron Gas Threads to suit customers' requirements.

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Illustration of Case No. 32B.

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		"A."	"B."	"C."
29	0, 1, 2	14/6	16/-	19/6
30	3, 4, 5	14/6	16/-	19/6
31	6, 7, 8	14/6	16/-	19/6
32	0, 2, 4	14/6	16/-	19/6
33	6, 8, 10	14/6	16/-	19/6
34	12, 14, 16	22/6	24/-	29/-
35	0, 1, 2, 3, 4	22/6	24/-	29/-
36	5, 6, 7, 8, 9	22/6	24/-	29/-
37	0, 2, 4, 6, 8	22/6	24/-	29/-
38	1, 3, 5, 7, 9	22/6	24/-	29/-
39	2, 4, 6, 8, 10	22/6	24/-	29/-
40	10, 11, 12, 13, 14	31/6	31/6	35/6
41	12, 13, 14, 15, 16	32/6	33/6	40/-
42	0, 1, 2, 3, 4, 5, 6	30/-	30/-	38/-
43	0, 2, 4, 6, 8, 10, 12	34/-	34/-	40/-
44	4, 6, 8, 10, 12, 14, 16	39/-	39/-	47/-
45	7, 8, 9, 10, 11, 12, 13	39/-	39/-	47/-
46	10, 11, 12, 13, 14, 15, 16	42/6	42/6	51/6
47	0, 1, 2, 3, 4, 5, 6, 7, 8	42/6	42/6	51/6
48	0, 2, 4, 6, 8, 10, 12, 14, 16	47/-	47/-	65/-
49	8, 9, 10, 11, 12, 13, 14, 15, 16	53/6	53/6	71/6

We shall have pleasure in making up special assortments to customers' requirements.

MADE IN ENGLAND.

Association were formed into a committee to provide a standard screw thread suited to the requirements of this industry - of sizes equivalent to 1/4" and downwards.

The only standard English thread in existence at that time was the Whitworth thread, originated by the late Sir Joseph Whitworth. In 3/16" upwards.

The character of this thread as a whole was unsuitable for the fine instrument trade, so this committee introduced a formula for screw threads in sizes no. 0 b.a. (measuring 6.0 m/m) down to no. 16 B.A. (measuring 0.25 m/m), suitable for the smallest screws for watchmaking. The pitch of no. 0 B.A. to be 1 m/m, and that of no. 16 B.A. to be 0.072 m/m, whilst the angle of the thread was to be 47°.

After completing their formula, the next step was to find a British manufacturer who would undertake to work to it and originate the threads required. After considering the matter they decided to approach Mr. T. Lehmann, who had been manager of a large telegraph instrument factory belonging to one of the members of this committee. he was prevailed upon to produce the first B.A. taps and dies in a range from no. 0 to 16 b.a., which it was considered would be the most suitable sizes for use in the British Isles. no. 0 b.a. standard thread was to carry 25.4 threads per inch, whilst no. 16 was to

have 134 threads to the inch.

As there were no lathes in general use for producing such threads in this country. it was necessary for Mr. Lehmann to invent machinery capable of originating the desired pitches accurately, although it had been previously shown that by adding a wheel of 127 teeth used on an English screw-cutting lathe, it would produce a pitch practically correct to within a 1/53,300th.

Her Majesty's Post Office Telegraph Department placed orders for a large quantity of taps and screw plates, so enabling Mr. Lehmann to proceed with the manufacture of these in commercial quantities. It was about the year 1887 when these standards became generally in use by the Post Office, who have continued to use them ever since.

Shortly afterwards large electrical corporations and scientific instrument manufacturers bought taps, etc., to this standard. So gradually they were brought into everyday use, and now they are known in every quarter of the Globe, orders reaching us regularly from Australia, India, Africa, New Zealand, Canada, South America, West Indies, etc.

Although our business commenced with the origination of the British Association (B.A.) standard screw thread, we have

during these 44 years extended our manufactures of taps and dies in all known standard threads, such as Whitworth. B.S.F. Metric, Iron Gas. Brass Gas, C.E.I., A.S.M.E., S.A.E., U.S.S., etc., etc.

The foregoing is an evidence of progress. But not being satisfied with past achievements although we produced the first British Association (B.A.) tap and die—we are now first in the field with an English made, relieved ground thread tap. For accuracy and finish there are no British or foreign taps to compare.

The firm is proud of the knowledge that it is supported by a staff who consider the interests of the firm and themselves identical. In our service organization our customers can always rely upon receiving the same courtesy and attention at the hands of any member of our staff, thus making our manufacturing and selling forces one solid whole.

The business has been built up solely on **Quality**—always the best.

Service—prompt and efficient.

Price—always competitive.

All screwing tackle is London made.

Your interests are ours—let us have an opportunity of proving this.

Samples for testing purposes are always at your disposal. ■

Prototype Tooling Manufacture



Richard Smith's tooling system, featured in MEW 248, raised a great deal of interest among readers. In this article, he gives further details of making the tooling. Part 2.

The endmill was blunt and very securely held and inside the chuck guard. After that I held it in the four-jaw chuck to face up the ends. I drilled and tapped for two M6 screws and attached a small fence to the edge which will face the headstock, **photo 19**. The fence makes it easy to align the boring bar parallel to the lathe axis. The block was mounted on the toolpost ready for drilling and reaming, **photo 20**.

The boring bar had been used in a four way toolholder and the clamping screws had marked the surface and took a bit of cleaning up before it would just go into the reamed hole. To clamp it I drilled and tapped for three soft nosed grubscrews that I had available – remember this is prototype to prove the idea, **photo 21**.

I needed to set the tip on the centreline so I faced a scrap of aluminium and rotated the bar until the tip was lined up with the scrap's centre and tightened the grubscrews.

Initial results are encouraging (I am still using it) but I'd rather use a split clamp than grubscrews.



Fence fitted to boring bar holder

External Threading Tool

The threading tool needs height adjustment so has to have a pillar. I had

just enough of the cast iron bar left try and get one out of it, **photo 22**. I found one more scrap of rusty steel and drilled and tapped and centre drilled it, **photo 23**, and mounted it on the faceplate as before and cleaned up one face, **photo 24**. Note the handle positioned to clear the chuck guard by putting it in the other side to normal. I drilled and bored it until the pillar fitted snugly, **photo 25**, before cutting off the surplus to form the tool blank, **photo 26**. Incidentally the pair of offcuts have been numbered so I can use them as equal packing. I sawed and machined both sides to 20 mm off the centreline and cleaned up the ends.

I have an external threading kit with a range of inserts. The inserts are held in the tool at a compound angle so the problem is how to duplicate this. There is actually a shim under the insert but as it is parallel I decided to not use it which reduced the depth of cut by half. The shim face sits parallel with the angled top face on the tool, **photo 27**, and this is the key to setting up. The face is angled in two directions so the tool blank has to be mounted similarly angled and then the face can be cut and the recess for the



Reaming boring bar holder



Finished holder



Facing a pillar



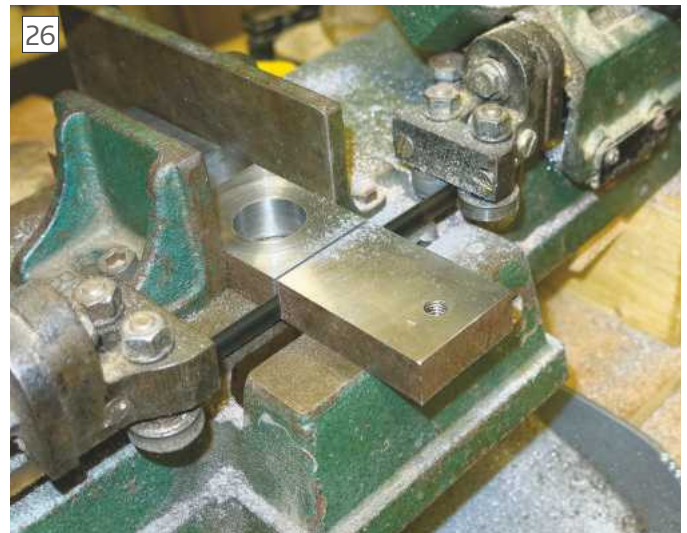
Centre drilling some rusty scrap



Scrap bar after cleaning up one face



Pilar fitted to blank.



Cutting blank to length

insert milled out. This face is too small to measure from so I placed a piece of gauge plate on top of the face located with a screw into the tapped hole for the insert. This provided a large enough face to use my digital angle gauge on. I clamped a

large and a small angle plate together and attached one of the offcuts from the insert holder with a central caphead screw. This arrangement provides adjustment in two planes at right angles – **photos 28 and 29**. There is a screw in a scrap under the small

angle plate which acts as a jack to help set and maintain position. The kit tool with the gauge plate on top was then clamped onto the offcut and up against the small angle plate and the digital gauge used to set the angles in two planes, **photos 30**

and **31**. The kit tool was then replaced with the tool blank and the setup mounted for milling with the large angle plate squared up with the table and the top angled face was milled, **photo 32**. I blued this face,

placed a threading insert on it, and scribed around it as a guide for machining the pocket. Because the tool axis is parallel with the large angle plate edge I could use the edges with a drawing square for

setting the angles to machine the inset pocket, first one **photo 33**, and then the other, **photo 34**.

The smallest cutter I had was 5 mm. First I machined the extended slot to include



Pocket for threading insert



Set up with multiple angle plates



Final setup for blank angled in two planes.



Checking angles



Final adjustment



Milling top angled face



Machining first pocket...



... and the second



Insert in place



Setting up ready to machine relief

the corner hole in several passes until just short of the full depth. This forms the top edge of the pocket. Then I reset the angle and machined the other side of the pocket to the same depth and a little short of the scribed line and nibbled out the remaining metal. Now I increased the depth of cut to the full value and recut along the bottom edge of the pocket until the cutter just touched the top edge of the pocket. I repeated this action at different cross table settings until all the bottom of the pocket had been covered except some of the initial slot. Reset the angle and repeated the first cut so all the bottom of the pocket had been covered and then took a final small cut along the top edge of the pocket. When I tried an inset it fitted nicely, **photo 35**. Time to drill and tap for the mounting screw – using the right tapping drill! Next I put the tool in the vice with the pocket bottom aligned by eye vertically with the square, photo 36, and machined the edge which created a relief as on the original kit tool. I sawed across and machined the face to remove surplus material and finally formed the clamp on the other end. The complete tool is shown in **photo 37**. ■



Finished tool.

Silver Soldering - A Comprehensive Guide

David Banham gives a wide-ranging overview of this important technique for metal joining - Part 3

Flux

Use either powdered (the most economic), or liquid fluxes (the most convenient).

Powder flux is mixed to the texture of single cream. Add a very small drop of washing up liquid (no more than the size of a match head), to create a wetting capability, where the flux will run and wet better. Store in a container with a good screw-on lid, so it can be used over a time, for increased convenience.

Holding Parts for Soldering

Here are some ideas for holding parts together while soldering.

- Hold parts with threaded components such as threaded joints or screws
- Use pins of the same material as the components
- Use a simple wedge, shim or packing
- Peening to create a burr or dimple in the metal so that the parts become a push fit.
- If the gap is large consider some thin shims pushed into the gap.

Peening involves making a dimple or raised spot by using the ball-peen (also spelled peen) hammer or a punch to deform the metal surface creating a higher point and mechanical contact with the mating piece. This can be achieved with a hammer, flat faced punch, or a centre punch. For instance, three or more small punch marks around the periphery of a round joint will hold the parts steady while silver soldering.

Temporary Clamps and Supports

These are only limited by your imagination and can involve supports, clamps, clips, pincers and forceps of various types and



Mechanical Third Hand Sold in Hobby Shops

sizes. Third hands are often quoted and are shown in **photo 14**. These hands can be useful, but are harder to set up than some other methods. Third hands also are not particular useful for pipe fittings or tubular or cylindrical objects.

The in the air method shown below features a useful device for circular components.

Some ideas that can be more useful are:

- spring binder (bulldog) clips used for paperwork
- wooden clothes pegs
- small crude toolmakers clamps are very effective for parts with flat faces
- surgical haemostat
- self locking tweezers
- small crocodile clips
- cheap G clamps-
- parallel faced pliers

Imagination in this area is important.

Also, there are those forms of prodder and pushers that hold items firm against

another object. A design for a clamp/prodder shown from an article by Stan Bray (founding Editor of MEW) is shown in **fig. 12**.)

A curved prodder of stainless or mild steel about 6 to 8" long, with a curved, and pointed end, is weighted by a piece of round steel about 1" diameter and say 1.25" long and a base made of a steel oblong block about 3 by 2 by 0.5". Two 2BA (10-32) cap screws to secure the rod to the weight and the block completes the item. Stan Bray states two or more of these are most useful.

Finally, there is the 'In the Air Technique' where the parts are held together, but not supported on the brazing hearth table.

An innovative design was shown on a web page by Macgyver, ref. 1, and its principles are illustrated below. Note that both the round table and the angular support could be replaced with other support shapes or grippers, such as toolmakers clamps. Various other designs have been published over the years, but this one is very effective, allows flexibility, and is easy to make.

The important components of Macgyver's Version is shown in **fig. 13**. The actual table and the angular support are shown in **photo 15**.

Photograph 16 shows the flexibility of this design, when creating a machine ball handle. It allows two components to be positioned for silver soldering where one component has to be aligned at an angle.

Cleanliness

A clean joint before the start of soldering is essential. Clean means:

- Free from oxides and dirt. Clean the metal mechanically, this is best done with emery cloth, emery braid for crevices and filleted areas, or wire wool. Larger areas may benefit from the use of a wire brush mounted on a spindle. Freshly machined metal that is free from oil and grease needs no additional cleaning.
- Free from grease, oils or other contamination. If the metal has been machined using lubricants or might have been contaminated by oil or grease while in the workshop, degrease the part with a commercial de-greaser. Do not use paraffin(kerosene) or petrol (gas) as a degreaser as they both contain additives

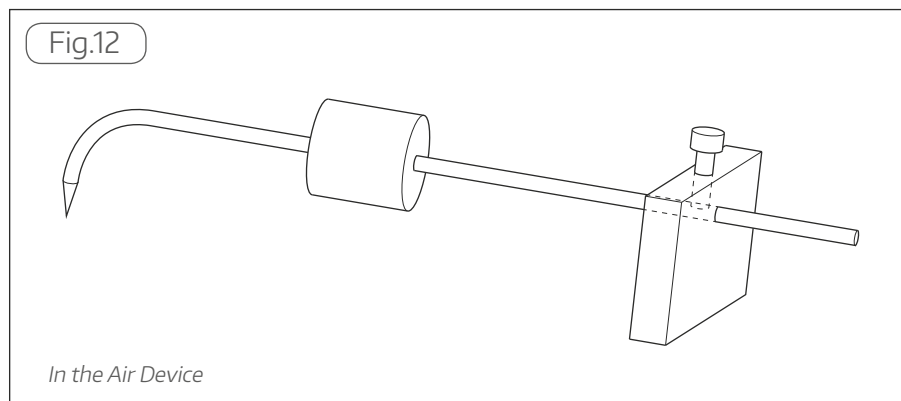
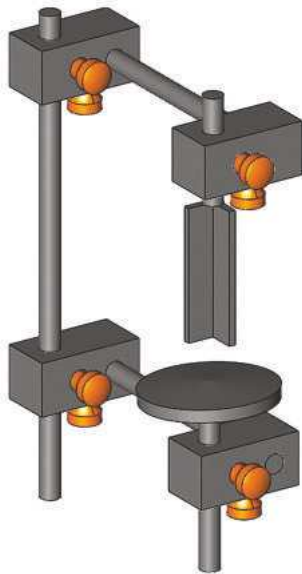


Fig.13



amounts of solder suitable for filling the gap, without running solder everywhere. Cut up small pieces of solder and store them in a clear tube. Pick out a suitable piece with tweezers.

Finally, you can carefully coat areas where you do not want solder to flow with anti-solder compositions as described earlier in the materials section. Again, use a suitable brush, but not the one used for flux, to coat these critical areas.

Heating the Parts

This must be done carefully, as heating to the correct temperature can cause problems. First apply very little heat, as you want the liquid flux to dry out. During the drying process parts can

and causes problems later.

It is often better to lay a small piece of solder on the joint and gently heat. Sometimes it is difficult to get the small piece to stay in place but consider some iron wire to secure it in place.

If you want you can place the solder in the joint with tweezers when the metal is at soldering heat. This ensures that you get only the right amount of solder, in the right place, at the right time. **Photograph 17** shows some reverse tweezers where you squeeze to release the solder held between the tweezers blades. These tweezers available from good tool stores or jewellery supply houses also have small insulated grips. Also shown is a haemostat which is self locking and a homemade toolmakers clamp used for clamping parts with flat faces.

Finally, for the soldering, you need a couple of prodders, which are two pieces of steel shaped at the end into a point and a spade like end. Each prodder needs to be long enough that they can be used to manipulate the solder at the joint without burning your hands. Sometimes solder needs to be pushed or prodded into place. The ends of the prodders should have a good coating of oxide on them. The first time you use them, coat the end in solder anti-run and let that turn to oxide. If a little flux is required to cause solder to run dip the prodder in liquid flux and apply to the work. Fancy prodders can be purchased from jewellery supply merchants made of

which will be left on the metal.

- All previous flux must be removed, if this is a second application of solder to the same piece. Remove old flux using the pickle bath, Scotch Brite pad, wire brush, and a metal 'pick' if necessary.

Once the joint is clean, apply flux and solder resist as necessary.

Flux Application

Wherever you put the flux, the silver solder will flow. It is therefore, important to only put the flux where you want solder. Application of the flux should therefore be conducted carefully. Apply flux in very small quantities, and just where you need it. This requires care and the use of innovative flux application tools, such as:

- A small brush, or a larger brush for larger areas.
- The small brush like tooth picks used to clean between your teeth, these have spines which hold the flux and they can be purchased with handles to get into difficult spots. See GUM Proxabrush Go-Betweens for a super little handle and brush with small replaceable brushes.
- A wooden tooth pick.
- A metal pricker (a piece of metal rod with a sharp end)

Careful application of flux to only the joint and not surrounding areas, will lead to less solder flow to unwanted places, as the solder always follows the flux. Neatness in fluxing using small tools for application of flux to the correct areas leads to neater joints.

Coat the joint areas with flux and assemble the joint. Wipe off any excess flux with a rag, or cotton bud.

Clean the silver solder if it is tarnished and dip the solder in the flux.

Stopping Solder

To stop solder from running where you don't want it, several techniques can be employed. First, use only very small

be moved as the drying flux tends to push small parts apart. This is one of the major reasons it is essential to secure the parts, and it may be better to place the solder after this drying has occurred.

After the flux has stopped bubbling, increase the heat, applying most of the flame to the largest part. Watch for the flux to change to a clear liquid with a glassy texture. This indicates that the parts have reached soldering temperature or are very close to temperature.

Chris Heapy best describes using the flux to assess whether soldering temperature has been reached: 'The first sign that you are nearing the required temperature is when the flux turns to a brown sticky goo. It will change from this appearance again to a light amber mobile liquid as the correct temperature is reached and it will seem to crawl all over the surface of the metal.'

Applying Silver Solder

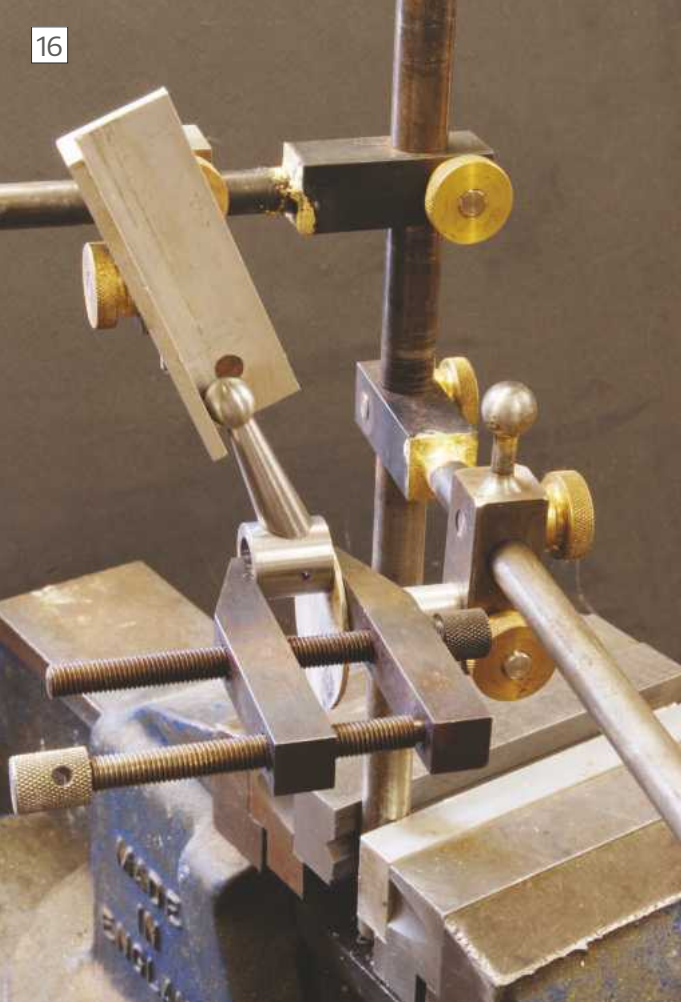
Although you see many videos and discussion about applying the solder using a rod of solder, I think it is more likely to deposit too much solder on the joint and make a mess.

A brush with flux on, or tweezers can be used to place a tiny piece of solder in the right place before soldering or solder can be applied as a small piece put on the joint when up to temperature with tweezers or similar. Dabbing the joint with a stick of solder is likely the least successful method.

Never put the silver solder stick or wire in the torch flame. If the parts to be jointed are hot enough, they will melt the solder, when it is touched or placed on the part. Too much solder just makes a mess,



McGyver's Device



McGyver Device - Holding Two Parts of a Machine Handle

fancy materials, at fancy prices!

If you need to make rings of solder to put round a circular joint, wind your wire/rod around a former to get the correct size. Secure both ends of the "spring" on the former. Using your brazing torch gently heat the spring. About 300C, you will see the wire relax as all the tension is removed. Remove your spring from the former and cut to make your rings. They will not spring open.

You can now dab the joint gently with the solder rod if that is your plan.

If the solder is in place, you are watching for the solder to first ball and then run or flash across the surfaces to be jointed. Play heat on the joint until you are sure the solder has run. Once the solder has run which it will do very quickly (virtually in as flash) you can turn off the torch and let the part start to cool.

Don't be in a hurry. You have done the most difficult part! Let the part cool down completely before moving it.

Pickling

The pickling process requires the part to be transferred to the pickle tank. Do not be in a hurry to put the soldered part in the pickle. Let the part cool to a low temperature before moving it to the pickle. Dropping red-hot work into pickle is spectacular, risky and unnecessary. Proceed with caution and wear safety equipment.

Beware of pipes and other holes where pickle can spurt out when it is placed in the pickle tank, especially if the part is too hot! Open the lid of the tank just enough

to be able to put the part in the tank. Replace the lid, take a break!

The time in the pickle is a variable, and depends on the pickle. For sulphuric acid pickles and depending on the oxide and flux to be removed consider 15 minutes to 2 hours. For less vigorous pickles the time can be much longer, up to 8 hours, and a warm pickle works faster. Over pickling is not harmful. When the component is removed, most of the material will already be removed or can be quickly removed with a brush while washing.

Washing

No matter how clean the component is when it leaves the pickle, it must be washed.

Some forms of used flux can be removed merely by soaking the soldered part in hot water for 30 to 60 minutes and scrubbing with a soft brush. This is often true of EasyFlo flux. If the flux is black and heavily oxidized more vigorous cleaning or pickling will be required. Yes, you can pickle more than once.

Use plenty of water, and ensure all pickle is washed off the component, plus any remaining residue. To assist with washing use a tooth brush or soft brass wire brush. If there are any corners with the residue in them, you can use a piece of silver steel (drill rod) with a point at one end and a chisel shape at the other, suitably hardened and tempered.

If you have access to a few dental probes, they would also be a handy kit. Ask your dentist what he does with old instruments, you may be lucky. The dentist scaling tools have to be replaced quite regularly, and these are ideal for model makers. They are made of best high carbon, stainless surgical steel.

How the Beam was Made

Since we have talked about the various aspects of silver soldering, we will come back to the model beam shown at the beginning of the article. If you can construct a beam like Bill's you are truly an artificer!

It represents a complicated silver soldered fabrication. The skill required to make this beam is weighty and this is not recommended as a first project! It does however show what can be accomplished with some knowledge, patience, and developed skills.

Each of the two beams is made up of about 20 parts all which were made from brass. The base for all the parts is the beam web, which is a piece of 1/8" brass. The outer rim has been wrapped around the web. The rim consists of 1/16" thick material, and is held to the web by a shallow slot milled in the rim material.

A piece of very thin silver solder sheet was inserted, between the rim and the web, to provide the solder for that joint. The beam is about 7 inches long, so the total length of the rim is close to 16".

The made parts and how they came together is shown in **fig. 14**.

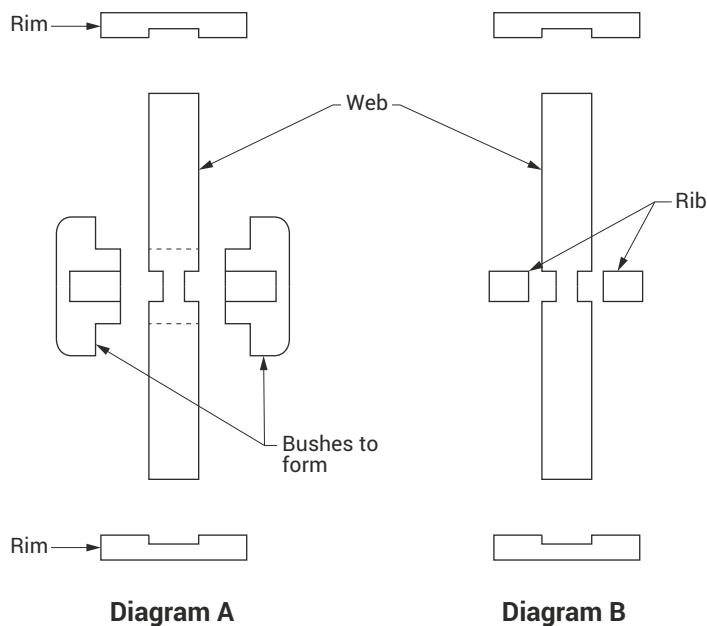
The next parts to be created were the ten flanges (five on either side) where the holes went through the beam.

Each pair of flanges is a two-part bush, and is inserted into holes in the beam web from either side as shown in fig. 14a. The bushes have a small notch or notches in



Reverse Tweezers, Hemostat and Homemade Clamp

Fig.14 & 14b



them to accommodate the central rib.

The central rib is 1/16" by 3/32" brass strip which is held in place by the notches in the bushes and a very shallow slot in the web of the beam as shown in **fig. 14b**.

The construction shows the use of slots and bushes to provide both positive locations for parts, and increasing the surface area for the silver soldered joint.

Small amounts of silver solder sheet, or rods were placed in all the joints. Before soldering, the rim was wired to the web by putting a wire completely around the periphery of the beam. Further, wire was used to secure the bushes at each of the five hole locations.

To solder the beam the various joints had a small amount of flux painted on the joint area. The beam was then heated by a small acetylene Turbo torch. Each area was heated until the solder was seen to run through the joint. At which point the torch was moved to the next joint area and again the joint was heated until the solder ran. Bear in mind Bill, has fifty or more years of making very small parts both in his professional career and with his model making.

When the beam was completed, it was pickled and washed.

The steel gudgeon pins were added after the holes were opened up and reamed to size.

The beam was finally sand blasted to clean up any marks and give the texture to the completed part before being powder coated instead of painting.

Soft Soldering

Many people reject out-of-hand the use of soft solder which is probably a mistake and could limit options available to do a particular task. It has several uses in an

amateur workshop, where those uses may not be seen in industrial settings.

Where a small, low pressure boiler or other pressure vessel, tank, or container has been riveted together or has been assembled with silver solder, and there is a very small leak; it may be readily caulked using soft solder (Comsol is particularly useful for this).

The torches, hearth, holding methods, used in silver soldering, can also be used for soft soldering, with either no or only very small adaptations. Sometimes the option between silver and soft soldering may be open. In this section, we will look at the uses for soft soldering as a possible alternative to silver soldering. In addition, there are areas where soft solder actually is a better solution.

Soft Soldering Uses

Soft solder melts at much lower temperatures and has little strength in tension compared to silver solder.

Soft solder can be melted using a low-temperature flame, or spot soldered with a soldering iron, and it can be drawn or spread along a joint.

Where there is a requirement for operation in or withstanding high temperatures, or a need for a very strong joint then soft solder it is not a candidate.

Soft solder can be used under pressure, to 40 to 50 PSI, but should not be used with high pressure or superheated steam. If the part will be the subject to high stresses it is also not a good candidate for joining with soft solder.

Sometimes two components must be joined, and a large joint face area is available for the joint; this may be an excellent candidate for soft solder. Here, both faces

can be tinned (coated in solder) individually and then be aligned, brought together, and then joined by applying heat, which allows the solder on the two tinned faces to melt and join the components. This technique, which is sometimes called sweating a joint was very popular up to the 1950's but has been less popular recently.

Since soft solder readily fastens to mild steel, brass, and copper small holes can be filled and patches fixed to all sorts of sheet metal components. Again, the components often can be tinned first and then sweated in place.

Soft Solder Content

Nearly all soft solder is a mixture of lead and tin, but recently lead-free solders have appeared. The proportion of lead and tin is variable depending on planned use, and some soft solders may contain antimony to 6%, or silver or other low melting point metals.

Soft solders most seen in hardware stores and engineering merchants will likely be plumbing or electrical solders. There are some specialty soft solders available; one of which is called Tix and used in the jewellery trade.

The two solders recommended for modelling work by Johnson Matthey are their JM6337 product which is a 63% Tin, 37% Lead solder that melts/solidifies at 183C, and Johnson Matthey Comsol which is a Silver bearing solder with greater joint strength, that melts / solidifies at 296C. Another advantage of this pair of soft solders is that they can be used where step soldering is required. Buy a solder that has a low span eutectic point, like the two above, meaning it is either solid or liquid. Some solders are designed to have a longer pasty stage, such as solders used by plumbers, and for lead sheaved joints for power and telephone cables, this type may be useful sometimes, but generally is not what is required for model engineering work.

Torches, hearths, and various holding devices used for silver soldering can also be used equally for soft soldering.

Soft Solder Preparation

The secret of good quality soft soldered joints are similar to those of silver soldered joints; namely, cleanliness, the correct fluxing and appropriate heat.

Joints may be cleaned up ready for soldering using a file, wire brush, emery cloth, wire wool or an abrasive cord or be freshly machined. If the preparation or previous activity has left lubricant, marking ink, or other residue on the part, this needs to be carefully removed with a degreasing solution.

If you are repairing earlier soldered parts that have come free, you may want to heat the part and wipe the soldered area with a cloth with a little flux on it. This will leave the part tinned and ready for re-soldering. If the joint is unclean after one application of the process, it can be repeated again. When the joints are

ready for soldering they should be coated in flux. This always applies other than for small scale, and circuit board electrical wiring.

Flux for soft soldering.

Non-corrosive rosin-based fluxes come as a greasy paste and are ideal for situations where it will be difficult or impossible to clean all the flux away after soldering, such as electrical work. It can be wiped around a joint with a brush or other applicator, including sometimes your finger.

More aggressive fluxes, such include the clear liquid called Bakers Fluid which consists largely of Zinc Chloride and some paste fluxes. A solution of Zinc Chloride made by dissolving zinc in hydrochloric acid until it ceases to fizz is called Killed Spirits.

These aggressive fluxes are corrosive, and all parts must be thoroughly washed in warm water after completing the joint. This makes it unsuitable for electrical work.

Tix Flux is a flux specially designed for use with Tix Solder. There is an equivalent type for Johnson Matthey Comsol solder.

Finally, soft solder for small electrical work is cored which means that there is a flux within the solder wire. Cored solder flux is rosin based. For larger joints fluxing of the joint is still required and flux all joints if possible.

Soft solder has much greater filling properties than silver solder. This has advantages in that joints can be looser but that may in turn lead to the need for more supports or clamps while the part is being soldered.

Heating of the joint is normally done with a soldering iron which is either electrical or heated in a soldering iron oven, often fuelled by propane or butane. Soldering can also be done with a torch. Some soldering irons fit on the end of a torch and be heated by the torch flame. Generally, the bigger the job and the thicker the metal, the more heat is required and for thicker metals, a torch may be better than an iron. Irons must be carefully cleaned and re-tinned occasionally as oxide builds up at the tip. The spirit lamp shown for lighting torches, may be used with a blow pipe to solder small objects.

Work holding can follow the same practices as silver soldering with loose joints stiffened by peening. Parts to be jointed can be held with iron wire or similar supports as silver soldering. An old pair of pliers can be used to advantage when tinning parts and for nipping two tinned parts together while sweating. When a soldered joint is completed, do not move the joint until the solder sets or you will get a cold or chilled joint. If the solder in the joint is not bright and shiny at the end of the operation, but is dull it is likely the joint moved while the solder was setting, and you have a cold joint that must be redone.

Using Soft Solder to Secure a Workpiece During Machining

One final use for soft soldering is to secure a small or difficult to hold component

while machining. Sometimes a face plate may be made for the lathe, which small parts requiring machining can be attached. This is sometimes described as a solder chuck. It consists of a disk of brass or mild steel which small parts are sweated. The disk can then be held in a three or four jaw chuck depending on the accuracy alignment to the lathe axis that is required.

Equally, you may have to mill a small component and cannot find a way to hold the component to the mill table. Again, the component can be soldered to a plate which can be attached to the mill table. This plate can even be a sacrificial plate. A sacrificial plate is one where you deliberately machine into the plate with the cutting tool or drill to ensure the component has been fully machined.

After completing the operation, the joint is broken by reheating the part and removing it from the disk. Remember to wipe off any excess solder so the disk or plate is ready for the next operation.

Silver Content of Soft Solders

Some soft solders are advertised as having silver content, although usually the silver is quite low. Hardware stores and engineering suppliers will sell soft solders with small amounts of silver (about 1 to 2 %) in their composition, these are all soft solders not silver solder.

These soft solders are useful for minor joints and items that will not be under pressure or stress. Never use soft solders where designs state silver solder is required.

High Temperature Soft Solders

Tix is a soft solder used in the jewellery trade and contains some silver, a UK equivalent is Johnson Matthey Comsol. It is considered to be one of the "hardest" soft solders available.

It melts at 275 F and has a holding power of 4,300 lbs. per square inch. Tix fastens to all ordinary solderable materials and may be used with a soldering iron or torch. Tix stays white and does not tarnish. A Tix solder package of 20 rods (3" length, 19-gauge) can be purchased and the supplier recommends the use of Tix Flux. The flux is described as a non-corrosive liquid flux that works with any soft solder, and it is harmless to skin and clothing. It washes off with water, even when dry. It is therefore, a useful addition for model making.

Useful References

1. [bbs.homeshopmachinist.net/threads/12654-Third-hand-idea](https://www.bbs.homeshopmachinist.net/threads/12654-Third-hand-idea)

The three pictures of the In The Air Holder are from the Home Shop Machinist chat site and posted by Macgyver, who has documented some excellent home shop activities on that site. Macgyver lives in Canada and kindly provided additional information and permission to use his material.

2. Soldering and Brazing by Tubal Cain - Workshop Practice Series No. 9, 1988,

ISBN 0 85242 845 6 published by Special Interest Model Books.

If you want to understand all aspects of silver and soft soldering and brazing, this book covers everything. It would be the first place to turn after reading this article, for a lot more information. The book consistently receives very good reviews, and has much good advice. But, there is much information to take in, and in Tubal Cain's (Tom Walshaw) tradition sometimes goes to the nth degree.

Chapter 10 is particularly valuable as it provides an 18-page description of various joint designs and associated techniques for joining parts.

3. Model Locomotive Boilers by Martin Evans - Their Design and Construction.

This book has very good chapters covering oxyacetylene torches for cutting, welding, and brazing, followed by a full chapter on silver soldering. Other chapters show how model locomotive boilers are designed and constructed and shows various techniques for creating silver soldered pressure vessel joints. If you are proposing to build a model locomotive boiler, this book is recommended.

4. JM Silver Brazing Alloys and Fluxes

A PDF available at the Johnson Matthey web site www.jm-metaljoining.com. This is an excellent technical document, with about 40 pages. It describes the company's various products and their uses in detail.

5. 'Design and Strength of Brazed Joints', M. H. Sloboda

This is also a document available from the Johnson Matthey web site. It is a technical description of silver soldering capabilities and techniques. Pages 7 and 10 contain interesting visual guidance on joint design. It also contains some interesting information for readers who want more details of how silver soldering technology works, how to construct industrial volume production joints, and covers brazing alloys other than silver solders as well.

6. Model Engineers Workshop Manual by Geo H. Thomas, pp 299 – 300 -Tee Publishing, 1992.

This book is an amazing collection of workshop tool projects, and has valuable advice, associated with the construction of the tools. The two pages on silver soldering offer sound advice, some of which has been incorporated into this article.

7. 'Uses of Soft Solder', Workshop Hints and Tips by Geometer, Model Engineer, Volume 3168.

This one page article provides numerous tips on Soft Soldering and where it can be used. Some of the tips such as the clamping tools, drawn in the article are applicable to silver soldering.

8. JM Soft Solders and Fluxes

Available at the Johnson Matthey web site and contains valuable information about soft soldering. ■

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A Tale of Two Screens



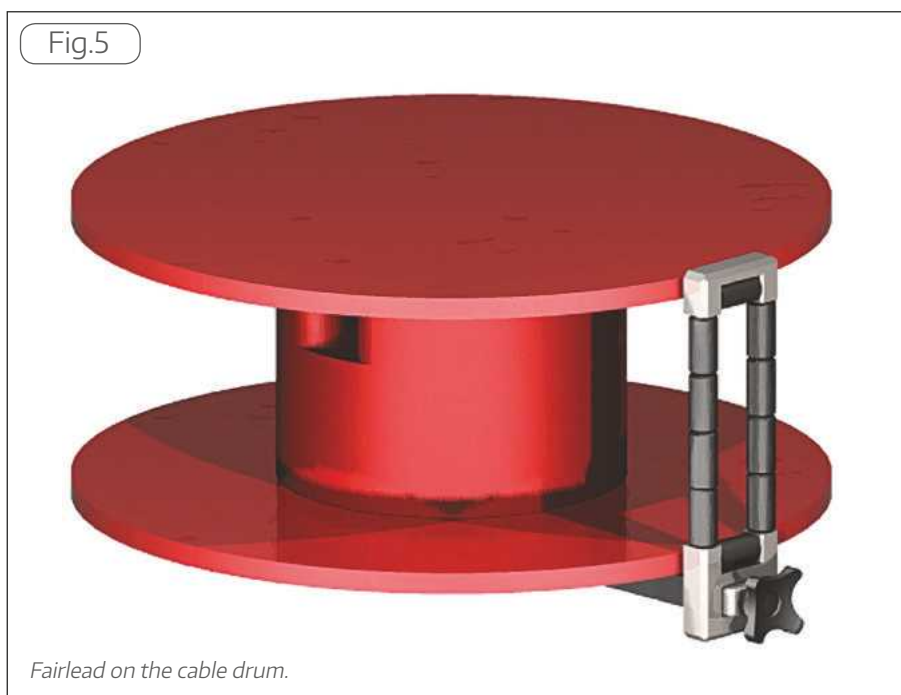
Bob Reeve recounts a story of CAD design with useful tips along the way. Part 2

I followed traction engine practice as can be seen fully rendered in **fig. 5**.

It did however depart from traction engine practice by using Acetal rollers and aluminium ends to the rectangular frame.

My design required a further refinement since the cable exit can be on the right or left if the handle is resting on the ground. Again, traction engine design was followed but this time copying the arrangements found on some ploughing engines which allow the fairlead to move round the drum on a swinging arm pivoted at the centre of the drum. This can be seen in **fig. 6**. The prominent knob on the end, allows the arm to be clamped in any suitable position between the fixed rollers or left free to find its own position as required. As will be noticed this is of robust construction since I anticipated it would need to withstand a few knocks. An unintended benefit is the weight, which is substantial and below the original centre of gravity, adding to the stability when the handle was vertical.

While the pivot for the swinging arm was being designed, I took the opportunity to improve the bearings on the drum. Originally the wooden drum ran directly on the steel tube of the frame with the weight of the drum taken by a 7/8" steel washer supported by a split pin. The new design, **fig. 7**, provided brass bushes that were a push fit in the wooden drum with the lower

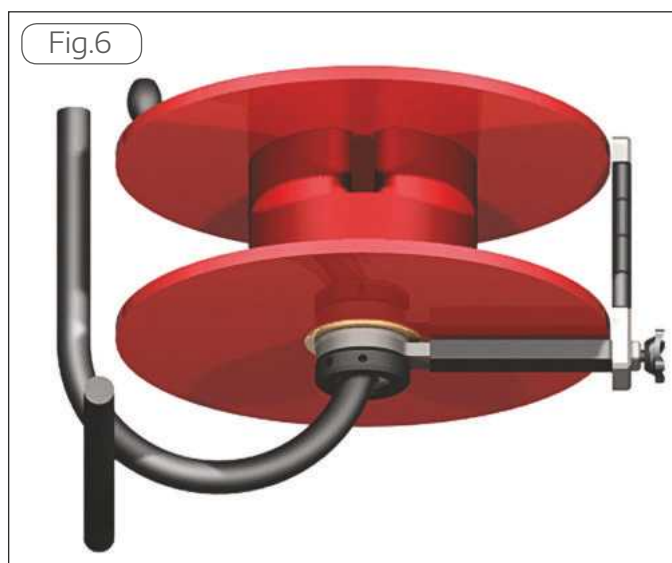


Fairlead on the cable drum.

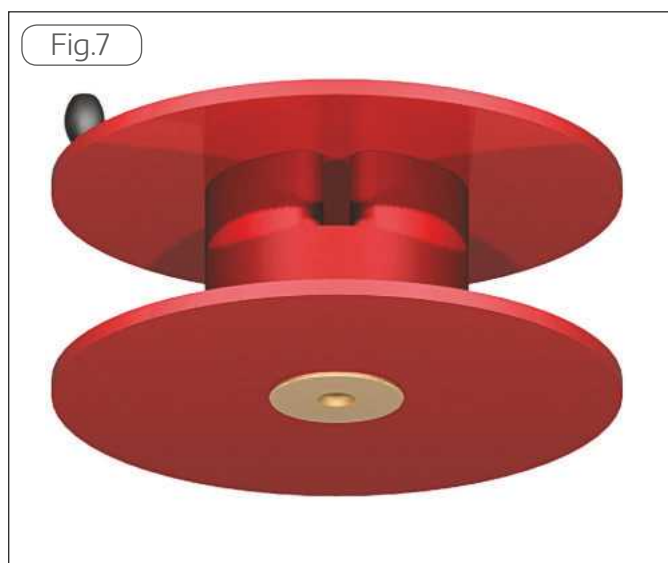
bush incorporating a large diameter brass flange to take the weight of the drum and cable when running on the steel collar that locates the swinging arm.

The second part of the problem was also solved using guide rollers, but this time

much larger and fixed about 120° apart round the drum periphery as shown in **fig. 8**. Some experimentation was thought necessary on the roller profiles. Two possible profiles are shown in **fig. 8**. The one with the conical ends worked best.

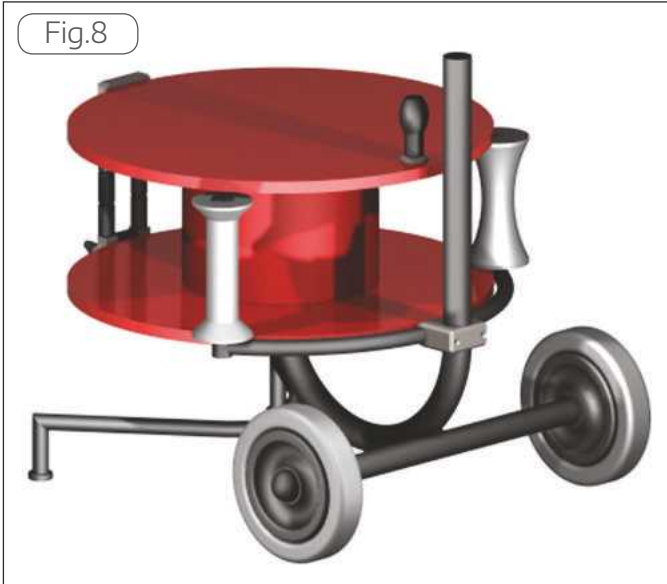


Swinging arm and bearing.



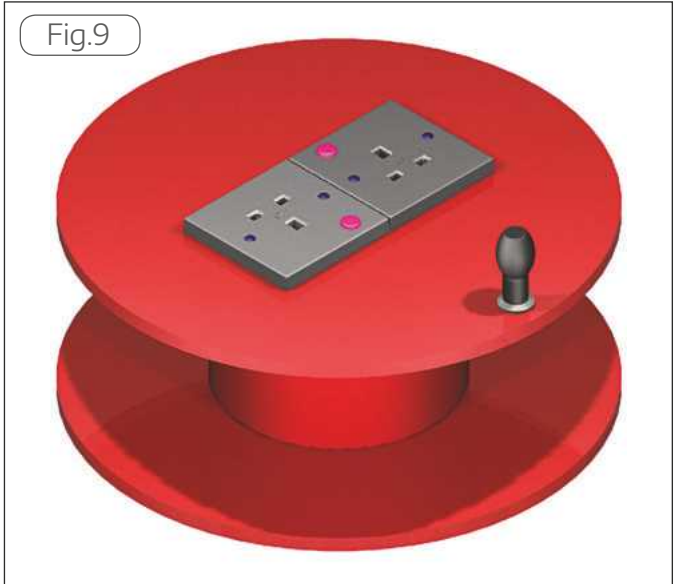
Brass bearing surface.

Fig.8



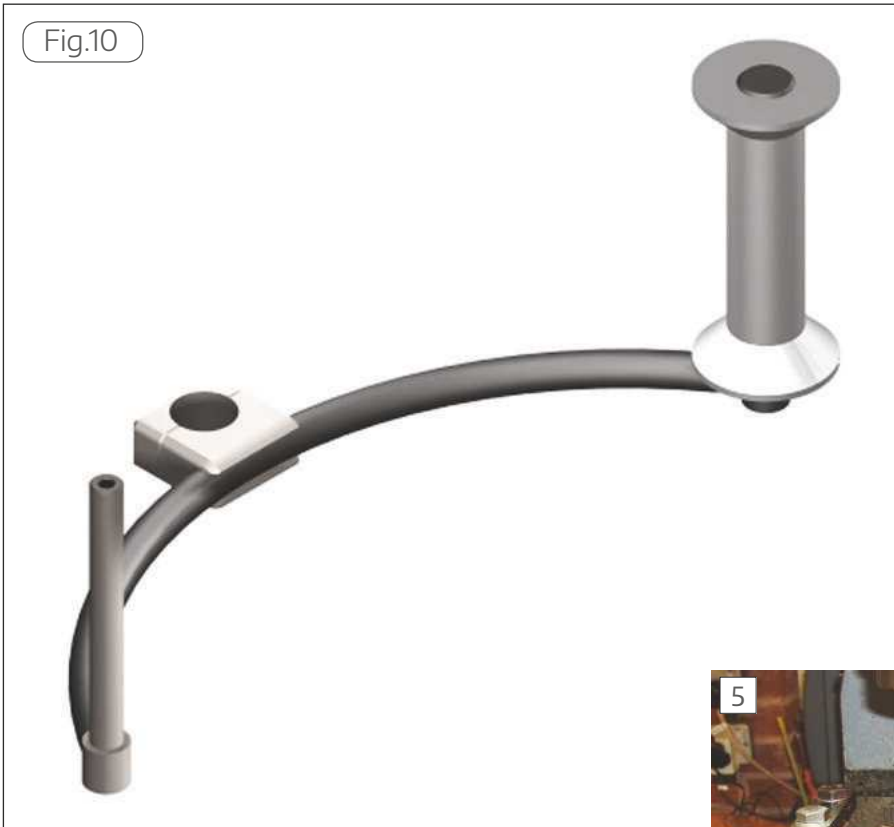
Guide roller designs.

Fig.9



Neon indicators.

Fig.10



Roller support arm.

Finally the two 13A power sockets were modified to include mains neon indicators, ref. 5, to indicate that power is available at the socket. These solve the annoying problem of finding the extension lead fully deployed and the hedge cutter plugged in but the power not switched on where the lead was plugged in 100ft away, **fig. 9**.

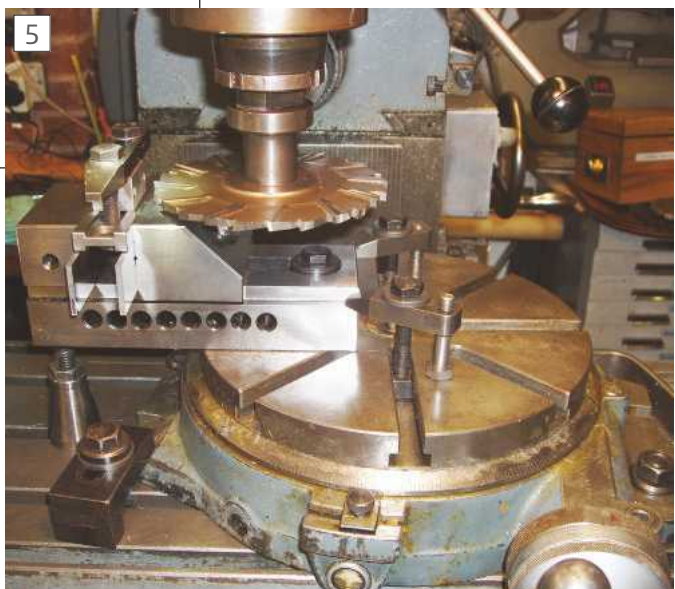
It was late autumn when I eventually got back into the workshop to carry out the modifications to the cable reel. Construction was fairly straight forward, but there were some interesting aspects. The rectangular tube used for the swinging arm, Bottom left photo 4, was made from 1" square steel

tube cut and welded up to form 1X1/2" tube. I had the 1" sq. tube in stock and I only needed a few inches of the 1X1/2" tube that I used. The other components shown go to make up the complete swinging arm and clamp. The components have been chemically blacked for rust

protection with the exception of the mounting flange which is in stainless steel and the end cap for the tube which is aluminium.

The fixed guide rollers are mounted on a curved support arm in 1/2" dia. steel tube, **fig. 10**. The roller spindles are turned components, silver soldered onto the tube. The clamp for this arm was mostly conventional milling and drilling with the exception of the curved semi-circular groove required to locate the curved tubular arm. **Photographs 5 and 6** show how it was done, with a machine vice mounted on the rotary table, note the jack supporting the vice. first for a roughing cut with a side face cutter then with a form cutter to give the required seating for the tube which was then welded in place. The rollers themselves are nylon

At the end of a project I usually try to assess if it was successful and if anything had been learned along the way. Assessing the success of this project was in three



Roughing cut.



Finishing cut.



Fully deployed.



Ready for rewind.



Guide rollers in action.

parts. The first being to assess if the modified cable reel was any more practical. The trolley was much more stable and would still work with the handle vertical, **photo 7**, or horizontal, **photo 8**. In the former, where the lead can just be seen plugged into an RCD socket in the distant garden shed, hence the neon indicators. However; 100ft is a lot of cable to haul through wet grass. The horizontal mode was more stable for rewinding, especially with one foot on the handle while rewinding was in progress. Note the repositioned fairlead.

The larger guide rollers were designed to keep the cable from spilling off the drum and brake any overrun as the cable is pulled out, **photo 9**. So far they have worked well with the heavy duty cable employed. The latter allows the full 3kW to be used. It could even cope with a bright red 150A MiG welder being used at the bottom of the drive. Though, as with all extension leads, it is recommended that all the cable be unwound to prevent overheating.

The next assessment was of the use of rendered images in a live design project. for me the design became more alive when I introduced rendering in fig. 5. Another possible way of measuring the success of CAD rendering is the degree of photo realism achieved. However, there is a price to pay for photo realism. The detail required is more than would normally be present and **fig. 11** shows the detail in one of the power sockets. The realism comes from details like the draft angles, filleted corners and countersunk screw holes, augmented by dramatic lighting effects. But the flying screw is a totally unreal effect. A superficially similar effect might be achieved with photo-editing software such as photoshop. But fig. 11 is a 3-D model and the screw will align with the hole no matter what the angle of view. A technical illustrator might use this to show how it was assembled. I wish I had been able to do this when I converted my X3 mill to CNC. I now need to dismantle the rather complex table assembly to do some maintenance. It would make life easier if I



The flying screw.

had illustrated how it all went together.

Perhaps a better test of a rendered CAD model is, "Did the real thing end up looking anything like the CAD model"? Readers can compare **photo 10** and **fig. 12** and make their own judgement.

Still on the topic of rendering, the original target was to improve the time taken to achieve the Quality Render in fig. 1. With the new system, this turned out to be about 6 sec but with the bonus that the draft render is completed in 3 seconds and followed by the quality render. However, there is now a choice of rendering software with which to achieve the quality rendered image. I am still experimenting to find which is best for my needs.

The third and final part of the assessment is to ask "Was it worth all the effort or should I have just bought a CAD workstation in the first place"? I think the best answer to that is that I have a twin screen setup that out performs those Sun workstations of yesteryear. More importantly it does what I require



The completed design.

for less than the least expensive Aria CAD workstation, supplied without a screen and without an i7 processor. But, as always, you pay your money and you makes your choice.

References;

Ref 1. www.paulthecad.co.uk

Ref 2. www.turbocad.com/TurboCAD/TurboCAD-Windows/TurboCAD_Pro-Platinum#93774-requirements.



The modified extension lead.

Ref 3. www.redway3d.com/pages/GPUList.php

Ref 4 www.aria.co.uk

Ref 5. Red mains neon indicator Order code VW69A Maplin Electronic

In our Next Issue

Coming up in issue 257

On Sale 14th July 2017

In the August issue, 257, of Model Engineers' Workshop, you can look forward to another great read:



David Addison fits a digital readout to his Warco WM16 Mill



Another visit to Mike's Workshop, where he shows us how to make and fit an adjustable bandsaw stop.



Jim Kent tells the story of his Myford 254 Lathe

Scribe a line

YOUR CHANCE TO TALK TO US!

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



Safety Rail

Dear Neil, Mr Lovell from North Waltham asks for some advice. The photo shows my workshop with a 'crash bar' across the whole machine bench that will kill power to the mill [behind the camera] lathe and drill if things get too hairy. Behind the hinged Dexion rail is a twist to release emergency stop switch that breaks the DOL starter circuits to all three machines and must be reset before further use.

In extremis with hands occupied it just needs a nudge with the hips to shut down. I recommend it as a complete solution.

Brian Wood, by email

The 2017 Bristol Model Engineering and Model Making Exhibition – 18th to 20th August

Dear Neil, the next major event on the calendar for model engineers is the Bristol Model Engineering and Model Making Exhibition which takes place at Thornbury, near Bristol, on 18th to 20th August. Thornbury Leisure Centre will be filled with a wide range of trade stands for tools and materials together with displays from clubs, societies and individual model engineers and model makers.

This year we are commemorating the 50th anniversary of the death of LBSC - "Lillian ("Curly") Lawrence - and recognising the contribution he made to the world of model engineering. Many of the clubs and societies attending this year will be displaying examples of locos built to LBSC's "words and music". He designed

166 models ranging from '0' gauge to 5" gauge and built over 50 himself, with some of his designs being up-scaled to 7 1/4".

We will again be presenting a series of talks and demonstrations in a separate lecture room at the exhibition. In particular, the demonstrations proved to be popular and we intend introducing more this year."

Outside, besides the miniature traction engines and the Gas Turbine demonstrations, there are plans to show a 'wood-burning' tractor, along with a couple of fairground organs to provide entertainment.

For more information and tickets visit the exhibition website at: www.bristolmodelengineers.co.uk/Exhibition/exhib.htm.

Steve Birch, by email

Centre Height Setting – amongst other things!

Dear Neil, I spend part of the year in Australia, I escape the cold English winter and go to my "other home". Its a long story, but I do have a workshop and a lathe at each end!

My MEW magazine comes to the Lincolnshire address so on my recent return this year in early May I had the pleasure of catching up with the three issues awaiting me.

Congratulations on a great read and every time I open one there are more ideas to set me off on yet another project or an experiment to try out. Although I have owned a lathe of sorts for many years it is relatively recently I have become seriously interested in making things for "fun" as opposed to necessary repair jobs. here I have a Warco 280 VF which I am more than happy with. Some hobbies lead to the necessity of having another on as a means to an end. I have been fairly well schooled in engineering principles all my life as my father was an enthusiast and a typical DIY motorist on the early 1920s when it was virtually a necessity. I have had an amateur radio licence now for over 50 years and that has led to a sideline of building Morse keys... Another good reason for a lathe and mill. now retired I earned my living mainly in the photographic trade, a hobby which paid off and I have for years been a 4WD enthusiast. Perhaps the ultimate in that one was a near six-month journey through Africa and the resulting experiences of wilderness Land rover repairs, not only to my own vehicle!

As last year, I attended the Model Show at Doncaster last week, hoping to see a selection of Milling Machines as I am thinking of up-sizing the small Seig X1 mill I use. It was disappointing to note that there was little on show, major vendors conspicuous by their absence. However, it was a most interesting experience and there were many traders offering accessories and gadgets to suit most enthusiasts. I did return with a lighter wallet and a heavy backpack.!

As said the magazine has lots of useful food for thought but I would like to mention that often there are seemingly un-necessary comment about obvious safety precautions and what I would consider plain common sense procedures, yet often a lack of explanation of simple terminology which I am sure many newcomers to the hobby might find mystifying. For instance. certain references to metals are, to me a bit confusing. Like "free cutting steel", EN1, EN3, BMS etc. Never have I seen in print much about the various qualities and uses of such variations. If one gets a few offcuts of metal from a scrapyard or skip, is there any easy way of identifying suitability for projects, It is often obvious but just what is the real difference in say BMS and a piece of rusty metal from a skip?

On a different subject, I noted the article in issue 254 by Mike Turner recently about finding the exact centre height of the chuck centre for a cutting tool. Years ago I was shown what surely must be the simplest quickest and sure-fire reliable way to do this (see photo).

Chuck a short piece of round bar around 1/2 inch diameter leaving an inch or so protruding. hold a six-inch rule vertically with a flat side to the curve and trap it against the bar with the tip of the cutting tool. The rule will be vertical if the tip is central, you can usually see it plainly by eye but my photo shows the principle and a square standing on the cross-slide bed which is an option.

Simply adjust the cutter to the right height so the rule is vertical. Thats it!

David Dunn, by email



Ball Turning

Dear Neil, I feel I must comment on the above article. By your contributors own admission he has a problem in turning brass to a good finish, and this is more than evident on the cover and also picture number 9. Master class? I do not think so.

There is also the statement that other authors, including G H Thomas, waste time by turning a separate ball for the small end of the handle. But if you have got to resort to files, emery cloth, (UGH) and polish, then I think it would be much more satisfactory to learn how to finish turn the job in hand, and where the time difference would be cancelled out.

George Thomas (what a great man) in his article on turning "Ball Handles" gives all the information required to do this work successfully including cutting tool angles, correct for the "up and over" attachment which he used and as a complete amateur I found that making these handles to those instructions was a doddle

As a 24/7 carer, it has been !5 years since I last did any serious work in my "Hobbies Room" (must not call it a workshop) and to stop the "pot calling the kettle black," I am still able to finish turn a ball in brass without any problem. For the record I am 87 and was a motor vehicle fitter in my working days.

Cliff Spooner, by email

Laser Centring

Dear Neil, I'm a reader of the Model Engineers' Workshop. In the April 2017 No.253 Alan Wood has an article on a Laser Centring Tool. He references Dan Gelbart's design and says that plans are not available on the net. The link below is where you can find the plans.

https://drive.google.com/drive/folders/OByWaTeq__NX1eWtXQjIwWnU3VOE

The youtube video is where Dan gives the address is at

<https://www.youtube.com/watch?v=otSjut1iGGk>

The magazine is amazing!

Luc Gyre, by email

Gear Cutter – Additional Information

Alan Aldridge returns with some further notes on GearCutter, described in MEW, issues 242 to 249.

With reference to my series of notes on making a gear cutting machine, two items were not included, namely a table concerning the operation of the indexing of the Workhead, ratchet and worm and wheel, and a drawing with associated table for laying out the dimensions for the backing off tooling. These are shown here with some extra notes on their use.

Workhead

Table 1, setting out information for arriving at correct indexing for cutting individual gear teeth is based on work done originally by Martin Cleeve, 50 odd years ago. My table is shorter but from it one should be able to work out the methodology for other gear tooth numbers above 72 tooth wheels. This table is not exclusive to gear cutting; it can be applied to any indexing arrangement using ratchets and the one shown in the accompanying photograph is for a dividing attachment.

The original Martin Cleeve table catered for just about every tooth number from 7 teeth to 360. Prime numbers present more and more of a difficulty as they grow larger and should be avoided. The worm and wormwheel combination can be almost anything but the basic requirements are for the wormwheels, which can be changed out, to cover any two of the factors 2,3 and 5. For preference, the wheel would have somewhere around 40 to 60 teeth. Those two numbers, of course, bridge possibly 90% of the work we would want. The ratchets add to the ratios to deliver other options and I have ratchets for 10, 11, 12, 13, 14 and 16 teeth. The basic ground rule is that the worm rotates 1 turn for 1 tooth pitch. The four examples below should give enough guidance as to how the ratchet indexing works for moving tooth to tooth for cutting procedures.

One complete turn of Worm = 1 tooth movement of the Index Wheel, so the basic calculation is:

$(\text{Index gear} / \text{Teeth required}) \times \text{ratchet teeth}$
Example: For a 25 tooth wheel
 $40 \text{ index wheel teeth} / 25 \text{ gear teeth} = 8/5 = 1 \frac{3}{5}$ or $1 \frac{6}{10}$ with 10 tooth ratchet

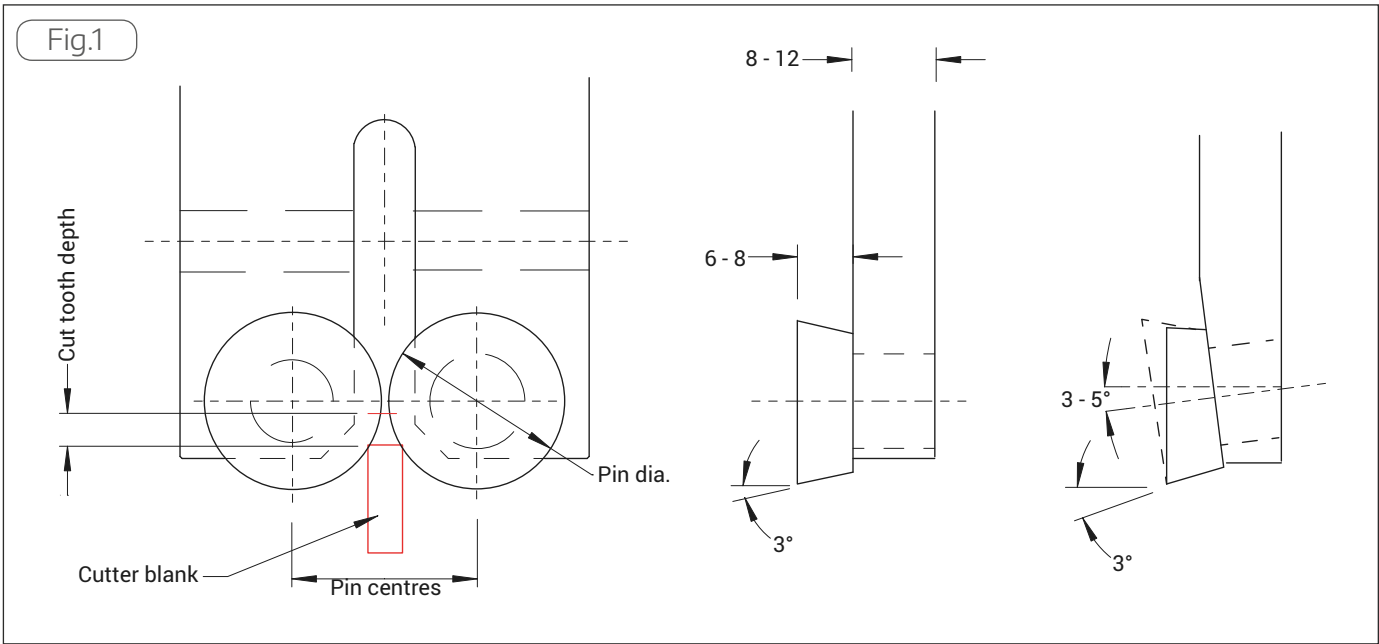
So, with a 10 tooth ratchet make 1 full turn and then turn 6 teeth out of the full 10.

Backing Off Tool

The making of the backing off tooling

Table 1: Indexing Table

No Teeth required	Index gear	Ratchet teeth	Ratchet turns & tooth advance
8	40	any	$40/8 = 5$
9	36	"	$36/9 = 4$
10	40	"	$40/10 = 4$
11	55	"	$55/11 = 5$
12	60	"	$60/12 = 5$
14	35	10	$35/14 = 5/2 = 2 \frac{1}{2} = 2 \frac{5}{10}$
15	40	12	$40/15 = 8/3 = 2 \frac{2}{3} = 2 \frac{8}{12}$
16	40	16	$40/16 = 5/2 = 2 \frac{1}{2} = 2 \frac{8}{16}$
18	36	18	$40/36 = 10/9 = 1 \frac{1}{9} = 1 \frac{2}{18}$
20	40	any	$40/20 = 2$
24	40	12	$40/24 = 5/3 = 1 \frac{2}{3} = 1 \frac{8}{12}$
25	40	10	$40/25 = 8/5 = 1 \frac{3}{5} = 1 \frac{6}{10}$
26	65	10	$65/26 = 5/2 = 2 \frac{1}{5} = 2 \frac{2}{10}$
27	36	12	$36/27 = 4/3 = 1 \frac{1}{3} = 1 \frac{4}{12}$
28	42	12	$42/28 = 7/4 = 1 \frac{3}{4} = 1 \frac{9}{12}$
30	40	12	$40/30 = 4/3 = 1 \frac{1}{3} = 1 \frac{4}{12}$
32	40	16	$40/32 = 5/4 = 1 \frac{1}{4} = 1 \frac{4}{16}$
35	40	14	$40/35 = 8/7 = 1 \frac{1}{7} = 1 \frac{2}{14}$
36	40	18	$40/36 = 10/9 = 1 \frac{1}{9} = 1 \frac{2}{18}$
39	65	12	$65/39 = 5/3 = 1 \frac{2}{3}$
40	40	any	$40/40 = 1$
42	60	14	$60/42 = 10/7 = 1 \frac{3}{7} = 1 \frac{6}{14}$
44	40	11	$40/44 = 10/11$
45	40	18	$40/45 = 8/9 = 16/18$
48	40	12	$40/48 = 10/12$
50	40	10	$40/50 = 8/10$
52	65	12	$65/52 = 5/4 = 1 \frac{1}{4} = 1 \frac{3}{12}$
55	40	11	$40/55 = 8/11$
56	42	12	$42/56 = 9/12$
60	40	12	$40/60 = 8/12$
63	35	18	$35/63 = 5/9 = 10/18$
64	40	10	$40/66 = 8/5 = 1 \frac{3}{5} = 1 \frac{6}{10}$
66	60	11	$60/66 = 10/11$
70	40	14	$35/70 = 8/14$
72	36	18	$36/72 = 1/2 = 9/18$



needs **table 2** and **fig. 1**, which I think are self explanatory but there are one or two extra points about the combination. As there is spread of tooth numbers for each form cutter there is substantially a built-in error except for one size, nominally the middle gear in a group. The width of the blank is critical. Too wide or too narrow will both give false sizing, therefore paring down the blank need extreme care. Similarly, the actual pin and pin centres need care. It is possible to calculate a closer number for all the pin and depthing but overall it is not a real problem as gears can run each other in which is acceptable in low speed we would generally use.

The setting out of the pins can be on a flat or on a sloping bar. In the drawing both types are shown. the pair need grinding down or are hardened after the pins or the bar are equally filed away or machined for the slope. In service the life of the pins is

Table 2: Gear Cutter Form Tool Data

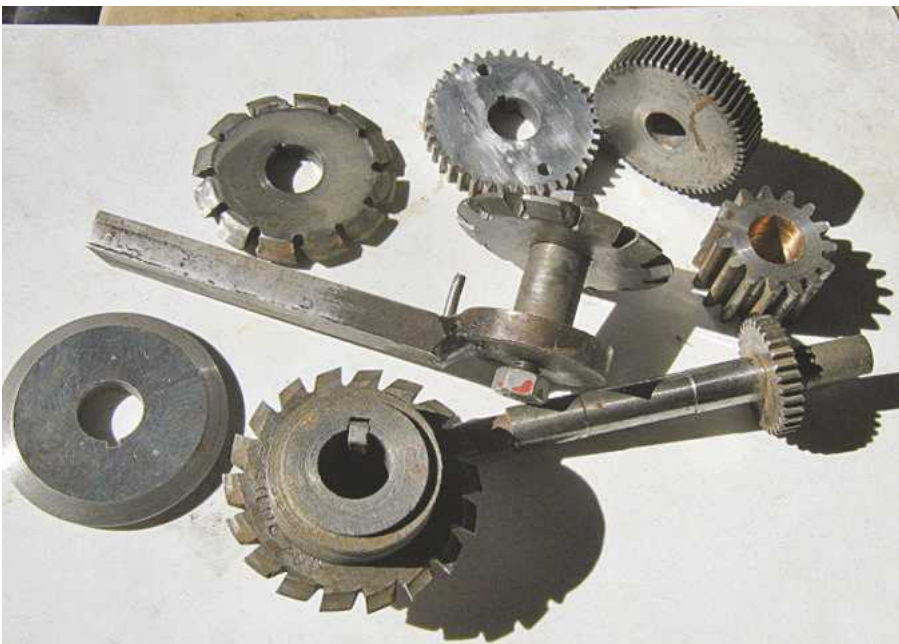
Circular Cutter No.	Gear Teeth	Form Tool Pin Dia	Form Tool Centres	Form Tool Cut Depth	Blank Thickness
1	135+	1172.7	1138.0	99.92	101.4
2	55 -134	477.7	484.4	86.67	101.4
3	35-54	304.0	321.0	78.68	101.4
4	26-34	225.8	247.6	75.05	101.4
5	21- 25	182.4	206.9	68.58	101.4
6	17 -20	147.0	169.8	64.60	101.4
7	14-16	121.6	150.0	60.63	101.4
8	12-13	104.1	137.9	57.17	101.4

limited, probably around three to four form tools and they should not be re-sharpened as the dimensioning will change.

Indelibly mark tools with number

punches for DP and cutter group.

Hardening the forming tool is, for me, in a bed of sand in a tin, where the tool is easier to see and watch for the colour change during tempering. We are looking for a pale yellow, which comes quite early in the process, after which the colouring goes to blue, which is a failure. The first heating should be with a broad flame heating the tin of sand, preferably a propane gas torch, steadily bring the tool up to red heat and holding that for a minute or two. Dip sand, tin and form tool in cold water and stir around at both heating and tempering. ■



Editor's Note:

The tables were omitted from the original series due to a number of errors and problems with the formatting. The errors have been corrected by the author, but due to the difficulties in sorting out the table formatting, new errors may have been introduced so please check before cutting metal.



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Measuring Minute Power Levels with a Dynamometer



SillyOldDuffer follows on from his Arduino dynamometer experiments with a home-made torsion dynamometer. Part 2

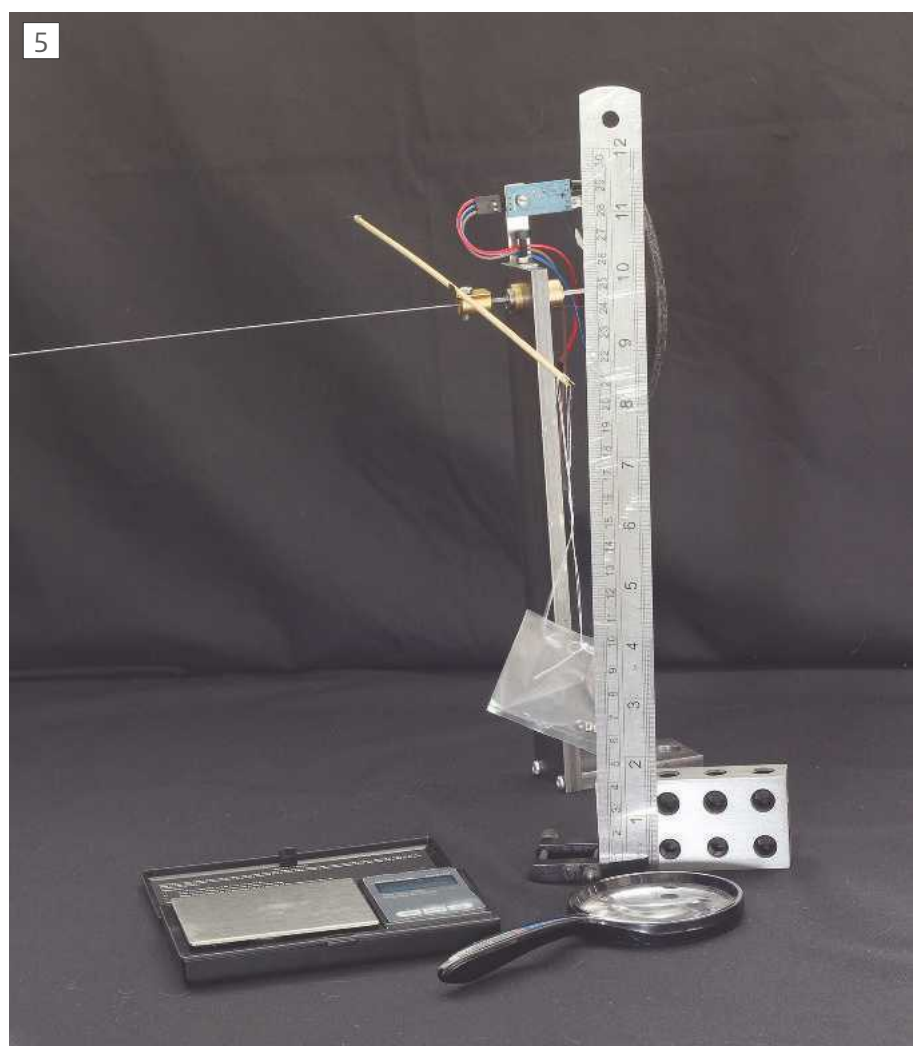
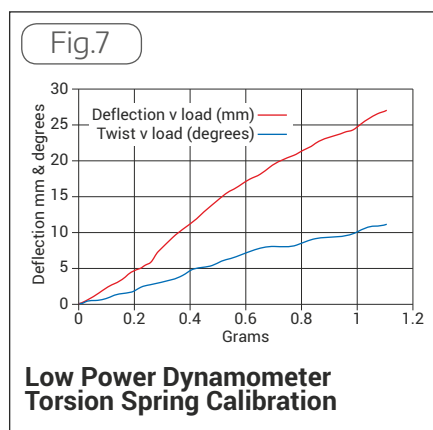
Calibration

It is necessary to calibrate the spring of the torsion rod before using the dynamometer. This is done by clamping the engine flywheel and by measuring the deflection of a weighted balance arm temporarily attached to the brake end. For lightness, I used a 290mm length of bamboo barbecue skewer glued to a brass fitting, **photo 5**.

A steel-rule is presented to the end of the arm. The arm end has a pin pointer to improve accuracy and readings were taken with the aid of a magnifying glass. A Height Gauge would do a better job.

A lightweight pouch suspended at the end of the arm was loaded with M2 hexagon nuts one at a time. The pouch was suspended a known distance from centre, in my case 141mm.

Later the pouch and hexagon nuts were weighed with a digital micro-scale. The results were used to graph the spring of the piano-wire torsion bar, that is the weight needed to twist the spring a known distance. For convenience, the graph, **fig. 7**, also plots the angle of twist resulting from a given weight, which is needed later to determine the equivalent Torque delivered by the engine. Deflection in millimetres was converted to twist in degrees from the tangent ($\text{height} - \text{deflection} / \text{arm length}$), where deflection is measured in mm above base using the steel rule.



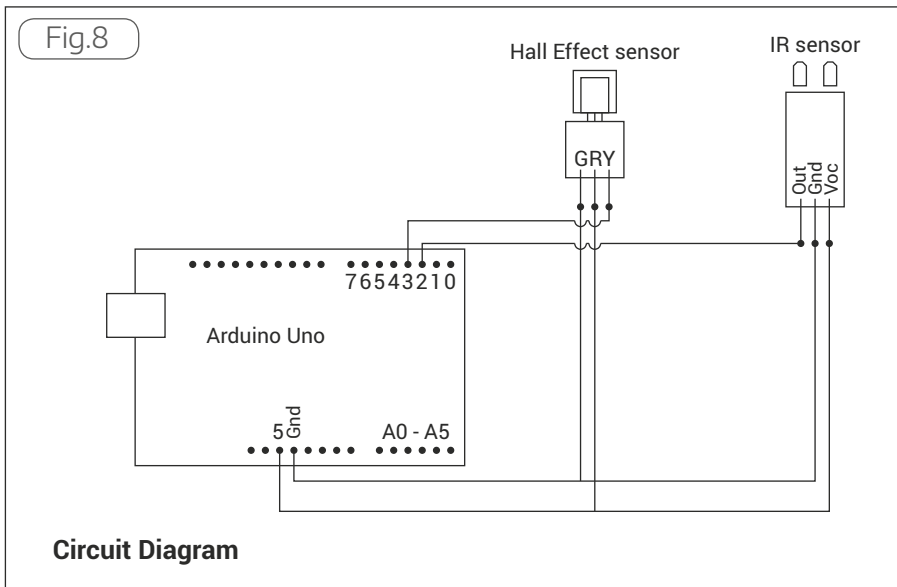
Balance Arm

Arduino and Sensors

The Microcontroller is an Arduino Uno bought online from www.arduino.cc, as the website also provides comprehensive instructions for setting up and programming Arduino microcontrollers I shall not detail them here. Briefly, download the free Arduino IDE (Integrated Development Environment); Create a new Sketch and copy the source code

(available at www.model-engineer.co.uk/dynamometer); change the value of TORSION in the source to match your calibration result; Connect an Arduino Uno with a USB Cable; Use the IDE Tools->Board to select an Arduino Uno as the target; Use the IDE Tools->Port to select the port that your Arduino is connected to; Verify the Source; and Upload the Program.

At this point the Arduino will run the



code. Sensor events are timed and tab separated results reported back to the PC. If one is connected, results are also displayed on an optional DFRobot LCD Screen. Results sent to the PC through the USB cable may be captured with the IDE's Serial Monitor set to 57600 Baud. It is convenient to cut and paste the tab separated results from the monitor screen into a spreadsheet to do calculations or graph the results.

To avoid soldering the sensors are wired to the Arduino with Jumper Wire Connectors via a prototyping board. The circuit is **fig. 8**.

Since my Coffee-cup engine was already fitted with a Hall-effect sensor I used that. I used a frictionless Infra-red (IR) detector to detect a sliver of aluminium foil glued to the black brake wheel. The Arduino works equally well with either type of sensor and

they are interchangeable. It is not necessary to change the program code.

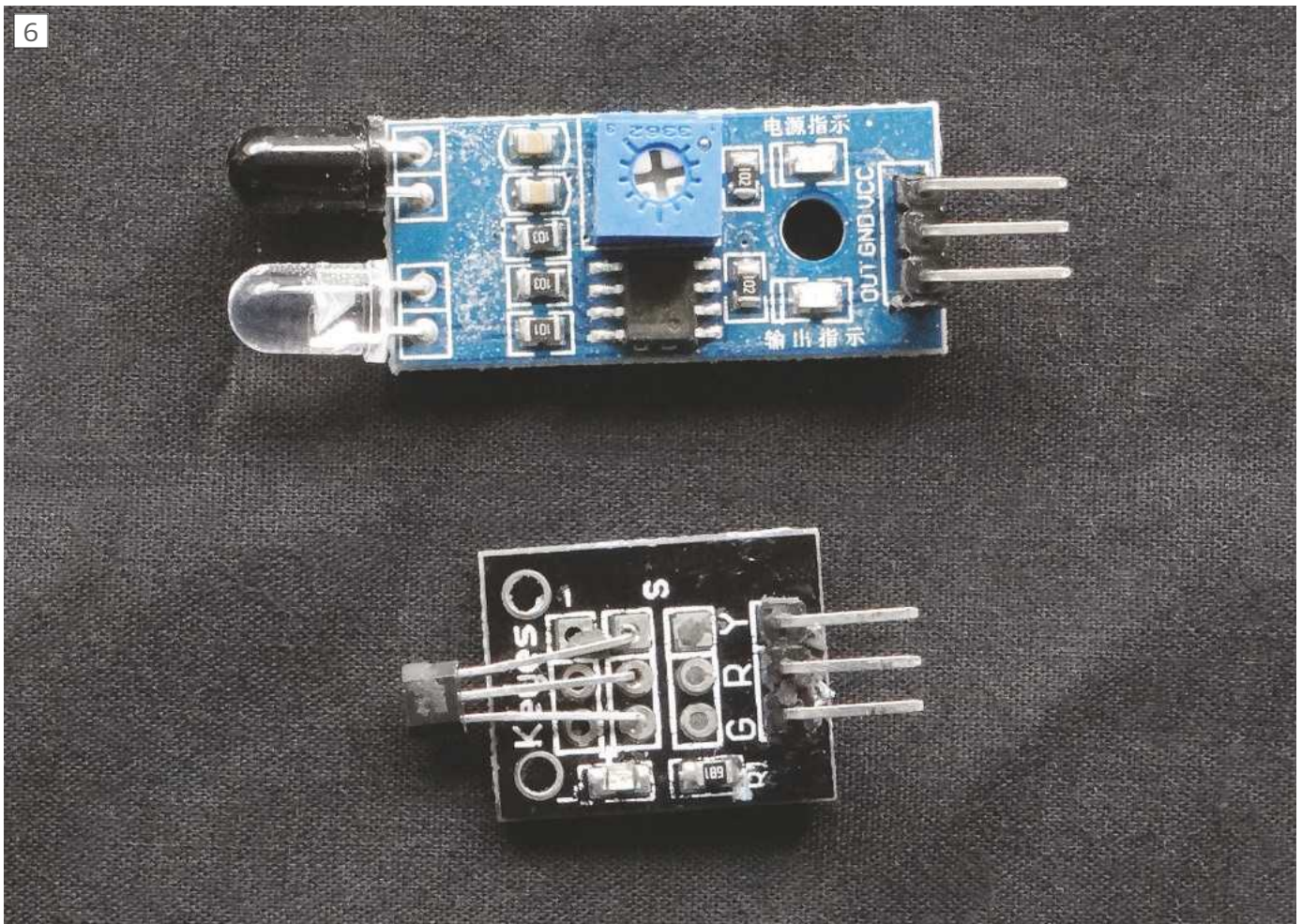
The easiest way to get suitable sensors, **photo 6**, is to buy them! An Internet Search for an "Infrared Obstacle Avoidance Sensor" will quickly reveal sources of sensors aimed at the Arduino hobbyist. There are two variants of the Avoidance Sensor, one with a single blue potentiometer to adjust sensitivity, the other has a second blue potentiometer, not normally used, that fine tunes the modulated IR signal. Both types work, I used the single potentiometer version.

The Hall Effect Sensor should be available from the same suppliers. It is easier to use a magnetic detector on the Coffee-Cup Engine's shiny aluminium flywheel than it is to blacken most of it to prevent unwanted reflections.

Both the Hall Effect Sensor and "Infrared Obstacle Avoidance Sensor" come with two red LEDs. One lights to show when power is applied, the other flashes whenever the sensor detects something.

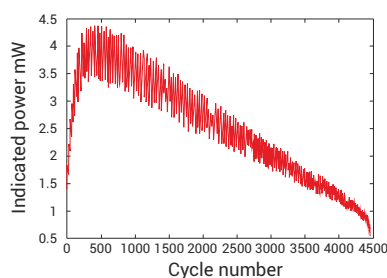
Wire the sensors to the Arduino as shown in the circuit diagram, **fig. 9**, and connect the Arduino to a powered-up PC with a USB cable. Adjustments are made by turning a cold engine by hand.

The position of the Hall Effect Sensor is adjusted, **drawing 2**, under the flywheel until a disc magnet glued to the wheel



Sensors used

Fig.9



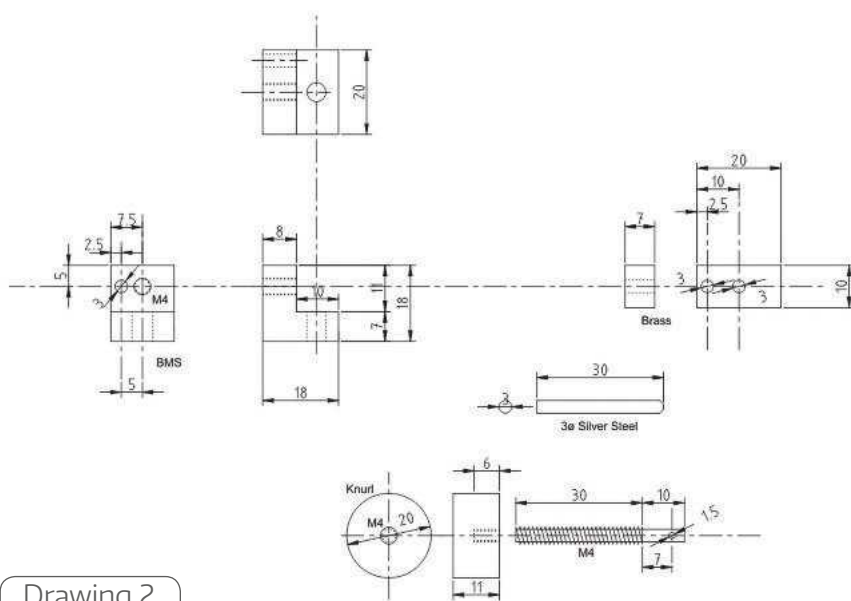
Coffee Cup Sterling

results in reliable detection. This is indicated by the sensor's "detected" LED. The sensor will probably need to be within 5mm of the flywheel magnet and it is necessary for the poles of the magnet to be the right way round. If your magnet isn't detected try reversing it.

On the "Infrared Obstacle Avoidance Sensor" the sensitivity potentiometer is adjusted to get reliable detection from the polystyrene wheel. The IR Sensor does not need to be close to the wheel, mine is 15mm away.

A disadvantage of the IR detector is the need to protect it from bright sunlight and unwanted reflections. This was done by: positioning the dynamometer so that the IR sensor points away from windows; putting a black cardboard guard behind the sensor devices; and by wrapping the body of the IR sensor and the IR emitter with aluminium foil, **photo 7**. On a dull day these precautions are misleadingly unnecessary – I was certainly fooled! However, after initially working well, the unguarded Dynamometer misbehaved badly due to false brake time triggers. After following

Dynamometer Sensor Adjuster



many false leads, the cause was found to be the sun. By mischance my early testing had all been done on one of the cool overcast days so typical of British high summer!

After the sensors are proved to be working it is necessary to align them relative to each other. This is done by slowly rotating the engine flywheel until the Hall Effect Sensor indicates that the flywheel magnet has just been detected. The flywheel is clamped in that position: I used a small Toolmakers Clamp, an Eclipse 410. Some care is needed to ensure that the flywheel doesn't move as the clamp is applied.

With the engine flywheel clamped, the polystyrene brake wheel is adjusted such that both trigger at the same time. The knurled brass nuts securing the black polystyrene disk at the brake end are slackened. Then the polystyrene disk is slowly rotated until the IR detector just sees the reflector strip, at which point the disk is locked by re-tightened the brass nuts. Getting the engine flywheel and the dynamometer disk correctly aligned is critical and achieving it is a weak point of this design - it is all too easy to accidentally twist the torsion rod whilst tightening the disk.

I found it helpful to add the screw adjuster as shown in **photo 8**. The adjuster is modelled on a bench vice and its purpose is to enable fine tuning of the horizontal position of the IR Sensor. It enables adjustments to be made without touching the polystyrene disk or disturbing the torsion rod. Although a tapped hole is provided in the moveable brass block for a bracket, mounting the IR Sensor on top of the brass block with a blob of modelling clay worked perfectly well.

Results

The heavily loaded engine completed 175 cycles (revolutions) before stalling after about 5 or 6 minutes.

The first 20 cycles were ignored to ensure that the engine had settled into a steady rhythm after the initial push used to start the engine injected unwanted external power. 2 cycles immediately before stall were also ignored.

Over the 150 cycle sample the engine averaged 37 rpm and a 3.1 degree lag. From the calibration graph (Figure 8) a 3.1 degree lag equates to a torque of $0.3g \times 141mm$



Foil wrapped sensor

(0.00004Kgm) and it was assumed that this is a representative sample of engine torque.

Applying the formula: $w = T \times 2\pi \times n / 60$ where:

w is power in watts

T is Torque in kg metres

n is rpm

2π is 6.28

$w = 0.00004\text{kgm} \times 6.28 \times 37\text{rpm} / 60 \times 1000 \text{ mW}$

$w = 0.15\text{mW}$

Later a much longer run was obtained from a carefully aligned dynamometer fitted with better bearings. Reduced friction also results in higher rpm, though it is still only about half that obtained from an unloaded engine. **Figure 10** graphs the result.

Conclusions

The first test run had the engine stalling after a very short 5 minute run at cycle 175. After disconnecting the dynamometer, the restarted engine ran happily for another 25 minutes. Therefore, in this run, the engine only produced enough power to drive this stiff version of the dynamometer when the engine was operating at it's most powerful.

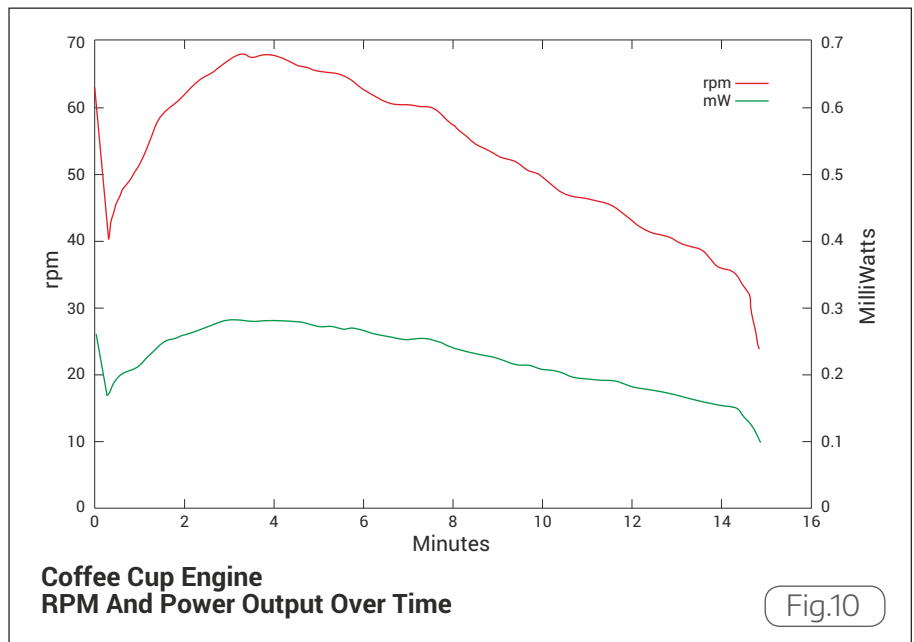
Analysis of the Pressure-Volume Loops produced by the earlier project show that my engine sustains about 4mW (peak 4.4mW) for about 5 to 7 minutes early in a run. Graphing, fig. 9, the Indicated Power obtained from each PV-Loop over a run of 4500 cycles shows that Indicated Power increases rapidly as the engine warms up on a fresh charge of hot water. Around maximum rpm, the engine outputs about 4mW for several minutes, before declining slowly to a stall roughly 30 minutes later. This supports the conclusion that the dynamometer brake was somewhat too heavy. However, during the maximum power period, indicated power of about 4mW compares with an output power of about 0.15mW which implies an engine efficiency of 3% or 4%

3%-4% may be optimistic. The Indicated Power on which the efficiency claim is based was calculated without a dynamometer load being connected. Since adding the dynamometer load markedly reduces rpm, it is likely that the comparison is flawed.

Next step is to collect all the data needed to calculate indicated and actual power from the same engine test. Unfortunately, this upgrade needs three interrupt ports and the Arduino Uno only has two. The easiest way to fix this is to upgrade to an Arduino Mega which has six interrupt ports. Credit Card time again!

A Note About Accuracy

There are many sources of error throughout this project. I would particularly draw attention to the relatively crude way the piano wire "torsion bar" was calibrated; to the possibility that the sensors at each end of the dynamometer are not zeroed accurately; to dimensional errors; to



comparing data from two different test runs, and to the zag-zag fluctuations of indicated power occurring between individual cycles graphed in fig. 9.

I haven't attempted a proper error analysis, but would not be surprised to find that my results are in error by 50% or more. And that's assuming there are no mistakes!

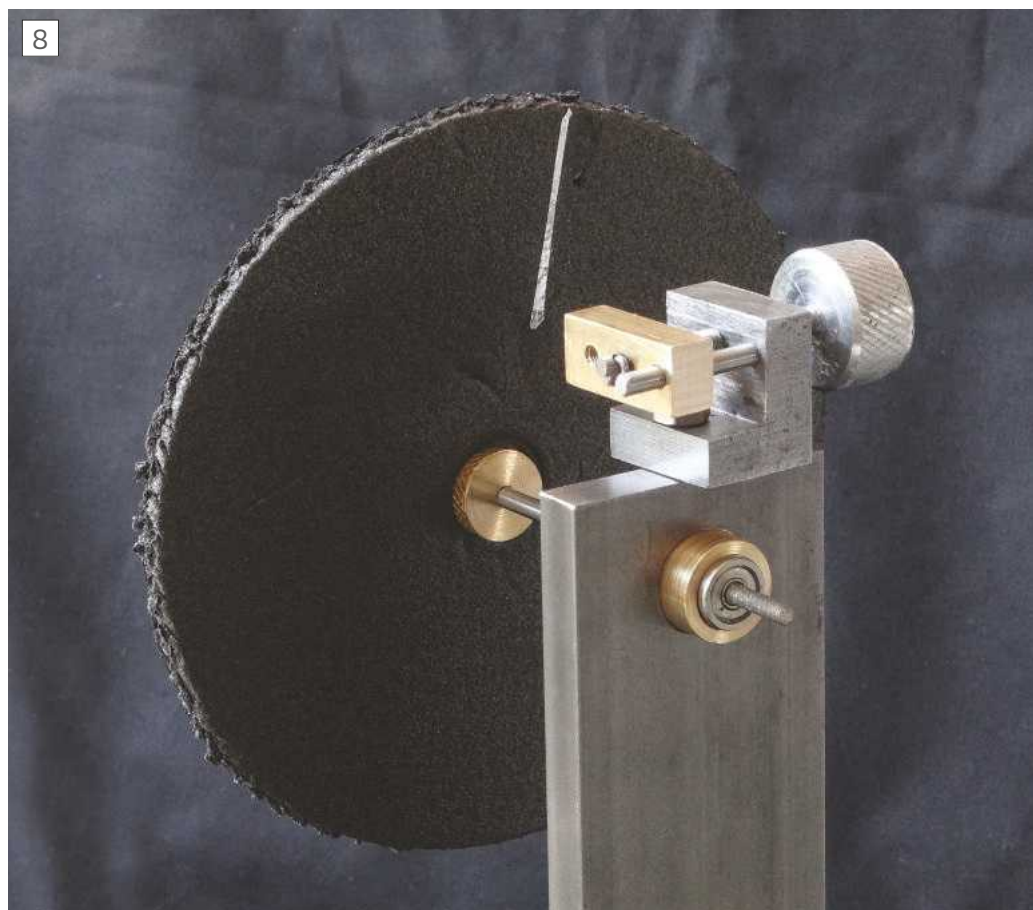
Please don't take the results too seriously! ■

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Sensor adjuster

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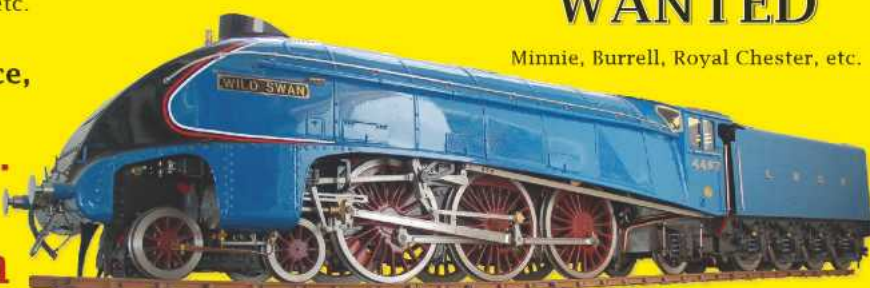
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