

No.68

OCTOBER 2000

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MODEL ENGINEERS'

WORKSHOP

THE PRACTICAL HOBBY MAGAZINE

THE VACUUM CHUCK

Holding thin workpieces

TILTING COMPOUND TABLE

A versatile attachment
for larger machines

MANUAL METAL ARC WELDING

Easily accessible
joining technique

CNC PROGRAMMING

An introduction to industry standards



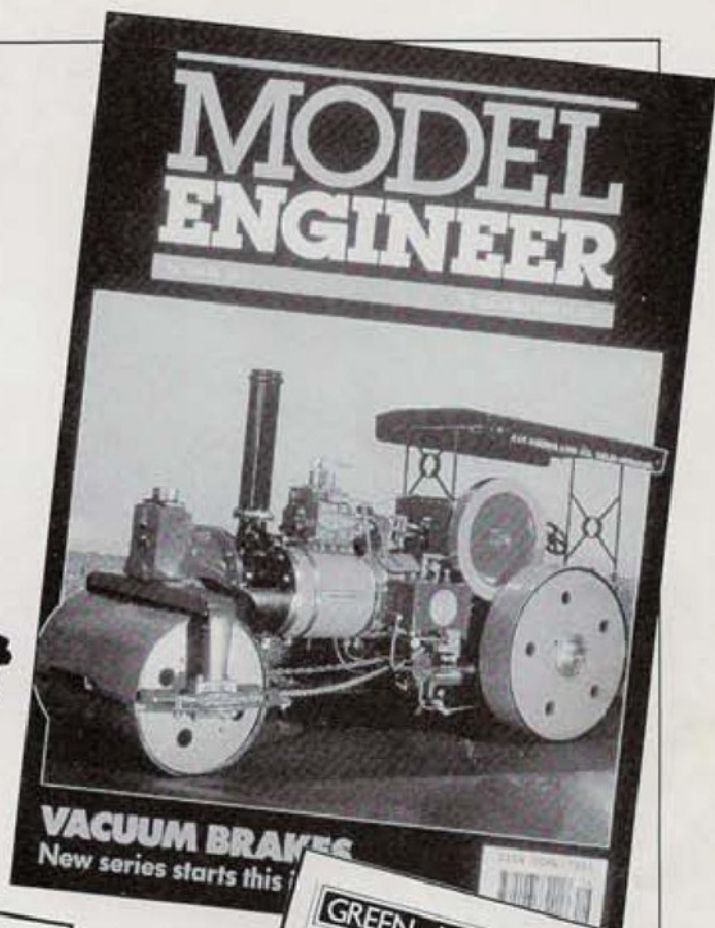
THE MODEL ENGINEER EXHIBITION

29th December 2000 - 1st January 2001

AT SANDOWN PARK EXHIBITION CENTRE, ESHER, SURREY

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...every fortnight



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On the cover

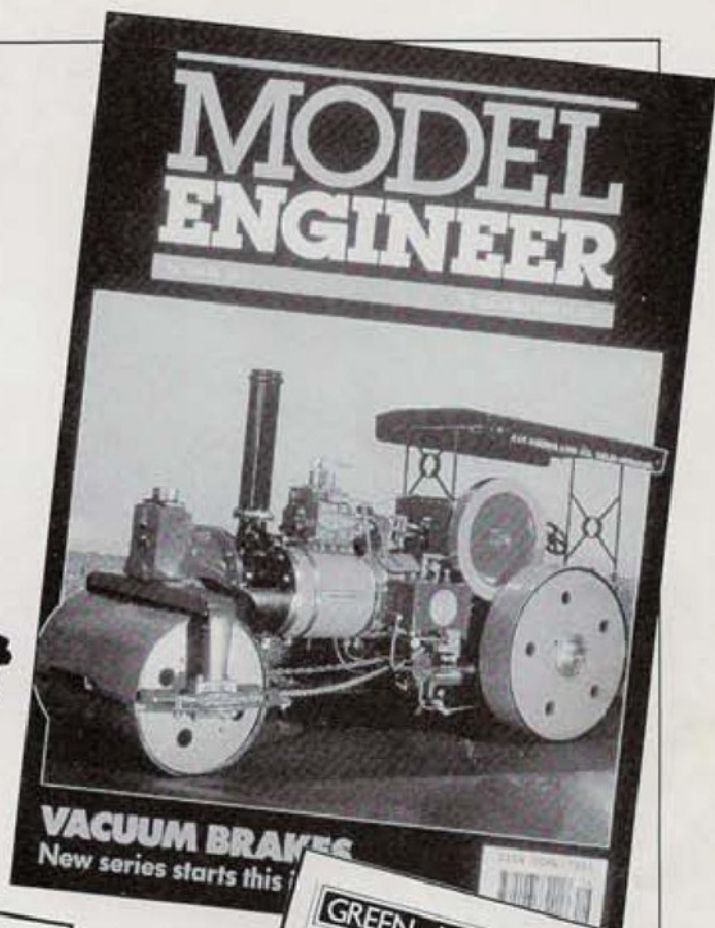
Manual Metal Arc welding can be a spectacular process, as can be seen from this photograph supplied by TWI Ltd (the organisation formerly known as The Welding Institute). A less ambitious approach is described by Trevor Marlow in his article which starts on page 45



Surface grinding on machines not specifically designed for the task can present problems due to the abrasive dust which may be created, but David Machin does admit to having been ultra-cautious in his efforts at masking. The inset shows the grinding wheel which was used to correct a deformity in the machine table. David's article starts on page 30


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ON THE EDITOR'S BENCH

Geoff Sheppard

By the time this issue is published, we shall be close to the start of the evening class season, a time looked forward to by many model engineers because it gives them an opportunity to practice their hobby in the company of like-minded individuals rather than in the solitude of their own workshops. There is much satisfaction to be gained from discussing projects and problems with friends who may have already trodden the same path or, equally in helping a newcomer who is less experienced. For novices, these classes provide an ideal introduction to the hobby, allowing them to gain some experience before setting out on the setting-up of a workshop. Indeed, the contacts made during these sessions may introduce them to sources of materials and perhaps second-hand equipment which will ease the financial pain substantially!

Now, however, we come to the problem. These classes are much harder to find than they were in previous years. We often receive requests for information on where to find suitable courses in a particular area, and try to help where we can, but it is getting more difficult. Where possible, we try to publish news of classes, but we are reliant on organisers and members sending us details. The fact that a course was run last year is no guarantee that it will be held in the next, so we exercise caution. Please do let us know of sessions being run in your area and we will try to find space to pass on the information. If you are interested, try ringing round the local schools and colleges to see if there is anything available. Who knows? If enough people enquire, it may encourage an establishment to put something on. Equally, if there is a class close to hand, I would encourage you to sign up, because if support begins to dwindle, cancellation is not far away. It's a hackneyed phrase, but 'Use it or lose it' is most applicable in this situation.

Why have things reached this state? The reasons are obviously many and complex, but a major factor clearly is that fewer schools have engineering workshops of any size. There now appears to be less value placed on the ability of pupils to have the opportunity to actually make things with their hands,

particularly in metal. The school curricula seem no longer require such skills to be taught or allow time for their inclusion. Additionally there appears to be a fear of litigation by parents if accidental injury should occur, so it is understandable if schools shy away from such subjects. It is therefore mainly those further education establishments which offer courses in engineering subjects which are now equipped to provide something for the hobby engineer. Interestingly, more and more colleges seem to be prepared to accept the 'amateur' on courses aimed at those training for industry, with a flexible approach to the projects tackled, as long as one 'signs up' for some apparent qualification at the end of it. I have a suspicion that it is a creative approach to attracting funding. Whatever the basis, why not take advantage of it while it is there? The availability of large and quite sophisticated machinery makes it possible to set about a job which would be difficult to accommodate in the average home workshop. Interestingly, going back to working alongside sixteen year olds can be quite refreshing - I know, I've tried it. Once the ice is broken, the right attitude can soon get one included in 'the gang' at tea breaks, and it is surprising how quickly one's opinion is sought and confidences exchanged. I found it great fun.

One of the criticisms levelled at the younger element is that they are obsessed with computers to the exclusion of all else. I was therefore interested to hear of the CAD/CAM in Schools Initiative. Launched by the Department for Education and Employment (DfEE) in June 1999, this project sets out to ensure that all secondary schools have access to CAD/CAM through a properly managed scheme with an effective training structure for teachers. Administered by the Design and Technology Association (Data), an educational charity which promotes design and technology in schools, in conjunction with the Warwick Manufacturing Group of the University of Warwick, the scheme is based on software provided free by the Parametric Technology Corporation (PTC). In addition, UK software company Delcam has made their ArtCAM:Pro software available in a similar manner, allowing 2D images to be converted to 3D profiles.

Pilot projects have proved to be overwhelmingly successful, with pupils often proving to be more creative than their teachers. Over 1500 schools are now equipped and the software licence allows them to have up to 300 workstations each, as well as allowing it to be taken home for use on laptops if they are available. There has been mention of CNC lathes and milling machines having been purchased, making it possible for designs to be turned into hardware. Projects already being tackled include karts and small rockets!

Obviously, the main thrust of this initiative is education for application in industry, with companies such as BAE Systems, Rolls-Royce, Jaguar Cars and Glaxo becoming involved, but perhaps here will be the inspiration for a revival of interest in hobby engineering among a new generation. I know that I quite enjoy designing a component on my CAD system, then turning it into a tangible item in the workshop. I'm not equipped for CAM yet, but Peter Rawlinson has shown us that it is a feasible proposition for those who wish to get hardware produced with minimum delay.

Turbocad relaunched

While on the subject of CAD, I am aware that a number of readers and contributors are users of the Turbocad software package and that there has been recent consternation over problems in contacting the manufacturer, IMSI. The re-assuring news I have just received via Peter is that, following a change of marketing strategy, this software is being relaunched through MediaGold International of 151 Freston Road, London W10 6TH Tel. 0207 221 4600

Modellers in the news

It is not often that we see mention of modellers outside our own sphere, but there have been some notable exceptions in recent months. This year both Cherry Hill (nee Hinds) and Gerald Wingrove have been awarded MBEs for Services to Model Engineering. Cherry was included in the Queen's Birthday Honours List, while Gerald was included in the Queen's New Year Honours List.

Cherry is, of course, famous for the exquisite range of small steam models, frequently of obscure prototypes which she has painstakingly researched before designing and building the miniature version. Her efforts have brought her many medals at the Model Engineer Exhibition over the years and she has been awarded the Duke of Edinburgh Trophy on no less than six occasions.

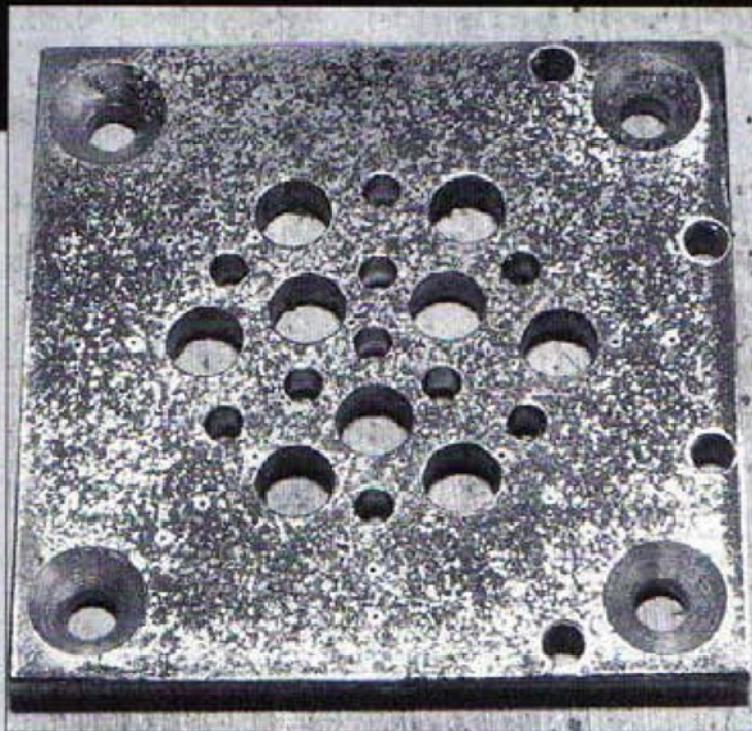
Gerald has been a freelance modeller for over 30 years, producing fine scale models, usually on commission, of interesting and elegant motor cars. Some have been produced for museums, including what was to become the National Motor Museum at Beaulieu, and others for private collectors. Commissions are often made by the owner of the full-size vehicle, providing a tangible reminder when, perhaps, it is no longer in the 'stable'. Working with his wife, Phyllis, Gerald usually builds in scales which allows full details of chassis, engine and transmission to be included. He is also the author of a number of books on the subject.

In quite a different sphere, the Reverend Will Mowll, creator of some fine ship models, including a Gold Medal winning version of SS Great Britain and the fine model of HMS Warrior which is now displayed alongside the prototype at Portsmouth, has been appointed a Chaplain to H. M. The Queen.

We offer our heartiest congratulations to these three ambassadors for our hobby.



THE VACUUM CHUCK



Philip Amos describes an interesting variation on the workholding theme.

1. Second hole pattern

If you wish to go metric use millimetres in lieu of inches and multiply E by 0.007 to convert to Newtons per square millimetre.

This formula is strictly true for a circular plate supported at its edges, but it gives a good indication of the performance of plates which also extend beyond the edge support.

For example, if the 'O'-ring were 25mm radius and the workpiece 1mm thick steel, the deflection in the centre if the plenum was completely evacuated of air pressure (14.7 psi) (which of course it won't be using only vacuum cleaner suction) would be:-

$$d = \frac{2 \times 14.7 \times 0.007 \times 25^4}{3 \times 30 \times 0.007 \times 10^6 \times 1^3}$$

$$= 0.13\text{mm}$$

So the first matter to address is to ensure that the deflections of the platen itself as a whole, and of the workpiece over each of the platen perforations are negligible.

The platen thickness was selected at 1/4in. thick steel plate as this was available. Assuming a 25mm radius of the hole pattern, the deflection at the centre would be:-

Introduction

The magnetic chuck is a most useful device for holding iron and steel parts for surface grinding, and it seemed that something similar to hold non-magnetic parts would also be helpful. Thus the concept of a vacuum chuck developed. Essentially it comprises a platen, pierced with many holes, attached to a plenum chamber beneath, which is connected to some form of vacuum pump - see **Drawing 1**.

This article describes the thoughts and experiments which produced the design criteria for a practical device.

Platen

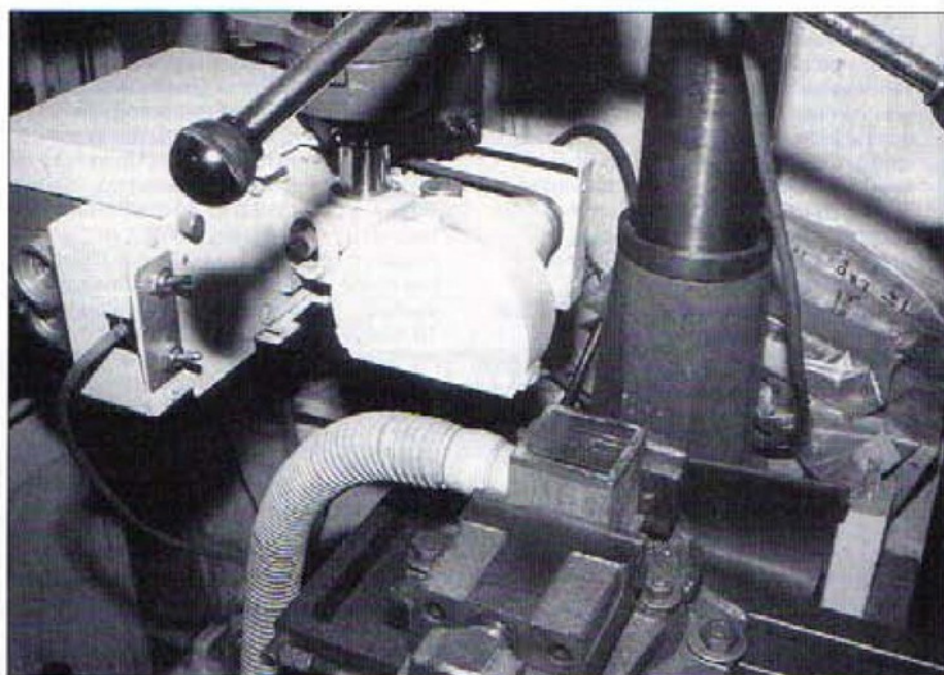
The initial idea was to surround the platen holes with an annular groove for an 'O'-ring seal, but it was soon realised that the small force available would not compress the 'O'-ring sufficiently to allow the workpiece to rest flat on the platen, leading to a bowed shape, as shown in **Drawing 2**.

The deflection 'd' in inches at the centre of a circular flat plate uniformly loaded is given by the formula (Reference 1)

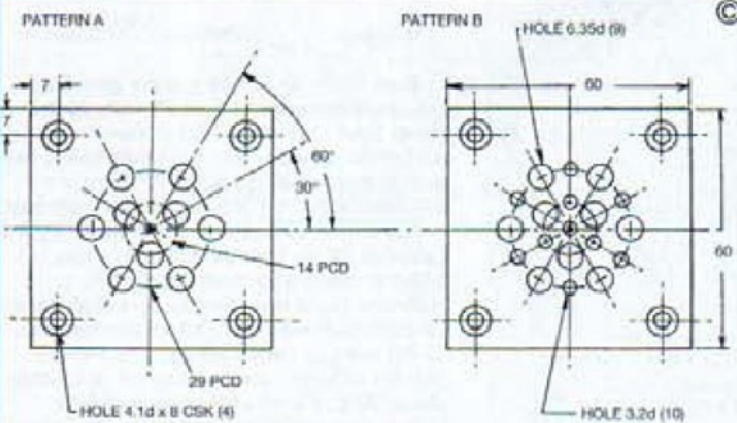
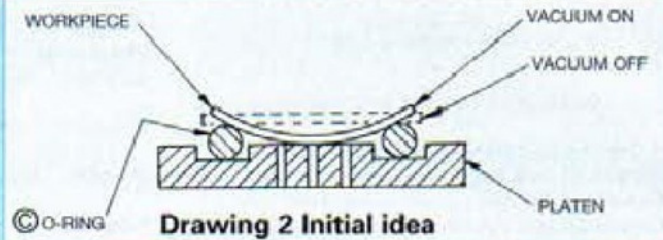
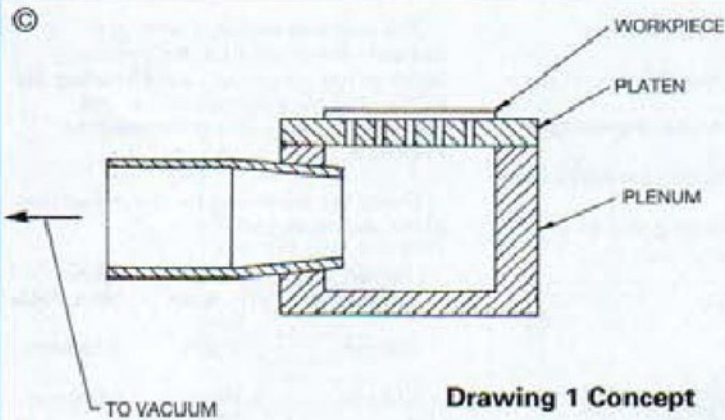
$$d = \frac{2wr^4}{3Et^3}$$

where 'w' is the distributed load in pounds per square inch, 'r' is the radius of the plate and 't' its thickness in inches, and 'E' is the modulus of elasticity in pounds per square inch.

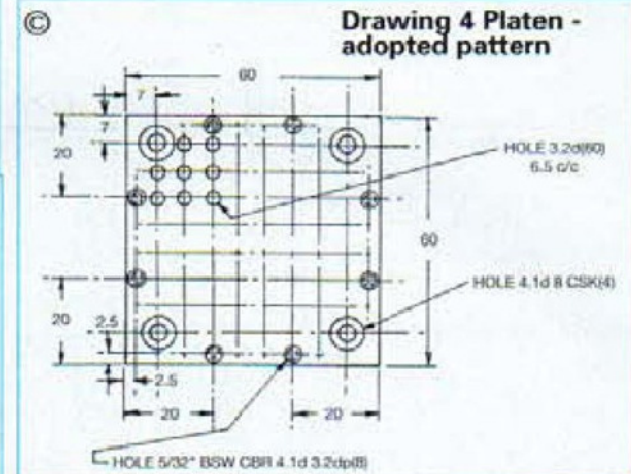
E is	42.5 x 10 ⁶	for silver
	30 x 10 ⁶	" steel
	16 x 10 ⁶	" copper
	14 x 10 ⁶	" brass
	10 x 10 ⁶	" aluminium



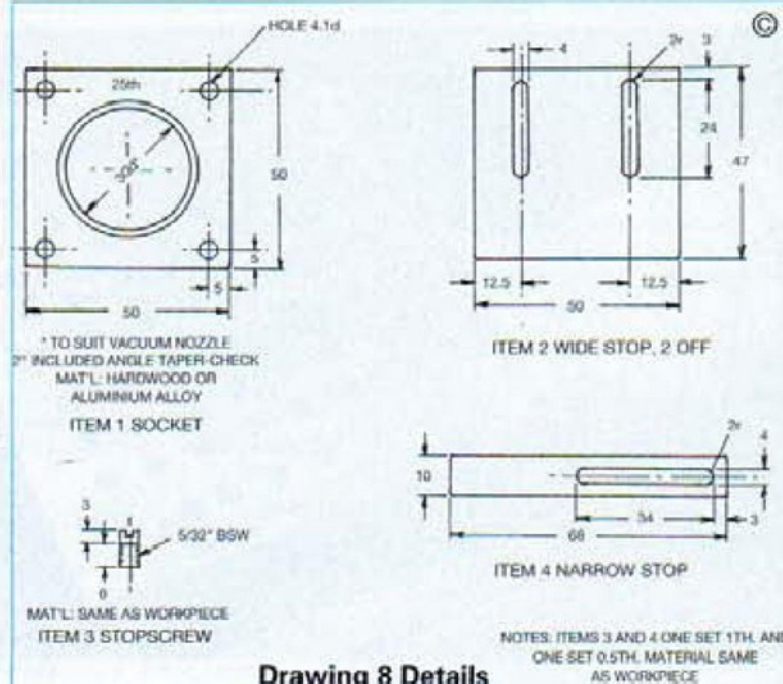
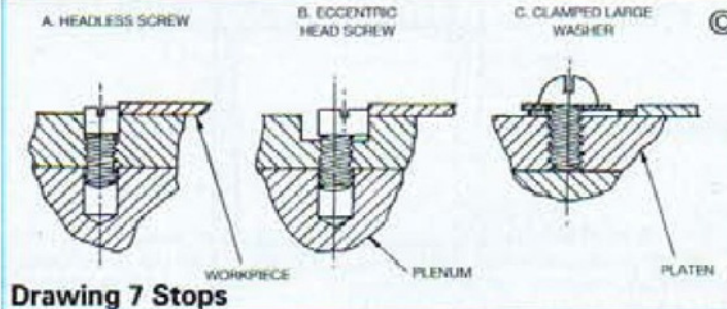
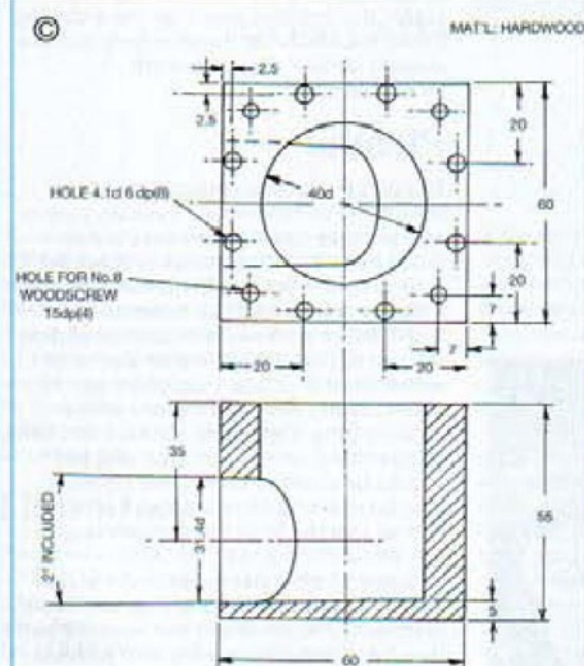
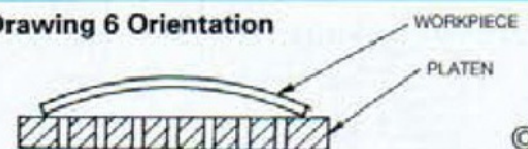
2. Quorn surface grinding set-up with vacuum chuck and workpiece.



MAT'L: 6.35 THICK MILD-STEEL



Drawing 6 Orientation



$$d = \frac{2 \times 14.7 \times 0.007 \times 25^4}{3 \times 30 \times 10^6 \times 0.007 \times 6.35^3}$$

= 0.0005mm which can be ignored.

For the perforations the first trial was a pattern of nine holes $\frac{1}{4}$ in. diameter - see **Drawing 3a**. Brass shim was placed over the platen and the vacuum cleaner applied, giving the following results:-

Shim Thickness	Appearance
0.05mm	Very noticeable depressions
0.08mm	Noticeable depressions
0.12mm	Barely detectable depression
0.25mm	Nothing visible

The trial was repeated with $\frac{1}{8}$ in. diameter holes added to the pattern between the $\frac{1}{4}$ in. holes - see **Drawing 3b**. In this case the presence of the $\frac{1}{8}$ in. diameter holes could not be detected- **Photo. 1**.

Doing the arithmetic for the deflections of the shims we get:-

Shim Thickness	Deflection Over $\frac{1}{4}$ in. hole	Deflection Over $\frac{1}{8}$ in. hole
0.05mm	0.57mm	0.036mm
0.08mm	0.14mm	0.009mm
0.12mm	0.041mm	0.003mm
0.25mm	0.0046mm	0.0003mm

Now with my Quorn surface grinding set-up (**Reference 2 and Photo. 2**) the lower limit of depth of cut is about 0.013mm, so with $\frac{1}{8}$ in. diameter holes, the deflections for shims up to 0.12mm are still significant. By going to $\frac{1}{16}$ in. diameter holes, all the deflections are reduced by a factor of 16, so only deflections of the 0.05mm shim would be significant. However there are other factors discussed below which adversely affect this option.

For ease of manufacture, a rectilinear pattern of holes was decided on, such that about 20% of the working area of 50 x 50mm was removed i.e. 8 x 8 holes $\frac{1}{16}$ in. diameter - see **Drawing 4 and Photo. 3**. This was quite arbitrary - perhaps a 12 x 12 pattern giving 46% removal might be better, but that involves a lot more drilling (more than twice as much in fact) and the present pattern seems to work satisfactorily.

Plenum

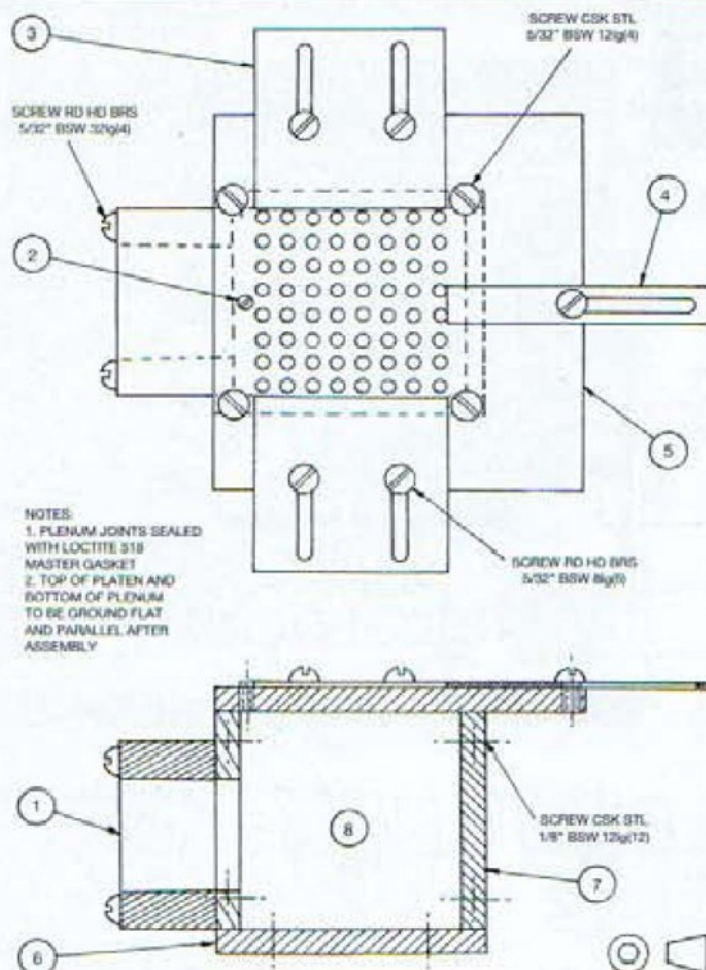
The purpose of this component is essentially to connect the vacuum pipe to all the platen holes. In my case it was made from a block of hardwood turned square on the lathe to dimensions 60 x 60 x 55mm. It then had two holes bored, one in the top of diameter 40mm, intersecting with one in the side of 30mm diameter with a taper of 2 deg. included angle for 35mm depth, to match the end of the vacuum pipe. This angle seems to be fairly standardised on vacuum cleaners, but should be checked before machining. It may be easier to bore the tapered hole first so that the fit of the vacuum nozzle can be confirmed.

Some of the outer holes in the platen did not have access to the plenum 40mm diameter hole, so this access was achieved by a bit of judicious paring with a chisel. The platen was secured to the plenum with four countersunk No. 8 by 20mm long woodscrews - see **Drawing 5**.

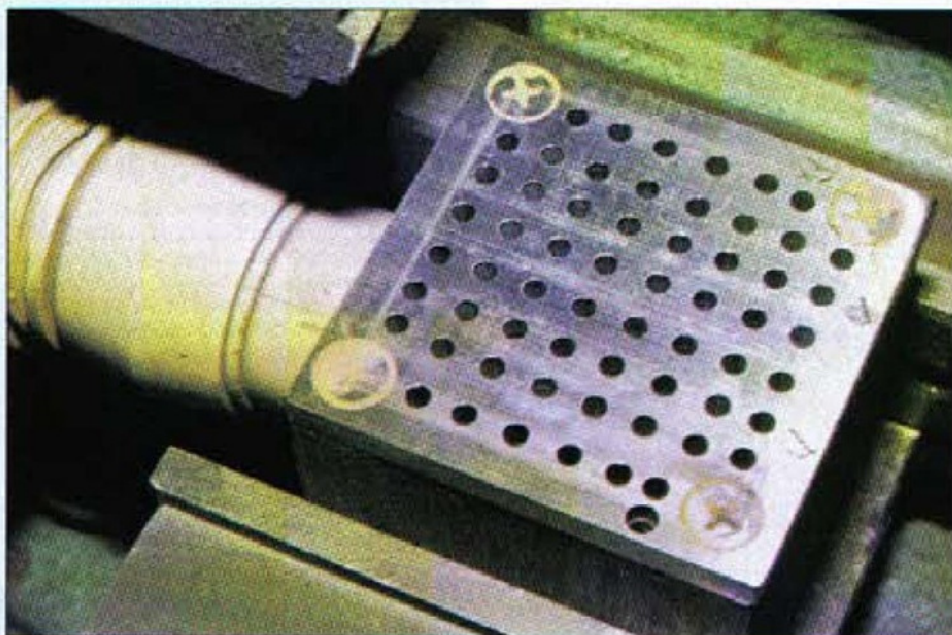
Vacuum

My set-up used my wet/dry Shop Vac cleaner which has a loaded input rating of 850 watts. Experiment showed that the family Hoover upright model, with a loaded input rating of about 485 watts, did not seem to have sufficient suction to operate the 50 x 50mm platen pattern.

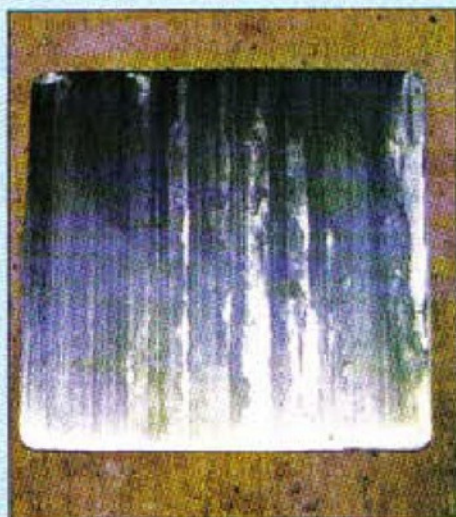
For any larger platen pattern it would



Drawing 9 Final design



3. Vacuum chuck platen with stop screws.



4. Steel sample.

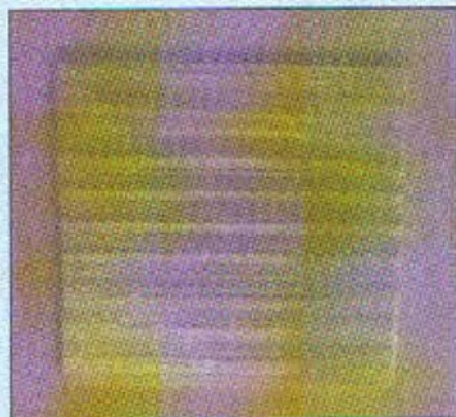
Steel	6 - 11m/sec
Bronze	15 - 18 "
Aluminium	18 - 21 "

This slow speed makes it essential to avoid dwell at any point, lest localised heating occurs and causes distortion in the workpiece, which can have disastrous consequences in spoilt work. The thinner the workpiece the more important this becomes.

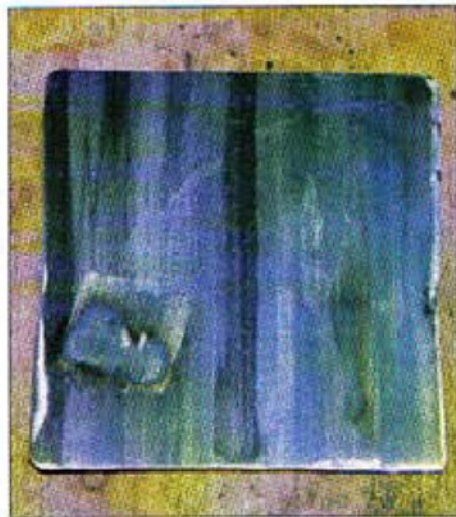
● After each pass and return, the wheel is traversed sideways by an amount up to $\frac{2}{3}$ its width. In my case with a 12.7mm thick wheel, three turns of the handle moves the work 7.5mm sideways or about 60% of the wheel width. On the thinnest pieces this was reduced to two turns or 5mm or 40% of wheel width in order to avoid heating. For 7.5mm traverse, seven passes are required for a 50mm workpiece width.

● From the above it will be seen that, to cover the 50 x 50mm workpiece, the longitudinal handle must be turned 280 times plus the traverse handle 21 times "there's a long, long trail a'winding"

● If grinding timber or thermoset plastics, a dust mask is essential for comfort and safety reasons. No doubt you will already be wearing eye protection, and maybe ear defenders because of the



7. Brass plate sample.



5. Steel sample with heat damage due to rotation on platen.

vacuum cleaner noise.

● Better results will be obtained if the workpiece is substantially flat to start with; hence it is worthwhile reverse rolling 'curly' stock to try to correct this curl.

● The following samples were ground (all 50 x 50mm):-

(i) Mild steel 0.63mm thick (24 BG) - see **Photos. 4 & 5**

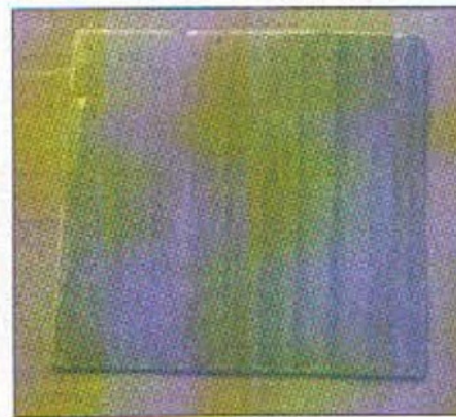
(ii) Bakelite 1.72mm thick (nominal $\frac{1}{16}$ in.) - see **Photo. 6**

(iii) Brass 1.2mm thick (18 SWG) - **Photo. 7**
0.41mm thick (27 SWG) - **Photo. 8.**

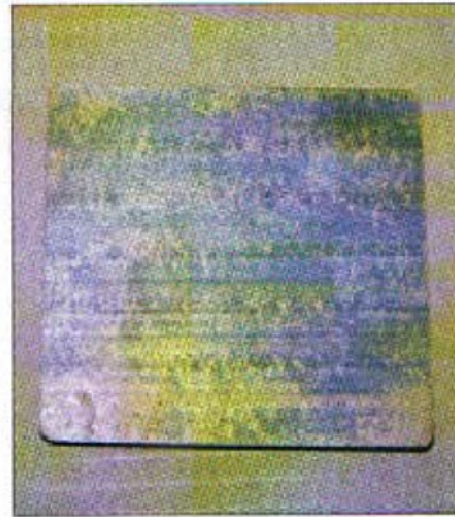
From these experiments it would seem that this set-up can be used with sheets down to about 0.4 or 0.5mm thick, but below this the workpiece is liable to be flicked out. Workpieces over about 4 or 5mm in thickness can be held in a vice so this may be taken as the thicker limit of utility of the device.

Suggested Design. (Drawing 9)

The milling vice on my drill/mill can readily accommodate 60mm opening which determines one dimension of the



8. Brass shim sample.



6. Bakelite sheet sample.

plenum. For a 50 x 50mm platen pattern the other dimension is also conveniently 60mm or so. Although the experimental plenum is 55mm high, the vacuum hose only just clears the lower side of the Quorn mounting plate, so this dimension has been increased to 65mm.

The platen size has been extended in both directions to accommodate the stop plates, which also serve to cover those platen holes which are not covered by the workpiece.

The screws securing the platen to the plenum are located well clear of the platen pattern. The plenum is built up from steel plate to form a box of stable dimensions, which can be ground top and bottom, for ease of use on successive occasions without further attention.

The hose socket on the plenum does not require such accuracy and may be made of aluminium alloy or hardwood as available.

Details are shown on **Drawings 8, 10 and 11.**

A set of stop plates of each material to be ground is desirable, so that the grinding wheels are not contaminated with different metals in the one operation. A set of each thickness 1 and 0.5mm may be beneficial.

Conclusion

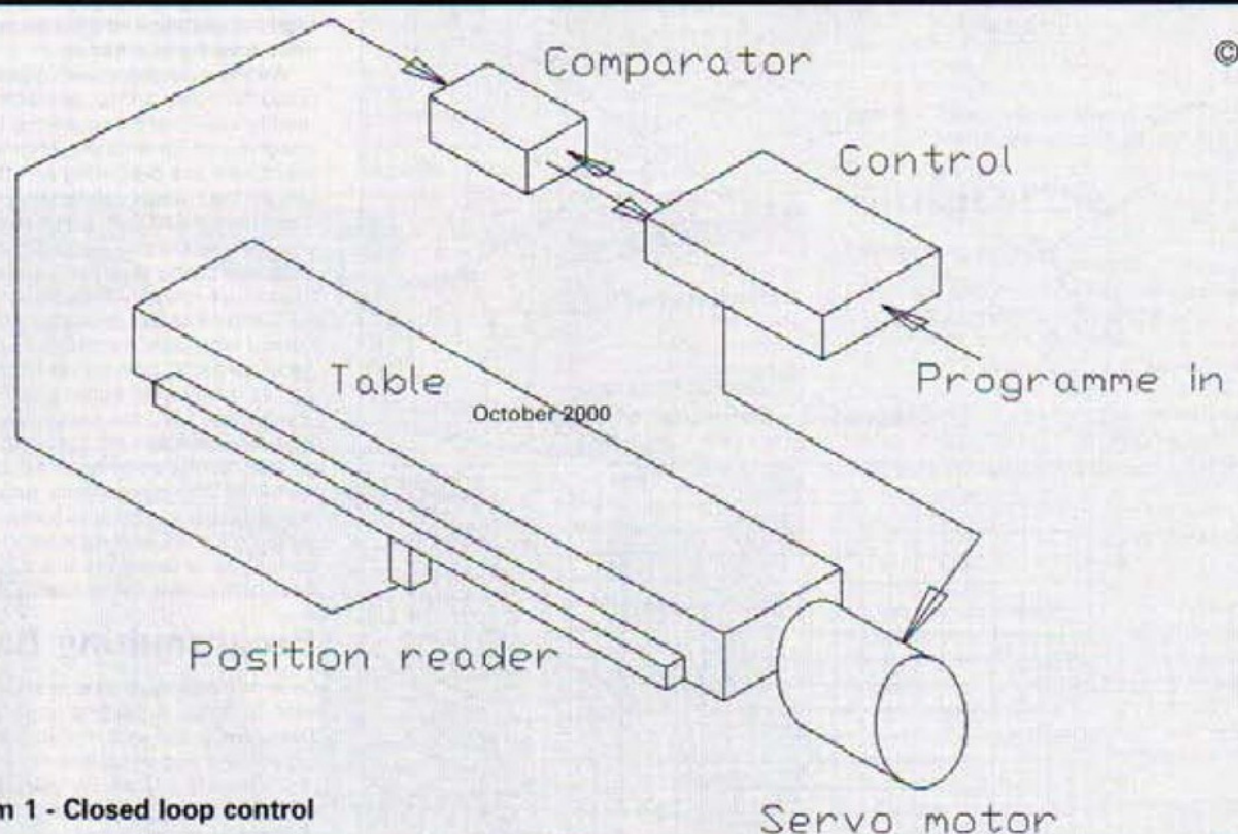
The vacuum chuck is a useful aid to grinding non-magnetic workpieces of limited thicknesses. It can be easily be made in the home workshop and operated with normally available workshop vacuum cleaning equipment.

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AN INTRODUCTION TO CNC PROGRAMMING

CNC systems, suitable for adaptation to home workshop equipment and which use industry standard programming methods, are now becoming available at affordable cost. Professional Engineer Trevor Wain of Derby spent his career dealing with such matters, so is well placed to give a brief introduction to the subject. In future issues, Peter Rawlinson will explain how he has incorporated one of these systems into the CNC milling machine he has previously described in these pages



Numerical control of machine tools, NC, was developed during the 1950s mainly in the USA. The need to produce better and more consistent aircraft drove the industry to develop better machining techniques. When you make any part you have work within a tolerance. With manual machining, to reduce costs, tight tolerances are applied to only the functional parts of the component. A generous tolerance to most of the component means a wide variation in weight and variation in weight means a variation in aircraft performance. With NC machining all tolerances are to the same precision, that is to the positional accuracy of the machine. In practical terms this

means that aircraft parts designed to be as strong as necessary at the minimum size of the tolerance have the minimum extra weight and weight variation, thus producing aircraft with better and more consistent performance.

Control systems for machine tools are either 'open loop' or 'closed loop'. **Diagram 1** is a schematic drawing of a closed loop system. A programme position command is read into the control. The position of the machine table is then checked and this position compared with the required position. If there is a difference, the servo motor rotates the leadscrew to drive the slide in the direction required until the comparator gives a

difference of zero. **Diagram 2** is schematic diagram of an open loop system. The control remembers the last position of the table and when a programme position command is read into the control, the required position is compared with the last position. If there is a difference the control calculates the number of pulses and polarity required, then sends them to the stepper motor. Stepper motors rotate a set angle for a pulse of electrical current. The stepper motor is connected to the leadscrew and, by sending a calculated number of pulses, we move the slide the required distance. The polarity of the pulse determines the direction. Leadscrews are usually of the recirculating ball type to

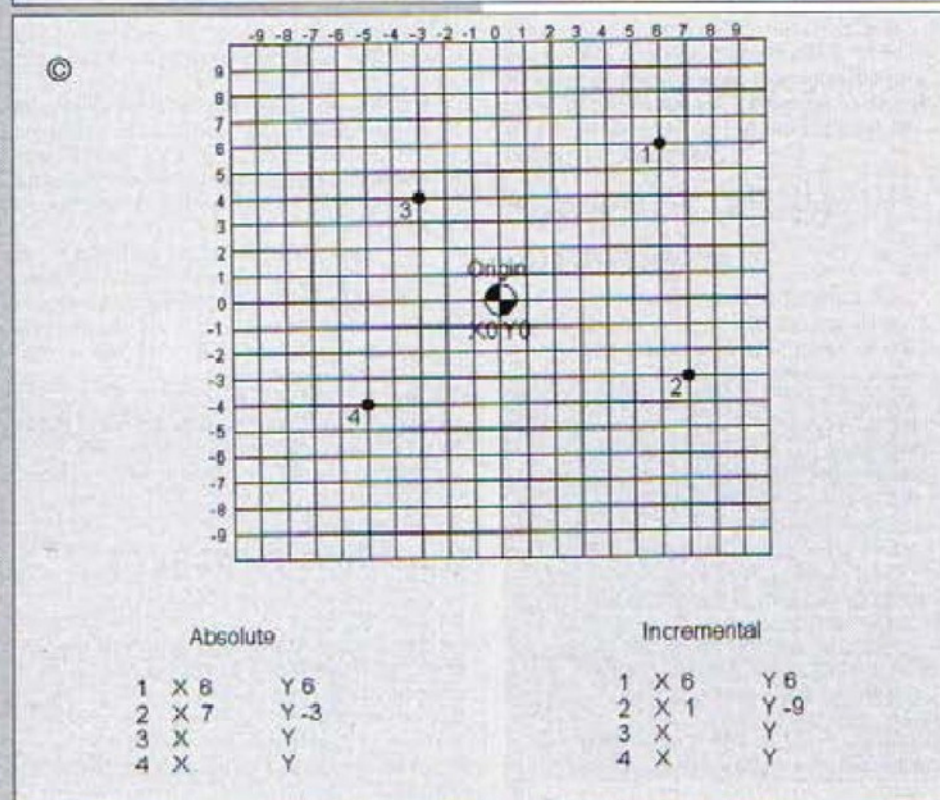
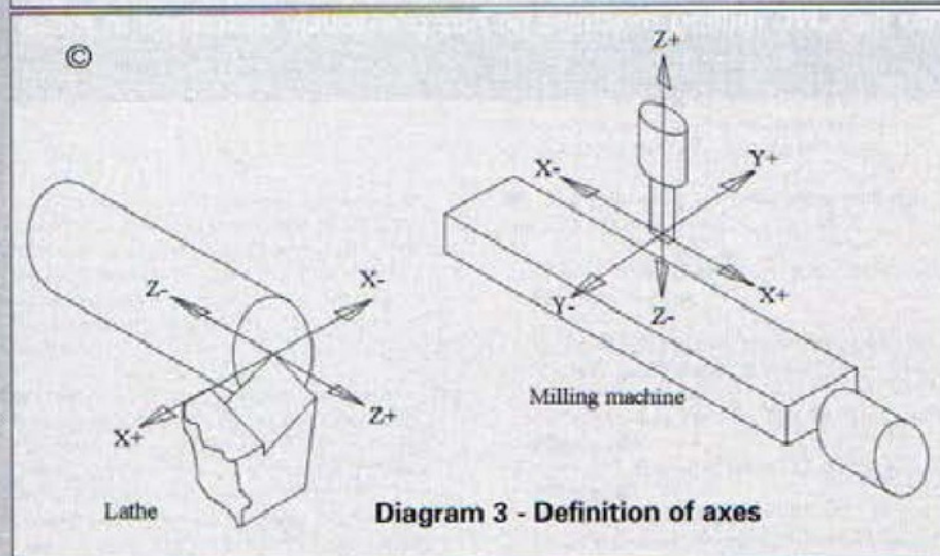
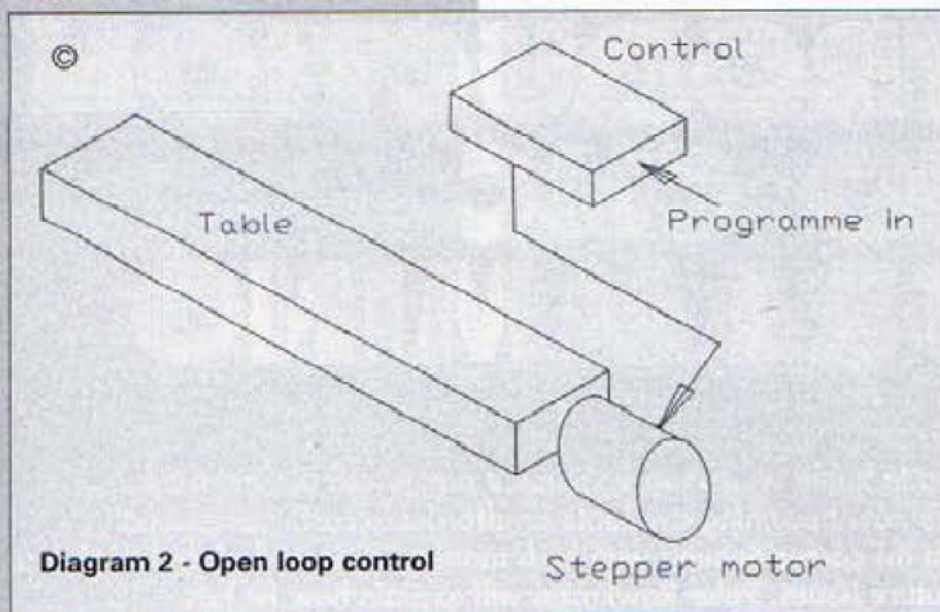


Diagram 4 - Absolute and incremental programming modes

ensure minimum and consistent friction. An open loop system is much cheaper, but loses its position if overloaded. A closed loop system is much more expensive but is more reliable for large machines. Model engineering systems are usually of the open loop type, but if used with care they are very reliable and accurate.

Early machines had very little memory in the control system and the programme was read piece by piece from either magnetic tape or punched paper tape. A loop was formed of the tape so that the programme could be repeated. With the rapid progress of computer technology, NC has become CNC - Computer Numerical Control - and now machines can store many large programmes in their own memory. Use of computers means that we can operate several axes on the machine at the same time; that is, we can alter the lengthwise and crosswise movements, depth of the cutter and the rotation of the component simultaneously. By doing this in a controlled manner, we can machine accurately components shaped in three dimensions, such as propellers or turbine blades. This type of component would previously have required casting and then expensive and inaccurate hand dressing.

With the development of cheaper powerful home computers and more readily available components, bolt-on CNC attachments for amateur engineering machinery are becoming an affordable option. Your approach to your hobby will determine if CNC will be of any benefit to you. For the person who gets pleasure from exercising their hand skills and wants to produce individual work, then CNC will be of little interest. However, for the person who uses his machines to produce accurate parts for working models or enjoys developing better models or equipment, CNC has many advantages. Accurate profiles with blended radii or splined forms, an easy switch between metric or inch dimensions, accurate reproduction of multiple parts, mirror imaging for left and right hand parts, scaling up or down are but a few of the possibilities that come readily to mind.

Programming Basics

Determining which axis or slide that we wish to move is the first requirement.

Diagram 3 shows the main axes of movement and directions for a milling machine and a lathe. By using this information we can instruct the machine which axis to move and in which direction by inputting a letter followed by a value. All commands are written as if the tool was moving, not the slide. For example X3.501 will move the tool in a positive direction along the X axis. Z-1.006 will move the tool in a negative direction on the Z axis. How a machine control interprets the movement commands depends if it is in 'absolute' or 'incremental' mode.

Absolute mode programming is when the position is given as a distance from the datum point, this being a point in three dimensional space set by the operator in relation to the component. The choice of position varies between turning and milling. When milling, it is usually a hole centre or a corner in the XY plane and the

top surface of the work in the Z plane. The position is chosen to give mainly positive values in the XY plane, positive values clear of the work and negative values with the cutter into the work in the Z plane. When turning, it is usually the centre of the work in the X plane and a point at the end of the component nearest to the chuck in the Z plane. Choice of these points gives a positive X value for the radius of the work and a Z minus value indicating a danger of the tool hitting the chuck. Absolute programming is the method preferred for nearly all programming as it is less confusing and much easier to check.

Incremental programming is when the position required is given as the distance from the current position. This can be very useful when performing repeat patterns at different parts of the work. It is very easy to become confused about the position of the tool, so it is better to restrict the number of incremental dimensions.

Most machine controls allow the programmer to switch between the two modes. **Diagram 4** shows a grid with a datum point and four positions marked on it. Below are two tables of co-ordinates, one for absolute and one for incremental programming. Two examples are given in each table. By positioning each point in number order, work out the rest of the co-ordinates.

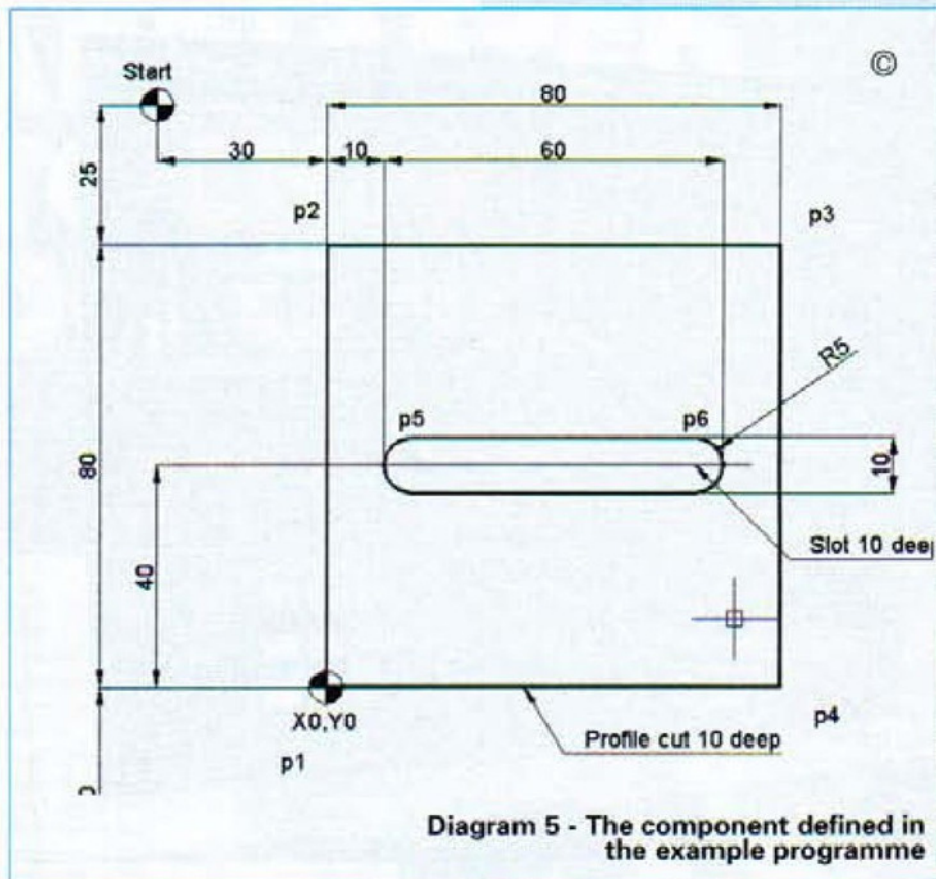


Diagram 5 - The component defined in the example programme



1. This 'Supermax' YCM-V65A Vertical Spindle CNC machine is one of a number used by Winson Model Technology to produce components for their kit-built small locomotives and traction engines.

Format of the programme

There are two main types of programme, the 'G' Code programme and the conversational programme. Conversational programmes are unique to each control manufacturer whereas G code programmes are mainly the same for all controls. It is the G code programme format that I will concentrate on. As it is confusing to deal with both the lathe and the milling machine at the same time all the examples are for a milling machine. Once the basics are understood, conversion from milling to lathe programming is easy.

A line of programme is called a block. Blocks are numbered and may contain notes, G codes, letter address information or M codes. All items usually can be entered together or separately and in any order. It is usual however to follow a set sequence to avoid mistakes.

A note is information that is not used by the machine but helps the programmer e.g. programme number, operation number, type of tool etc.

A G code, or preparatory code, performs several functions - a basic list is given below. G codes can be modal or non-modal. A modal function applies until it is cancelled. A non-modal function applies only once.

G codes which initiate basic motion functions

G00 (modal) rapid traverse point to point
G01 (modal) linear feed movement
G02 (modal) clockwise circular arc feed
G03 (modal) anticlockwise circular arc feed
G70 (modal) select inch dimension system



2. The operator's control panel on one of Winson's machines

- G71 (modal) select metric dimension
- G90 (modal) select absolute dimension mode
- G91 (modal) select incremental dimension mode

G codes which develop the basic capabilities of the basic motion codes

- G30 (modal) cancel mirror image
- G31 (modal) reverse direction of X dimensions. (mirror image)
- G32 (modal) reverse direction of Y dimensions (mirror image)

G codes that initiate stored cycles

- G77 (non-modal) facing cycle
- G78 (non-modal) pocket mill cycle
- G80 (modal) cancel fixed cycle
- G81 (modal) drill cycle

Letter address information is used to establish basic information

- X X axis move
- Y Y axis move
- Z Z axis move
- F feed value
- T tool number
- S spindle speed

Note all the above are modal and remain in force until cancelled by a new value.

M or miscellaneous functions

- M00 programme stop
Used to load work, change clamps or check work
- M02 end of programme
- M06 tool change

The examples above are just a few of the codes available. Manufacturers tend to

have their own versions, so a check is always advisable.

Example programme

Writing a programme to produce a component involves not only the mechanics of producing the code but also the practical machining considerations. The example below is written for a manual tool change machine with a 'Boss 6' control system. Programmed operations will machine the outside profile with a 20mm dia. end mill and the slot with a 10mm dia. slot drill. Datum in the XY plane is as shown in the drawing. Datum in the Z plane is the top surface of the material. Profiles and slots cut with a single pass, as in this programme, are very rough. To produce an accurate part the programme would require roughing and finishing cuts for each operation. **Diagram 5** shows the component for the example programme below.

```

N1 G71 G90
N5 G00 X-30.0 Y105.0 M00
N10 Y-40.00 S1500 T1 M06
N15 X-10.00 Y-15.00 Z1.00
N20 G01 Z-10.00 F75
N25 Y90.00 F150
N30 X90.00
N35 Y-10.00
N40 X-10.00
N45 G00 X-30.00 Y-40.00 S2000 T2 M06
N50 X15.00 Y40.00 Z1.00
N55 G01 Z-10.00 F75
N60 X65.00 F150
N65 G00 X-30.00 Y105.00 M02
  
```

Block N1 sets the units to metric and the co-ordinate system to absolute.
Block N5 gives a rapid traverse to the

start position that allows the work to be loaded without catching your hands on the tool. Note that the blocks are numbered in steps of five to allow a block to be inserted without altering the whole of the programme. Block numbers are mainly for the convenience of the programmer. For most controls they need to be in order but not need to be sequential.

Block N10 rapid traverses to the tool change position, G00 and X-30.00 are modal and do not need to be repeated. S2000 sets the spindle rpm and T1 selects tool 1 data. M06 is the M code for a tool change and on this system initiates the following sequence:- Retract the tool as high as it will go, stop the spindle and apply the brake. The machine will now wait until the restart button is pressed. At this point the operator can change the tool to a 20mm dia. end mill and then press the restart button. On restart the brake will be taken off and the spindle will start at 1500 rpm.

Block N15 rapid traverses to point 'p1', 1mm above the surface of the work. A 1mm clearance is left so that the tool is not rapid traversed into the work if the machine over-runs slightly. The tool moves in an XY plane first, followed by the Z move. This ensures that the tool does not strike any clamps on the way to position. The position is the radius of the tool away from the work in the X plane. Extra clearance is allowed in the Y plane so that the end mill can be fed down without blocking the centre as it is not end cutting. The amount of extra clearance depends on how much material is to be removed.

Block N20 feeds the tool down to depth at a feed rate of 75mm per minute. It is normal to end feed cutters at approximately half the lateral feed. Feed rates are set on the high side so that the operator, if required, can reduce them manually at the machine control panel.

Block N25 feeds the tool to position 'p2', the radius of the cutter clear of the profile in both X and Y.

Blocks N30, N35 and N40 feed the tool around the rest of the profile.

Block N45 moves the tool in rapid traverse to the tool change position. Note that Z plane move is carried out before the XY move so that the tool is not snapped off in the work. In this case M06 specifies the tool is retracted as far as possible and the spindle stopped. The tool is now changed to T2, a 10mm dia. slot drill that will run at 2000 rpm on restart.

Block N50 feeds the tool to point 'p5', the start of the slot, 1mm above the surface.

Block N55 feeds down 10mm into the work at 75mm per min.

Block N60 cuts the slot.

Block N65 returns to the start position. M code M02 initiates the following sequence:- Retract the tool as far as it will go and stop the spindle, rewind the programme to the start and await the restart button.

A new part can now be loaded and the whole sequence run again.

I hope that this short introduction has helped you understand why CNC is employed and how an engineer goes about producing a part. I also hope that it has stimulated an interest in this fascinating subject.



A FABRICATED TAILSTOCK FOR A DIVIDING HEAD

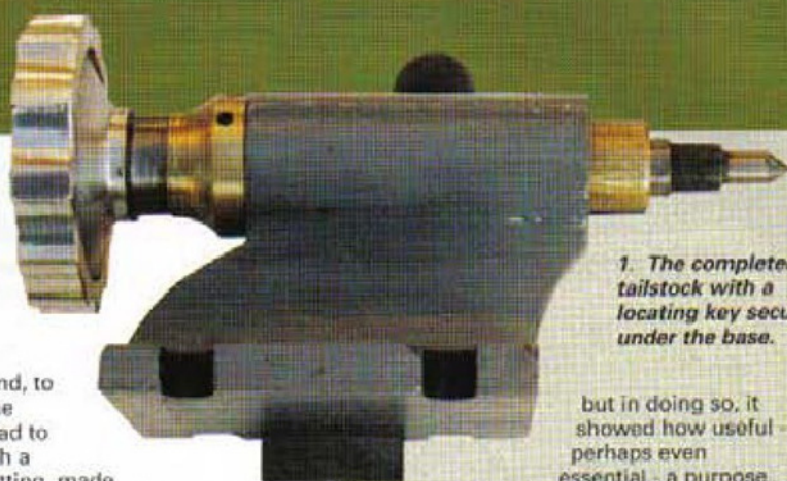
Norman Hurst describes how he fabricated a matching unit for his indexing head

Several years ago, I made an 'indexing head'. Although it does roughly the same job, I did not call it a dividing head as that suggested a large, commercially made item. However, the tailstock that I will be describing in this article could be used with most dividing or indexing devices - home made or otherwise.

When I made the indexing head, it had a low height to its centre line, as it was only being used on the lathe. I didn't need a tailstock at the time and one didn't get made. I now have a converted mill-drill and the uses and scope of this device have

increased. I recently needed a tailstock to carry out some milling on a steel workpiece and, to overcome the problem, I had to make do with a temporary fitting, made from a piece of scrap cast iron and a pointed screw. It served its purpose,

but in doing so, it showed how useful perhaps even essential - a purpose made tailstock could be. I decided to make one.



1. The completed tailstock with a locating key secured under the base.

Fig. 1

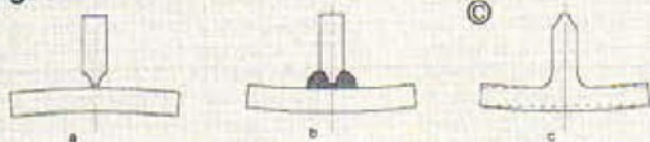


Fig. 2

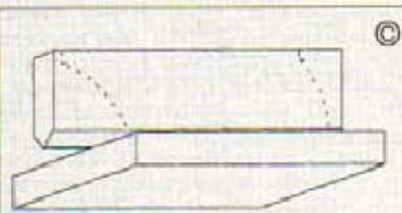


Fig. 4

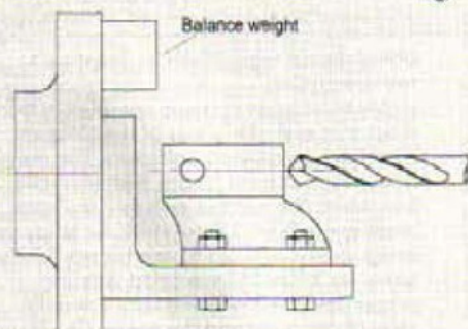


Fig. 3

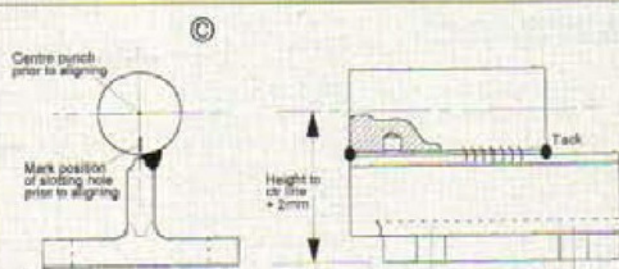


Fig. 5 Main body

Mat'l mild steel

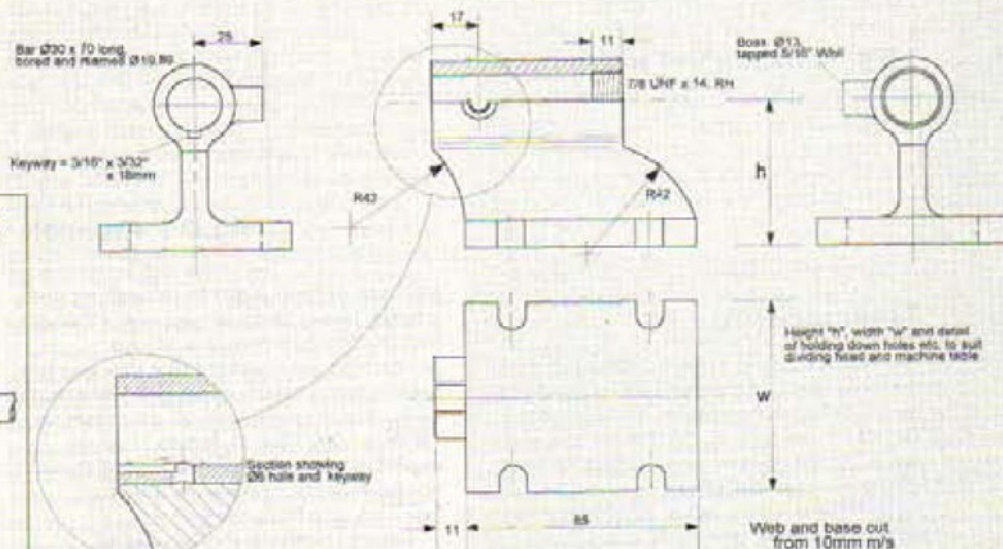


Fig. 6 Barrel

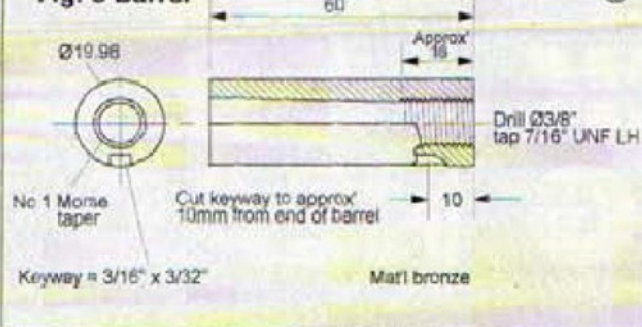


Fig. 8 Locking handle

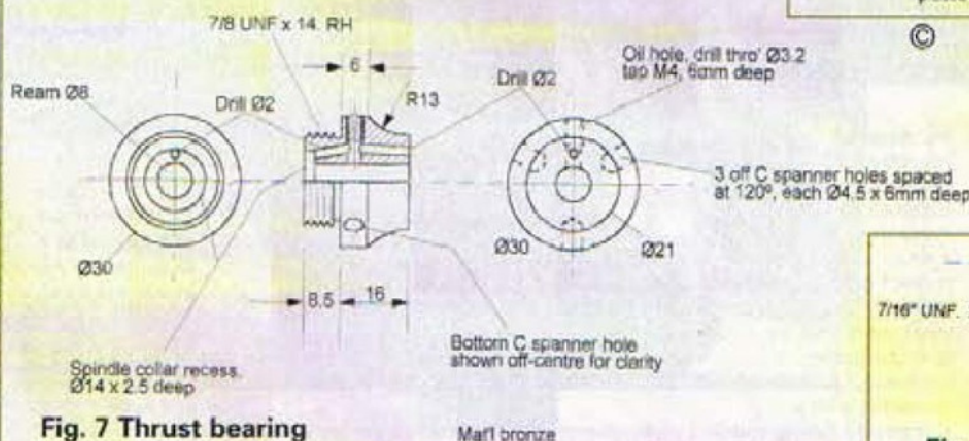
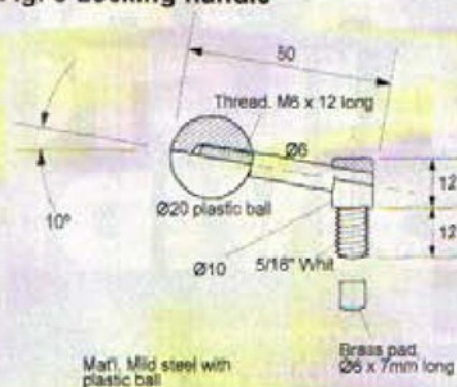


Fig. 7 Thrust bearing

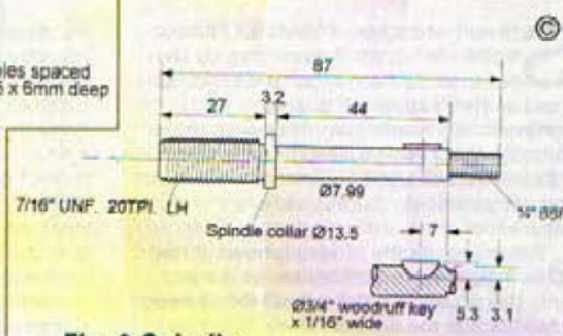


Fig. 9 Spindle

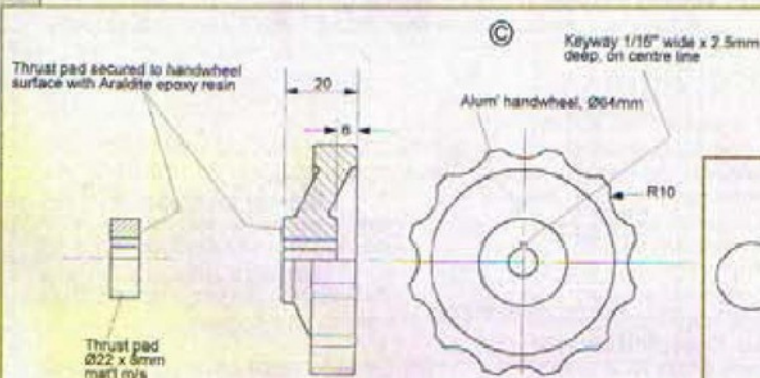


Fig. 10 Handwheel and thrust pad

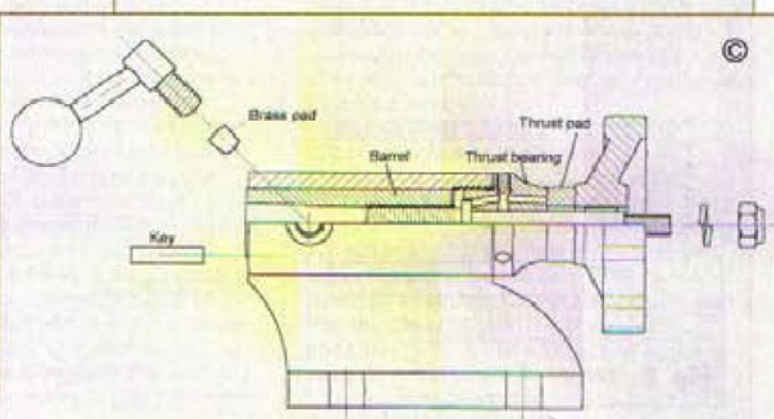


Fig. 11 Assembly

Description

The spindle of my indexing head has a No 2 Morse taper and the same threaded nose as my lathe, and can therefore accept the lathe's 3in. or 4in. chucks. I knew that the height to the centre line was slightly over 2in. to take the 4in. chuck, but I couldn't remember what the exact height was. On checking, I established that this dimension was 2.100in. I now knew the approximate overall size for a tailstock, but not how to go about the job. At first, I again considered cast iron, using an inverted T shaped block, the crossbar of the T being

the base or foot. Apart from needing quite a large, heavy piece of cast iron, I thought that the finished item would look amateurish, so I decided that this was not satisfactory. I briefly considered casting the body in aluminium, as was described in MEW in 1995 (Ref. 1), but as I had no experience in casting, I felt that this would not be suitable. I finally decided to fabricate one from mild steel.

Before I describe the fabrication method, I would point out that if the constructor does not have access to welding equipment, a pattern could be made and the main body cast in aluminium or cast iron. Machining and

fitting details would then be identical to my description.

My tailstock was made completely from stock material; the grade of the different materials used being unknown. The main body was cut from 30mm diameter steel bar, whilst the vertical web and the base were made from 9.8mm thick, ex shipyard scrap steel. I decided to use bronze for the barrel as it would have good wearing properties when working with the mild steel of the body and the screw. The thrust bearing was made of the same grade of bronze, as this also would be a suitable material for use with the spindle and the hand wheel thrust pad. This bronze

originally came from the scrap yard and was the spindle of a large (probably 8 or 10in.) gate valve, the type of valve used in the petrochemical industries. The hand wheel was made from aluminium alloy - this material coming from a factory scrap bin - with a mild steel thrust pad secured to it with Araldite.

Notes on welding distortion

When a 'tee' piece is fabricated with fillet welds, the flanges tend to pull in towards the welds, giving a convex curve to the outside of the flange; the greater the weld material, the greater will be the distortion. One way to reduce this effect, is to bend the flange material the opposite way before welding, so that the outside of the flange has a concave surface. The welding will still pull the flanges in toward the welds, but the final result will give a flatter surface. If the flange is comparatively thick (as with my base), the easiest way to bend it is by heating. If it is to be bent cold however, a really heavy blow will be required (assuming a large press is not available). The amount of 'bend' will depend on how thick the flange is and how much welding is to be carried out. As far as I know, there are no rules or formulae to tell us how much, so it just depends on experience - or luck.

Manufacturing

Welding the main body (Fig. 5)

With my 'tee' piece (the base/flange and the web) I bent the base to what I thought would be sufficient. With a straight edge across the width, I could just get a 0.013in. (0.33mm) feeler into the hollow. After welding, I found that the base had still pulled up into the convex shape, but not excessively, and the base could be machined flat without losing too much thickness. With hindsight, I realised that it would have been better to have given it about a 0.020in. (0.5mm) curve.

The reader will notice that I am mixing Imperial and metric dimensions. The reason for this is that although I prefer to design and work in metric, many of my tools, such as feeler gauges, taps, Woodruff cutters etc., are (veteran) Imperial items. In this article, the dimensions and other details quoted refer to the way in which I made the tailstock, but some of these are arbitrary and can be changed to suit the constructor's requirements. I have not given dimensions for the holding-down slots or for the height to centre line because, in most cases, they will be different to mine.

The end view drawings, **Figs 1a, b and c**, show the curved or bent bases - in an exaggerated manner - before and after welding. 1a indicates a curved base, with the web prepared for welding. 1b shows the result of an insufficient initial curve - after welding - whilst the dotted lines on 1c indicate how the base would need to be corrected.

In Figs 1 and 2, I have shown a weld preparation ('prep') at the lower edge of the web. For this application, some readers may feel that this is not necessary and that only fillet welds would be required. I prefer



2. Finding the height of the barrel. Templates for the curved sections of the tailstock can be seen on the bench.

a good penetration weld, but it is a matter of personal choice. Remember however, that when the work is shaped and cleaned up, it should look solid and not have a small line or gap along the joins.

With all welded fabrications, there will be residual stress remaining, and this job is no exception. For the beginner or inexperienced, it may be necessary to point out that unless these stresses are removed, or certainly reduced, the fabrication will not be dimensionally stable and there is a probability that the work will 'move' at some time; very often when being machined. The most thorough method of removing this stress is by heat treatment, but I use a quicker and, in my experience, totally adequate system. After welding, I give the work a good hammering. This method - apparently - sends shock waves through the fabrication, which then relieves most of the built-in stresses. It appears to be speeding up the traditional weathering or ageing method which is very often employed. Give this method a try, I think that you will find it satisfactory. Of course, you must hammer near the welds, but on a section where bruising or other damage won't matter. I must admit that after this 'stress relieving', I still give the work a few days to settle down - just in case.

Prepare the base and web generally as shown in **Fig. 2**, leaving ample allowance for forming the web curves or correcting errors in alignment, height of web etc. Tack weld the web to the base, making sure that it is positioned squarely. If it isn't, tap it square with a hammer before final welding. Don't weld one side entirely before the other, or the web will pull over towards the weld side - weld short lengths on alternate sides. When this stage is complete, carry out your preferred stress relieving system, i.e. heating, hammering, ageing, or ignoring!

When you are satisfied that the work is stable and won't 'move', dress the welds with an angle grinder and a file, generally as shown in **Fig. 1c**. If necessary, dress the upper surfaces of the base, as shown by

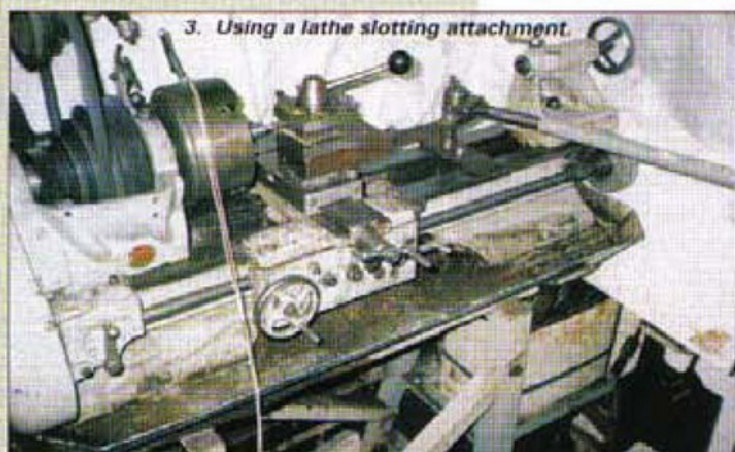
the dotted lines in **Fig. 1c**. Although this isn't strictly necessary, it will make it 'look right'. Next, cut the holding-down slots or holes, then rough machine the underside of the base to act as a datum. If the web has been welded slightly out of square, now is the time to correct it by machining one side more than the other.

In my design, there is a blind keyway in the bore of the main body. The way that I produced this was by slotting into a hole, the hole being large enough to accept the slotting tool. This worked for me, so I suggest that this would be a satisfactory method to adopt. Firstly, cut the 30mm diameter bar to length plus an allowance for machining, but don't bore at this stage. Drill a 6mm hole, 18mm from one end, about 7mm deep. This will eventually become the slotting hole. Mark the end of the bar, in line with the hole, to assist you in locating when aligning it with the web. Mark the centre of the bar in order to position it correctly above the web. Grind, machine, or file the top edge of the web, to give the weld 'prep' and the correct height. Position the bar so that the slotting hole is on the underside (**Fig. 3 and inset in Fig. 5**). This part of the bar will be welded in, along with the lower part of the hole. Tack the bar into position, but about 2mm too high. This allowance is made for two reasons:-

1) It allows for shrinkage of the weld and the consequent lowering of the bar

2) It will leave sufficient allowance on the underside of the base for finishing to the exact height to the centre line.

After tacking, check that the bar is parallel to the base and aligned to the web. If necessary, saw through one of the tacks, tap the bar lightly (a heavy blow will break the other tack) until the bar is aligned, then re-weld your tack. Complete the weld on both sides of the bar/web with alternate runs, similar to the base welds. Next, cut the small locking boss to size (I used a short piece of 1/2in. diameter steel bar) and weld into position. All welding on



the tailstock is now complete.

The web curves can now be cut. To get these looking correct, first draw the shapes on a piece of card, cut these out and use them as templates (**Photo. 2**). Trim and square off the ends of the base and dress all welds. The work is now ready for machining.

Machining the main body

Check the height from the base to your centre line mark. It should be about one millimetre more than the final dimension. If it is less than 1/2mm, the hole in the body must be bored slightly high, i.e. above centre, in order to leave sufficient material under the base for machining and scraping.

The drilling and boring should be carried out on the lathe. Set up the assembly on an angle plate fixed to a face plate, if possible using the tailstock's holding down slots or holes. Depending on the size of the lathe and face plate, the work may need to be mounted on the inside of the angle plate as shown in **Fig. 4**. It should be positioned with its nose end towards the face plate. I drilled mine the other way around and then realised that I had made a mistake. It could be mounted upside down on a Keats angle plate, either the commercial type or a home made, angle iron item (Ref. 2), but the locking boss may obstruct the set-up. Also, special U-bolts would probably be required, so this method may be more difficult.

This tailstock is designed to take a No 1 Morse taper, which is about 11.6mm diameter at the large end. The minimum wall thickness of the barrel (ignoring its keyway) at that point should be at least 3mm, which gives a minimum barrel diameter of 17.6mm. This dimension would also be the bore of the body, which in turn would be the same as, or smaller than, the core size of the thrust bearing thread. The nearest standard size thread to meet this condition is $\frac{7}{16}$ in. UNF, which has a core diameter of 19.89mm. If the bore of the body is kept to that diameter, the minimum wall thickness of the barrel will be approximately 4.1mm, which is a more acceptable figure. A bore diameter of 19.89mm is satisfactory if a suitably sized expanding reamer is available. If it isn't, the constructor can either make a special one, or ream out with a standard size reamer, e.g. 18 or 19mm, or $\frac{3}{4}$ in., in which case there would be a small step or shoulder in the bore. At a pinch, the body could be bored to its full size in the lathe.

but in my opinion, reaming is preferable.

After the bore in the bar is complete, and without disturbing the work, cut the internal thread (7/8 in. UNF). This was the reason for mounting the work in this position - it ensures that the thread is concentric with the bore. Next, make a facing cut across the end of the body to clean it up.

Before discussing the keyway, a short description of my lathe slotting method may be useful. A slotting tool is clamped in the tool post. A linkage system is attached to the top slide, which has had its screw removed. The top slide - with the tool post - is free to slide backward and forward, operated by the linkage. The linkage fulcrum and the carriage are clamped to the lathe bed and the whole arrangement is operated by an extended handle (see Photo. 3). The chuck/faceplate holding the workpiece is locked to prevent rotation. In the photo, a keyway is being cut in a component and the chuck has been locked by engaging the back gear, but with the bull wheel drive pin engaged. The cord attached to the chuck has a weight attached to constrain any back gear slackness. One advantage of this system is that the extent of the slotting tool movement can be controlled by carefully adjusting the fulcrum position and hence, the linkage movement.

Cutting a keyway by this method is quite tedious work; also, a substantial tool is necessary to overcome its 'spring'. Wherever possible, I try to ease these problems by giving the keyway a good start. A sacrificial plug - of a similar material to the work - is wedged in the bore, with the surfaces flush. The join between the work and the plug is centre punched at the point where the keyway will be cut. A hole is then drilled into the work and plug, in the direction of the keyway, and to the same length. When the plug is removed, the component has a semicircular groove. The keyway can then be cut in the normal manner, but with less metal to remove. The size of the drill and the exact position of its centre are, of course, most important.

If you carry out your slotting in the manner described, now is the time to cut the keyway in the bore, while the angle plate is set up. Remove the tailstock from the angle plate. File or machine a piece of 15mm thick mild steel, so that it can be wedged in the bore, generally as described in the previous paragraph. Centre pop on the join, or just to the plug side of it. Drill the assembly in the drilling machine, using

a $\frac{3}{16}$ in. or 4.7mm (No 13) drill until the drill breaks through into the hole. Remove the plug and again mount on the angle plate, but this time reversed, so that the nose is now pointing away from the headstock. Revolve the face plate until the keyway position is on the centre line, i.e. on a horizontal plane. Lock the system at this position. The keyway could be cut on either side, i.e. on the operator side, or on the far side. I prefer the latter, as you can see what is happening as the keyway is being cut. It is especially so with our job, as we would have the angle plate and the base in the way if we cut the keyway on the operator side. Mount a $\frac{3}{16}$ in. wide slotting tool in the toolpost and adjust the fulcrum position so that the tool comes to the end of its stroke in the slotting hole. Surprisingly, as the keyway gets deeper, the linkage angles alter slightly and it will be found necessary to again adjust.

If you haven't got any slotting equipment, it will probably mean back to the old fashioned way - cold chisel and file! I suppose that if you had a drill for cutting square holes, as described by Derek Winks in 1993 (Ref. 3), then the keyway could be cut at the 'plug' stage. I wonder if this has ever been done?

Before you remove the work from the lathe, take a cleaning-up facing cut across the end. This cut will now include a small section of the web and weld metal. Now remove the work from the lathe. Drill and tap the locking boss and lightly run the reamer through the bore again to remove any burrs from the tapped hole or the keyway. Final machining of the base will be carried out after the barrel has been made.

The barrel (Fig. 6)

As mentioned, a No. 1 Morse taper centre will be used with this tailstock, and as this has a diameter of about $\frac{3}{8}$ in. at the small end, the best spindle thread to match this size is $\frac{7}{16}$ in. UNF, having a core diameter of 0.374in. Therefore, if the barrel is drilled right through $\frac{3}{8}$ in., the thread can be cut at one end and the Morse taper formed at the other.

Mount the barrel material in the lathe. Machine across the end surface and then machine the outside to be a good sliding fit in the bore of the body. Drill partly through with the $\frac{3}{16}$ in. drill, deep enough for forming the taper. To speed this process, the barrel can be drilled in steps (Ref. 4), prior to boring and/or reaming. The No 1 Morse taper reamer that I used was slightly under $\frac{3}{16}$ in. at its small end, so

it didn't have any restriction in the drilled hole. Forming the taper whilst the barrel is still in the lathe will ensure concentricity.

Reverse the barrel in the lathe, align it so that it is running true with the outside diameter and machine the end to give the correct length. Drill $\frac{3}{16}$ in. (or your preferred tapping size) until the drill breaks through into the first hole. If the drill runs out slightly so that the two holes don't quite line up, don't worry as it won't really matter too much. Now screw cut or tap the hole $\frac{7}{16}$ in. UNF. Ideally, this thread should be left handed, as this will allow the conventional right-hand rotation for advancing the centre. If you wish to use a standard R.H. tap, then remember that you will be operating the tailstock handle the opposite way.

The one remaining operation on the barrel is the cutting of the keyway. This is straight forward and could be done using your usual method, whether it be milling machine, lathe, vice or vee blocks. A slot drill or end mill could be used, but I prefer using a Woodruff cutter. I think that it gives a better finish - especially in the bronze material. Don't cut the keyway the full length of the barrel, but just leave it short at the threaded end. This will ensure that the barrel will not fall out if it has been wound forward past the end of the thread, which could happen.

The thrust bearing (Fig. 7)

Again, the thrust bearing - also in bronze - is a straightforward machining job. Because of the short length of thread however, it would be preferable to cut this thread in the lathe, rather than using a die. Three C-spanner holes will be needed to be drilled equally spaced around the diameter, together with oil holes to lubricate the thrust bearing and pad, all as shown on Fig. 7.

The locking handle (Fig 8)

The barrel locking handle consists of one short length of 10mm diameter steel screwed $\frac{3}{16}$ in. Whit. and another of 6mm diameter, screwed M6. The 6mm bar should be a push fit in the hole of the larger bar and secured with Loctite or Araldite. Make the smaller bar about 2mm over length so that it protrudes through. After the adhesive has set, file this protruding end back to give a flush surface. I made the ball from a grey nylon type material, but Bakelite or the equivalent would be suitable. 20mm balls are available commercially and in a catalogue that I have, they are shown as red or black Bakelite. Surprisingly, there is mixture of standards in this catalogue, the diameter being given in millimetres (20), but the thread in Whitworth ($\frac{1}{16}$ in.)! A small brass pad should be used when assembling, to protect the surface of the barrel.

The spindle (Fig 9)

The thread is the same as that in the barrel and, as mentioned previously, preferably left handed. The spindle should be a good fit with the thrust bearing bore. In Fig. 9 I have shown a nominal clearance between the two of 0.01mm, but make it as close as you can without binding or tightness. The collar will be slightly longer and with a slightly smaller diameter than the recess in the thrust bearing to maintain

clearances. Make a small chamfer on the threaded end of the spindle to compensate for eventual spreading of the end due to contact with the centre. In this design there is a Woodruff keyway in the spindle, the idea being that the handwheel is free to move over the key. Strictly speaking, this is not good practice as Woodruff keys should be tight fitting without allowing any axial movement. However, ours is only a light duty and this method will be suitable. If you are a perfectionist, then a feather key is the type to fit.

The handwheel and thrust pad (Fig. 10)

The handwheel bore is not as critical as the spindle diameter, but should not have excessive clearance. The key however should be a close sliding fit (as also would a feather key). I made my handwheel with 12 curved serrations, but other forms of serrations or knurling would be satisfactory. As with the case of the ball handle, it may be possible to buy a suitable handwheel, but the bore would probably need modifying. If you decide to form the serrations as shown in Fig. 10, these would be cut with a standard 20mm end mill or with a ball-nose slot drill. A dividing head or rotary table would normally be employed, but if you haven't got one of these (or a CNC machine) but you have a mathematical bent, then a calibration list could be made out and the milling performed using x and y co-ordinates. As a last resort, holes could be marked out and drilled on a large blank before machining to the final diameter.

The thrust pad will be bonded to the handwheel. I prefer Araldite for this type of application, but there are other adhesives on the market. The thrust pad bore and keyway can have generous clearances, as it is only the faced surface that is in contact with the thrust bearing. The keyway in the pad does not play any part and is only there to enable the handwheel to be removed or fitted.

Aligning and assembly

Assuming that the Morse taper has been formed concentrically with the outside diameter of the barrel and assuming that the barrel itself is a close fit in its housing, these facts can be used in obtaining the exact height to the centre line; the height from the base to the top of the barrel being the height to centre line plus half the diameter of the barrel.

Position the barrel about one half of the way into the body and place the tailstock on a surface plate or your equivalent (glass plate or machine table). Calculate the overall height - as mentioned in the last paragraph - and using a height gauge, check the existing height, which (of course) should be greater than the required dimension. I don't have a height gauge, so I made a male gauge to the required dimension from a piece of scrap steel, which I then used in conjunction with a dial indicator (Photo. 2). If you follow this latter method, use a length of steel or brass and machine the bottom end to obtain a flat surface. File the top end and check the length with a micrometer or vernier gauge until you get

the correct reading. If you leave a slight domed surface at the top end, you don't have to worry about keeping the two ends parallel. Repeat the operation with the barrel in the other end of the body. You will probably find that this dimension/reading is different to the first one, but hopefully there is enough metal at both ends to clean up to the finished size. Obviously, the difference between the required figure and the actual dimension is the amount to be removed. This would be done by machining, grinding, filing or scraping, depending on how much there is to be removed, your facilities and your skill. Assuming that all other machining has been done correctly and that the same dimension has been attained at both ends, then the centre-line will be parallel to the base.

Now fit the $\frac{3}{16}$ in. square key in the front end of the body. One end will have a radius filed around to sit in the slotting hole, but don't bother to make the radius a perfect fit. Keep the other end a millimetre or so too long, so that there is enough to file off flush with the nose. The key should be a tight fit in the body keyway, but a sliding fit in the barrel, both on the sides and over the top. It is best to start with the key slightly oversize and file down to get a correct fit. This will possibly mean making a 'stepped' key, but this is an acceptable method.

The assembled tailstock is shown in Fig. 11 in the 'centre ejected' position. If you have only cut the barrel keyway part of the full length, then the barrel is entered from the handwheel end, otherwise it can be entered from either end. Screw the thrust bearing up fully and tighten with a C spanner. Lubricate with an oil feeder through the threaded oil hole and close it with an M4 grub screw. A spring washer and a $\frac{1}{4}$ in. BSF nut will be needed to tighten the handwheel and thrust system. I used a Nylock type nut which makes the spindle end look neat. The handwheel with its thrust pad will now be fitted. Screw the nut down until resistance is felt when turning the handwheel. The thrust bearing will now be in contact with the spindle collar on one side and the thrust pad on the other; hence the requirement for lubrication at these two points.

Photo. 1 is of the completed item with a centre fitted. A locating key has been fitted under the base; this fits into a machine table tee slot to ensure that the centre is in alignment with the indexing unit. This is also shown in Photo. 4 and will be discussed in a future article.

Photo. 4 itself shows all components except for the small Woodruff key. The C spanner was a second-hand one which had been adapted for this job.

References

- Ref. 1. MEW No 31, page 52. A. Bourne. Tailstock for a small lathe.
- Ref. 2. MEW No. 8, page 28. H.M. Turnbull. An economic angle plate.
- Ref. 3. MEW No 14, page 14. D.Winks. Drilling square holes.
- Ref. 4. MEW No 22, page 53. H.Hall. The mathematics of taper turning.

A TILTING COMPOUND TABLE

After setting up his workshop, newcomer to the hobby Geoff Allen decided to embark on a major project. His first effort was greeted by acclaim by the model engineering world so, encouraged by some constructive criticism, he decided to refine this major accessory for milling machine or lathe - and produced another award winner.

My interest in the hobby was stimulated by four months forced rest from work due to spinal surgery. The operation was very successful and left me with no pain but I had to restrict my activities to allow healing.

A good friend of mine, an engineer, invited me to go to some machinery auctions with him and persuaded me to buy a Hembug Lathe with collets, screw threading capability, 3- and 4-jaw chucks and a quick change toolpost, all for £500. We also visited the auctions held on the day after the sales, to go over the unsold and unrepresented items. It was on one of those visits where we bought a very substantial quantity of tooling and equipment, including rotary tables, vices and angle plates for scrap value, i.e. £150.

In my spare time I went round the machinery dealers and bought an ex-aircraft industry jig-borer, covered in rust and bird droppings, non-functional but

basically very sound. A deal was struck for £250 for the jig-borer and an Elliott shaper.

My workshop was now set up and tooling was made for the jig-borer as I had no 2MT equipment to suit. At the end of this I had an excellent workshop with good 3-phase equipment, run by a phase

converter which worked very well, all for a relatively modest outlay.

A few 'how-to' books from friends in the trade introduced me to threading,

1. The versatility of the unit makes the table a valuable attachment for a variety of machine tools.



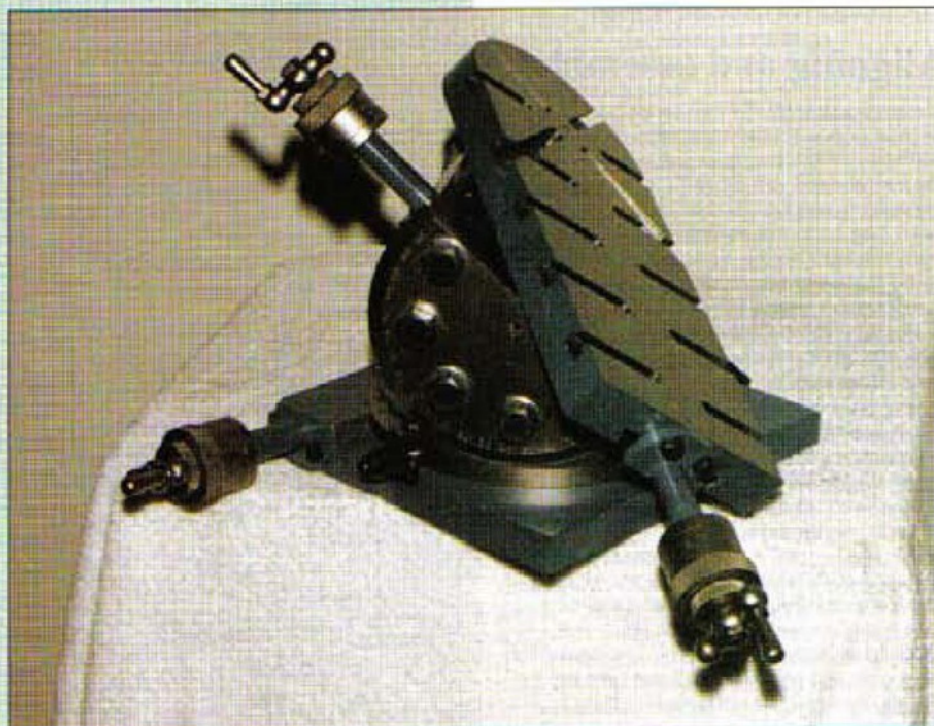
milling

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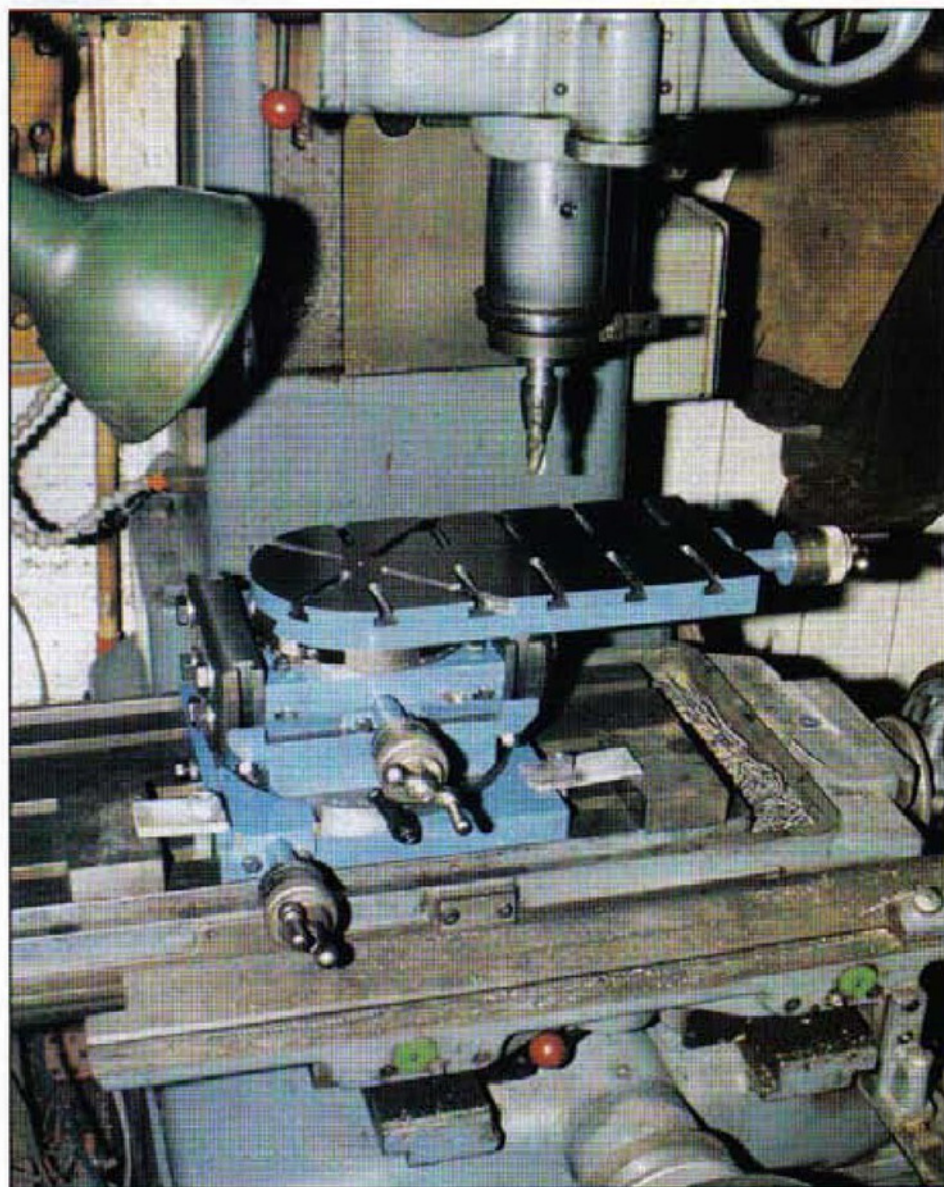
feeds. My birthday arrived and with it came a machine vice and an X - Y vice. They looked good in the catalogue, full of Eastern Promise, so I didn't blame the wife when they arrived. The machine vice was loose in the jaws and frankly useless but luckily there was enough of a base to rework into to a useful item. The X - Y vice was very lightly built, from flimsy castings, and was so poorly made as not to be convertible to a useful tool. I kept it, however, as I decided that I could make a better one myself, so used it as an example of what not to construct. I'd got my first project.

The design concept

I decided it would be more use with a rotary function between the X and Y axes and soon realised its versatility would be greatly increased if whole could be angled to make my jig borer into a very capable miller. Mounted on a rotary table seemed even better. The main problem, as I saw it, was to keep the height of the unit to a minimum, even when fully equipped, so for this reason I decided upon an inverted drum and saddle arrangement. The idea of a vice top was now discarded in favour of a slotted table, thus reducing height and greatly increasing its adaptability. At this stage I had a rough sketch of the basis of



2. The work table can be rotated to optimise accessibility.



3. It is primarily intended for use on larger milling machines. The work table surface has an overall length of 315mm and a width of 140mm.

the idea and so went to a special steel stockholder. After invading his discarded pieces and billet ends and ordering some specifically cut bits, I could start cutting metal.

To reduce depth, I discarded the idea of a worm gear for the upper pivoting table and ensured that the whole bearing surfaces of the various decks were in contact, so that each layer supported the other against distortion and greatly improved the strength of the finished unit.

I devised the build methods described in order to ensure good fits without specific measurements and high accuracy without the skill needed to achieve it! After three years I had finished the job, all marked up and numbered, ready for use.

A model engineer saw the piece and suggested that I exhibit it at one of the major exhibitions. I wasn't too keen, but went along to the International Model Show at Olympia and decided to take up the challenge. Two months later the table was refinished and polished, ready for showing at the National Model Engineering and Modelling Exhibition at

Harrogate in the same year. There, the editor of M.E.W. and other members of the model engineering world expressed great interest and I came away from the exhibition with a First Prize for the first item of work I'd ever produced.

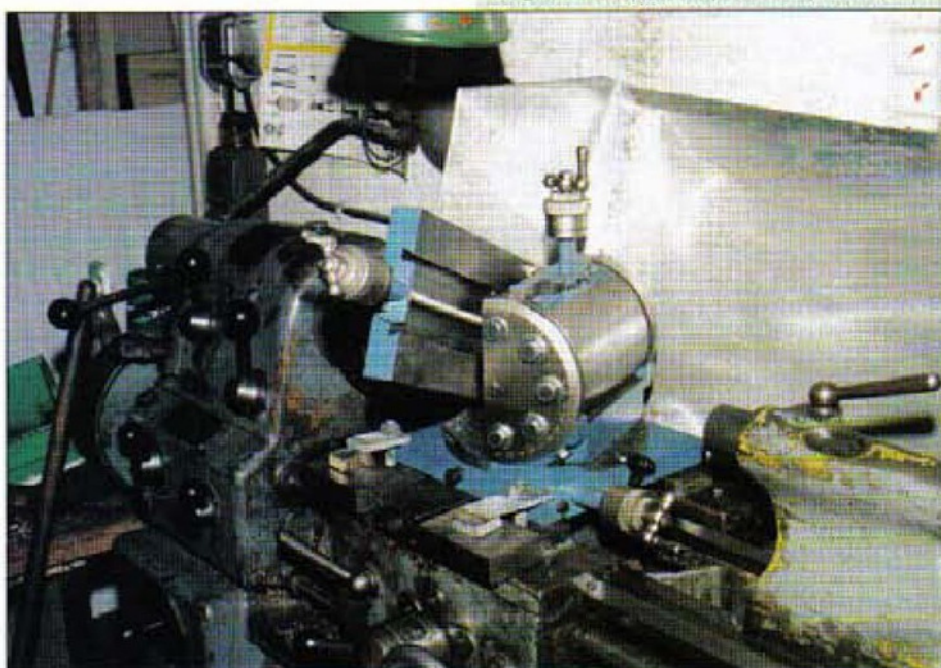
My table and I went on to win a trophy at the Midlands Model Engineering Exhibition and then a Silver Medal and the Bowyer-Lowe Trophy at Olympia, the latter being awarded for the originality of the design. I subsequently entered it into the Duke of Edinburgh Trophy competition, unfortunately without success.

A second bite at the cherry

Good as it was to have such recognition, I felt that some aspects of design of the prototype could be improved upon. It was not easy to centralise the upper table relative to the base and the base rotary table was of weak design. Advice from the experts suggested that, if I were to make another example, cast iron would be a more appropriate material for such an accessory because of its inherent vibration damping characteristics. Accordingly, I made the patterns and had castings made in SG iron.

The worm wheel and gear were redesigned and some layers strengthened, the top ones being altered so that they could be easily lined up to facilitate quick setting to centre. The new version was entered, together with the patterns, at the beginning of last year, at the International Model Show at Olympia. This new design also gained a Silver Medal.

From the time I first exhibited right up to the present, I have found the 'hierarchy' of the hobby, from publishers to judges to very capable engineers very willing to give advice, even though, at the time, I was not a member of any related organisation. I was (and am) completely untrained, have not been to any evening classes, and my engineer's vocabulary is, to say the least,



4. The unit can also be used on larger lathes, the base casting being 220mm square.

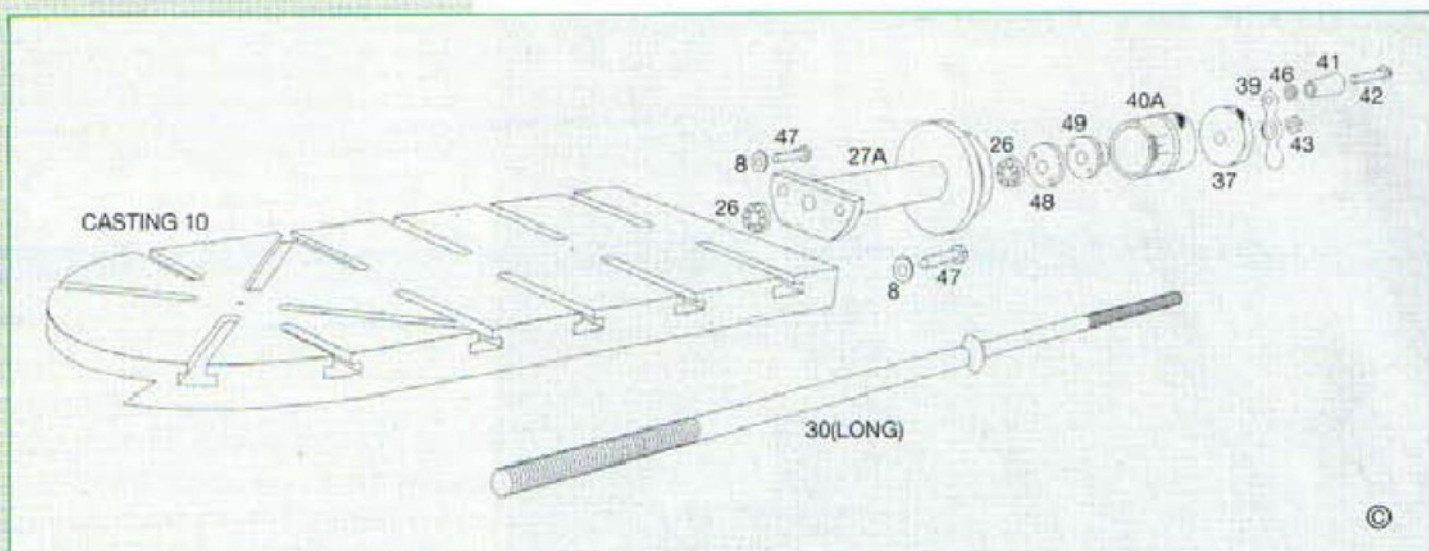


Fig. 1 Slotted Work Table Assembly

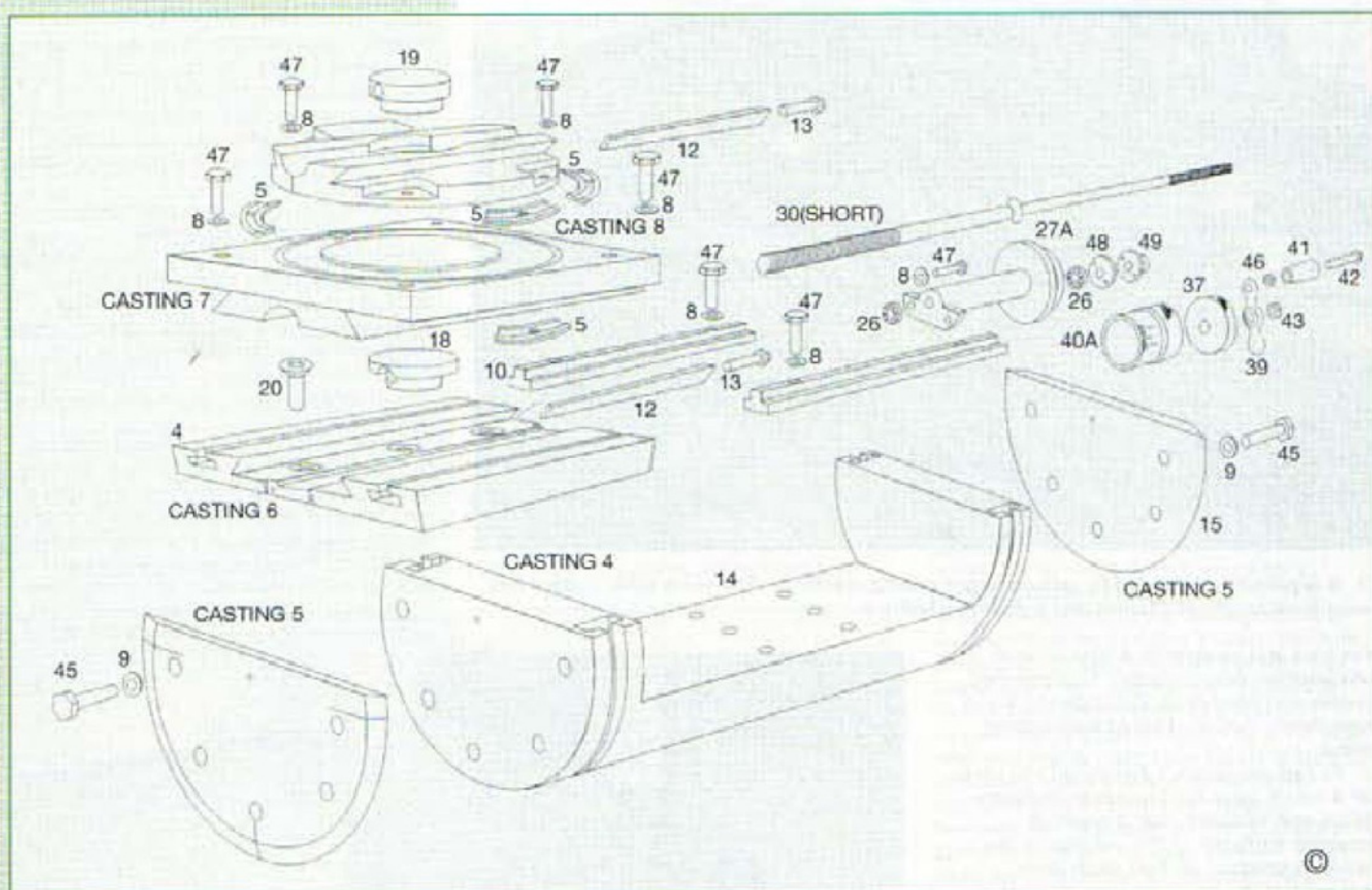


Fig. 2 Tilting and Pivoting X-Y Assembly

limited. Despite all this, I have found no sign of the 'in-crowd' favouritism which exists in many organisations and which deters the newcomers.

When reading these articles, please recognise the above and remember that the words relate to how I constructed the attachment. I'm quite sure there are many very capable and knowledgeable engineers out there who would be able to make the table more efficiently. You're even allowed a quiet titter when you recognise some daft and dangerous method which demonstrates my depth of knowledge of the hobby!

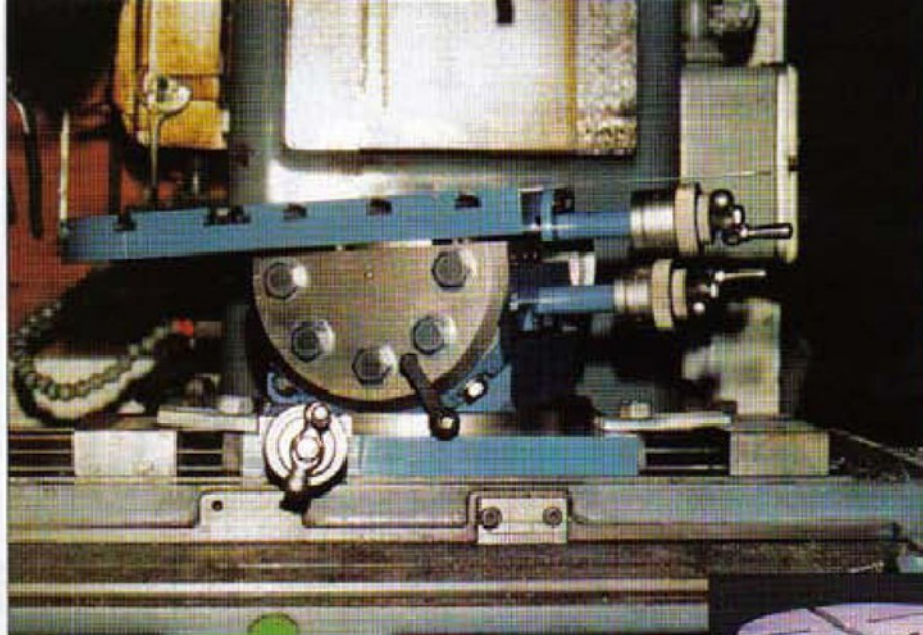
Supply of castings

Having taken the time to produce the drawings and patterns for the castings, it seems a pity not to see them used, so I have made arrangements with a local foundry to make additional castings if any reader would like to have a go at this project. As the foundry is not too keen on getting involved in making the carriage arrangements, I am prepared to act as the go-between, so my address is added to the end of this article. I can also let prospective builders have a full set of

drawings and some further suggestions on methods of machining.

Order of machining

The castings can be machined in two separate groups, either making from the base up to the saddle, or making the top first and then the base to fit. I think that the most accurate method is to make up the Bottom Slide casting (Drawing 4) to fit the mating Rotary Bottom Slide (Drawing 3) which will have been made to fit the rotating component of the Top Slide (Drawing



5. With everything 'set square', the overall height of the unit is approx. 150mm. It is also suitable for use on a substantial pillar drill.

6. The patterns for the casings make an impressive display.



2). The actual slotted Top Slide or work table, of course, matches the latter.

This 'X - Y' assembly can then be mounted on the rotating and tilting assembly which is made to Drawings 14 and 15, 17, 32 and 31. A study of the three isometric drawings (Figs. 1, 2 & 3) should make things a little more clear! Apologies for the apparent confusion in the numbering, but the drawings were completed first, then the patterns numbered in the sequence in which they were made. It was only then that the method of machining was settled, but by using this order of work, the surfaces can be machined in situ, as built up, without the need to relocate each piece, both saving set-up time and maintaining the set accuracy of the equipment used.

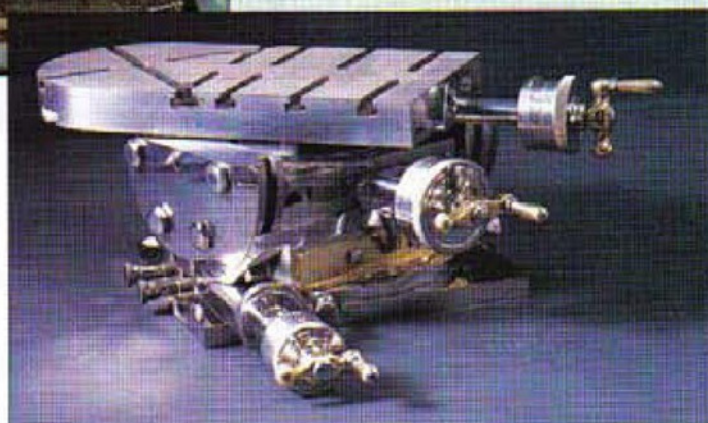
The significant number of ancillary components can be made before or after machining the main castings, according to the maker's wishes. The worm gear assembly and its carrier (Drawings 34, 35, 36 and 38) should be treated as a group.

By carefully selecting the order of machining and assembly it is possible to match the pieces accurately without the need for the strict dimensional precision which would be necessary if

components were being manufactured on a production basis.

In a future article I will make some suggestions as to how to go about machining the major components, from experience gained in making my version.

Supply of castings:- Contact Geoff Allen at Park House, Wortley Park, Sheffield S35 7DE Tel. 0114 2887713



7. The prototype fabricated unit, awarded the Bowyer-Lowe Trophy for its innovative design.

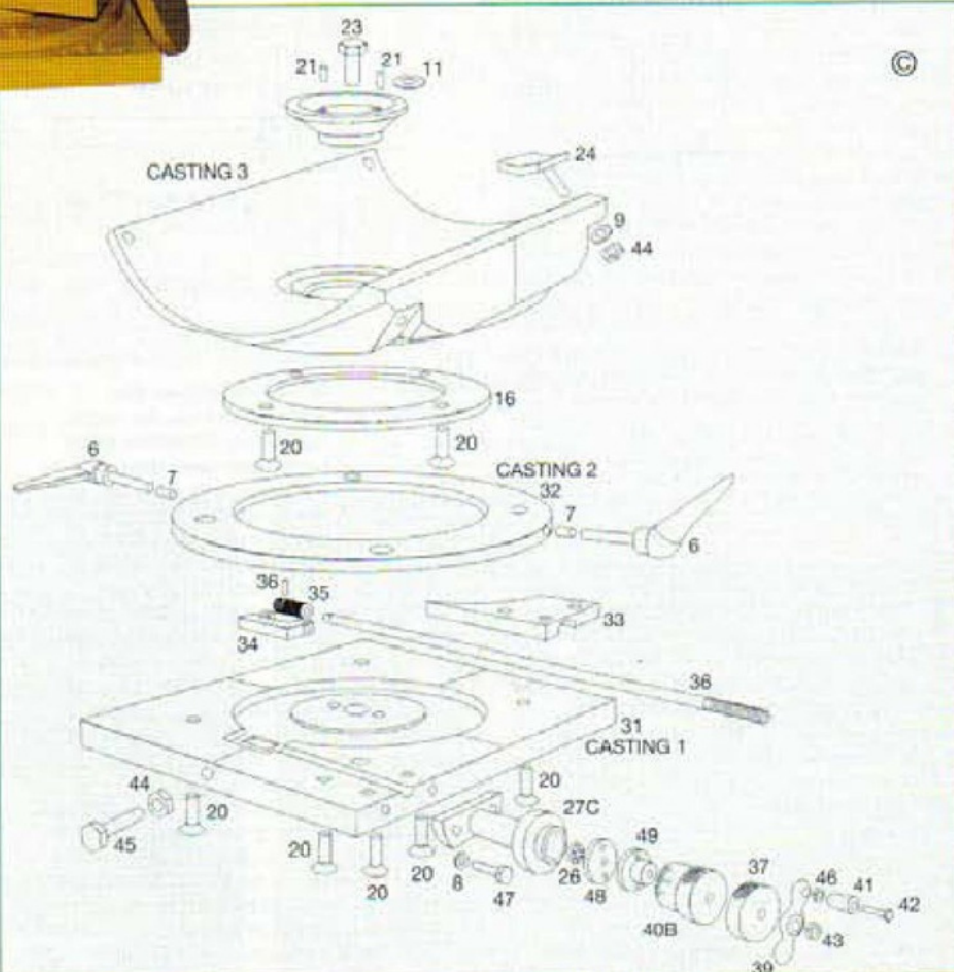
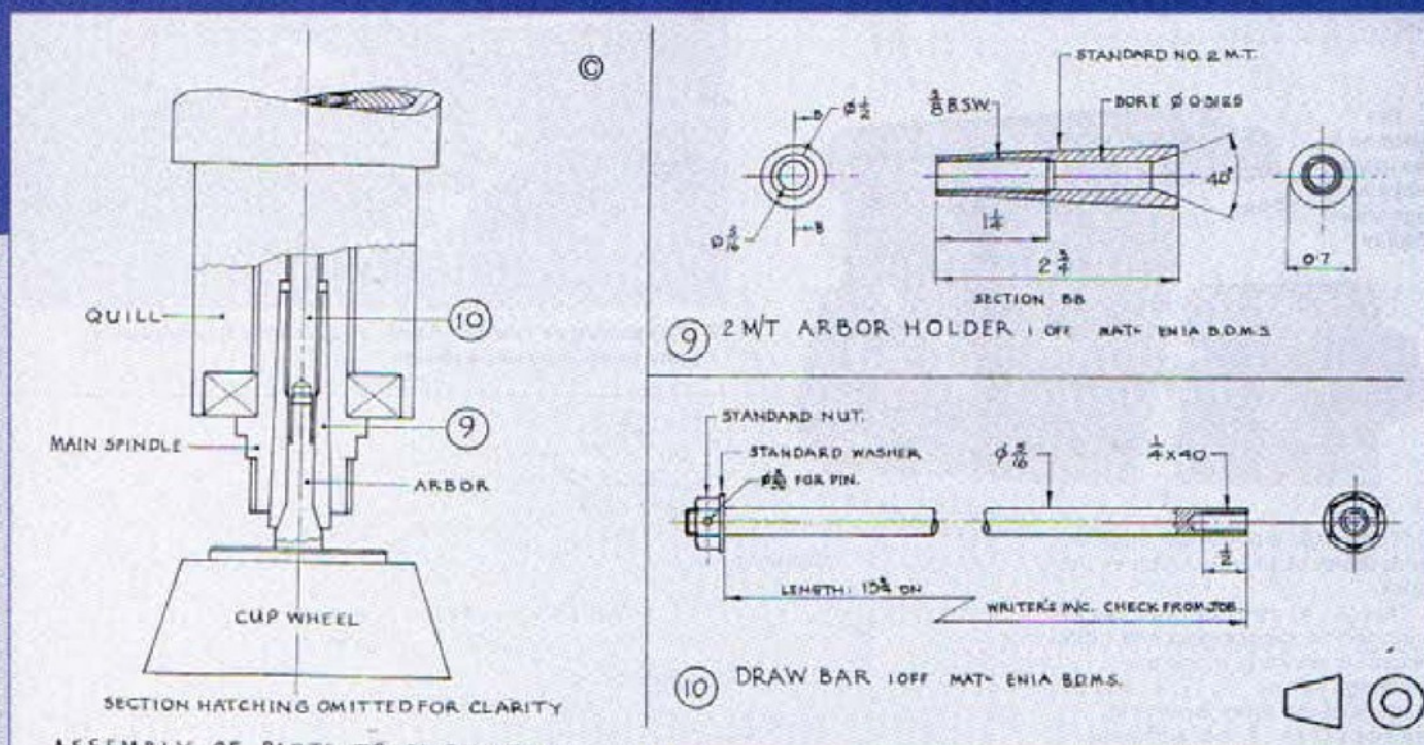


Fig. 3 Rotary Table Assembly

THE VERTICAL MILLER AS A SURFACE GRINDER

In our last issue, David Machin described how he found that the table of his vertical milling machine was no longer flat. A simple adaptation allowed him to correct the problem and also gave him the ability to carry out the occasional surface grinding job



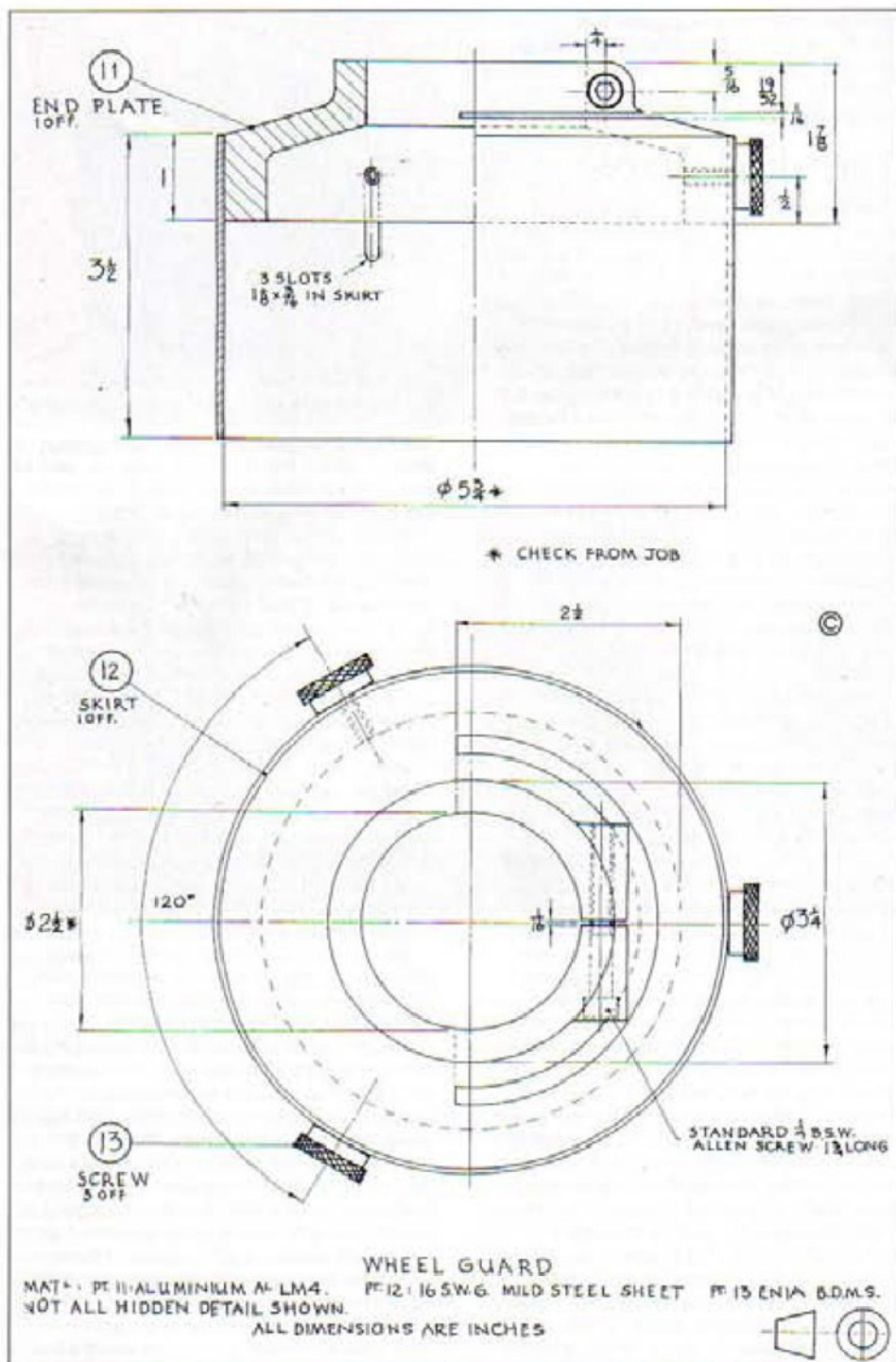
The plan was to use a 3in. cup wheel from my Quorn set-up, but mounted on the miller spindle and driven by the miller's own motor at top speed. This was initially rigged up to see if the traverse of the table was adequate to reach all parts. It was, but not sufficient to clear the wheel. However, since I was starting from a hollow, only the last pass would be a potential problem.

The General Arrangement drawing shows a section through the quill assembly and the parts needed to adapt the fittings of one machine on to the other. The item numbers run in sequence from those described in the previous article. Part 9, called an arbor holder, is simply a No. 2 Morse taper with a standard 3/8 BSW

to suit the Quorn grinding wheel arbors. Part 10 is a specially machined draw bar of 5/16in. dia. but with a 1/4 x 40 internal thread. 5/16in. is a convenient diameter because it will pass through the core of the Whitworth thread. When fitted, this screws over the 1/4 x 40 thread of the Quorn arbor and neatly secures it. Because of the fine thread this cannot be tightened as much as the standard draw bar, but since that has already tightened the arbor holder, this is no problem. Also, the grinding wheel is easily removed for dressing, and the arbor holder can easily be removed by the standard draw bar at the completion of the job.

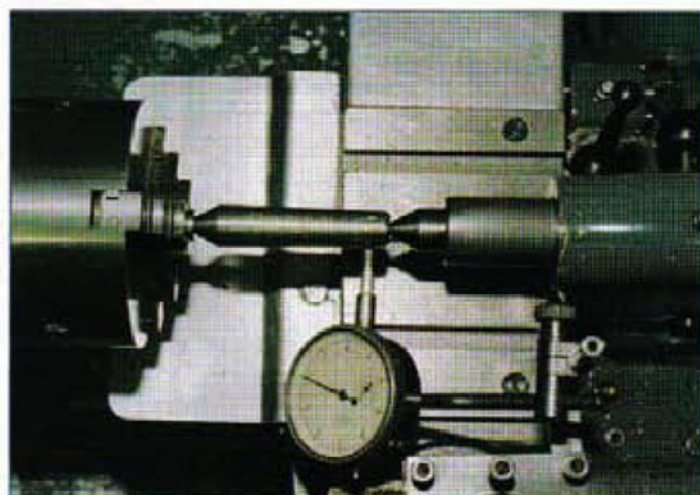
The parts are shown on the detail drawings. The Morse taper on Part 9 was machined after careful setting over of the

cross-slide. A few words on this may be useful, since I believe I have not seen the method which I use - which I find the easiest - discussed in M.E.W., though the method is very well known. I start by checking and adjusting, if necessary, the alignment of the tailstock with the headstock, using the usual test bar between centres, discussed several times in these pages. If you are not familiar with this, I would refer you to your lathe handbook. Next, chuck a stub of mild steel of about 1/2in. dia. in the 3-jaw chuck. Face and centre drill. Fit a centre in the tailstock and mount another centre as shown in **Photo. 1**. Lock the tailstock to the bed and adjust and lock the tailstock barrel to ensure that the middle centre is firmly located. For the sake of accuracy, undamaged and clean centres are essential, of course. Next set up the d.t.i. in the tool post, and bring the stylus exactly to centre height. Set the compound (top) slide to a preliminary setting of about 1 1/2 deg. and partly tighten the screws. Wind in the cross-slide so that the stylus touches



the middle centre as shown and set the d.t.i. dial to zero. Using the compound slide handle, wind the stylus along the centre, from one end to the other. This will show an error, which is then adjusted by small movements of the compound slide swivel base. These movements are so small that I use a small length of wood to gently tap the compound slide. Once an adjustment has been made, the process of traversing the compound slide to test for parallelism has to be repeated. This may take several attempts before the slideway of the compound slide is parallel with the taper, confirmed when there is no variation in the d.t.i. reading. Tighten the adjusting screws, check again, and if all is well, the taper setting equipment can be removed. A suitable piece of bar of about 3/4 in. dia. can then be chucked and the taper machined. Having spent so much time setting up for taper turning, I usually machine a small batch of tapers for future use, leaving various extra lengths of 3/4 in. bar stock to suit whatever requirement I might have, although in the case of the arbor holder, no surplus is needed. It should be noted that the tapped draw bar hole of 3/8 in. BSW should be completed before the taper is parted or sawn from the parent stock. In the case of the arbor holder, it is important to drill and tap 3/8 in. BSW to normal depth, and make no attempt to drill the tapping hole all the way through, as this must be carried out with much greater accuracy at the next stage.

Having completed the taper, the embryo arbor holder may be fitted into the lathe spindle taper directly, making sure that all mating surfaces are really clean. The lathe draw bar, if you have one, may be used to tighten the arbor holder, but this is not essential. A brisk insertion movement will ensure a good wringing fit, just as it does when fitting an ordinary centre. The next stage is to face and centre drill, then drill using a small pilot drill, allowing it to enter the cavity caused by the previous tapping drill. Open this up to, say, 9/32 in. dia., and then, using a small boring tool, bore to exactly 5/16 in. dia. (0.3125 in.) to suit the arbor of the grinding wheel. It is a good plan to make sure that the arbor will actually fit the newly made bore closely and without shake. Finally, set over the compound slide to 20 deg. and bore the taper. All this careful machining should ensure a true running grinding wheel; an essential requirement for the intended



1. Setting the lathe top slide to machine the Morse taper arbor.



2. The new arbor accommodates Quorn grinding wheel arbors which are secured by the new draw bar.



3. The assembled components. The draw bar passes through the Morse taper arbor.

application.

The special draw bar (Part 10) is a simple piece of turnery; the only important points are to ensure that: (a) the end where the $\frac{1}{4} \times 40$ thread is to be machined is checked for true running, using a d.t.i. If there is any doubt about your 3-jaw chuck, use a 4-jaw and adjust carefully for concentricity, before carefully drilling and tapping. This should give a close fit without any possibility of binding caused by an eccentrically tapped hole. (b) The correct length is carefully machined such that the grinding wheel arbor is securely held. One or two threads in engagement is simply not enough! One way of ensuring this is to leave the draw bar a little longer than the measured amount, and after completing the $\frac{1}{4} \times 40$ thread only, assemble the parts in the miller spindle, with the $\frac{1}{4} \times 40$ thread fully home in the grinding wheel arbor. This will leave the other end protruding above the spindle at the top of the headstock. A scriber can then be used to mark the draw bar where it emerges from the top face of the spindle. This end of the bar can then be threaded to the marked point. A washer fitted between nut and spindle top will give just the required clearance to ensure firm and safe hold on the grinding wheel arbor. Note the use of a cross pin to make sure the $\frac{5}{16}$ in. BSF nut doesn't unscrew once positioned. A piece of $\frac{1}{8}$ in. dia. welding rod is quite adequate for this.

Each end may be peined into tiny countersinks in the nut flats, afterwards carefully filing flush to make sure that you can fit the spanner! The completed parts are shown in **Photos. 2 and 3**.

The wheel guard

To ensure safety, I next made a wheel guard. This literally guards against a wheel burst, highly unlikely in view of the wheel speeds being used but, in the interests of safety, very necessary. The consequences of an unguarded wheel burst I leave to your imagination so, I repeat, a guard is a necessity. The drawing shows the details and **Photos. 4 and 5** the finished guard. It is larger than is strictly necessary for the cup wheel, because, looking to the future, I have bought a ring wheel which is intended to be used specially for this kind of grinding work. This wheel and the mild steel casting from which will be machined the mounting plate is shown in **Photo. 6**. These items were originally from a kit of parts for a surface grinder which is no longer marketed, but these items are still available from Model Engineering Services.

Part 11, which I have called an end plate, is an aluminium casting. If anyone would like a casting, I can probably arrange a supplier. Part 11 is secured directly to the quill of the miller by a standard $\frac{1}{4}$ BSW Allen screw via the split lug, and Part 12, the skirt, is secured to Part 11 by three 2BA screws, specially made with large knurled diameters for easy hand tightening. Part 12 is made from 16 SWG mild steel sheet, and has axial slots at 120 deg. for the screws, so that adjustment may be made to the guard height, relative to the grinding wheel. I took a few photos of the making of these parts, as some readers may find a short description useful for similar tasks in the future. It is difficult to produce an exact diameter when rolling up a cylinder from sheet, so make the skirt first. The casting can then be machined to suit. To calculate the size of the development (rectangle) to make the cylinder, first multiply the inside diameter required by π . In this case, 5.75in. dia. $\times 3.14 = 18.055$ in. The cylinder height is 3.5in., so the rectangle measures 18.055 $\times$ 3.5in. The easiest way of forming a cylinder is by using bending rolls as shown in **Photo. 7**, these being made to the Martin Evans design, the drawings for which I believe are still available from M.E. Plans Service. If you do not have a set of rolls, you may find one available at your evening class premises, or it is possible to



4. The completed wheel guard assembly.

machine a block of wood to 5.75in. dia., around which the rectangle may be bent to form the cylinder. In this case, it would be essential to anneal the metal first.

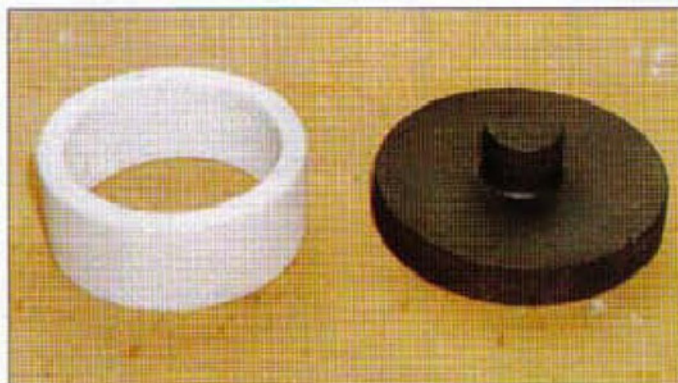
Clean up the joint edges with emery cloth and bring them together by hand bending, so that a good smooth butt joint is obtained. If this distorts the circular form, don't worry as this can be corrected after brazing. Flux and wire up with soft iron binding wire, as shown in **Photo. 8**, placing small pieces of brazing spelter on the joint. Heat up the whole of the cylinder first, so that distortion due to uneven heating is minimised, then concentrate the flame on the joint area and heat to a bright red, at which point the brass spelter will melt and flow into and through the joint. It is a good plan to have a length of $\frac{1}{8}$ in. dia. mild steel rod with a pointed end to act as a persuader if the molten brass will not flow in the required direction.

Next clean up the joint area on both sides with a file so that any excrescences of brass are removed. The cylinder can then be re-rolled to regain the circular form. On my bending roll it is necessary to remove and replace the top roller to do this, and then reverse the process to regain the cylinder! Commercial rolls don't usually have this drawback. **Photo. 9** shows what a two hour immersion in neat Harpic will achieve in removing the black oxidation. Before this discovery, I would spend a long time laboriously removing oxide with files and emery cloth. Heavy oxidation may require a longer soak with intermediate brushings. Note that rust will form quickly after treatment unless preventative action is taken. A word of warning: handle the item to be de-oxidised with rubber gloves, wear eye protection, and rinse thoroughly in clean water before handling with bare fingers.

To complete the skirt, it only remains to



5. Wheelguard components. The slotted holes permit adjustment for variation in wheel depth.



6. A ring grinding wheel and the casting from which its mounting plate will be made.



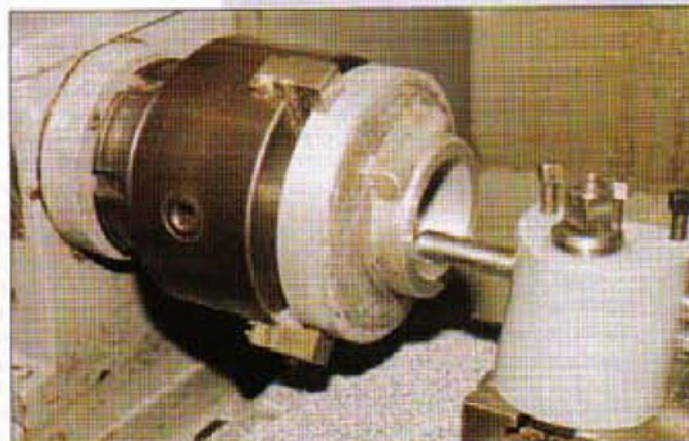
7. Rolling the skirt of the wheel guard.



8. The rolled skirt is secured with iron wire while the brazing operation is carried out.



9. A well-known brand of domestic cleaner makes an effective de-oxidiser!



10. Boring the guard end plate is a second operation.

mark out and cut the slots. An elaborate set-up could be used for this, involving the dividing head mounted on the milling machine, but on the sledge hammer/crack nut principle, I simply marked out, chain drilled and filed the slots. (Chain drilling is producing a row of holes closely spaced). Careful marking out for drilling, so that drilling at a smaller size first and then opening up the holes to a larger size will make filing from one hole to the next a matter of moments. A round needle file will be necessary to do this, and a warding file (a specially thin file for filing the wards on keys) is useful to complete the straight sides of the slot.

The casting can now be machined by gripping by the smaller diameter in the 4-jaw chuck and setting it to run as truly as possible; face and then machine the outer diameter to fit the cylinder. Here we are aiming at an easy slide fit so that adjustment can be readily made as the grinding wheel wears down. You may find, as I did, that the cylinder isn't as perfectly circular as you thought! No matter, the cylinder will be flexible enough to take the form of the more truly circular casting. It is as well, though, to be aware of this when measuring the cylinder prior to machining the casting. Moral: measure the cylinder at several diametral points. Note 1: The bore is not machined at this setting as it is difficult to reach the bore to measure the diameter to bring it to the correct size. Note 2: Sharp-eyed readers will have noticed that Part 11, as drawn, has been modified from the one shown in the photo. This is because the casting I made proved

to be heavier than is really needed. If any castings are requested, I will modify the pattern to conform to the published drawing.

To complete the lathework, grip in the 3-jaw chuck by the newly machined (nominally 5.75in.) diameter, with the boss protruding. The 'external' jaws will be needed here. Face, centre drill, drill and bore to fit the quill of your miller. You will now appreciate that it is much easier to machine and measure the bore at this stage than it would have been earlier. Here a close, push fit is required. If you can measure this, I would suggest a bore diameter equal to quill dia. + 0.003in.

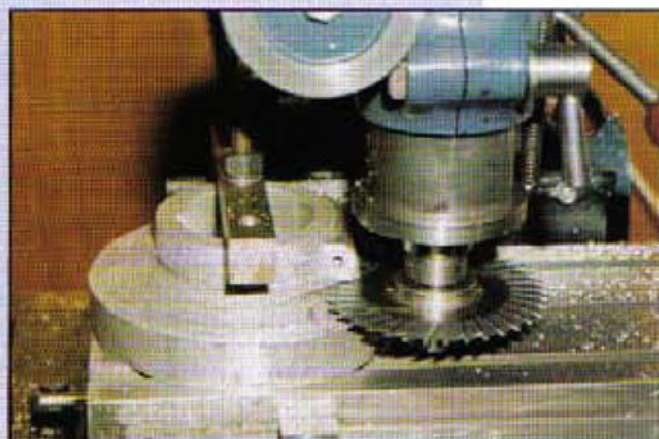
Photo. 10 shows the boring operation. To finish the casting we need a clamping arrangement to (gently) fix the guard to the quill. The method of doing this can be seen on the drawing, a horizontal slot being cut under the lug at a depth just beyond the axial centre line. This can be seen in the front elevation. Referring to the plan view, another slot is cut at right angles through to the bore. This allows the pinch bolt to draw together the now flexible collar, to grip the quill. The operations required to facilitate the above are as follows: First, drill and tap for the pinch screw, whilst the casting is still solid at this point. **Photo. 11** shows the set-up. The edge of the lug should be set vertical, to ensure that the axis of the hole to be drilled will be parallel to the lug. When drilling and tapping has been completed, the clearance hole is drilled down to a depth equal to half the lug length, at which location the slot will be cut later. The

clearance hole is counterbored for the head of the Allen screw, the photo actually showing the flat bottoming of this counterbore - a first use of the facility to use drills of differing length without losing the setting, thanks to the keyway!

Photo. 12 shows the slotting being



11. The new triangular key arrangement rapidly proved its worth when forming the tapped hole for the clamping screw.



12. Although not of sufficient size to complete this operation, a slitting saw provided a good start.

started. The slot couldn't be taken to full depth since the slitting saw is only 4in. dia., so it had to be finished by sawing, as shown in **Photo. 13**. Of course, it could all be done this way, but it is helpful to have a machine start. **Photo. 14** shows the final slot being machined.

The tapped holes for securing the cylinder need to be carefully marked through from the slots in that component. Drilling and tapping is a simple matter, but it is important ensure that the holes are square to the casting, so that the screws will be flush to the cylinder and not at an angle. The screws, Part 13, are an easy turning exercise and require no comment from me.



13. Completion was by less sophisticated means!



15. Slight over-kill perhaps, but protection of machine ways from grinding dust is always a wise precaution.

Setting up for grinding

Having secured safe working practice I could now, at last, attempt the grinding. First a few preliminaries:- The headstock was set as truly vertical as possible. For this I grip the d.t.i. in a drill chuck mounted in the miller spindle, so that the stylus will sweep a large arc over the table and can then

show any setting error. The headstock is then adjusted accordingly. When contemplating grinding the table, I feared that grinding dust, which could contain grinding wheel particles, could ruin the slideways and tube/column sliding surfaces. To try to overcome this, I used newspaper and adhesive tape to cover these items. These precautions can be seen in **Photo. 15**. As I later found, this was probably not necessary because the wheel was dressed on the Quorn, thus leaving grinding wheel dust behind on that machine. Grinding the table only produced iron dust on the miller. However, the dust was very fine, and a mask was essential.

Now to the actual grinding. With the cup wheel fitted to the miller, the machine was set to its top speed of 1500 rpm and, using the micrometer down feed, 'cuts' of

0.0005in. were taken each time. This may seem a small amount, but in grinding terms it is a standard cut. Trying to take more would stall the motor. Since I was using the miller as a surface grinder, the table feedscrew had to be wound at quite a speed. I found it necessary to re-dress the wheel on the Quorn after each pass.

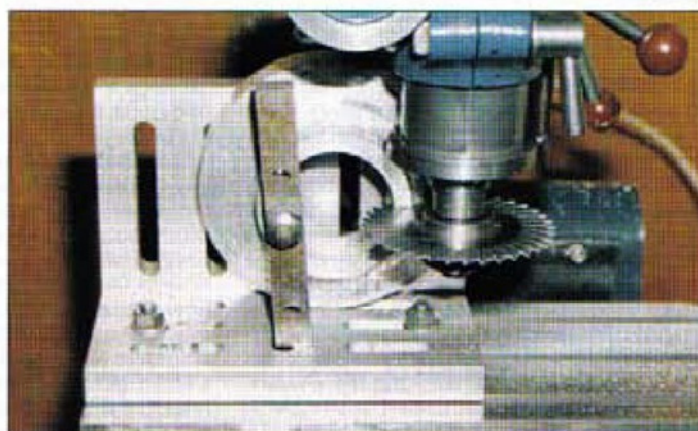
Each time, the procedure was to carefully and gently feed down the wheel until it just touched the highest spot. As the table was hollow, it could then be positioned so that the wheel was central, and for all but the last cut, the start of the cut made without actually touching the table, as already mentioned. However, I needn't have worried because, when the last cut was completed and the wheel positioned at one corner, I merely switched off the motor and let the spindle come to a stop. It did leave extra grinding wheel marks, but on testing the truth of the table, the d.t.i. showed no deviation at this point, or at any other, so I was pleased that the gamble had paid off.

Photo. 16 was taken to show the set-up without the guard, though it should be emphasised that the guard must be fitted before attempting to run the wheel.

On testing the accuracy of the keyway system with the newly ground table, I found that this was now 0.00025in. in 5 1/2in. Much better, and worth all the trouble.

My thanks again to the three gentlemen who inspired the keyway modification.

Model Engineering Services, Pipworth Farm, Pipworth Lane, Eckington, Sheffield S21 4EY.



14. A return to the angle plate set-up allowed the final cut to be taken.



16. Surface grinding restores the machine bed to acceptable flatness.

MODEL ENGINEER EXHIBITION NEWS

Following the announcement of the re-launch of the Model Engineer Exhibition as a separate entity, there has been a most encouraging response from the model engineering trade. At the time of going to press, the majority of the space allocated for trade stands has either been booked or is in the final stages of negotiation. The current list of firm bookings include the organisations shown in the box below.

The Model Engineer Exhibition will take place at the Sandown Park Exhibition Centre, Esher, Surrey from Friday 29th December 2000 to Monday 1st January 2001.

The centre piece of the Exhibition will, as always be the competition for the magnificent collection of trophies donated over the years by friends of the Exhibition and for the medals and certificates awarded in each class. The list of classes has been revised this year because the Military Modelling Section, the Space, Science Fiction and Fantasy Section and some of the Aircraft classes will be judged at their own exhibitions.

Individual Loan Section exhibits are more than welcome to augment the displays put on by our friends from the various Clubs and Societies. A list of

classes and an entry form for both Competition and Loan Sections are published on pages 58 and 59 of this magazine. Photocopied entry forms are accepted if readers do not wish to remove pages.

As usual, the organisers are planning to stage demonstrations of a variety of related and interesting activities, with experts in each field on hand to answer visitor's queries.

Advance booking forms for tickets will be available in the near future, with significant discounts available on tickets purchased before the event.

AB Tools
Bidwells
Brimarc
Carpenter & Howlett
Chronos Limited
Classic Clock Kits
Compass House Tools
Peter Dunk
EKP Supplies
HD Tools

Hobby Ltd
JB Tools
Key Solar Systems
LA Services
LB Restoration
Maxitrak
Myford
Paper 'n' Steam
Phoenix Promotions
Overlander

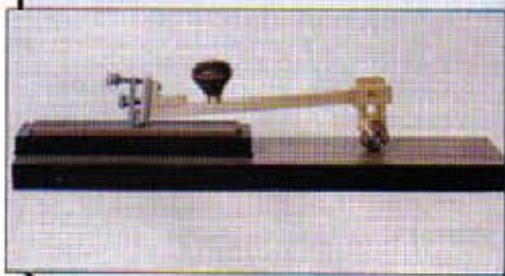
Railway Correspondence &
Travel Society
RDG Tools
Shesto
Starkie & Starkie
Tools 2000 (Expo Drills)
Toolstop
Tracy Tools
Warco
Wilmington Engineering

IN OUR NEXT ISSUE

Coming up in Issue No. 69 will be

A HONING JIG

Designed specifically for restoring the edge of carbide tool tips, this ingenious device was created by Derek Winks

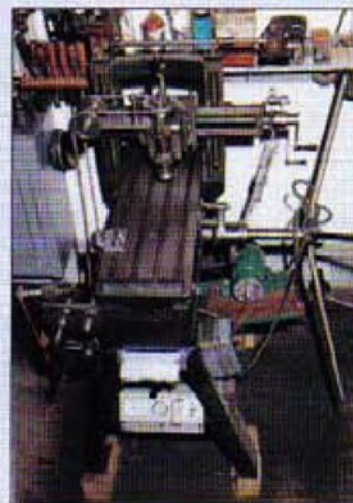


CNC MILLING

Peter Rawlinson explains how he adapted his home-built CNC milling machine to operate under the control of a 'G-code' system

LIFE WITH A PLANING MACHINE

A scrap-yard discovery is resuscitated by Jack Frazer



Issue on sale 27th October 2000

(Contents may be changed)

SPARK ERODER DIELECTRIC

Peter Rawlinson brings news of a product which he believes to be very suitable for use in the home workshop environment and suggests a design for a suitable filtration system.

As readers who take an interest in the more unusual home workshop processes will probably remember, about a year ago I wrote two articles on spark eroders followed by some further thoughts and ideas. These included, among other things, the dielectric which is required to make the whole system work. I am sure that you will remember that I had tried paraffin, water and, later a 5% standard suds solution, and also at this time I mentioned some of the problems that could be encountered due to the toxicity of a number of the purpose-made liquids.

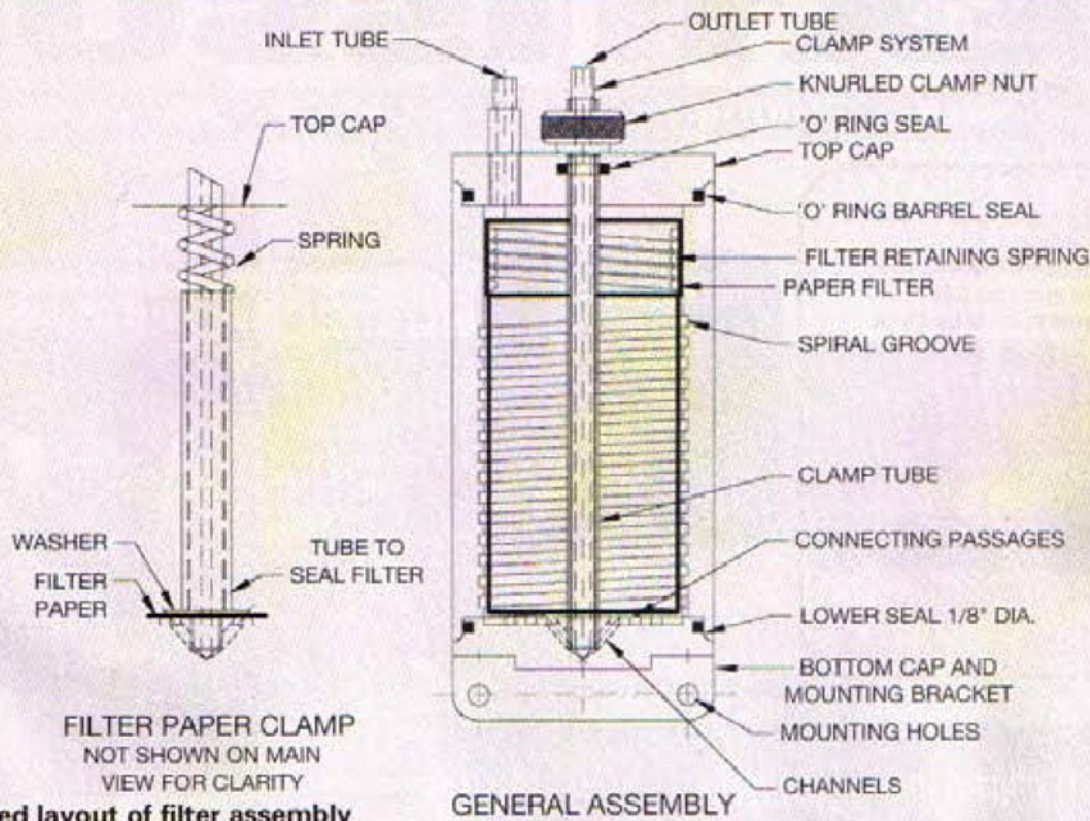
About five months ago, a large envelope dropped through the letter box from Adrian Mounsdon, a gentleman with whom I have corresponded before. It seems that he had recently visited the MACH 2000 machine tool exhibition at the National Exhibition Centre at Birmingham and he had found

the stand of a company called Oel-Held (UK) Ltd. of particular interest. He thought that one of their products may be of use to readers who may be using or contemplating building spark erosion machines, so brought it to my attention. I am most grateful for the literature which arrived in the envelope and for the trouble he has taken to send them to me.

What caught Adrian's eye was a fluid made by Oel-Held called IONOPLUS-Dielectric IME-MH, a fluid which seems to have none of the usual drawbacks and is offered at a price does not make its use impossible in the home workshop as it costs only about £1.80 per litre (plus, of course, the dreaded VAT). As we only use a small amount, it would only be like buying a couple of gallons of petrol, and as it is quoted as having a life in industrial applications of approximately five years, it



1. The completed filter assembly.





2. The fluid transfer passage was formed by screwcutting.



3. Grooves in the base transfer the fluid to the central outlet tube assembly.

should last us even longer, our requirement usually being small and infrequent. The minimum quantity available is 25 litres, but if the costs were to be shared, perhaps between a number of members then the outlay would be reasonable.

The company concerned also offers many similar products for the industrial sector, for such processes as milling, grinding, wire EDM, lapping and drilling. One of their publications 'Important Facts About Spark Erosion' covers in very great depth the whole subject of spark erosion and filtration, including twin pump filtration systems. I have been given permission to use some of the material from this brochure, but this I have done very sparingly because most of the information is related to applications which are somewhat in excess of our requirements. For those interested, I have included their address at the end of the article.

Experience with IONOPLUS-Dielectric IME-MH

I have now had the opportunity of using this dielectric and the worst job was the cleaning out of the old suds-based dielectric which I have been using. This proved to be no mean task, especially where the pump and pipe work were concerned. The dielectric is a most outstanding colour which, being far from artistic, I find difficult to describe. It is a light lemon yellow with a metallic sheen (the manufacturers call it fluorescent) but it is really the performance that matters, and I have not been able to fault it on the occasions when I have used it. It seems to be considerably safer than other fluids encountered.

My trials to date have used the dielectric without filtration, only putting a powerful magnet in the tank, immediately under the pump inlet. Of course, it is of paramount importance to have the dielectric cleaned before it is re-used, and the manufacturer's brochure covers this topic fully. In the past I have had time to put the contaminated fluid in a tall, narrow bottle and in a few days the particulates settle out of the

liquid. However, this method is still wasteful of liquid and does take time.

Filtration

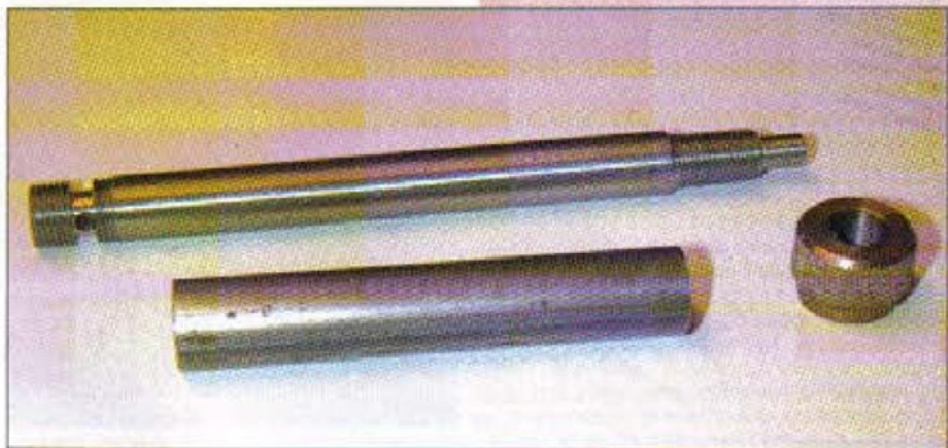
I am in the process of developing a filter system which I feel will be possible to make in the amateur's workshop and within a sensible budget. Where as the Brochure suggests the use of paper or special filters, I thought that these could prove to be too expensive, so I have been looking at the use of standard coffee filter papers as they have a good filtration capability. Another option would be to use car oil filters as they are easy to obtain and, being made in huge quantities, are relatively cheap, and of course it is possible to obtain a suitable mounting unit from a car breaker's yard (some are readily removable, but others are built into the engine block.) The drawback is that I think that they would soon clog and need replacing, negating the price advantage.

The ideal solution is to use a metallic filter which is cleanable, but again we encounter prohibitive cost, so its back to the coffee filter type. In my installation, the tank, pump and electrode are all located on the same basic level on the machine, and it would seem that the best solution would be to put the filter after the pump and before the electrode. Although this is not ideal as the contaminated fluid still passes through the pump before it is cleaned, it does allow the pump to force



4. An internal spring holds the filter paper against the upper wall of the housing.

the fluid through the filter under pressure. If a pump similar to a standard suds pump is used, as suggested in a previous article, then there will be little harm done and there will still be enough pressure to operate the dielectric delivery system. My trials so far with the coffee filters although not finalised have been successful.



5. Components of the central tube.



6. The central tube fitted to the base.

A filter housing

As the filter is now pressurised, it will be necessary to build a small container and I would suggest that this takes the form of a vertically mounted tube with removable end caps, each cap being fitted with a pipe connection to suit (Photo. 1). I use the silicone tube sold for use in the fuel delivery systems of model aircraft, as this is very flexible and impervious to most liquids.

The lower section of the container requires something like a series of internal grooves which will allow an optimum area of the filter paper to be used. However producing these seemed to require an inordinate amount of work, so I ended up screw cutting an internal groove (Photo. 2). An alternative method would be to wind a spring out of something like 1.2mm dia. wire, with 1mm between coils, the outside diameter being a few millimetres larger in diameter than the bore of the container. This, slid into the container, would hold itself in place. With either method, when the filter is placed inside, there is a spiral path for the fluid to follow to the bottom once it has been pressed through the paper.

A similar device is also required on the bottom of the container, but this can be produced on the lathe, creating a series of interconnecting grooves (Photo. 3).

The screw cutting method of producing the spiral is by far the simpler as long as a suitable lathe is available. It must be carried out only, say, half-way up the length of the container as it is necessary to seal the outer surface of the filter paper at the top to the inside of the container. This I did by winding a further spring out of 1.2mm dia. wire so that, when fitted, it pressed the paper close against the side wall in the plain section (Photo. 4). Other ways are, of course, possible and if the wall thickness is adequate then the filter paper could be trapped between the cap and the tube end.



7. The top cap showing the seal groove.

The drawing shows my second design of filter housing which includes a feature which allows the inlet and outlet connections to be at the same end. This requires the use of a seal, but these will be needed anyway and simply consist of standard 'O'-rings of the appropriate size. The tube up the middle, as well as being used as the outlet pipe also holds the end caps in place and therefore removes the need to screw cut the container to attach the caps. Additionally it acts as a guide for the outer tube and spring which are fitted to hold the lower end of the filter paper in position, thus avoiding leaks from inlet to outlet (Photos. 5 & 6).

Inserting the filter paper must be done carefully to avoid tearing it. A large washer fitted under the foot of the central tube would help here.

Photo. 7 shows that, in my revised version, I used an alternative design for the end cap arrangement which allowed the use of a thinner wall tube for the container and made for simpler groove machining, the seal now being on the outside of the end caps, so a simple parting tool could be used.

The 'O'-rings can be made up from the cord material, cutting to length and joining with super glue. I have found that the best way of bringing the ends together is to use a right angle guide and to align them.



8. The filter paper is shaped over a former.

More often than not, the 'O'-ring sticks to the guide, but as long as an excess of adhesive has not been used, I have found that it peels away without problems. The small ring for the central tube is probably best purchased, as the small diameter and length of the material makes it most difficult to hold and fit together with any degree of accuracy.

I have found that the filter paper is best shaped over a male former (Photo. 8) which is made from a piece of material which is slightly smaller than the bore of the container. One end has a central tapped hole equal in diameter to the central shaft. Mine was made from a piece of 40mm dia. nylon rod, turned down and tapped to suit a coarse thread 3/8in. screw with a steel washer.

By first punching a hole in the centre of the paper and then securing it to the end of the former with the screw and washer, it is clamped in position while the rest of the paper is carefully bent over and down the former. By folding neatly, it is possible to maintain a maximum of treble thickness, the resulting cup being cut to length and fitted into the housing, with the clamp spring fitted. The top edge of the cup may be sealed, while on the former, with a very narrow strip of Sellotape, but care is needed as the edge must be able to expand under the pressure of the clamp spring. This spring is not that easy to fit and I found that a maximum length of the order of 2 1/2 turns was advisable.

System pressure

The pressures generated by the type of pump I have suggested are quite small and not likely to exceed 5 psi although, in theory, much higher pressures are possible. In the past, using a single stage 300 gallon a minute pump, I have measured 12 psi, and multi-stage centrifugal pumps are used to feed water against boiler pressure. If you do have a worry that not enough pressure is being generated in your system and you do not have a suitable gauge to check it, simply attach a long flexible tube (say 12ft.) to the pump outlet and fill the system with water. With the pump running, hold the end up in the air and continue to raise it until the flow stops. Measure the height of the end above the pump in feet and divide by 2.2 to find the pressure in psi. For example:- measured height 8ft. 6in. divided by 2.2 equals 3.86 psi. The pressures through your system will depend on the diameters of pipe used and the height of suction, but if a suds type pump is used, immersed in the reservoir tank, then this will not affect the pressure.

Although my system has now been in use for some while without problems, it is not yet possible to say how often it will be necessary to change the filter paper. However, the ones I am using cost about 85 pence for a packet of 40, so are cheap to replace.

I hope that the foregoing is of interest and, as usual, I am at the end of the telephone (01233 712158) if I can be of help.

Supplier:- Oel-Held (UK) Ltd., Unit 16 Colomendy Business Park, Rhyl Road, Denbigh. LL16 5TA. Tel. 01745 814777 Fax. 01745 813222 Email oelheld@hotmail.co.uk



Lathe projects for beginners (2)

Following the introductory article in Issue 67, Harold Hall gives step by step instructions on the machining of the major component of the mini surface gauge which forms the first project

Having gone into so much general detail in the last issue, let us now get down to some actual project work. All the drawings for the mini surface gauge were published in the last issue, together with Photos 1 to 3 and sketch Sk 1. However, for those who may have missed that issue, the drawing of the Base, the first component to be machined, is reproduced here.

Base (Item 5)

This, requiring the material to be reduced in diameter from 40mm to 12mm over a length of 55mm, gives plenty of scope to experiment with differing speeds, feeds and depth of cut. Whilst differing tools could be tried, this would over-complicate the issue, so carry out the operation with the knife tool of your choice (replaceable tip for preference, high speed steel or brazed tungsten carbide).

First, cut a 77mm length of 40mm dia. material, trying to keep the cut end as square as is possible, something I must admit to finding difficult if using a hand-held saw. Place this in the 3-jaw chuck, (the 4-jaw is, of course, always an alternative when chucking round stock, so I will not continue to quote the option), fitting the reverse jaws, as described in Issue 67, if the diameter is too large for the normal jaws.

A very important fact will immediately become obvious. With the normal jaws the length of grip will be much greater than that exerted by the reverse jaws; typically, if the work piece enters the chuck body,

around 30mm, but if larger than the through hole, still by about 16mm. The steps in the reverse jaws will grip only around 8mm, thus limiting the length of material that can be safely held without additional support. As a guide, keep to a length no more than equal to the material diameter, rather less at the larger diameters. There are some situations where the length can be increased, as we shall see.

The sawn ends are likely to be out of square with the axis, so if one of these is held firmly against the jaw treads (for want of another description I am using the stairway terms of treads and risers) whilst the chuck is tightened, then the outer end of the bar will not run true because the limited length of grip of the riser will have minimal effect in pulling the bar into line. Therefore, tighten the chuck only just enough to grip the part without falling out, rotate the chuck by hand and ease the outer end until it is running reasonably true. Rotate the part against the end of a blunt object such as a piece of wood mounted on the top slide, advancing the cross-slide slowly to reduce the gap as the chuck is rotated by hand. A piece of white card located behind the gap will aid visibility (useful in many situations) while the part is adjusted to run true. The chuck can now be fully tightened, followed by a final check on concentricity.

UNDER NO CIRCUMSTANCES, attempt this process with the lathe running, even slowly. **Photo. 4** shows this having been done though the photograph was taken after the end had also been centre drilled.

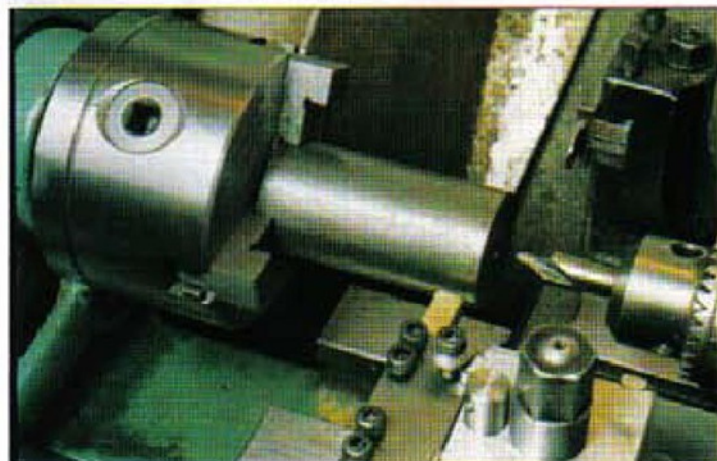


Centre drilling

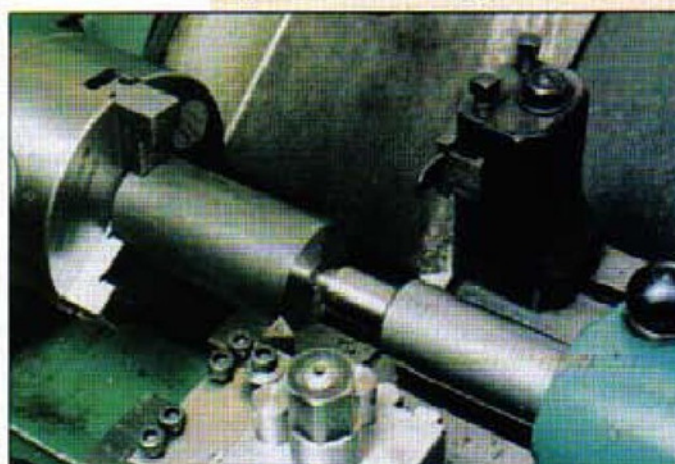
The part is now ready for centre drilling, in preparation for supporting with the tailstock centre. With the part running at about 1000 rpm and using a 1/4in. dia. (BS3) centre drill, drill to 5mm diameter. Extreme caution is always recommended at this stage as it is possible, if the part is running a little off-centre, for the out-of-balance forces to throw the part from the chuck as it runs up to speed. Hence the recommendation to limit the projection of the workpiece, even for this task. Of course, running the lathe at a somewhat slower speed is one way of helping to avoid any problem.

Facing an end

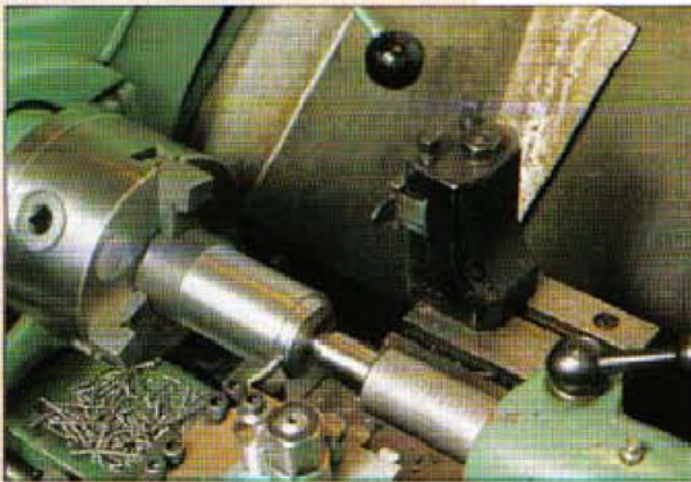
The task is now to face the outer end of the part while it is supported by the tailstock centre. Make sure that it is the hard centre that is fitted and apply a drop of oil to its tip. Advanced it to engage the centre



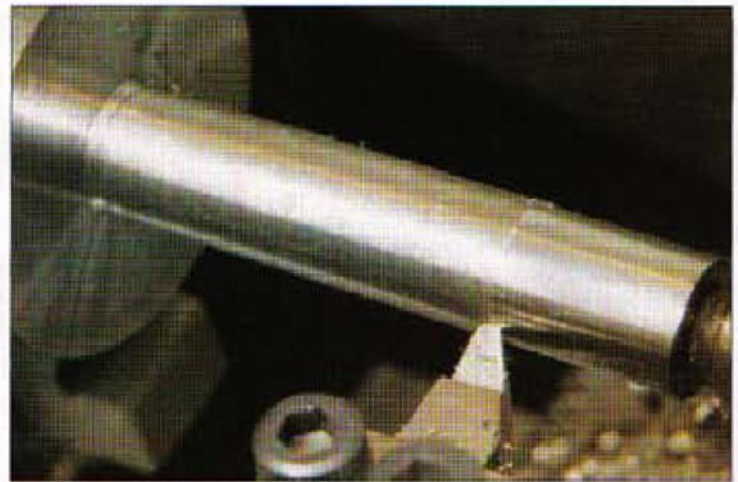
4. Advancing the cross slide slowly, with a small piece of wood in the tool holder, eases the workpiece to run true as the lathe is TURNED BY HAND. The chuck is initially only lightly tightened.



5. When working with this length of workpiece, the outer end must be supported, either with the tailstock centre or with a fixed steady.



6. There is plenty of material to remove, providing opportunities to experiment with speed, depth of cut and feed rate.



7. Using a tool with a radiused end and a sharp edge will result in a good finish.

drilling until resistance is felt, then lock the barrel of the tailstock. When using the tailstock centre, it is often necessary to re-set the tailstock occasionally, as the heat generated expands the work piece. With so little machining necessary on this occasion, this should not be a requirement.

Using the chosen knife tool, face the end as close to the centre as is possible. Unless you use a half centre, no matter which form of tool is used, it will not be possible to get right into the centre drilled impression, but, as we shall see shortly, this is unlikely to be a problem in this instance. **Photo. 5** shows the operation. Whilst it has been said that any form of knife tool can be used there are subtle differences of which to take note. The 'conventional' knife tool has a top rake (**) which limits its use to cutting with its left edge is when fed right to left. Used for facing, it will be fed perpendicular to the part's axis, so the cutting edge must be set at a slight angle, with the tip closer to the chuck. With the tool set like this, start at the centre of the work piece, applying a depth of cut (right to left) of say 0.05mm, and face the end by winding the cross-slide towards you. In this way the tool will cut on its intended cutting edge. There are few hard and fast rules in this activity, and if the tool were fed in the reverse direction, it would cut, though almost certainly producing an inferior finish. A replaceable tip cutter is likely to have a top rake that permits it to cut on all its sides and on the radiused corners, so it will cut quite adequately whilst being fed towards the centre, cuts 0.5mm wide being quite feasible. Many of the methods used in the past with the tools of the day are no longer appropriate with the more adaptable form of cutting edge found on today's replaceable tipped tools.

Reducing the diameter

With the first end now surfaced, albeit not fully to the centre, the part can be removed and fitted the other way round. The smooth square end can be held against the 'treads' of the jaws prior to tightening, the unfinished centre portion sitting within the opening at the centre. This time the work piece should run adequately true without further adjustment, and can be similarly centre drilled. As some lengthy turning operations are to be undertaken, this time centre drill to 8mm, so as to give a larger bearing surface for the tailstock centre. This

will require a larger centre drill, of course, a BS5 ($\frac{7}{16}$ in. dia), but a BS4 ($\frac{5}{16}$ in. dia) will probably suffice. Again lubricate and adjust the centre as described but, this time, with a lot of metal to be removed the temperature is likely to rise causing things to expand, thus increasing the pressure of the centre in the centred end. It will be necessary therefore to release the centre and readjust it periodically (between cuts, not while a cut is being taken).

With the part properly chucked and supported, a start can be made on reducing the outer diameter to 12mm over a length sufficient to give a base depth of 21mm, experimenting with differing speeds, depths of cut and rates of feed during the process. With the machine running at 300 rpm, or thereabouts, take a first cut of 1mm depth, hand feeding at a rate at which you feel at home. Do this for experience, even if your lathe is equipped with automatic fine feed. There are no hard and fast rules regarding speeds, feeds and depth of cut. What works, works, but so do many other combinations.

Follow with cuts of 1.5mm and 2mm depth. If your lathe is sound, then more than 2mm should be possible, but stick to this maximum at this stage (**see Photo. 6**).

Continue reducing the diameter but, whilst speeds are not as critical as some lists would have one believe, 300 rpm will seem to be on the slow side as the diameter reduces. Theoretically, one should attempt to keep the surface speed constant at all diameters, so at half the diameter double the speed. Therefore, at about 20mm diameter, increase to 600 rpm and approaching 12mm to 1000 rpm. If for any reason, you feel these speeds are high, run the lathe slower, but try to increase the speed in approximate proportion as the diameter reduces.

Finishing cuts

When the diameter reaches 12.3mm change to the finishing tool shown in **Sk 2** and

Photo. 7. This is used to take cuts of no more than 0.05mm and can take very fine cuts if honed to a fine edge. The significant aspect of this tool is that whilst it is fed along the lathe axis, as with a knife tool, the top rake runs from front to back. Other writers will suggest other favourite tools to acquire a good finish but, when finishing to a very precise diameter, this tool takes

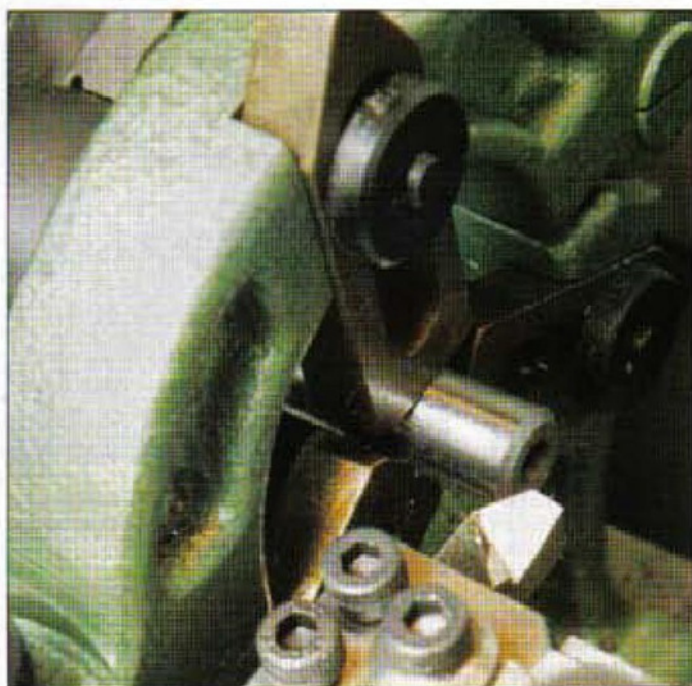
some beating.

Producing the 'finishing tool'

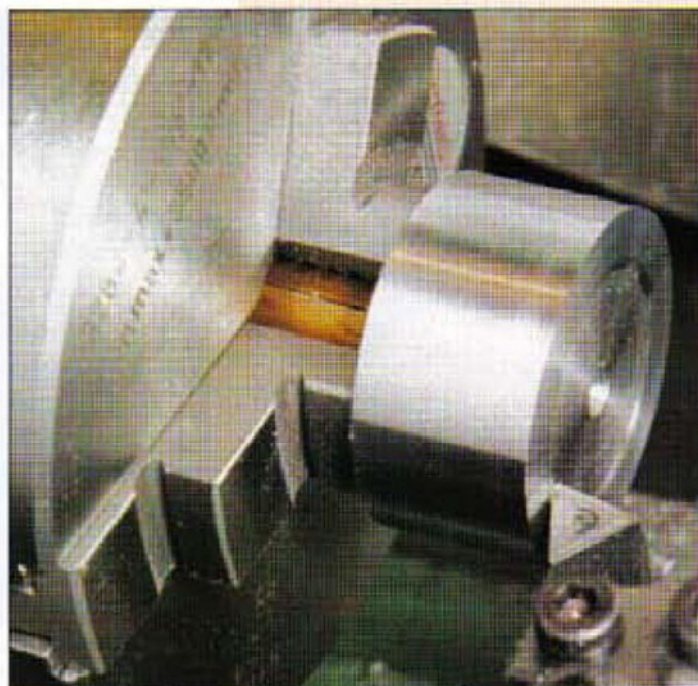
Shaping the tool is simple, as there are no clearance angles on either side, only on the front edge, with front to back rake on the top. **Photo. 8** shows the front edge being finished on the side of the wheel (use the side of the wheel for light grinding only) using the 'Hart' grinding rest (Ref. 1) with another of my additions to this useful off-hand grinder accessory,



8. Shaping the end of the tool shown in **Photo. 7.** An adjustable tool rest such as this will give much better results than unaided free hand grinding.



9. A fixed steady is an essential accessory for serious lathe work.



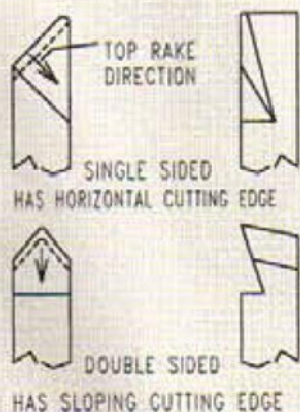
10. Recessing the underside of the base using a standard knife tool. If the tool rubs rather than cuts, try a shallower angle.



FOR 230M07 STEEL A TOP
RAKE OF 20 TO 25 DEGREES
AND FRONT CLEARANCE OF
5 DEGREES IS SUGGESTED.

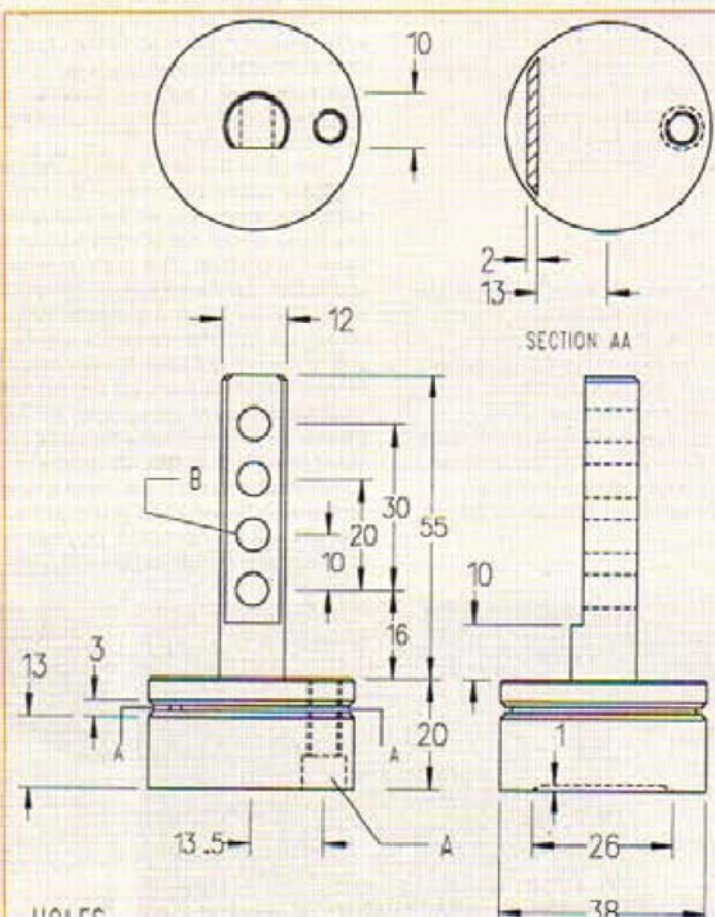
Finishing tool

SK2



Chamfer tools

SK3



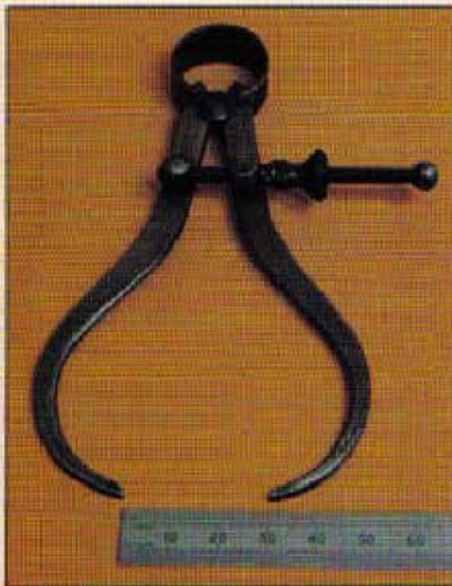
HOLES
A. M6, COUNTERBORE 8mm DIAMETER 6mm DEEP
B. 6.1mm DIAMETER, 4 OFF

MATERIAL
40mm DIAMETER 230M07 STEEL



Base

Item 5



11. Although much more sophisticated measuring equipment is now available at modest cost, callipers and a rule are still quite adequate for many jobs.

an auxiliary side table. No 'run of the mill' off-hand grinder comes with adequate work tables (most are very inadequate), so whilst you may not be able to find the time to produce a 'Hart' and certainly not one of the 'all singing, all dancing' tool and cutter grinders which many of us envy, an improved table should be a must. (Ref. 2).

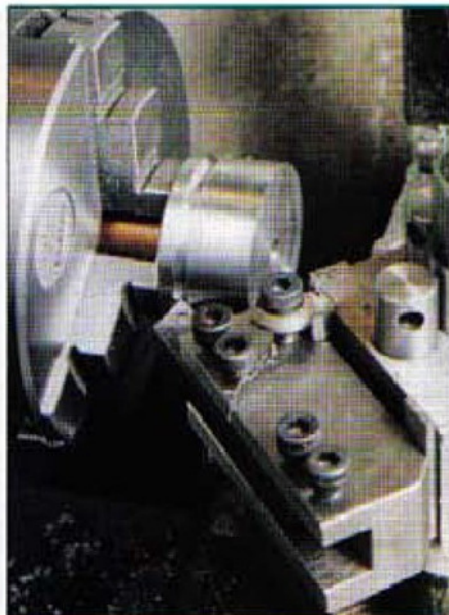
Following grinding, finally finish the cutting edge of the tool with a fine carborundum stone.

Back to the base

With the 12mm diameter finished, return to the knife tool and very lightly face the top of the base, leaving it still a little over 20mm long. To do this move the tip of the tool so that it just touches the 12mm diameter and, feeding it to the left to produce a cut of about 0.05mm depth, face the surface by slowly winding the tool out, repeating the process as necessary to achieve a fully machined face and a 20mm + dimension.



14. If you do not yet have a drilling machine all is not lost. With a drill pad on the top slide, the four holes in the column are drilled. The top slide is set at an angle to miss the tailstock, feed being applied by the leadscrew.



12. Using a left hand knife tool with the top slide set to 45 deg. to produce a vee groove.

Using the fixed steady

The next stage is to face the top of the upright to bring it to a length of 55mm. Retracting the centre and machining the end while unsupported is an option, but the sawn end, even at that small diameter, may give an intermittent cut. Caution is therefore advised and use of the fixed steady to support the part recommended.

Disengage the centre and fit the steady in a position some 20mm from the end. Re-apply the centre and set the steady arms to touch the 12mm dia. upright portion and tighten in position. This is an undemanding application for the steady, so more will be said of its use in future projects. With the steady set, remove the centre and face the end of the upright to arrive at a length of 55mm. While the steady is still in place, also chamfer the top of the upright, as shown in **Photo. 9**. This illustrates the use of a single sided chamfer tool (**Sk. 3**), ground from high speed steel, though if you have a range of replaceable tipped tools you may have one that will suit the operation, perhaps needing to be set at an angle to give a 45 deg.



13. Even if you have a milling machine, using the lathe is still worthwhile in some cases.

chamfer. Care must be taken as this may result in the tool fouling the chuck, so the dedicated chamfer tool is preferred. It will also make a good early exercise in shaping your own high speed steel tools.

The base can now be removed from the chuck and reversed for machining the underside and the outer diameter, but a return will have to be made to the normal jaws. Having paid so much attention to giving the upright section a good finish, it would be a pity to mark this by clamping it in the chuck without some measure of protection. The ideal material is thin copper sheet, about 0.006in. (0.15mm) thick, the sort used for making copper pictures and readily available from good craft suppliers, but a thick paper will suffice. Bend a strip of either around the upright, taking care to see that it does not overlap, place in the chuck with the top of the base resting against the jaws, tighten and face the underside to give the 20mm dimension.

The gauge, when finished, will sit more precisely on the surface plate if the base is recessed in the centre. Do this by setting the knife tool round to about 30 deg. and, starting from the centre, wind the tool out taking a cut of about 0.1mm depth, stopping some 6mm short of the edge, as seen in **Photo. 10**. Repeat until the recess is 0.5mm deep and 26mm diameter. If the tool tends to rub, set it at a shallower angle and take lighter cuts.



15. With the drill pad turned through 90 deg. the hole in the base can be similarly drilled.

Next, turn the outer diameter to 38mm, checking this with a micrometer, a vernier or use the good old fashioned method of callipers and a rule (**Photo. 11**). Do remember to reduce the lathe speed now that you are again machining a larger diameter.

Method of adjustment

The method of fine adjustment of the height of the scriber point is, to say the least, unconventional, but having finished my gauge, it is tried and tested, and I can confirm that it works. It provides only a small range of adjustment, say plus or minus 0.5mm. A slot is cut in the base to leave a thin web, the elasticity of which provides the required flexibility. To attempt to move the pointer by this method too far too often is to risk a fatigue failure of the web, rendering the gauge useless. Coarse adjustment must always be carried out by repositioning or tilting the pointer on the upright.

The drawing for the base shows the web clearly in the Section AA view and quotes a thickness for this of 2mm, but this is for guidance only and the width should be reduced in stages after assembly until the adjustment can be achieved with relative ease.

For many people, the only one way of creating the slot will be to saw it and whilst this should be no problem, it is likely to give a visually poor result, especially if cut by hand. A way of overcoming this is to turn a groove first so that the edge produced is regular, this then being used as a guide for sawing, camouflaging the wavy edge produced by the saw. A vee form slot is produced for this purpose, using a left hand knife tool with the top

slide set to 45 deg., making the groove as illustrated in **Photo. 12**. Make the chamfer on the top side of the base using the same set-up. Access to the edge will be easy, but do take care to make sure that the tool does not foul the chuck in any way.

Fly cutting

There are some holes required, together with a flat which we will now create on the lathe using a fly cutter (Ref. 3), as seen in **Photo. 13**. Even if you have access to a milling machine, it is still worth considering using the lathe for simple tasks, as some jobs may be easier to set up on the lathe and a few, much easier.

If you have a drilling machine, and I assume most will, the most logical way to make the holes would be to use this. However, for those who do not, I am illustrating in **Photo. 14** how the four holes in the upright can be produced using a lathe. Little explanation is required other than to mention that, rather than marking out the holes and then centre punching, their positions were established using the lathe's leadscrew dials and the holes started with a centre drill - actually easier than marking out and drilling. With the same drill pad, but rotated through 90 deg., the hole in the base for the adjustment screw can be drilled and counterbored, see **Photo. 14**. Choose a drill to give around 65% thread depth (5.3mm) as this will make tapping the hole an easy operation, minimising the possibility of tap breakage. (see pages C1 to C20 of the Model Engineers' Workshop Data Book). Hand tap the hole completely through from below.



Terminology

Top Rake This is the angle from the horizontal of the top face of a lathe tool. The value employed varies according to the material being turned, but for home workshop use, this is not that critical, typically anywhere between 15 and 25 deg. when used on free cutting mild steel. The cutting tip is usually higher, the rake sloping downwards from this point. In some circumstances, a tool with 'negative rake', which has the cutting tip at the lowest point is used. Some plastics cut better with a negative rake tool and some grades of brass are best machined with tools with zero rake.

Right Hand Tool As previously explained, throughout this series, a tool which has its cutting edge on the left of the tip and which cuts from right to left is referred to as a Right Hand Tool.

References

- 1 "Hart multi purpose grinding rest" M.E.W. Issue 21 page 46
- 2 "The Sweeper lathe tool grinder" M.E.W. Issue 28 page 12
"Sharp tools for beginners" M.E.W. Issue 59 page 52
- 3 "Fly Cutters" M.E.W. Issue 3 page 17
"A Pair of Fly Cutters" M.E.W. Issue 29 page 44

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Would readers wishing to make use of this facility please note that the maximum total value of items accepted for a 'For Sale' entry is £50.

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● Quick Change Toolpost to suit Unimat 3 & 4, Clarke CL300 & 500M, Myford ML7 lathes. £30 plus postage.
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● Miniature engines: PAW 19 £25, Fox 15 £25
Tel. 024 76382113 after 6.30 pm.

● M.E.W. Issues No. 14 and Nos. 22 to 65 consecutive, many in binders, all in mint condition. £2 each plus postage. Also M.E. magazines from 1941 to 1988, many in complete years and in binders. 20p each plus postage.
Tel. Pat Twist on 01562 890475 (Littleton, Hampshire)

● 1/2 hp 240 volt single phase motor, in good condition £15, 240 volt contactor £2, complete packet of Z link belting (RS catalogue price £64) £12, Moore & Wright 0 - 2in. micrometer in good condition £8, 25 metres of 2.5mm Artic Flex, ideal for extension lead, £10.
Prefer buyers to test and collect, otherwise to arrange collection.
Tel. 01723 362537 (Scarborough)

WANTED

● For Holbrook lathe now being restored, Fixed and Travelling Steadies, spanners (genuine), 60T gear wheel plus any for odd threads. I would also be interested in any other maker's tools/attachments and any information on same would be welcome.

Tel. 01981 241092 (Email: paul@pontrilas2000.freemove.co.uk)

● Operation/Instruction Manual for Flamefast DS 120F Brazing Hearth/Forge (Year 1984) and Fume Extractor Hood for above. Also required: Floor mounted finisher, air compressor, 150 psi, 16 cfm, fine dust extractor (about 2KW) for removing waste from hardwood turning.
John Summers, 26 Kilmory Road, Lochgilphead, Argyll PA31 8SZ Tel. & Fax. 01546 602827

● Machine Manual for Pfauter Gear Hobbing Machine RS 000 (circa 1937). Also, any information on this machine would be greatly appreciated.
Tel. Jack Townsend 01904 768791 (York)

● M.E.W. back issues, No. 2 (Autumn '90), No. 4 (April/May '91), No. 5 (June/July '91).
Peter Littlejohn, 35 Rosewood Place, Paraparaumu, Wellington, New Zealand.
Tel. 0064-04-9023142

TRADE COUNTER

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

New Chronos Website

Chronos Limited of St. Albans have been in contact to let us know that their new website is up and running. It contains their catalogue showing their complete range of model engineering tools and materials, together with an on-line order form for speedy Internet ordering. There are links to other relevant sites and news regarding their attendance at exhibitions and open days. The site is updated monthly with news of additional items and special offers. They are also compiling an e-mail mailing list to customers, offering catalogue updates by e-mail to those requesting the service.

The website can be found at www.chronos.ltd.uk

Chronos Limited, Unit 8, Executive Park, 229/231 Hatfield Road, St. Albans, Herts AL1 4TA Tel. 01727 832793 Fax. 01727 848130 E-mail: chronos_uk@aol.com

.....and also The Shesto Website

Recommended as "The ideal way to locate hard-to-find and innovative tools from the comfort of your home", Shesto Ltd. have also launched their website. For over 90 years Shesto have specialised in sourcing and supplying quality miniature precision tools, and now list over 900 products which can be viewed and selected on their easy-to-navigate site.

Special offers at advantageous prices will be available each month, together with news of interesting products which have reached the market.

All orders placed via the site for delivery within the UK will be shipped carriage free, and as the site uses the latest web security system, Shesto claim that orders can be placed with complete confidence.

Visit their website at www.shesto.com

Shesto Ltd., Unit 2 Sapcote Trading Centre, 374 High Road, Willesden, London NW10 2DH Tel. 020 8451 6188 Fax. 020 8451 5450 E-mail: sales@shesto.co.uk

Spark Erosion equipment in modular form from Concept edm Ltd

By making the various units available in modular form, Concept edm of Maidenhead have made it possible for the owners of small milling machines, bench drills and drill stands to adapt them for

use as highly versatile spark erosion facilities at a budget price, direct from the manufacturer.

The modules listed in their current literature are as follows:-

VM2 Work Tank (Price £250.00)

This module contains a 240mm x 170mm drilled and ground steel work table, dielectric inlet and outlet connections plus an adjustable weir to regulate the dielectric height to a maximum of 70mm above the work table. Flanges on the 270mm x 200 work tank are provided to attach to a table or platen.

VM3 Dielectric Pump/filter (Price £350.00)

With a fluid capacity of 10 litres, a filler level/strainer and a fine output filter, this module incorporates a 230V single-phase pump which will supply ample fluid to fill the work tank rapidly and permit by-pass surface flushing if required.

VM4 Workhead (Quill) (Price £850.00)

The low inertia of the whole servo system gives very fast response to changing conditions within the spark gap. The quill drives through pre-loaded precision linear bearings and is actuated via a re-circulating ball screw driven from a DC motor which incorporates an iron-less rotor giving a total stroke movement of 50mm. A touch contact magnetic sliding depth-stop micrometer and a dial indicator give precise erosion depths. A universal joint is attached to the rear and is included with the workhead making it possible to align the quill at an angle in the X-Y plane.

VM5 Pulse Generator (Price £1,200.00)

Contained within a case 230mm x 230mm x 400mm this forced-air cooled transistorised pulse generator incorporates selected components whose manufacturer-guaranteed ratings greatly exceed the conditions to which they will normally be subjected. The control panel is laid out in a logical manner to ease setting-up, with colour coded switches and controls. With 12 pre-set Pulse ON times and an infinitely variable Pulse OFF time, power levels are selected via five colour coded switches. The removal of debris particles from the spark gap is facilitated by the provision of two controls, one to periodically retract the work head (quill) and the second to adjust the period between retractions. This module requires a 230V single-phase power supply, a moulded IEC mains lead being supplied.

VM6 X-Y Machine Stand (Price £160.00)

This provides an X-axis movement of 120mm and Y-axis travel of 100mm with a Z-axis support up to 300mm.

The prices quoted are for UK delivery and exclude VAT, carriage, packing and insurance. As an introductory offer, the VM6 Machine Stand will be supplied free when a complete system (i.e. VM2, VM3, VM4 and VM5) are purchased as a single order.

Concept edm Ltd., Brick Kiln Industrial Estate, Malters Lane, Pinkneys Green, Maidenhead, Berkshire SL6 6NQ Tel./Fax. 01628 639854



ELECTRIC ARC WELDING TECHNIQUES

Manual Metal Arc Welding

Of the welding techniques available to the home workshop enthusiast, Manual Metal Arc Welding is the least complex and most economical method available. Trevor Marlow gives advice on the selection of equipment and use of the process



1. With just a little practice, quite substantial jobs can be tackled, but not with a bottom-of-the-range welding set! This photo, kindly supplied by TWI Ltd shows the potential of MMA welding in the construction of substantial fabrications.



2. The faithful old MMA welding set. The only thing you adjust is the welding current. Since purchase, the set has been modified by fitting a small fan, effectively making it a 'turbo' model. The modification has allowed continuous use when using thick welding rods or 'sticks'.

This is the first in a series of articles in which we look at useful techniques and capabilities used for joining metals. It is possible that you already possess the necessary apparatus, in which event the article is really intended for others, but you may still choose to examine the range of benefits suggested by the author, on the offchance that you may find yourself with yet another capability or with the answer to a knotty problem.

If you have not yet ventured into the technologies that will be described in this series of articles, it is hoped that you will find the articles unbiased and useful in making the decision whether to invest your time and money in gaining the capability. The articles concentrate, quite deliberately, on the factors you will need to consider in choosing what will be best for yourself, passing on knowledge derived from some years of use of the technique.

Manual Metal Arc (usually abbreviated to MMA) or 'stick' welding must be a strong candidate for the most useful joining capability at lowest cost. However, be warned from the outset that, in the home workshop context, MMA welding has one

big downside, in that it is not really practicable for welding thin sheet steel. For techniques that can provide excellent results on such thin materials without necessity for any high level of skill, refer particularly to a subsequent article on the Metal Inert Gas (MIG) welding processes.

Cheap and cheerful welding

How on earth did we manage without it?

If you have ever been a little careless in making connections to your car battery, you may have learnt the hard way that, provided with something that can supply a bit of current, it is all too easy to liquefy metal. Occasionally in such pyrotechnic experiences it happens that a molten bridge between two pieces of metal will remain continuous while it solidifies. That is a weld. It may be an accidental weld, and it may not be a very good weld, but it is a weld. Our two pieces of metal have become joined by the solidified bridge. Since that bridge is

itself metal, it may well have the strength that we associate with metals.

In our accident with the car battery, we will probably view that weld with annoyance. Consider however if at another time we wish to deliberately join two pieces of metal. We might consider the use of adhesives, solder, braze metal, rivets, crimping or one of many other possibilities. At different times, each method has its own particular value, something which we should never forget.

The factors that dictate the best joining method for a particular situation are almost endless. We may for instance need to be able, at any later time to disassemble the joint, or we may need to avoid any fire risk in the assembly area, or we might require the joint to possess the highest possible strength.

However, the situation is not totally random, because to serve a particular function (say, for such as supporting other structures, or serving as a containment), when we need a lot of strength in a small space, our most useful basic materials will often be metals. Without such a constraint, then for maximised benefits we might well do better with a wood, or a concrete, or a plastic. If we do find metals to have special value, a reality is that those metals that cannot be joined by our everyday welding, brazing or soldering processes will find very limited applications so, if you can weld it easily and reliably, then the overall usefulness of the metal is vastly increased.

In our homes and workplaces we now have copper, iron, and aluminium, all around us, either as fairly pure metals, or as alloys, or as derivatives such as steel. It so happens that all those metals, and many more, can be welded, but the different physical and chemical properties of each metal make it necessary that we tailor the welding processes accordingly.

For example, the high thermal conductivity of copper means that we need to have unusually intense local heat input if we are to attain melting point, while in the case of aluminium, we have to use techniques that prevent or disperse the oxides that form so readily on its surfaces. While there are such detail differences in method, when compared with alternative joining techniques, then for a steel, welding will usually win hands down when we make comparisons from the many standpoints of convenience, need for preparation and setting up, lowest total cost, portability and strength of bond.

Interestingly, for many applications, we subconsciously measure the true value of our metals and alloys by the ease and convenience with which we can assemble several parts into a whole. The alternatives to welding usually demand far more effort in one way or another. For instance, to use rivets, you will usually need to maintain high accuracy through prior stages of marking out, centre punching, drilling and clamping. With welding, the inverse is true. One of the greater joys of a welding capability is that you can so easily 'tack' metal sections into a desired end product, then easily break those light bonds if there is need for repositioning, and finally make the substantial welds that will, if anything, be stronger than the sections that they join.

Having made the point that there is nothing intrinsically difficult about welding copper or aluminium (but please do note



3. Strengthening a roof structure was quick and easy using the MMA welder. Trusses were assembled in situ using 50mm x 50mm box section steel, making it easy to match the steel sections to the existing structure. During the assembly, there never was a requirement to lift or hold anything heavier than one length of the box section.



4. A need to modify some big hinges led to the construction of this simple forge hearth. All materials were left-overs from other jobs. The MMA is perfect for making such things out of doors, even working in more than a stiff breeze.

that there are occasional alloys that, because of constitution, are seen as difficult or impossible to weld) we can direct our attention specifically to the welding of iron and steel. We first examine why you might choose to attain that capability, and then compare the derived benefits with the total costs, starting with the up-front cost, then on to running costs, the 'cost' of any inconvenience in the storage of the equipment, and of your time, and so on.

As a starter, please observe that it would be difficult to overstate the value of being able to weld iron and steel. These materials now provide a bedrock to our civilization, often proving to be the best choice at acceptable cost, or even at any cost. The consequence is that iron and steel, in almost any section and thickness will, at modest cost, be delivered to your door by your local suppliers.

What benefits then can you expect to derive from gaining welding capability? The answer is: almost all those that you can visualise, and many times that number that you can only begin to guess at! In any workshop or garage environment, the obvious examples are making special brackets, special tools, special ...everything! By the assembly of several simpler pieces into a more complex whole, it becomes possible to create articles which might otherwise be totally beyond any other fabrication capability (e.g. a complex manifold). Damaged or worn items can be reclaimed, simply by replacing lost metal and then machining the item back to the 'undamaged' condition. Think, for instance, of the number of times in the past that you have removed metal from a workpiece and then bitterly regretted it, realising that you have made a mistake and becoming painfully aware of the time it will take you to start again from scratch. There will be situations where recovery may not be simple or even possible (perhaps with a silver steel

component), but in many cases there is a possibility.

If you are prepared to believe for now that Manual Metal Arc or stick welds can be very good things, we can now look at the first stages of detail of how you might make them in your workshop. To whet your appetite, a few of the many possible applications are shown in the accompanying photographs.

Principles of operation

In the wider world of science and technology, there are at this time perhaps ten or more different metal welding techniques. Of those methods, most involve the solidification of a bridge of molten metal and the simplest way of creating this bridge is based upon the principles involved in our accidents with car batteries. Much heat energy can be developed in an electric spark, with consequence that the local temperature rockets. Metals at each side of an arc may well be liquefied into one pool, that single pool then solidifying into a bridge as our arc is moved elsewhere. Believe it or not, with that description we have said almost everything there is to say about MMA welding.

Equipment

How then do we set about creating the required conditions? Firstly, we need a source of electric currents to deliver electrical energy of broadly similar magnitude to that developed when we accidentally short circuit the car battery. Naturally, it is very necessary that those currents should not be lethal, since sooner or later all operatives will unthinkingly interpose themselves between live and earth. So, to be intrinsically safe, we use low voltages, and to be able to get the high energy while using low voltage, we need to generate high currents. For most of us, the source of electrical energy will be the mains supply so, almost universally, and

with good reason, stick welders use transformers in one way or another (there are some welding units that utilise batteries, with or without vibrating devices, intended to make welding easier. The best advice to the beginner must be: steer clear).

Selection

We can now give thought to the optimum purchase for your requirements. Because it is so important, it is here necessary to repeat the warning that, if you primarily need to weld sheet metal, perhaps to keep an old car on the road, you almost certainly DO NOT want a MMA welder. For those thinish-metal purposes (metal thinner than something like 1.5mm), you almost certainly will be best served by the user-friendliness of the Metal Inert Gas or 'MIG' welder, which will be the subject of a later article in this series.

The MMA welder tends to 'burn through' thin material so, instead of getting a pool of metal that will solidify on cooling, you tend to get a hole. There will, in fact, often be a minuscule weld around the hole, but you cannot count on it having any strength. If you try to join the holes, all you end up with is ... a much bigger hole! In desperate circumstances there are ... tricks ... to make the best of a bad job, but you will always do a far better job with the more appropriate apparatus. For completeness, it must be mentioned that there are other welding apparatus that can allow far finer work even than the MIG welder, but their use demands considerable investment, forethought and practice, so in this series they only get a mention.

For the easiest and cheapest general purpose welding of steels with thickness greater than about 2mm, you can expect a lot of change out of £100 if you buy the basic 'bottom of the range' MMA apparatus. The suppliers usually provide you with everything you need to start welding, typically the set, an earth lead with



5. You can go on holiday with a much easier mind, secure in the knowledge that all your machine tools are welded to the floor! A potential thief would have to use an angle grinder or other power tool to remove the welds, and would probably not risk the attention drawn by the noise of that operation. (Remember of course, before securing your lathe by welding, that the holding-down nuts should not be more than finger tight, to avoid distortion of the lathe bed and that the machine should be covered to protect it when welding).

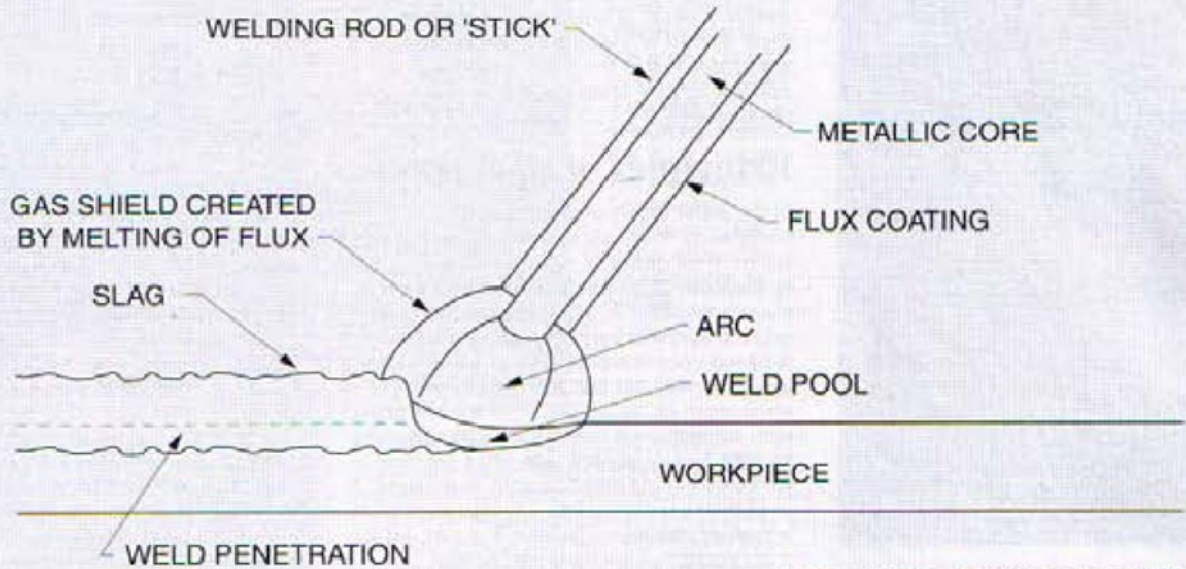


Fig. 1 - Manual metal arc welding

connection clamp, the working lead with stick-holder, a few 'sticks', a hand-held mask, and a chipping hammer to facilitate the removal of slag from a completed weld (**Photo. 2**). You will see sets and all those ancillaries advertised at less than £50. For about a tenner you can buy enough further 'sticks' to last you into the indefinite future.

Rating

At this initial purchasing stage you will need to make a fairly important decision: essentially whether to opt for a low amperage machine or for a high amperage machine. You might decide that the cheapest is good enough, or you might be tempted to purchase up-market, possibly opting for a set with a higher model number, which is the

way that the manufacturers tend to identify those sets which will run at higher amperages and for longer periods. A useful guide when selecting a set is that the welding current requirement is determined by the diameter of the stick you intend to use, about 40 amps per millimetre (1A per thousandth of an inch) being typical.

Another aspect of the manufacturer's jargon is to identify sets with internal cooling fans as 'turbo' models, ostensibly because of the use of a cooling fan, but no doubt in reality because of the commercial wisdom of using the association, now well-imprinted in our minds, between turbocharging and high performance.

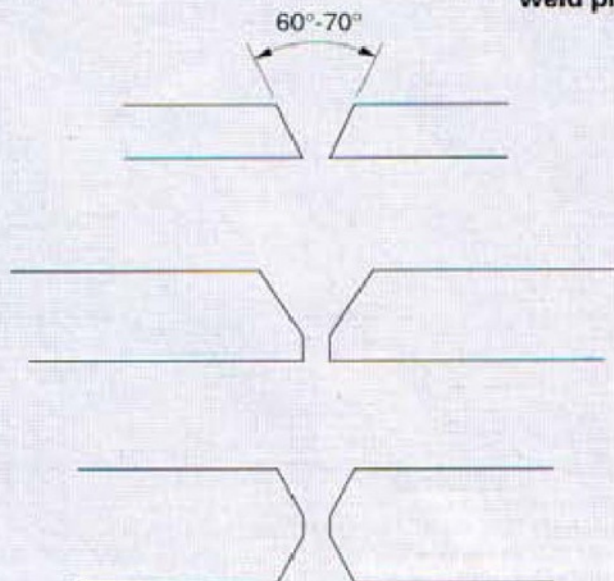
If you have ever had to wait for a welder to cool down before you can continue a welding task, or had to build up a big weld

using only thin rods, you might in consequence be very appreciative both of higher amperage availability and of a better duty cycle. (Duty Cycle in this context being what percentage of your time can be spent actually welding, the remainder percentage being how much time you need to spend waiting for the welder to cool down.)

Most sets now have a thermostatic switch that should trip out before there is any danger of damaging the set. You should not buy any set that does not have such switching included in its specification. That said, there can be subtle benefits in buying the cheapest available apparatus.

Despite the inevitable short circuits which will occur when the electrode sticks to the workpiece, coupled with the high probability that you will attempt to weld with electrodes that are too thick for that particular welding set, the bottom-of-the-range set is constructed so as to be likely to survive those overloads. It is almost certain that it will be during your early learning period that you will subject the set to the worst abuse it will ever see. Damage to the set tends not to be particularly cumulative, so it is likely that you will either burn out the set completely or it will very probably not suffer significant damage, so it is odds on that if you do not destroy the MMA welder during its guarantee period, it will last for ever. Because of the pressures that manufacturers and vendors are now under to supply goods which are 'fit for purpose', the reputable ones seek to ensure that you do not need to return them. Do however, before making a purchase, assess the probability of the vendor still being trading and contactable over the full length of the guarantee period, for obvious reasons. Buying off a 'Dell-Boy' supplier will not be your best option: it is far better to stick to the larger and long-established suppliers as their prices are usually as good as any. As a starter to the selection process, you might choose to look at what is on offer from the advertisers in this magazine and use their specifications and prices as a benchmark against which to compare those from other sources.

Fig. 2 - Methods of weld preparation for a butt joint



Size and portability

There are other good arguments for buying at the bottom end of the market. One benefit is that the cheaper sets tend to be physically smaller and hence might sit neatly in a corner or under a shelf, whereas a bigger set might need to be stored where its presence might represent an on-going nuisance.

To be sold at low cost, cheaper sets must only contain the minimum of materials and so are usually lighter than the up-market sets and can often be classed as truly portable and can, for example, be carried up ladders with comparative ease. The models with higher capability have to be fitted with rudimentary wheels before they can even be moved about on level, solid surfaces, so they seldom leave the garage or workshop where they are stored. It may not be possible, for instance, to wheel the larger sets to the bottom of the garden, because the wheels will sink into soft ground, and navigation of any step or slope can cause real problems. Seeking to provide a temporary mobility by lifting the heavier sets into a wheelbarrow is not without grave risk to spine and groin!

Buying second-hand

Because there is so little to go wrong, MMA welders often turn up on the second-hand market at prices which are tempting. However, you would be wise to be mindful of the long term availability of spares and consumables.

An exception to that longevity rule can apply to a less common, older, type of MMA welder, the oil cooled/insulated variety, that you might well purchase second-hand. They will last forever, but NOT if the coolant level is allowed to fall below that recommended, so get into the habit of checking levels periodically. The only other downside with the oil cooled models is that they are usually very heavy indeed, often taking two very strong men to lift them, so in practice they are only as portable to the degree allowed by their wheels. They are however popular with people needing to do continuous welding of thick sections. That balance of portability, performance, and up-front cost is discussed in more detail below.

Making 'big' welds

While the bottom of the range models have a lot going for them, there can be times when you will be better served with an up-market model allowing higher amperage and more continuous running. To explain why, we must pause for a moment to examine in a little more detail what we need to do when we have to make 'big' welds.

What actually happens in MMA welding is that, since the arc is generated between the metal down the centre of the welding rod and the metal of the workpiece, both those metals are melted, whereupon they immediately mix to form that pool of metal that will solidify to provide your bridge of metal, the weld (Fig. 1). If you visualise that process, say for a rod of diameter 2.3mm being applied to a workpiece of great thickness, you will readily appreciate that, in the contact region, the surface layer will liquefy because of the intensity of the arc. Because of the high thermal conductivity of the workpiece metal and the fact that the heat can dissipate in all directions, the

liquefaction will not be to great depth.

Keep that visualisation in your mind. With it, you will be in a good position to understand the influence of almost all the variables in MMA welding, and you will near-instinctively know what to do both when preparing to weld and when making adjustments to settings and technique. The subject is so important and valuable that it deserves its own article, but can be sufficiently illustrated for this MMA topic by an example such as welding two half inch plates edge to edge (a 'butt weld' in the jargon of the trade). From your first attempts at welding, you will come to realise that the depth of the welding pool is, very broadly, equal to something like twice the diameter of the rod you are using. So with half-inch plate, even if you apply weld to both sides, something like the middle quarter inch of that plate-to-plate junction will not be welded. Such a weld might well be sufficient for a lot of crude applications but, for the purposes of this illustration, we have decided that nothing less than a full through-thickness weld is good enough. How do you weld the middle bit when you cannot get at it? Fairly obviously, you need to weld the middle bit first and to get access to that region, you need to cut away any material that will be in your way when making those first 'runs'. In our illustration, where we have access to both sides of the half inch workpiece material, we can arrive at the required preparation by simple removal of

the corners of the butting edges, so that we are left with deep vees at the joint line (Fig. 2). We should, in the removal of the corners, leave a 'land' that will, after the first runs from each side of the plate, have been molten full through-thickness with no gaps. Then, having made that good 'root', all that remains is to replace the material at the corners with weld metal, having been careful to remove the slag created during the first 'pass'. In that replacement, the requirement for success is that the workpiece surfaces are truly liquefied, which is made easy by having the good access allowed by the vee-cut preparations.

Notice now that, without reference to any books or welding standards, you have worked out what the preparations should be, and the order of the welding operations, and in consequence have arrived at a full through-thickness weld.

All situations that you meet will be amenable to similar analysis. Faced with a particular construction job, look at where you need to make the joins in that assembly, decide if you need to remove any material from corners to enable you to make welds sufficient for the particular purpose, remove the corner material, oh-so-easily with a small angle grinder, and all that remains is the genuine pleasure of the actual welding.

It is only relatively rarely in the home workshop that we want to do full through-thickness welds on thick material, and hence have to remove a lot of metal from the



5. Shelves like this can be assembled in situ when access is difficult. The availability of 50mm x 50mm L-section steel makes it easy to provide sliding shelves, each of which will carry all the scrap metal that you can crowd onto it. You can customise shelf heights to allow optimum storage of your various hedge trimmers, alligator saws and the like.

corners. It is therefore only on these occasions that we come up against a significant deficiency of the 'bottom of the range' welder. We often do not need to do any preparation to weld thin material, and even when we do, we do not need to add a lot of metal. Therefore, the melting of a thin stick will provide enough to nicely fill the gap, but welding thicker metal requires the deposition of more material by making a series of 'runs'. An up-market welding set will allow you to use thicker sticks and hence you would be able to make the complete weld in far fewer runs. Often, even when welding thickish (say 5mm) structural sections, a better set will allow the complete weld to be made with only one run. It will have the further advantage that it can provide the higher currents for longer periods before the thermal switch is actuated, hence you will be less likely to spend time waiting for things to cool down.

This said, it is worth remembering that the cheaper unit will always remain as portable, as sufficient and as storable as when it was new. In course of time you might well decide to invest in one of the 'inverter' units (only relatively recently available at acceptable cost) that allow better performance together with ultra-portability, but it is odds on that you will choose to retain your faithful old friend. It will still do almost everything you ask of it, and if you should happen to drop it off the roof, you will not have to arrange a second mortgage, which would be the scale of things if it was your new inverter unit that had fallen to earth.

You should not, when weighing up whether or not to purchase your first welding set, allow yourself be put off by doubts as to whether you can develop the manipulative skills required to make good welds. Acquisition of sufficient skill to stick things together in a rough fashion will take a few minutes, particularly if you take a few minutes to learn some simple 'tricks of the trade' which will ease the way.

Additional facilities

If you do decide to invest in an MMA welder, the 'carbon arc brazing' accessory is well worth the extra £20. In use, an arc is generated between the tips of carbon rods. Since that arc is not directly and initially associated with melting metals or fluxes (processes which take up a lot of energy), there is vast heat availability. The method is useful for the bigger brazing jobs using the higher melting point brazing alloys, but you will find better and diverse uses in many kinds of forging, heat treatment and metal forming. The use of just one carbon as a kind of 'hot finger' can be very useful in one-off situations.

Build your own?

Because of the basic simplicity of the requirements, it is not unknown for brave souls to make their own welders. Unless you really know what you are doing, that course is not recommended. It is unlikely that you will end up with the optimum operating characteristics, and there is the possibility that, in some fault condition, you just might get mains voltage at your welding torch or workpiece. It is a far better idea to buy an inexpensive welding set, so that you can start with a safe, purpose-designed apparatus.

SAFETY

Further, on the subject of safety, **NEVER, EVER** be less than totally fastidious in the use of protective clothing and a welding mask. Both ultraviolet and infra-red rays are emitted from the arc, with the possibility of burning exposed skin and eyes. The condition known as 'arc eye' is no joke and may well have very serious implications in the long term.

Potentially toxic fumes are also generated from the molten materials, so welding should only be carried out in a well-ventilated area and, if possible, some means of fume extraction arranged.

It also goes without saying that you do not attempt to weld if there are any flammable liquids, flammable vapours, paper, sawdust or similar potentially hazardous materials in the vicinity. Include steel wool in that list as it ignites easily from one spark and the combustion generates an incredible amount of radiant heat. **ALWAYS** have a selection of fire extinguishers immediately to hand and in working condition, just in case things start getting really exciting!

The importance of the flux coating

There is one point of detail that is very important. Easy arcing will only occur if the working end of the stick has a full complement of flux coating. When an arc is struck, the flux melts to form a gas and slag which protect the weld pool from contamination from the surrounding atmosphere. The slag solidifies on cooling and can then be chipped away.

If for any reason the flux has flaked off the electrode, it will be quite a struggle to initiate arcing. In fact, if you examine events in detail, you will find that proper arcing only initiates after any protruding metal at the working end has been melted or eroded away.

Striking an arc

The primary difficulty experienced by the beginner is that the stick will either refuse to strike an arc or will arc momentarily and in doing so will weld itself to the workpiece. The key feature here is that, to expert and novice alike, it will always be difficult to strike an arc with a totally cold stick. Conversely, a warm stick will allow you to strike an arc with relative ease, and with a truly hot stick it is near-impossible not to strike an arc when you bring its working end into proximity with the workpiece. After you have been welding for a second or so, the stick will reach an optimum temperature. Actually, the arcing causes the immediately adjacent stick material to melt and to transfer to the workpiece, so the stick warming process is in fact running ahead of the arc. The practical consequence is that any weld re-start process is much easier than the original start. The rule to remember is, that if the stick is hot, striking an arc will be easy. Similarly, if the workpiece is hot, striking an arc is relatively easy. If both the stick and the workpiece are hot, you can quite literally strike an arc with your eyes shut! (It can, in

fact, be a useful trick to preheat the workpiece if you need to make a weld in a place that is so inaccessible that you cannot see it).

So, you want a hot workpiece and a hot stick. How can you get them hot when the initial circumstances dictate that you will have trouble in initiating the arc? The easiest way is to firstly check that you have your full complement of flux coating, then drag the working end of the stick very lightly, and quite briskly, along the workpiece. That glancing contact will cause initiation of the arc but not create those circumstances that lead to the working end of the stick welding itself to one spot on the workpiece.

Repeating that stroking action a few times quickly leads to a hot working end on the stick even if it does not significantly warm the workpiece. With the enhanced tendency for a sustained arc that follows from the hot stick, all you now need to do is to slow down on the rate of the stroking along the workpiece. The slower traverse results in a sustained arc and its natural consequence, a controlled deposition which you will find leads to a perfectly acceptable weld. Hey presto, you are in business!

Inevitably, some of your earliest welds will be a long way from perfect. The novice will find that it takes a little time and attention to keep moving the stick towards the workpiece at the same rate as the arc causes shortening of the stick. Teachers and texts will tell you that to get a good weld it is necessary to keep the arc length at a fixed value, something like 3mm for a home welder, but the operation is quite forgiving, in that an arc will often be maintained even when the rod is actually resting on the workpiece. At the other extreme, when you tend to allow the working distance to become too great, you will get prior warning both by sight and by sound that the arc is threatening to extinguish. Even if the arc does momentarily extinguish, it doesn't matter a great deal, since the immediate region of the rod will be as hot as it ever gets, and the arc will easily re-initiate when you move the end closer to the workpiece.

Most of your earliest welds will look a little ... grotty. Such appearance is only to be expected. On the positive side, you will observe that if you seek to pull those welds apart, the apparently flimsy and slag-entrained bridges of metal will be far stronger than you imagined. The consequence of that deceptive strength is that your earliest welds can serve reasonable functions. You would not of course, simply as a matter of common sense, trust your early welds in any function that could result in hazard or injury.

In this article, intended to guide you in the things that matter if you have interest in developing an inexpensive welding capability, there has not been space to touch on things like welding deformations, changes in metal properties due to the welding, the consequences of flaws in the welds and the adjacent material or the consequences of residual stress. They are all important topics, but for a lot of hobby/home workshop welding you simply will not need to know. For the most part you will simply need to modify your technique to make your problems go away. It is hoped that there will be opportunity to make some suggestions in a later article.

Happy Welding!



ELECTROMAGNETIC DEVICES

Part 3 - Winding construction

Tony Claridge gives some practical hints on winding coils

The stresses to which windings are subject

There are several methods of making windings, but some are better than others. Before we get down to manufacturing techniques, it is important to be aware of the principal form of electrical stress which afflicts windings. You may recall that I mentioned the resemblance of electromagnetic energy storage to the energy stored in rotating flywheels. If you poke a strong bar between the spokes of a flywheel, there will be ructions as the wheel is forced to give up the energy stored in it; this is calculated from the expression:

$$\text{Energy} = \frac{1}{2} \times I \times \omega^2$$

where ω is the speed of rotation in radians per second and I is the moment of inertia of the flywheel.

There are $2 \times \pi$ radians per revolution, so ω equals $2 \times \pi \times \text{revs per second}$.

You may know that the equivalent formula for a mass moving in a straight line is:

$$\text{Energy} = \frac{1}{2} \times m \times v^2$$

where m is the mass and v is the speed

What may come as a surprise to you is that there is a similar storage of energy in an electromagnetic field. The corresponding formula is:

$$\text{Energy} = \frac{1}{2} \times L \times I^2$$

You will recognise I as the symbol for current, but L may be a new one for you. The property is called inductance, and the unit is called the Henry, after yet another of those scientists. It conveniently has the dimensions of 'flux linkages per amp' and this is an easily remembered way to think of it. So inductance can be pictured as the amount of magnetic field which links with the turns of the winding which causes it, divided by the current which flows in the coil to bring about the field.

Now in order to see what happens when the current is suddenly stopped, which is the equivalent to poking something between the spokes of a flywheel, we need to look at **Figure 1**.

This shows in sketch (a) the situation before the switch is opened to interrupt the current. Now if you will allow me to use a kind of anthropomorphic way of describing what happens, the coil, finding the current falling, sets out to stop this from happening. It does this by using some of its stored energy to generate within itself a voltage to keep the current flowing. The situation then becomes that shown in Figure 1 (b). The voltage it produces is of a polarity which tends to keep the current going, which at first appears to be opposite to that which caused the current in the first place, but if you look at the polarity which is needed to maintain the current all should become clear. What takes place is precisely equivalent to the situation where attempts are made to stop a flywheel instantaneously. We know that in reality the flywheel takes time to come to rest, and in the

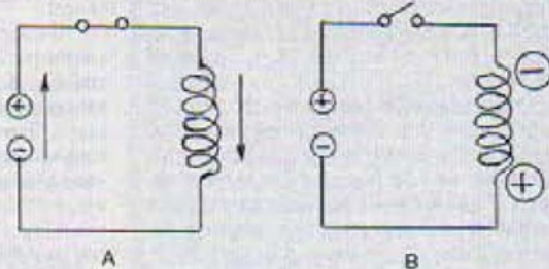


Fig. 1

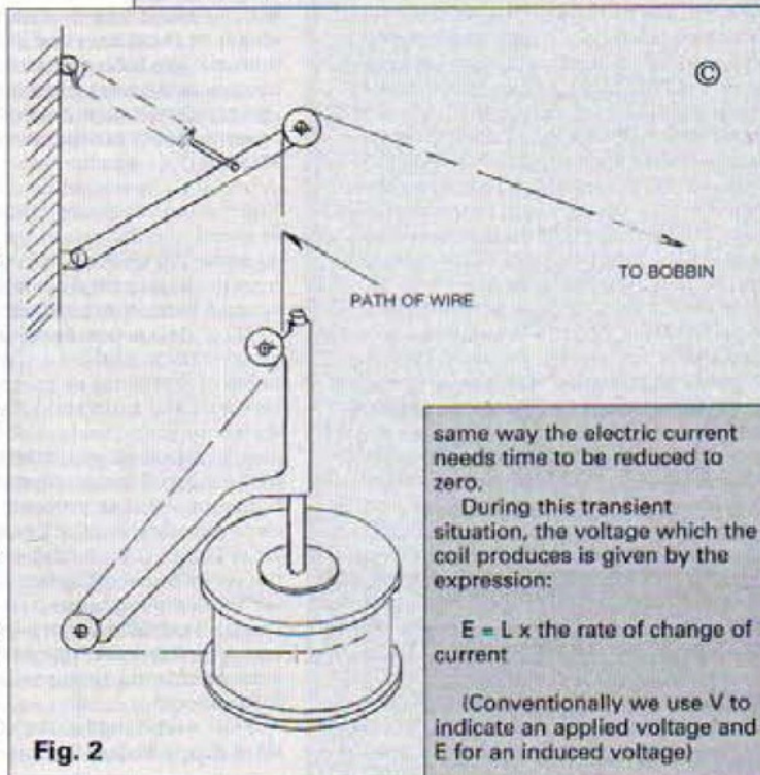


Fig. 2

same way the electric current needs time to be reduced to zero.

During this transient situation, the voltage which the coil produces is given by the expression:

$$E = L \times \text{the rate of change of current}$$

(Conventionally we use V to indicate an applied voltage and E for an induced voltage)

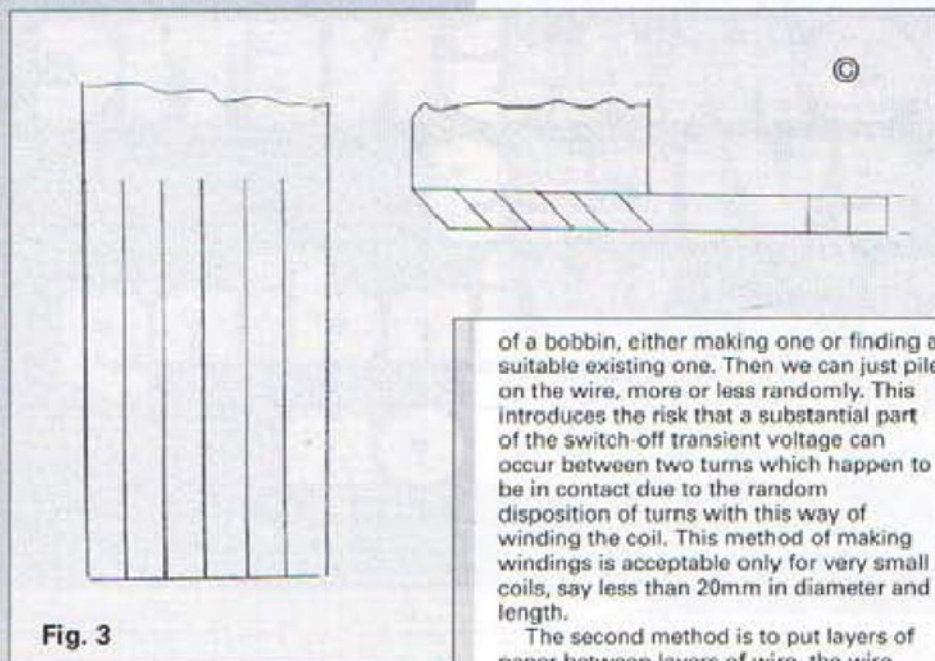


Fig. 3

The purpose of this explanation is to make the point that at the instant when the current is switched off, the induced voltage can be enormous. It is not unusual for it to be several hundred times the normal applied voltage. Its exact level depends on how quickly the current reduces. This effect is used to produce the sparking plug voltage in a conventional ignition system. It follows that there occur very high voltages between individual turns of a coil during switch off, and to a lesser extent when switching on. For this reason it is important to manufacture windings in a way which can accommodate this effect.

The voltage produced can be lessened by providing an alternative path for the current to flow through as the field collapses, though this slows down the rate of decay. Simple resistors can be used, as shown in Figure 1(c). There are also special resistors available whose resistance falls as the voltage across them increases, and the ultimate suppression is achieved by connecting a diode as shown in Figure 1(d). Diodes have an extremely low resistance in one direction and an extremely high one in the other direction. When dealing with modern electronic systems, which are easily damaged by even small voltage excursions, it is almost standard practice to fit diodes across every coil. These must be chosen with care to ensure that they are rated suitably.

Now all this is to make the point that windings have a hard life sometimes, so they should be made carefully if they are to last for the life of the equipment in which they are used. Fortunately modern enamels as used on copper wire are much better than those which were available fifty or more years ago. The use of cotton or silk wrapped wire has just about disappeared, though if you happen to have some of this kind in stock, by all means use it.

Methods of making coils

There are three ways to wind a coil of the kind we might want. First we can get hold

of a bobbin, either making one or finding a suitable existing one. Then we can just pile on the wire, more or less randomly. This introduces the risk that a substantial part of the switch-off transient voltage can occur between two turns which happen to be in contact due to the random disposition of turns with this way of winding the coil. This method of making windings is acceptable only for very small coils, say less than 20mm in diameter and length.

The second method is to put layers of paper between layers of wire, the wire being guided to lie with the turns alongside one another to form a smooth layer. To stop the wire at the ends of each layer from slipping out, it is necessary to stop the layer of wire a little way from the edge of the paper, and ideally to make each layer of wire slightly narrower than the one below. In the professional manufacturing field, this method is sometimes refined by folding the edges of the paper back on itself, often three or four times, so as to act as a retainer to keep the wire from slipping out. This is not a bad way to make coils, but without a crimping machine to fold the edges of the paper, it is a laborious process to make the folds.

So we come to the method which I always use, and which is frequently used in the manufacture of high quality windings. It begins by making a bobbin. The generic name for stuff like 'Tufnol' is 'synthetic resin bonded paper (or cloth)', usually referred to as SRBP or SRBF. If you can lay hands on this kind of material, ideally in thicknesses of 1½mm or thereabouts, then a suitable bobbin can be made easily, using either contact adhesive or epoxy resin glue to join the pieces. I have not tried the model-makers' 'Plasticard' as an alternative, but I would expect it to be a suitable alternative to SRBP. A word of warning: all bobbins tend to shrink slightly due to the wire tension, so make the sleeve part to be a loose fit over the iron core. A diametric clearance of around ¼ to ½mm should be adequate.

Next, decide where the wires are to emerge through the end flanges and drill holes of 2 or 3mm as necessary. It would be tragic and frustrating if you had the start connection to the coil snap off, so always attach an insulated stranded wire to the start of the winding before you begin the winding process. This is best done by soldering the flex to the winding wire. The enamel must be removed from the wire before soldering, of course, and with the larger gauges it is usually OK to scrape it off with a sharp knife. However, a better method, and one which is almost essential for the smaller gauges is as follows:-

Pour a little methylated spirit into a tin lid and light it. The flame is almost

invisible, so take care. Then hold the end of the wire in the flame until it is red hot and immediately plunge it down into the spirit. The quenching action removes every trace of enamel and the wire is ready for soldering. 10 or 20mm is long enough for attaching the flex. Stripping the end of the flex for a similar length and twisting the two conductors together before soldering will make for a perfect joint.

Next, thread the flex through the (right) hole in the bobbin flange, and anchor the joint with a bit of masking tape. It is best to take the flex and its retaining tape round a full turn of the bobbin so as to provide a truly firm anchorage for the lead. Make sure that the tape completely isolates the joint from the winding wire which is to be applied next.

The bobbin must then be mounted on some kind of a mandrel. I mostly use a wooden mandrel drilled through for a spindle, with the assembly being retained by lightly nipped large washers and nuts, leaving the end of the long bolt or screwed rod which is the spindle long enough to be held in a chuck. Then the flex lead must be anchored to prevent it flailing about while the coil is wound. I just wrap it round the spindle and secure it with masking tape.

The set-up which I use for coil winding is to clamp my belly brace in the bench vice with its axis horizontal, and the driving wheel and handle free to rotate. By knowing the gear ratio of the drill spindle to the driving wheel, I can count the turns as they are applied by counting the number of turns of the driving wheel. No doubt some readers will prefer more sophisticated arrangements, but I would stress that hand winding is greatly to be preferred for the delicate task of winding thin copper wire. I prefer to have the wire feed coming from behind and over my shoulder, but this is not important. The wire spool may be located wherever suits you, but it must rotate freely. This means that its axis should be horizontal. For very fine wire, the tension in pulling the spool round may be more than the wire can cope with. For wires of less than 0.2mm diameter, a different wire feed is needed. The spool is positioned on a vertical shaft and does not rotate. Instead, an arm which rotates on the same shaft carries a pair of take-off pulleys which peel the wire from the spool. **Figure 2** shows the idea. It is important that the pulley system is light in weight and preferably has some springiness, as in my sketch, to avoid any sudden change in wire tension.

My preference is for hand guidance of the wire onto the bobbin. The wire will naturally lay itself into closely spaced turns if the guidance 'lags' slightly and the wire tension is maintained merely by pinching it between finger and thumb. You may like to wear a glove if you have a lot of winding to do.

Now we come to the business of insulating each layer of wire from those below and above. We use paper, preferably kraft paper, though I usually use any brown paper which is not glazed. A thickness of 0.1mm is fine for most wire sizes, though something thinner is better for very fine wires; say 0.05mm. Now comes the clever bit. The width of the paper should be 3 to 5mm more than the space between the bobbin flanges, and

both edges are then snipped to a depth of 2 or 3mm at intervals of perhaps 10mm. If the strips of paper are folded, the task of snipping the sides is not too tedious. The idea is that the edges of the paper curl up as the wire presses them between the flanges. This prevents any turns of wire from slipping down to a lower level. A layer of paper is inserted after each layer of wire is completed, with enough length to provide a short overlap at the ends of the turn.

It is necessary to maintain tension on the wire throughout the winding process since it is springy enough to go slack and result in a spongy coil if tension is not maintained. If you are using my method of finger control of tension, then inserting the paper needs the third hand that we all wish for from time to time. However, with a little thought one can usually manage. Locking the wire spool or the winding handle is the simplest method.

When the winding process is completed, then another flexible lead can be soldered to the end of the wire, which can be anchored with masking tape while this is done. If you want to use the methylated spirit way of stripping the enamel, then it is OK to cut the wire leaving enough slack to carry out this operation, and then wrap this final length round the coil before anchoring it with tape. Don't forget to anchor the flexible lead firmly when it is threaded through its hole in the flange. Finishing off can be done with one or two layers of paper and one of masking tape. A completed coil is rather vulnerable, to accidental knocks, and the finishing layers offer a certain amount of protection. Incidentally, if your former has sharp corners, an initial layer of paper at the start will reduce the extent to which the corner can dig into the wire. You could also round the corners off with a file.

Alternatives to Enamelled Copper Wire

For some applications, coils can be wound from copper or aluminium foil, cut to a width which just fits between the bobbin flanges. In fact a foil winding doesn't need flanges; there is only one turn per layer! For high currents foil can be very attractive, and a useful side benefit is that heat generated in the middle of the coil can escape to the outside more easily. It is worth looking at kitchen foil for some applications, even though the resistivity of aluminium is about 60% more than that of copper. There is an easy way to bring out the leads from foil, which is explained in **Figure 3**. You will know that it is not easy to solder aluminium, though it is not impossible to do so, but the oxide which forms on its surface is quite a good insulator, and it may be worth experimenting by leaving out the interlayer paper. The gross amount of conductor in the coil's cross-section is higher than with any other kind of construction. If you can get hold of anodised aluminium foil, then this approach is certainly worth considering.

There is one more factor in coil manufacture which merits a mention. The use of varnish to impregnate the winding

and stabilise it against internal movement is fairly common in the professional world. Varnish can also be used as a sealant to prevent moisture from penetrating the coil when it is not warmed by being energised. While there is some benefit in the latter, achieving full penetration of varnish into a coil is difficult, even with the use of solventless varnishes.

The usual industrial process consists of:-

- preheating to ensure dryness
- applying a vacuum to remove air from the winding
- immersion in the varnish while still under vacuum
- pressurising the winding to assist penetration
- draining the varnish and further heating to finish the varnish polymerisation process.

The whole process is carried out in an autoclave of course. Even then, there is no certainty that the varnish will have penetrated completely. On balance, forget it, but a few coats brushed on the outside will help to keep out the damp.

Getting rid of the heat

It is important to prevent coils from getting too hot because the organic materials such as varnish and paper are always on their way to reverting to their carbon based origins. The pace of this chemical degradation is determined by a formula known as Arrhenius' Hypothesis, which says that the rate of this process is proportional to the log. of the absolute temperature. As far as we are concerned, the rate of deterioration is doubled with every eight to ten degrees increase in temperature. We should try to stay below 75 deg. Centigrade to achieve a life of twenty or more years. If you can keep your hand on the coil, it will be OK.

All kinds of conductor offer a certain amount of resistance to the flow of electric current so, whenever a current flows, heat is generated. The amount is given by the expression:-

$$\text{Heat} = I^2 \times R$$

where R is the resistance of the coil and I is the current. If this expression is combined with Ohm's Law, we can also calculate the heat produced as:-

$$\text{Heat} = \frac{V^2}{R}$$

Now all this heat has to escape to the outside world. To compound the task, since heat only flows 'downhill', i.e. from higher temperatures to lower ones, it follows that the temperature is higher in the middle of the coil than near the outside, and, even worse, the fact of its being hotter makes the rate of heat production even higher because the resistivity of copper goes up by about 0.4% for each degree rise in temperature.

That well-known law about the perversity of inanimate objects ensures

that all the materials which make good electrical insulators are also excellent thermal insulators. The only exception to this is boron nitride, a ceramic material which is wildly expensive; we can forget it! The analysis of heat production and removal in coils is manifestly extremely complicated, so for many ordinary applications it is usual to rely on some rules of thumb, and not even attempt to make scientific calculations. So here are a few of these rules which served me well during my professional life.

- 400 watts per kilogram of copper causes a temperature rise of 1 deg. C per second. (This assumes no dissipation of heat, and applies to short time ratings)

- Watts/Kg in copper at 20 deg. C = $1.904 \times (\text{amps per mm}^2)^2$
Increase the watts/Kg by 0.4% for each degree above this temperature.

- Dissipation from a typical coil with acceptable temperature rise for continuous operation is 0.25 watts per mm² of surface area. Use only the outside of the coil. Assume that heat flow through the bobbin is negligible.

- Most coils in the sizes we will use will have current densities in the range 1.5 to 3.0 amps/mm². The smaller coils will use higher current densities than will bigger ones.

Permanent Magnets

All the business of designing and making coils can be avoided by using permanent magnets to establish magnetic fields. So why don't we forget all the problems we have just dealt with? The short answer is that you can't switch a permanent magnet off! All the same there are lots of applications where they are the ideal answer to a requirement and in some cases they can be used in combination with windings to confer special characteristics on an item of equipment.

Everybody knows a bit about magnets, so let us begin by saying that they are materials which stay magnetised after the windings which set up the field have been switched off. One way to think of them is to picture them as being made of lots of tiny bar magnets which are randomly distributed until an external magnetising force is applied, whereupon they all swing into line with one another and stay in line when the magnetising force is removed. Strictly speaking all ferritic materials, and some others as well, behave as permanent magnets, though pure iron, particularly when it is in the annealed condition, retains almost nothing. As steel is made harder, by heat treatment, work-hardening or alloying, it retains its permanent magnet properties more. Until the 1920's, tungsten steel was a very popular choice for permanent magnet applications, though by today's standards it has very indifferent properties.

The subject of permanent magnets and their applications, and also the plethora of new, greatly improved materials which are now available, needs a chapter to itself, and will be dealt with in some detail in the next instalment.



A USEFUL SCREW PRESS



1. The new screw press in use.

This article describes the making a useful screw-operated press which will exert a substantial amount of pressure and, in doing so, rediscovering the uses of applied geometry. This press is approximately 16in. long, has a stroke of 8in. and will take a 5in. diameter job. The size of the press is not critical and a similar unit could be made to suit individual requirements.

This tool (Photo. 1) was made as the result of necessity, which is the usual reason for making most tools. It was a modification of an existing piece of equipment, but the complete tool could be made easily, the only equipment needed which may not be generally available being a MIG welder.

I needed to press out a long phosphor-bronze sleeve bearing from the top gear pinion of my Triumph motor-cycle gearbox. The usual trick of using a bench vice to press out the bearing was not possible on this occasion due to the length. The answer was to modify a tool that I had bought at a car boot sale several months previously. I have found these events to be a good place to find all sorts of tools, so it is worth the effort to find those boot sales that have stalls with engineering bits and pieces. On talking to some stall holders, who are obviously making a living from such sales, it is

John Harris of Maidenhead recommends that readers should keep an eye on car boot sales for cheap items of engineering equipment. Here he describes how he converted one such item to solve a problem

evident that they have no engineering knowledge and buy their stock as job lots from auctions. Quite frequently you will come across unused drills, milling cutters and slot drills, together with many other useful items. I have found that these are often odd sizes, but as long as you don't need a specific size, 50 pence for a $1\frac{1}{32}$ in. drill or even £3.00 for a surface-rusted but new Jacobs chuck is well worth the money.

Whilst looking round this particular sale, I found the tool shown in Photo. 2. I bought it for the handwheel, which was the sort of item that would 'come in useful' sometime, and for £2.50 was an 'unmissable' bargain.

The tool started life as a car starter motor spring compressor, the sort used before pre-engaged starters on cars became the norm. When inspecting my 'find' I had realised the possibility of using it as a press, but did not pursue the idea at the time. I did use it for another job 'as was' without success, in fact bending the original $2 \times \frac{1}{4}$ in. anvil plate very easily.

To be able to press out the long bearing, I needed to have a press with a long stroke, an anvil which wouldn't bend, with a large enough hole to pass the bush through. The base of the 'boot sale' press was substantial angle which did not look like it would bend and the ram looked strong enough for this and other jobs which might come along.

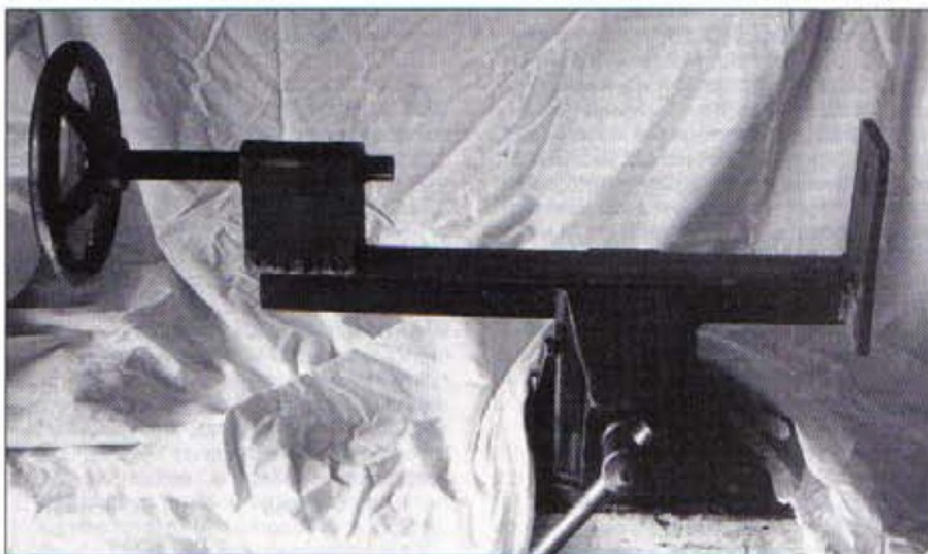
The tool had the screwed ram, $\frac{7}{8}$ in. UNC passing through two large nuts welded between two plates of $2 \times \frac{1}{4}$ in. material which, in turn, were welded to a $2 \times 2 \times \frac{1}{4}$ in. drawn angle (Photo. 3). The point about the type of angle is important as, in use, the tool is gripped in the bench vice jaws and angle which isn't parallel will tend to move.

The ram support gave me the idea of using a piece of tube mounted on similar plates as an anvil. In my scrap box I had a length of 2in. diameter tube, $\frac{1}{8}$ in. wall. The anvil is a $2\frac{1}{2}$ in. long section of this tube, with the ends trued in the lathe.

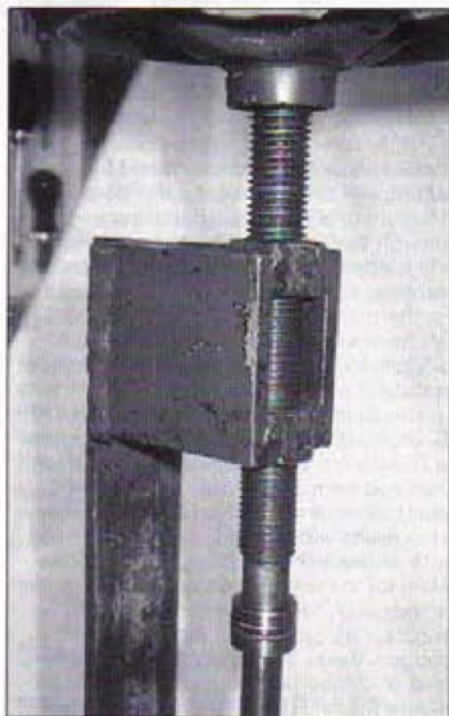
The next job was to make the supports for the anvil. This was where I had to buy a short length of 50mm x 12mm BMS strip. Imperial sizes, with which I like to work as I can visualise inch measurements, are no longer available from my usual metals stockholder.

Two lengths 2in. long were used for the supports, a length chosen to allow the anvil to overhang the support plates. Adapter plates for particular jobs locate on the overhang, and items that may have a recess in them will clear the anvil supports. These plates had their ends trued by holding them in the 3-jaw chuck. The long sides were squared off from the chuck face and light cuts taken to square the ends - not the best practice, but quick and accurate enough for this operation.

The original anvil was now sawn from



2. The original tool, as found in the car boot sale.



3. The screwed ram, now fitted with the pressure head assembly.

the angle and the end of the angle filed square. The two support plates were very carefully clamped in position on the angle and this is where the applied geometry came into play. The centre height of the ram from the angle was measured. The centre of the anvil and the centre of the ram had to be on the same line. The anvil tube sat on the inner edge of the two support plates. To find the height of the support plates was the problem that could be solved with applied geometry.

The distance between the inner edges of the plates was measured with a vernier, which was probably overdoing the accuracy. This gave me the length of a chord across a 2in. diameter circle. I could now work out the distance from the chord to the outside diameter of the tube. The height of the support plates was the radius of the tube, less the height of the chord, deducted from the centre height of the ram.

The formula to find the height of a segment of a circle is:

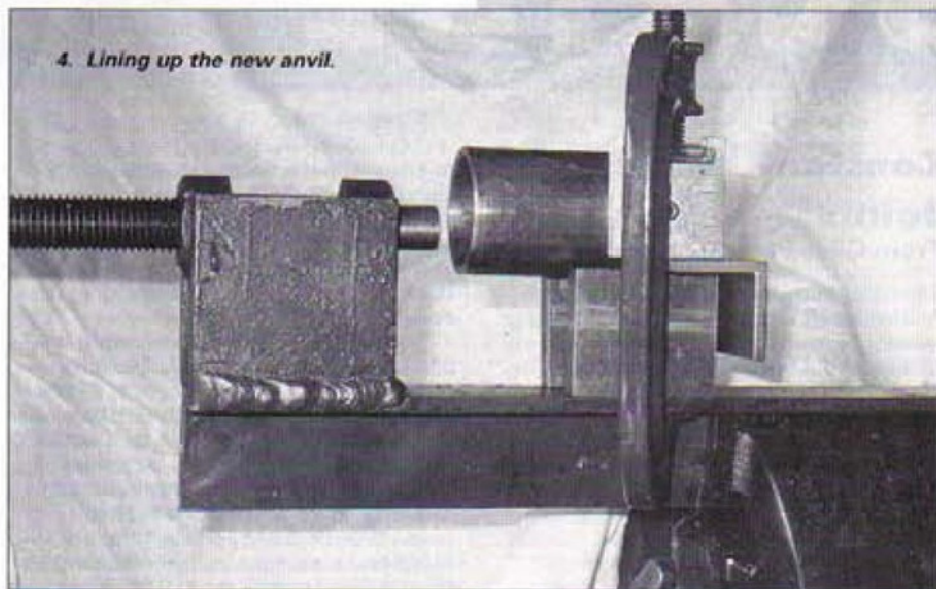
$$h = r - \sqrt{r^2 - (l/2w)^2}$$

Where h stands for height of the segment of the circle, r for the radius and w for the length of the chord.

A modern calculator with square root and other functions takes all the hard work out of using geometry or trigonometry to solve simple problems like this one.



6. A pair of new anvil plates.



4. Lining up the new anvil.

The support plates were again placed in the 3-jaw chuck and reduced to the correct height. The finished supports were placed on the angle and the tube laid on top and the result measured (Photo. 4). The centre height was right, those lessons all those years ago did have some use!

The support plates were carefully clamped into place (Photo. 5) and then MIG welded on to the angle. The tube was clamped in place and the centre height checked again before it too was welded on. Don't look too hard at the welding - it is not very neat, but it works.

The next requirement was a pressure head. As it stood it, the ram would work but needed some method of allowing the screwed shaft to rotate, but not the pressure head. This was solved by finding a small, slim thrust race in my box of bearings. It was marked 'Made in Japan', but where it came from or what it had been used for previously I have no idea.

I turned a mild steel top-hat shaped piece that would be a tight push fit in the hole already in the end of the ram. This was drilled and reamed to take the pressure head which would stay stationary when the press was in use. This pressure head, again mild steel, was made to accept the thrust race and fit in the hole in the top-hat shape. The two parts are held together with a screw and washer, then pressed into the ram. The fit of these parts is not critical, just a good running fit will do, as the aim is to have the screwed ram rotate whilst the pressure head remains stationary. These items can be seen in Photo. 3. The pressure head was drilled and tapped to enable press tools to be attached if need be. This also allows the press to be used as a very light puller, but I do have ideas for a Mk II version which will be a lot stronger when used in this mode.

To use my new press for the purpose I originally envisaged, it needed an adapter plate to fit on the anvil. A couple of plates were made by cutting lengths from the 50mm strip, after truing the ends in the 3-jaw chuck, centring them in the 4-jaw chuck and machining a recess to locate on the anvil. A hole large enough for the gear was bored in one adapter, the second plate being plain, to give a flat anvil (Photo. 6).

A fitment was carefully turned to allow the old bearing to be pressed out and the



5. The anvil support plates were carefully clamped in position before welding.

new bearing to be pressed into the gear. As can be seen from the photographs the press works perfectly. As can also be seen, a spacer had to be used because the screwed ram was not long enough (Photo. 7). This problem will be solved on the Mk II version by using a longer ram, which comes out of the scrap box. The local fastener suppliers, some months before I bought the press, had lengths of 7/8 UNC studding for sale at 20 pence each. I thought they could be turned down to provide round stock, but they are the right size for the press ram Mark II.



7. The job which inspired the whole project.

SCRIBE A LINE

Constant Velocity Joints

From Giles Parkes, Newbury

The letter from Anthony D. Rhodes in M.E.W. No 67 was of more than passing interest to me as a non-engineer and builder of the Helix Gear Hobbing Machine. When I built my machine there were no drawings for the C.V. joints and so I did what was easy and practical and made some pretty coarse universal joints. The drawings and construction of mine were covered in my article in M.E.W. No 57 on the device for making hobs.

It has been pointed out to me repeatedly at exhibitions that my joints were inadequate and all that I can say is that they work. I fully accept that they are not perfect and that the gears produced by them will have the deficiencies described by your correspondent but we must remember that the machines we use in model engineering and the tolerances to which we work are less exact than in mainstream engineering. It is not as though we are producing gears for passenger carrying aircraft engines where tolerances and exactitude are of vital importance. I suspect that the imperfections in gears produced on the Helix machine with coarse universal joints are less than can be measured at home and totally irrelevant when it comes to their performance in models or home-made workshop equipment.

Having said that, it would be good to know how to make a perfect C.V. joint in the size appropriate to the Helix machine, and then I might have a chance of becoming a proper engineer instead of what I suspect George Thomas meant by a 'fairground engineer'.

Editor's Note: I have had a call from Bob Worsley of BW Electronics to say that he has acquired a small number of ex-surplus constant velocity joints which may be suitable for use in this application. He can be contacted at 12 Mussons Close, Corby Glen, Grantham NG33 4NY Tel./Fax. 01476 550826

Atlas lathes

From John Payne, Witney, Oxfordshire

A letter in M.E.W. Issue 66 from A. N. Eastwood was of interest to me for I also have, and use a great deal, a 9in. South Bend lathe that is now 57 years old. It has been in the family since it was new and over at least 50 of these years it raised the blood pressure of both father and son because the 1in. wide leather belt drive from the countershaft was a washout.

I reconditioned the lathe a few years ago and converted the drive to Poly-vee belt, something which is simple to do by removing the crown from the pulleys and cutting ten vee grooves in each one at $\frac{3}{32}$ in. centres. The headstock to countershaft centre distance was reduced

to 12in., with the countershaft assembly standing vertically behind the headstock and a small 3-phase inverter-driven motor at the back of the countershaft bracket. Poly-vee was also used on the primary drive. It has been a most delightful success.

The lathe was fitted with a Norton box and lacked 19 tpi and metric. The drive from stud to gearbox is via gears, 20:56, and if 19 is substituted for the 20, then 19 tpi can be cut by selecting 18 tpi. Pitches of 0.5mm, 0.75mm, 1.0mm, 1.25mm, 1.5mm, 1.75mm and 2.0mm can be cut by selecting 48, 36, 24, 16, 14 and 12 tpi respectively. It is not perfect; 1mm (0.0394in.) comes out at 0.03952in. and 19 tpi (0.0526in.) comes out at 0.0555, but I find it quite satisfactory for short threads.

There was always some unquantifiable 'niceness' about the South Bend, and this 'niceness' is now much enhanced with a variable speed quiet drive which is quick to change and which doesn't slip.

Grinding Inconel turbine wheels

From Richard Bartlett, Coventry

After reading Eric Eadon's article (M.E.W. Issue 67) on the machining of the central plain 8mm bore in a model gas turbine wheel made of 713 cast Inconel, readers might have come to the conclusion that these high-nickel, high-chrome, molybdenum and manganese-bearing alloys are particularly difficult to machine. This is not the case once one is aware of the properties that can cause problems. The Inconel and Nimonic alloys are tough, but not particularly hard as supplied. Due mainly to their negligible carbon content, these metals are not heat hardenable. This means that there are no hard spots in small castings due to 'chilling', and one need not be concerned when offered a purple/blue slice that has been taken from a 100mm diameter bar with an elastic wheel.

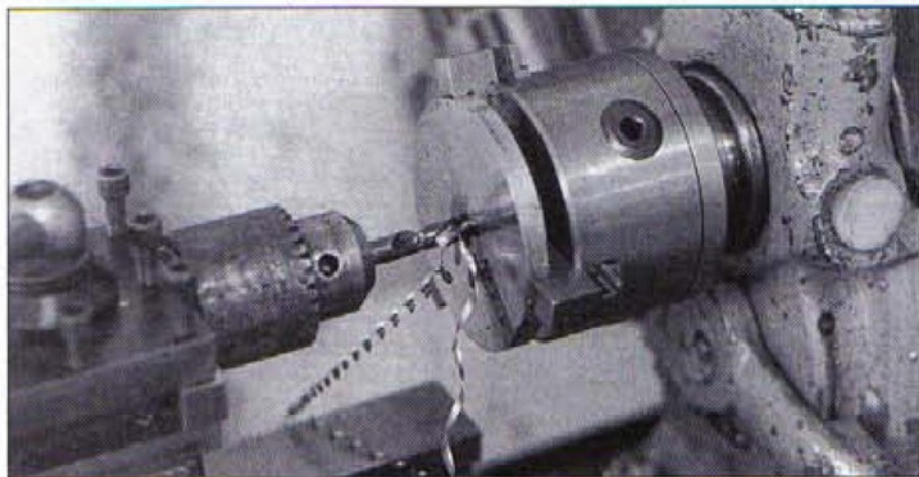
The properties of high strength and rapid increase in hardness due to mechanical working have a knock-on effect, most noticeable in home workshops with less than rigid machine

tools. The higher forces required for cutting will cause greater deflections between tool and work. If these are enough to cause rubbing, then the work will harden; the cutting force will then increase etc., and the tool will fail. Furthermore, the skin of hardened work left from a failed operation will make it difficult for the reground tool to start 'free cutting'.

The Golden Rule is NEVER ALLOW THE TOOL TO RUB. A reasonable cutting speed is 25 feet/min and don't leave yourself with the need for a 2 thou depth of cut. My 40-year old worn out Myford likes at least 5 thou depth with about 5 thou per rev feed with ordinary 3% soluble oil suds. Eric's word for these materials was 'exotic'; mine is 'exacting', for unlike most model engineering materials they will not be bodged. If you do not recognise a tailstock feed of '2-thou per tooth', then it is best to mount the drill chuck in the tool post. One can then set the changewheels to the feed per tooth x number of teeth to give the appropriate feed per rev. The enclosed photo shows an 8% Cobalt HSS stub drill supported in this way. Because application drills of this type are made for drilling tougher metals they have a thicker web, which results in a longer chisel edge in the point to rub on the work. Using a 5/16in. centre drill, then a 4mm. 8% Co HSS application drill with split ground point as a pilot eliminates the possibility of rubbing and, as is seen in the photo, the swarf is continuous from both cutting edges. Resist the temptation to 'peck' when drilling holes of less than 2 diameters in length, as once the cutting edge is engaged in the cut and the swarf is clearing the hole, the best you can do is keep the coolant aimed into the flutes. A re-start entails that rubbing before cutting phase which has to be avoided whenever possible.

Old/small machines wind up into the start of the cut, so load the drive train by holding the saddle feed wheel back until the change gears tell you the drive is working. Release once the cut starts.

Reamers have six cutting edges at this 8mm size, which means that 12 thou per rev feed would be a reasonable starting point. My reaming drill is 7.5mm which gives approx. 10 thou depth of cut which I rate as quite heavy for reaming, and use



cutting oil and 300 rpm. The H7 hole produced is of good finish and this one shows 4 tenths total run-out from central, is round and parallel. The HSS standard reamer looks and, more importantly, feels to be as keen as before cutting and this one has done five or six turbine bores at these rather heavy feeds.

An eccentricity of 2 tenths is insignificant in the Compucut CNC procedure as the bore is produced first and the rest of the turbine machined from this datum.

To produce a batch of turbines with minimum eccentricity, boring the centre after the blading operation, as in Eric's job, the reaming allowance would be shared with a single point boring tool, giving 5 thou depth for each operation. On this basis, I would estimate that one reamer would do the batch of holes if the feed were reduced to about 8 thou per rev.

I hope that readers may find this helpful.

Shaft speed measurement

From J. W. Lee, Bourne End, Bucks

I read Harry McCarty's article on this topic with interest, as I have made several circuits with the LM2917 chip, and now feel that I am on 'first-name' terms with it, so would like to make some comments which I hope will be useful.

Ignoring the obvious printer's errors in connector numbering in Fig. 3, there is one error here which may confuse those not familiar with this chip. C2 is the range capacitor, not C1 as indicated.

Harry McCarty's circuit is based on the Maplin circuit for which the printed board was designed. This circuit is intended to drive a rev. counter for a petrol engine, and has a number of components which are not required for the present application.

R1, R2 and ZD1 are there to protect the chip from the large negative pulses from the coil and C1 and R3 filter out multiple pulses due to contact breaker bounce. All of these can go, though we can find a use for R3. Just replace R1 and R2 with wire links. D1 is protection against reverse polarity connection, and can be omitted if your battery can't be wrongly connected.

The input must swing positive and negative with respect to the inverting input to the discriminator. (pin 11 on this chip). R4 and D2 bias the discriminator so that the input does not have to swing negative with respect to earth, though it must swing above and below about 0.7 volts. I prefer the 8-pin version of this chip, in which the inverting input to the discriminator is tied to earth, so the input must swing either side of earth. However, this requirement is easily satisfied with a differentiating circuit; a capacitor in series with the input followed by a resistor to earth. I would suggest 0.1 mF and 470K. On this board, put the 470K resistor in place of R3. The capacitor could be put in place of R1, but I would suggest putting it on the sensor board, as this simplifies the provision of an alternative input, such as an inductive sensor, which can be plugged in place of the optical sensor. Replace D2 with a wire link and omit R4. With this

arrangement the DC level of the input is irrelevant, and a much smaller input swing, typically around 50mV p-p at pin 1 of the chip is sufficient.

Considering Fig. 4, since R7 and R9 are the same value (390K), it would be possible to put one 390K resistor in one of the common lines to serve both ranges, thereby saving one resistor. However, I would prefer the following arrangement:

Use only one capacitor, 0.068 mF, for both ranges (no capacitor switching). Use a 560K resistor for the 0-1000 range, and a 47K resistor plus a 22K pot for the 0-10000 range. This gives an output of 4.79 volts nominal, still plenty for the application, and saves two capacitors, one resistor and a pot.

To set up, select the 0-1000 range, set 1000 rpm as described by Harry McCarty, and adjust the meter series pot to read full scale. Now select the 0-10000 range, and either set for 6000 rpm, again as described, or disconnect the sensor, and feed in a small voltage at 100 Hz from a full-wave rectified transformer (a much more certain way to get an accurate figure) and adjust the 22K range pot.

A word of warning about the power supply. On a nine volt battery, there will be only 1.44 volts across R5, which gives 3.06 mA, and around 3 mA is required for the tach and op-amp alone. This doesn't leave a lot to spare for the charge pump, or to keep the Zener in its linear area. Consequently, as soon as the battery voltage falls below 9 volts, the voltage on pin 9 will fall, and although the device may seem to work, it will not be accurate. Cut R5 down to 330 ohms in this case, and conversely increase it to 1200 ohms if going to an 18V supply.

P. S. When I wrote the above, I had the RS data sheet on the LM2917N-8, (the 8-pin version) and I assumed that the 14-pin version was identical apart from the pin-out. I have since seen the complete data sheet, and I find that there is one significant difference between the two versions; the 14-pin version has no input protection. Consequently any input which swings about zero volts, such as an inductive sensor, must have sufficient series resistance to keep the negative current to a low value. This shouldn't affect the present application, as the maximum current from the sensor is less than 1 mA, but it should be borne in mind if any other sensor is used with this device. The 8-pin version can accept inputs up to +/- 28 volts. It is available from Electromat, Catalogue no. 302-047, and the price is £1.56 plus VAT. There is no ready-made board available for it.

Harry McCarty responds:-

I have noted Mr Lee's comments with interest, and reply using his sequence.

I undertook this project with three major aims:-

1. It should work.
2. Bearing in mind that the readership will be mechanically inclined, I endeavoured to reduce complication, retain versatility and avoid involvement with mains voltages.
3. Avoid unnecessary expense.

I can confirm that there are three errors in Fig. 3 (a) The range capacitor is C2 not C1 as indicated, (b) Input ground should be 3 not 1 as indicated and (c) The lower L/Hand pin on the chip should be pin 1, not pin 14.

(a) & (b) were in my original draft, (c) is a printers error. My apologies!

The Maplin circuit was indeed designed for use as a car rev. counter and for shaft speed measurement, three components are not required. However, retaining these ensures that the device can be used for the original purpose and the cost saving is less than 25p.

I would not advise the removal of D1 as, in my experience, people inserting PP3 batteries do sometimes make contact at the wrong polarity, not worth the risk at 7p.

Regarding R4 & D2, this is a good point and I intend to see the effect of this mod, - it will increase the sensitivity. I have experimented with a home-made inductive sensor, but looking at the ease of marking a shaft against arranging a ferrous tip or tooth to pass the inductive sensor, it is far simpler to mark the shaft. I did increase the sensitivity and encountered errors due to the sensor false-triggering due to marks and scratches on the rotating bar.

The comment on Fig. 4 (R7 & R9) advises the use of one capacitor for both ranges. I avoided this as the chip manufacturer states that using approx. 500K ohms ensures the best linearity and 47K-79K would degrade the linearity with minimal saving of cost. I agree that one 39K could be used at a saving of 7p. This modification would reduce the output voltage to 4.79 volts, enough for this application, but probably not enough for the line of light display at a nominal of 5 volts that I mentioned in the article.

Concerning the calibration, I have avoided the use of mains derived voltages for safety reasons and, as stated in the article, I had difficulty achieving 10,000 rpm and thought that this may be the general case. However, it is a better calibration point. If a couple of solar cells were available, these could be exposed to 50Hz light, providing a 100Hz input and avoiding 'messing with the mains'.

Power Supply:- I did mention in the article that the 9 volt battery was marginal and called up additional cells, avoiding another PP3 to reduce expense.

In conclusion, I would like to thank Mr Lee for his very worthwhile comments - he is certainly on 'first name' terms with this device. As an aside, I would like to see his work on the LM2917 chip.

An aid to neat drawing

From Ted Fribbins, Long Ashton, Bristol

May I add to Mr. Loader's excellent "Plain Man's Guide to Drawing" instrument set (M.E.W. Issue 64)? A draughtsman's Erasing Shield is an invaluable device, particularly when rubbing out on circuit diagrams.

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