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MODEL ENGINEERS'

WORKSHOP

THE PRACTICAL HOBBY MAGAZINE

METAL INERT GAS WELDING

An introduction to the process

BUILDING THE 'WORDEN'

A tool and cutter grinder from a kit



A DRILL EXTENSION

Aids progressive drilling

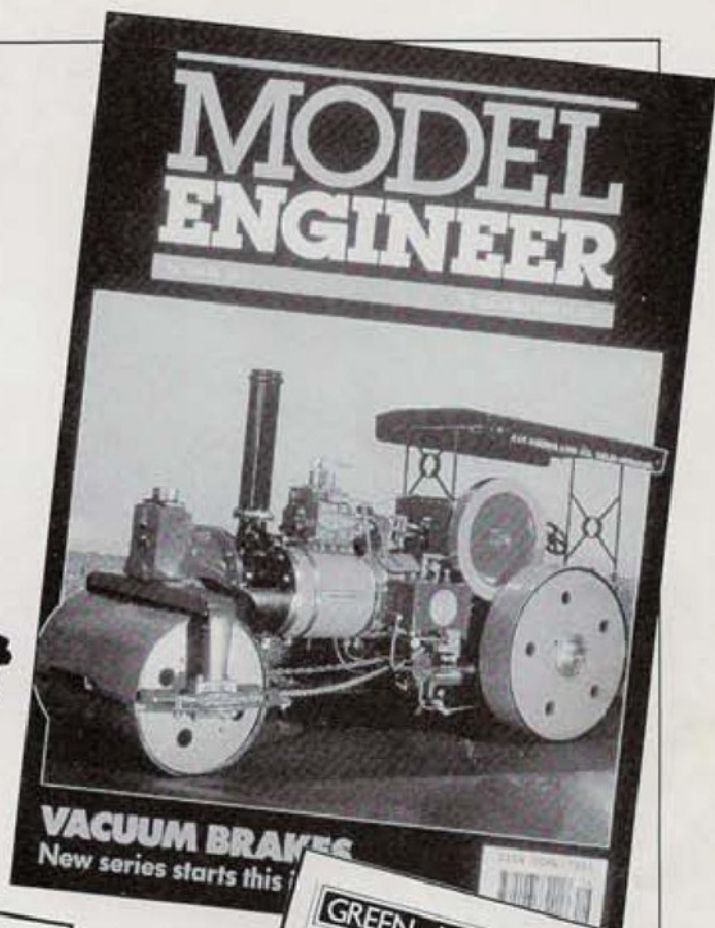


THE MODEL ENGINEER EXHIBITION

29th December 2000 - 1st January 2001

AT SANDOWN PARK EXHIBITION CENTRE, ESHER, SURREY

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



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

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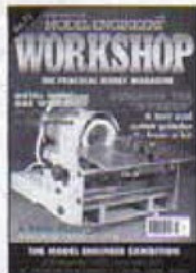
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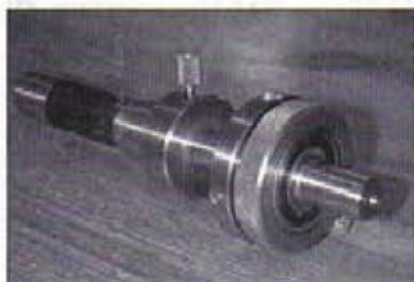
Editor: Geoff Sheppard

Nexus Special Interests, Nexus House, Azalea Drive,
Swanley, Kent BR8 8HU tel. 01322 660070 fax. 01322 667633



On the cover

An example of the 'Worden' Tool and Cutter Grinder, the building of which is described in an article starting on page 38



Peter Rawlinson's extending drill chuck arbor allows various lengths of drill to be used without upsetting the basic machine settings. His constructional article begins on page 43

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EDITORIAL

Editor
Geoff Sheppard

Editorial Administrator
Sarah White

PRODUCTION

Designer
Carol Philpott

Copy Control Manager
Lucy McGeough

Printed By
Polstar Colchester Ltd

Origination by
Derek Croxson Ltd.

SALES

Sales Executive
Mark Pinkney

MANAGEMENT

Group Managing Director
Tony DeBell

Divisional Managing Editor
Dawn Frostick-Hopley

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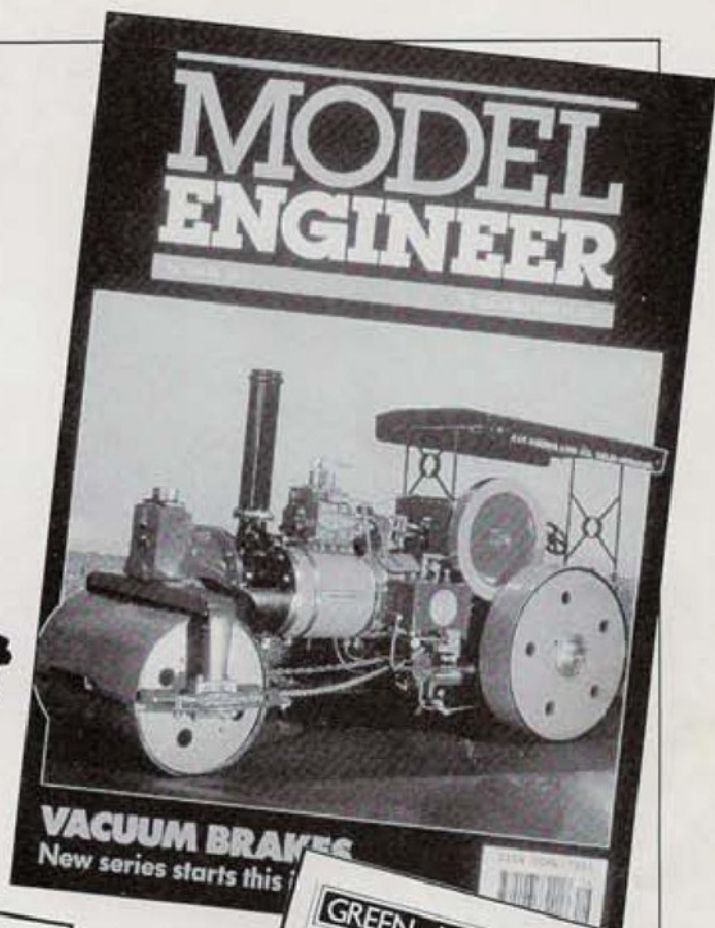
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ON THE EDITOR'S BENCH

constructed an attachment for a canoe which allows a one-handed person to operate a double-ended paddle.

The value of these and a number of other projects was recognised at a recent exhibition, NAIDEX 2000 held at the NEC, Birmingham, when awards were presented for a number of categories, in the presence of an audience of disabled people and health care professionals. Five NAIDEX awards were presented by REMAP Vice-President, Professor Heinz Wolff, who also presented his own award for the best electronic submission. The Inman Award, donated by co-Vice President Professor William Inman was for work-related projects, so went to Essex North East, and the shaver stand was judged to be of benefit to a number of people rather than a single disabled person, so was given The New Horizons Trust Award.

Quite a few of the current REMAP volunteers are home workshop enthusiasts such as ourselves, but members of our fraternity have also benefited from their efforts. Tools capable of being operated with one hand are a frequent requirement, while the workshop activities of one of our number have been made much more enjoyable by the provision of a chair equipped to run on a rail, so that he can move from lathe to milling machine to other equipment arranged along one bench.

REMAP's volunteers fall into two groups. About half are problem solvers - engineers, many of whom are professionally qualified in mechanical and electrical disciplines, supported by experienced machinists and carpenters, together with ingenious handymen and DIY-ers. The other group consists of problem identifiers, including occupational therapists, district nurses, teachers, social workers, doctors and others in the caring professions. A panel may have around 15 members and will probably meet monthly to review progress on existing projects, receive new cases for discussion and decide on action. Usually two members take responsibility for a project - an engineer and an occupational therapist - thus observing a balance of professionalism.

If you feel that you would enjoy a technical challenge and have a few hours spare time available, why not use them to help this worthwhile cause? All you need to do is to call the REMAP National Organiser, John Wright on 01732 883818 or the National Organiser for Scotland, John Golder on 01294 832566 and one of them will arrange an introduction to a convenient local panel, the members of which will give you a warm welcome. More information will be available in the 2001 edition of the REMAP Yearbook which is due to be published by the end of January and is available from the above Organisers at a cost of £5.60 including postage. By purchasing a copy you will give the funds a welcome boost.

In other spheres of volunteer activity in the UK, I am aware that efforts are

being frustrated by the weather. The recent heavy rains and swollen rivers have caused chaos in some areas, including the valley of the Bristol Avon in which our Brass Mill is located. We were inundated to a depth of 4ft., something we have seldom experienced at this time of year. Very large wooden items were floating around like matchsticks and much of the display material has been ruined, particularly the panels on which photographs and diagrams were mounted.

When the waters subsided we were confronted by a very thick layer of an evil smelling mixture of silt and vegetable matter containing all manner of obnoxious items. An assault with brooms, shovels and wheelbarrows was successful in dealing with the bulk of the problem, then a pressure washer proved invaluable in shifting the finer material. It will, however, be many months before we get back to the condition in which things were seen at our final Open Day of the season, just about a week before the waters started to rise. We are keeping anxious eyes on the weather forecasts, hoping that we do not get another flood in the coming weeks.

However badly we were hit, all members of the team were very conscious that, at the end of a clean-up session, we could lock the door and walk away. We are not nearly as badly affected as those whose homes and businesses have been in a similar state. We can only imagine how heart-breaking it must be to have to start salvaging treasured possessions, many of which it will be impossible to replace. We hope that none of our readers has had home or workshop ruined. Small tools can usually be salvaged, and modern de-watering fluids can work wonders, but a silt-filled machine gearbox or saturated electrical equipment is another matter.

It seems that we in the UK have not been alone in experiencing flooding, television pictures having shown us that some areas of Australia have suffered similarly. We have a significant readership in that part of the world, so we hope that you too have escaped the worst of the problem.

Turning now to more hopeful matters, this issue of M.E.W. will be published just a few days before Christmas, so all at Nexus join me in sending readers the compliments of the season and expressing best wishes for 2001. Looking back over the past year, all the publicity surrounding the Millennium Dome prompted me to compare public reaction with that accorded to the similar event held nearly 50 years ago, the Festival of Britain. My recollection is that there was a much more positive response then - perhaps there are so many more major events in the world now and getting to them presents little difficulty, so we have become much more critical and selective. I remember, in 1951, together with a school friend, cycling the 120 miles to London to visit the South Bank and Battersea Park, and also to attend my very first Model Engineer Exhibition. 50 years on, I suspect that the event to be held at Sandown Park over New Year will be the occasion for a small celebration.

My first, and very sad duty this month is to record the passing of one of our contributors. Robert Newman of Lancing, West Sussex died a couple of months back.

Robert sent us a number of articles over the years, the majority of which offered a slightly different slant on problems encountered in the home workshop. I particularly enjoyed his contribution on hand turning and his instructions on how to make dead-blow hammers. I regret that I never had the opportunity to meet him face to face, but enjoyed quite a few good-humoured telephone conversations, and will miss his cheery greeting. We send sincere condolences to his family and friends.

The fact that many of our fraternity are in the older age groups means that, inevitably, we shall suffer these losses from time to time. The same problem is affecting REMAP, the charity which helps to provide technical equipment for disabled people. During a recent conversation with their National Organiser, John Wright, he was telling me that it is about eleven years since their last campaign to recruit more volunteers, and they now have a need to seek additional help. A part of this need has been generated by the increasing number of referrals, some 3000 of the six million or so people with disabilities in the UK having been helped last year.

Some of the devices produced by the 1500 members of the 106 local panels (the 107th is just being established in the Isle of Man) are designed to help with the business of just getting on with life. For example, Devon South constructed a stand for an electric razor, allowing it to be used by someone who is unable to use their hands, while Lincolnshire devised a WC rail for a schoolchild. Work related items also feature, Essex North East having helped someone to be able to continue working in a Post Office by designing a handle for a document stamp which absorbed the shock of the stamping process.

Leisure activities are not forgotten, the Tyne-Tweed Panel having produced a line casting device - something like a Roman catapult - for a beach angler, and a husky racing rig which enables a lady with cerebral palsy to continue to enjoy the sport in the forests of the area. For watersports enthusiasts, Devon North

LATHE SPINDLE LENGTH STOPS



1. Mark I set of parts showing how the screwdriver can hold the screwed rod in place while tightening the locknut with a tube spanner

Sooner or later all lathe users encounter a need to precisely position parts axially in lathe chucks or collets. Some sort of stop is required, but these do not seem to ever be supplied as part of the original outfit, and rarely can be obtained as optional extras.

Various designs for such equipment have appeared from time to time in 'M.E.', 'M.E.W.' and elsewhere as References 1 & 2 indicate. This article relates to two such devices which now grace my workshop, and which show some differences from those previously described.

Mark I

My first attempt, the device shown in **Drawing 1 and Photos. 1 & 2**, was to be a minimalist approach - a tapered plug (Item 1) in the spindle bore through which a length of screwed rod (Item 2) was used to set the required stop position, and which could be fixed by a locknut. Three various diameter caps (Items 3, 4 & 5) were made to use with different ranges of work diameters.

The screwed rod was adjusted using a long screwdriver in a slot in the end of the rod, and the locknut tightened with a tube spanner. Thus the screwdriver blade could operate down through the tube spanner to



2. Caps, each stamped with its length addition when screwed on to rod

hold the screwed rod in position while the spanner tightened the nut.

The axial position of the end of the screwed rod could be checked from the face of the chuck or from the end of the chuck jaws with a depth micrometer or a vernier caliper. The thicknesses of the three caps when threaded on to the screwed rod were measured and recorded by stamping on each cap.

For a couple of decades this device served its purpose to some degree, but it was neither convenient, nor very accurate, so at length it was decided to supplant it with something more sophisticated.

Mark II General

The new equipment owes much in concept to those of Tubal Cain in Reference 1 and Harold Hall in Reference 2. Because my Taiwanese lathe has a relatively large spindle bore it was possible to separate the various functions.

The determining dimensions of my lathe for this project are as follows:-

- Axial length of spindle 365mm
- Spindle bore diameter 35.5mm
- Spindle end taper MT 4 1/2
- 3 & 4-jaw chuck internal bore dia. 41.5mm
- Outside diameter of spindle at non-chuck end 42.2mm

The device has two sets of parts:-

- a. Tapered plug with various sliding stop rods.
- b. Screwed rod with end supports and

A simple lathe stop system, suitable for a larger lathe, is described by Philip Amos

positioning nut held in spindle bore by an expanding split tapered sleeve.

These are shown in **Photo. 3**.

Design

a. The tapered plug (Item 6) occupies the full length of the tapered section of the spindle bore. It has a reamed 1/2in. diameter axial hole in which silver steel 1/2in. diameter stop rods slide.

The length of the simplest stop rod (Item 7) is such that one end projects 3mm from the rear of the tapered plug when its other end is just level with the outer end of the chuck jaws (3-jaw chuck - it projects further with the 4-jaw chuck).

The second stop rod (Item 8) is turned down to 6mm diameter for a slightly greater length than the axial length of the chuck jaws. This allows it to be used with material down to 1/4in. (6.35mm) diameter.

The third stop rod (Item 9) has a flat disk of 40mm diameter attached at one end such that it will fit easily through the chuck bore - see **Photo. 4**. This can be used to position larger thin components accurately axially in the chuck jaws when there is not much to grip on.

It may be that rods with larger disks might be useful in positioning work in the chuck reversed jaws, but so far I have not had any such jobs come to hand, so I have not made these additional rods, and will delay doing so until a definite requirement emerges.

All the rods have been machined to a common axial length to facilitate measurement - see later. These rods are positioned axially by the screwed rod arrangement described below.

b. A nut, Item 10, has its inside tapped 1/2in. NF for 13mm length and the remainder of its length drilled 3.3mm diameter to clear the screwed rod. Its outside has a tapered portion (20 deg. included angle), a parallel portion and a slightly reduced portion threaded 3/4in. BSPF. This nut engages with the expanding split taper sleeve, Item 11, which internally has a matching 20 deg. included angle taper, split with four slots, and a parallel portion. Externally it has a parallel portion which is relieved in its middle range, and also has a large knurled handwheel formed on it.

A knurled nut (Item 12) threaded 3/4in. BSPF is used to draw the tapered nut into the tapered split sleeve, causing it to

expand and grip on the spindle bore. These components are shown separately in **Photo. 5** and assembled in **Photo. 6**.

The outer end of the screwed rod has fixed to it (with Loctite 680) a large diameter knurled handwheel (Item 13), and there is also a large loose knurled locknut threaded 1/2in. NF (this is identical to the handwheel, Item 13).

At the inner end there are two centralising supports, Item 15, threaded 1/2in. NF and pinned in place with 3/0 (1/8in.) taper pins - see **Photo. 7**. Why two? Well, for use as a length stop for components which extend in from the chuck beyond the front face of the taper plug, the screwed rod does the whole job - the taper plug and stop rod in this case being removed. However, if the stop position required causes the end centralising support to be in the location of the spindle taper, then the increased diameter means no support is rendered. Hence a second support is provided at a distance which allows it to locate in the parallel part of the spindle bore.

If a case arises where the screwed rod must be withdrawn so far that the second support fouls the positioning nut, then it can be removed by knocking out the taper pins, unscrewing both supports and then replacing the end one.

The cover door for the lathe change wheels must be open to allow use of this device - see **Photo. 8**. After the device had been finished it became evident that a minor change in the design of the sleeve

and positioning nut, as shown in **Drawing 5**, would allow its use with the door closed - but I don't intend to remake it now. The change involves an increase in axial length of both components (Items 10 and 11) of 25mm, shown as Items 10A and 11A.

Manufacture

This is not a blow-by-blow description, but draws attention to some salient points.

a. Tapered Plug

The lathe's original equipment headstock sleeve MT 4 1/2 - MT 2 was supported on a MT2 centre and set up with its smaller end towards the tailstock. The centre was held on a female centre in a headstock sleeve and a normal centre in the tailstock - the latter having been previously checked for its fore-and-aft position. The taper turning attachment was adjusted to match the MT 4 1/2 taper using a dial indicator and then locked in that state. The tapered plug outside shape was then machined to size held in the 3-jaw chuck and supported by a tailstock centre. It was checked with a MT 4 1/2 gauge and Prussian blue and slight corrections made with a Swiss file.

The tapered plug internal diameter was then drilled, bored and reamed to an easy sliding fit on the silver steel stop rod (with no wobble) and was the parted off to length.



3. Mark II set of parts with all three stop rods - one inserted in the tapered plug

Stop Rods

I initially tried using Loctite 680 to attach the disk to the third stop rod, but found after several attempts that it would not stand up to finish machining, so I then silver soldered it in place and machined the face to ensure that it was at right angles to the rod axis.

b. Nut and Sleeve

Dimensions for the nut and sleeve were determined by full size layout drawings, starting from the spindle bore diameter of 35.5mm. To ensure this bore was parallel and circular, I put an expanding reamer through it, and removed a few minor irregularities.

From the drawing it seemed that the thread for the draw-in nut should be about 1in. diameter, and as fine a thread as I could find for which I had a tap and die. This proved to be 3/4in. BSPF, 14 tpi with a nominal outside diameter of 26.14mm, so the parallel portion was made 27.00mm diameter and the taper 20 deg. included angle following Harold Hall's design. The taper was machined using set-over of the topslide, and both internal and external tapers were machined at the same setting.

The splits in the sleeve were made with a hacksaw as no convenient means presented itself to hold the component securely for cutting with a slitting saw.

The sleeve, draw-in nut, locknut and screwed rod handwheel were all knurled in one operation, and then each parted off the bar.

After pinning in place, the outer face of the end support was skimmed at right angles to the screwed rod axis, with the latter held in brass shims in the 3-jaw chuck, and the outer face of the handwheel was similarly treated.

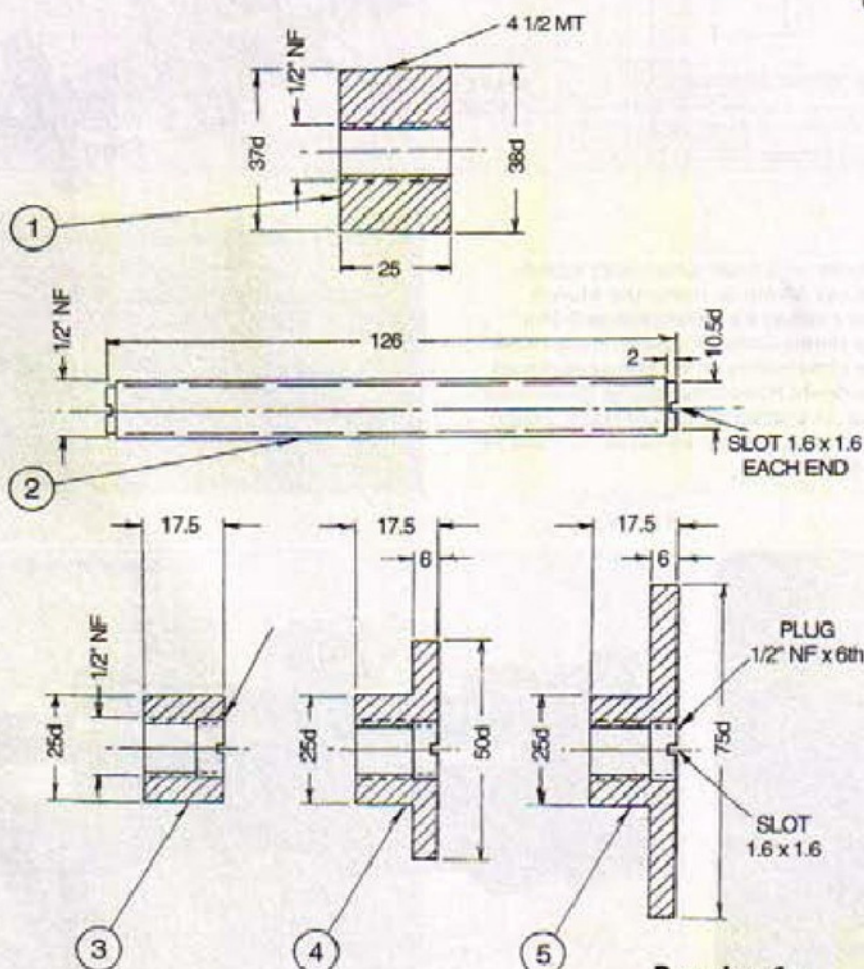
Use

From **Drawing 5** it will be seen that the depth of the stop bar behind the ends of the chuck jaws - 'F' - is given by the expression:-

$$F = A + B + C - D - E$$

$$= A + (\text{constant})$$

Thus the depth can be readily measured by the use of a micrometer or vernier

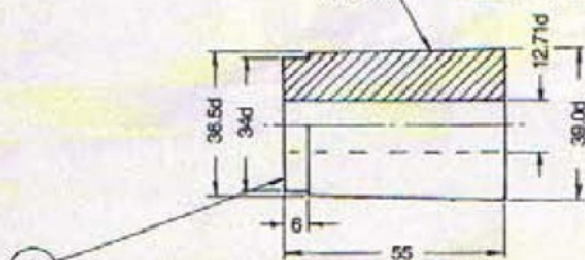


Drawing 1 - Details Mark I Material Mild Steel

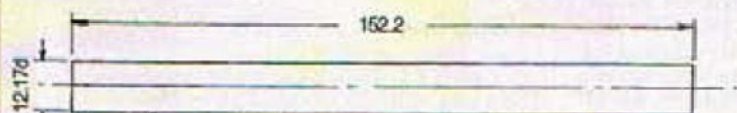
©

MATERIALS: ITEM 6 - MILD STEEL
ITEMS 7 & 8 - SILVER STEEL
ITEM 9 - SILVER STEEL & MILD STEEL

MT 4 1/2



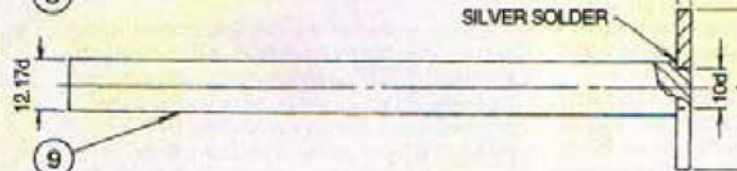
6



7



8



9

Drawing 2 Plug and Stop Rods

caliper across the handwheels (distance A) and applying the constant. This ease of measurement was a principal aim of the concept.

Conclusion

The devices described in this article may be found useful in the home workshop.

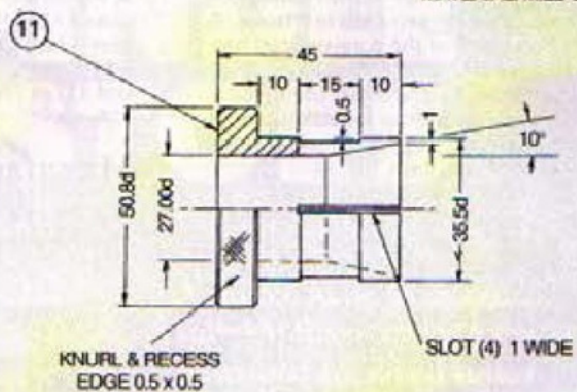
For those who have lathes with spindle bores say 30mm or more, the Mark II concept would be recommended. The actual dimensions, of course, must relate to the dimensions of the lathe concerned.

No doubt it could be scaled down even further, but probably Harold Hall's design in Reference 2 might be easier to make for a smaller lathe.

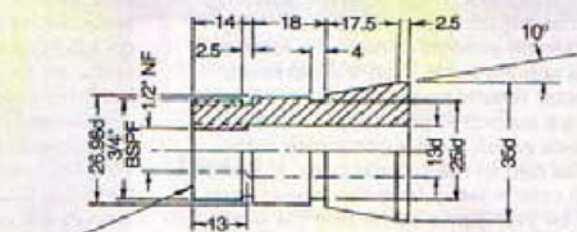


4. Flanged stop rod positioned with 3-jaw chuck

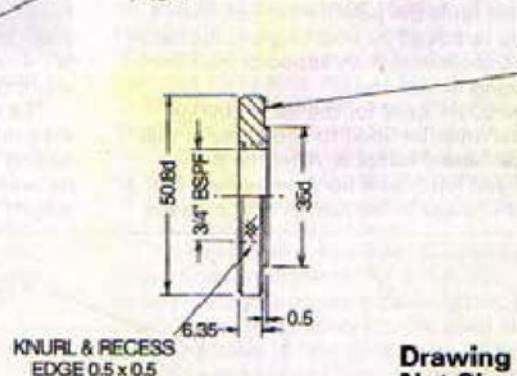
MATERIAL: MILD STEEL ©

KNURL & RECESS
EDGE 0.5 x 0.5

SLOT (4) 1 WIDE



10

KNURL & RECESS
EDGE 0.5 x 0.5

12

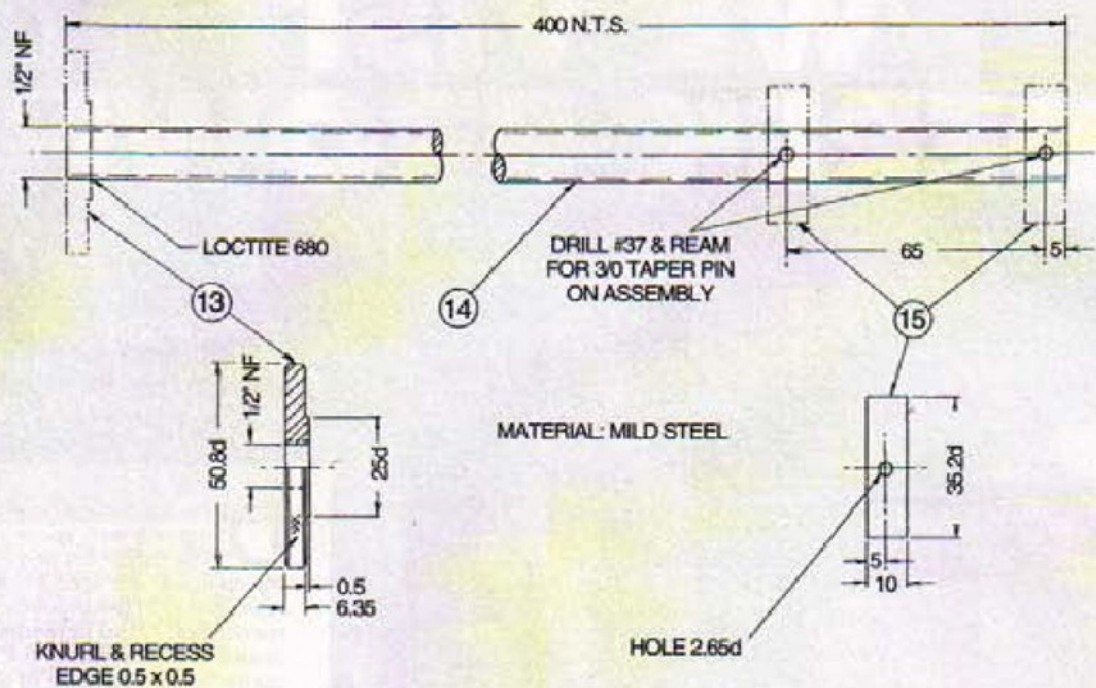
Drawing 3
Nut Sleeve and
Ring

References

1. Workholding in the Lathe - Tubal Cain - WPS 15 1997
2. A Lathe Backstop - Harold Hall - MEW 10 Apr/May 1992
3. Machine Tapers - Philip Amos - MEW 56 Feb 1999



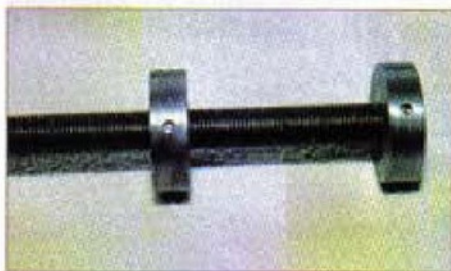
5. Separated components - 1/2in. NF locknut, 3/4in. BSPF draw-in nut, sleeve & nut



Drawing 4 Handwheel, Rod and Supports



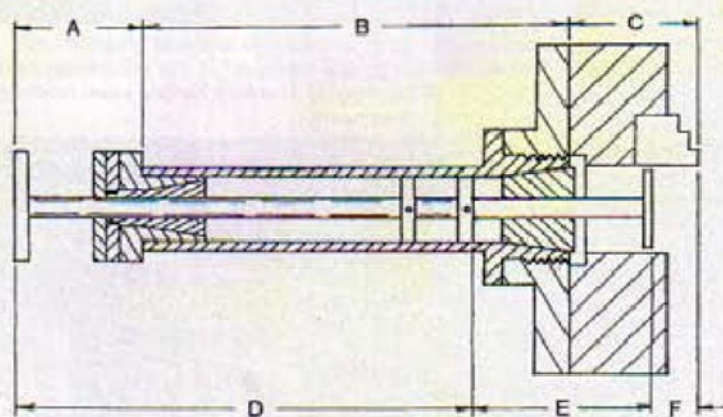
6. Assembled components



7. Operating end



8. As fitted in lathe spindle with change gear guard door held open



$$A+B+C=D+E+F$$

$$\text{so } F=A+B+C-D-E$$

$$=A+\text{CONSTANT}$$

in my case

$$B=365.5$$

$$C=98.5 \text{ (JAW)} \quad 82.9 \text{ (4 JAW)}$$

$$D=399.5$$

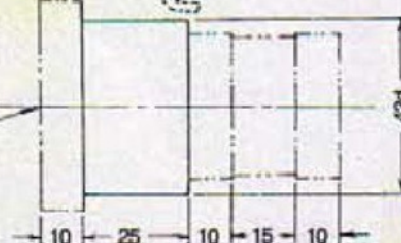
$$E=152.2$$

$$\text{so CONSTANT} = -87.7 \text{ (3 JAW)} \quad -103.3 \text{ (4 JAW)}$$

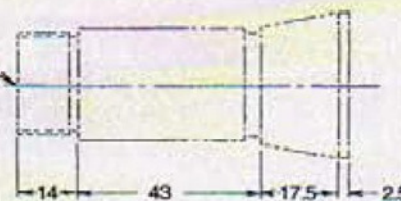
SPACE FOR
CALIPER LEG

COVER POSITION

11A



10A



**Drawing 5
Diagrams**

WE VISIT DEREK BROWN



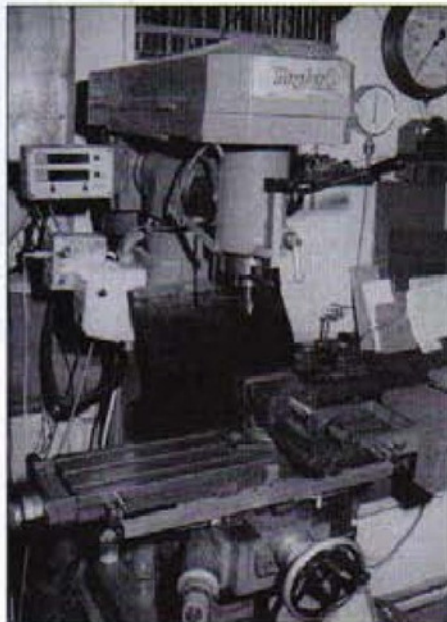
While in Lincolnshire the editor took the opportunity to call in on a fellow SMEE member

Derek Brown is a retired Chartered Engineer who spent his working life in development and management in the chemical and food industries, specialising in thermodynamics and fluid mechanics. Active in model engineering circles for many years now, Derek is currently the Chairman of Stamford MES and a keen supporter of the Society of Model and Experimental Engineers. He is usually to be found at those national exhibitions at which the SMEE have a stand and workshop, demonstrating a variety of techniques, particularly the sharpening of very small drills. He has also taken an interest in the application of computer aided drawing to model

1. Derek has made a study of the sharpening of small tools and has given many demonstrations at exhibitions where he can usually be found in the workshop organised by the Society of Model and Experimental Engineers, of which he is a keen member. He also lectures on the uses of CAD for model engineers

2. The construction of small locomotives is another of his interests. This 7 1/4 in. gauge Hunslet was started as a joint project with his friend Tony Priest who died soon after work commenced. Derek carried on to complete the engine which is now named in memory of Tony





3. Prominent in Derek's well equipped workshop is his Myford VME milling machine which is fitted with an 'Ortec' X-Y digital read-out system. Redundant pressure gauges make an interesting addition to the workshop wall



4. The table power feed mechanism is a substantial home-built device



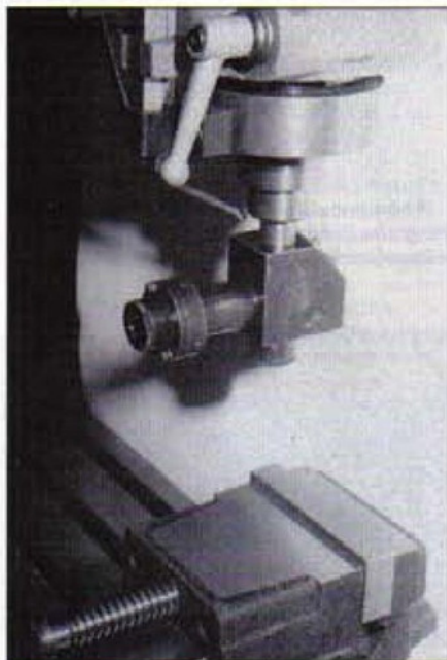
6. The device seen on the machine vice in Photo. 3 is this versatile magnetic clock stand equipped with a variety of fittings to aid workpiece alignment

engineering projects, having set up his system at exhibitions to give demonstrations and lectures. He always draws a large and receptive audience. Encouraged by the response he set about writing a book on the topic, this having now been published as No. 29 in the Nexus Workshop Practice Series.

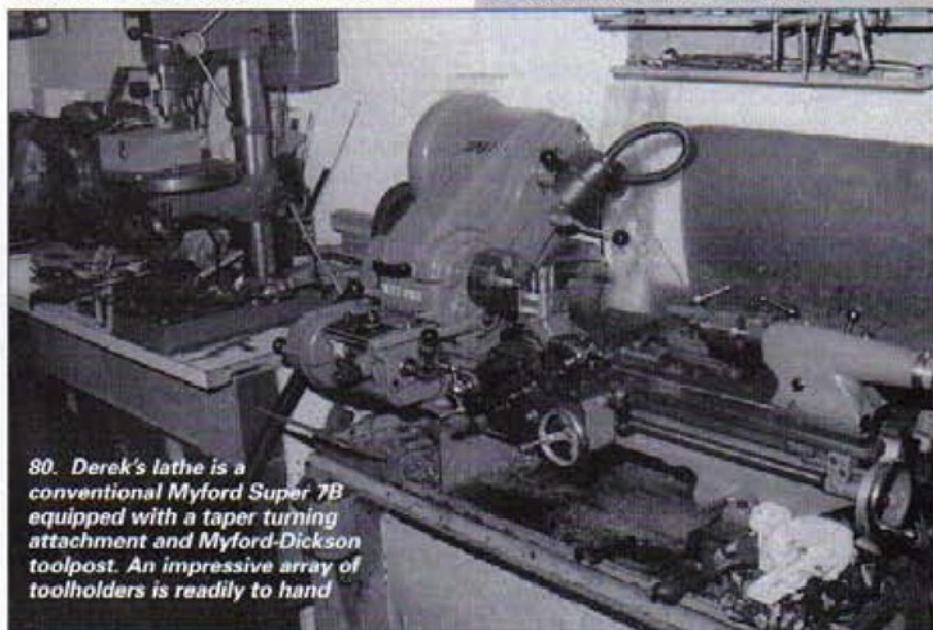
Derek's workshop is not large, but is well equipped, as can be seen from the following photographs.



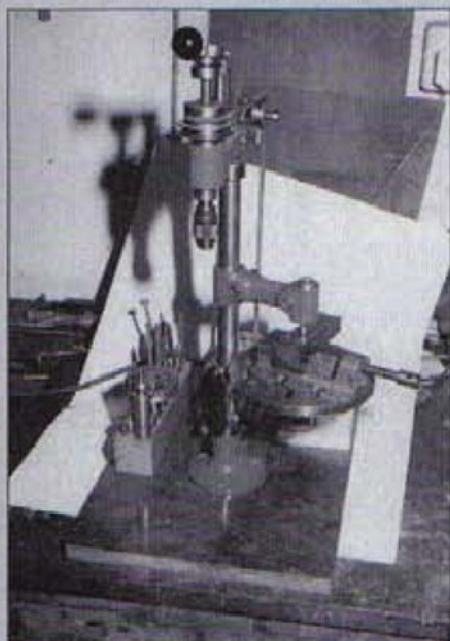
5. Another view of the table feed gearbox which is occasionally removed from the machine to be displayed on the SMEE stand at model engineering exhibitions



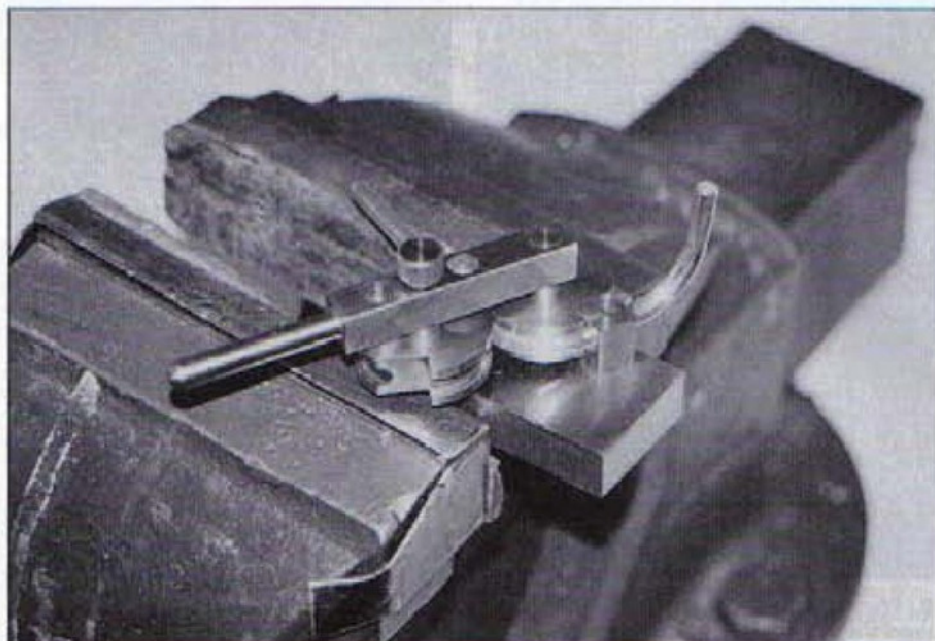
7. An accessory made for use on the milling machine is the optical alignment microscope developed by Derek and his colleague Dick Stephen. This unit was described in 'Model Engineer' Issues 4103 and 4105 (September/October 1999). Also to be seen is the pipe which brings coolant to the tool



80. Derek's lathe is a conventional Myford Super 7B equipped with a taper turning attachment and Myford-Dickson toolpost. An impressive array of toolholders is readily to hand



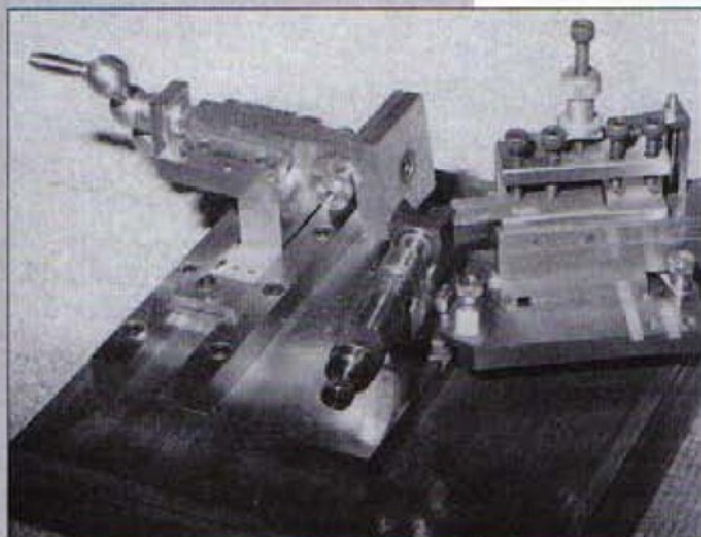
9. No workshop is complete without at least one George Thomas project, this being his Pillar Tool



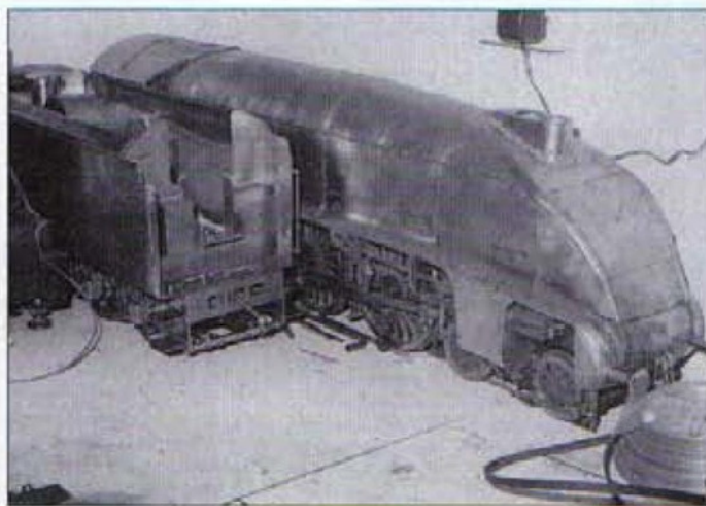
10. Derek is always prepared to spend time making small tools if this is necessary to achieve the correct end result. Quite a number of these small pipe benders have been made by readers after he described it in M.E.W. Issue 64



11. When we visited Derek he was putting the finishing touches to a small precision lathe tool honing jig



12. The completed jig became a Silver Medal winner at the last Model Engineer Exhibition



13. Another locomotive project, now nearing completion is a L.N.E.R. Class A4 Pacific

NUT RUNNERS

Dissatisfaction with commercially available items led Derek Brown to produce a set of spanners which met his requirements



1. Some pretty awful Terry's spanners alongside some rather more presentable examples.



2. Box spanners and socket spanners, all commercial examples with their own disadvantages.

When our distinguished editor was in my workshop a few months ago he warmed to the method I used for making nut runners and has twisted my arm to share the secrets with all readers!

In common with, I would guess, many model engineers I originally bought a set of the unbeautiful Terry BA spanners. These have severe limitations in use insofar that they require a huge amount of clearance all around the nut or bolt head and this just is not available in many of the corners of a nicely turned out model (see Photo. 1). One step up the market is the accurately made chrome vanadium spanner, but again this has limitations on access, as does its cousin the ring spanner.

It was therefore inevitable that I bought a set of 'box spanners', all rather clumsy but fulfilling a useful need in the armoury. Over the years I have followed these with commercial wooden handled box spanners and a socket set with all the common sizes of socket, but all these tools have one thing in common - they require plenty of radial clearance around the hexagon - enough to swing a cat, so to speak (Photo. 2).

In consequence, several years ago I started to experiment with home-made box spanners of the nut runner pattern and have found the manufacturing method easy and the product durable

enough for the purpose, although not built for everlasting life! A selection of home-made nut runners is illustrated in Photo. 3; all are to fit 10BA nuts and standard head bolts of that size and they are shown for comparison alongside one of the commercial box spanners of the same size. The photograph makes it apparent how clumsy the commercial article is by comparison. Production of the items is easy provided that some basic size considerations are observed.

In any hexagon, the distance across the corners is 15.5% greater than the measurement across flats. This determines that we need a core hole for the female hexagon somewhere between these two measurements and from experience, take a figure around 6% greater than the across-flats measurement; this will ensure a small amount of stretching of the metal as the hexagon is formed.

Chuck a piece of silver steel of convenient length and diameter and drill the correct size shown in Column 6 of the table for a depth of $1\frac{1}{2}$ times the nut or bolt head thickness. Next drill the BA clearance size for say $\frac{1}{2}$ in. depth beyond this hole, so as to enable the nutrunner to be used over a protruding thread. Now turn the O/D of the silver steel to a diameter 0.030in. greater than the core hole size, so that you should have a short cylindrical portion with a 0.015 in. wall

thickness. Take this diameter back far enough to clear any obstructions as necessary (Fig. 1).

Now we are ready to form the hexagon by deformation of the metal in the core hole and for this purpose use an Allen key, either in its entirety or cannibalised for the purpose. These keys are of course cheap enough for this purpose, but if it goes against the grain to cut one up, then grip it in a short split bush with a hole drilled through just big enough to take the hexagon across-corners size (Fig. 2). By holding it thus in the 3-jaw chuck, the 'heel' of the Allen key will press against the chuck body and allow the key to be forced into the hole. The business end of the Allen key should be slightly rounded to allow it to enter the hole which it is to deform.

Now, if you examine the data in the table you will notice that 2, 5, 6 and 9BA hexagons are slightly larger than the keys to be used. In these sizes, after forming the hexagons waggle the keys around in the hexagon holes while the pieces are still in the chuck. This will enlarge the hexagons to the correct size; not much movement is required to open out the sizes by a thou or two. Alternatively, you can finish to size by forcing a nut or bolt head into the tight hexagon. On the other hand, for 4, 8 and 12BA the keys as bought are slightly too big and these should be stoned down to size on a coarse oilstone.

Now check progress: if you have worked to the correct dimensions the hexagons will be well formed and will be a good fit. Do check at this stage of the proceedings, since if there is any reworking to be done, it is a simple matter to part off the end of the part and start again.

I should mention that, with the abandonment of some Imperial rolling facilities, some of the sizes on commercial screws are bastard sizes. Thus for example

BA size	Dia	A/F hex.	A/c corner	Hole size	Drill	Allen key	Error
2	0.185	0.324	0.374	0.343	$1\frac{1}{32}$ in.	$2\frac{1}{16}$ in.	
3	0.161	0.282	0.326	0.299	7.6mm	$\frac{9}{32}$ in.	-0.01in.
4	0.142	0.248	0.286	0.263	6.7mm	$\frac{1}{4}$ in.	+0.02in.
5	0.126	0.221	0.255	0.234	A	$\frac{7}{32}$ in.	-0.03in.
6	0.110	0.193	0.223	0.205	5	$\frac{3}{16}$ in.	-0.04in.
7	0.098	0.172	0.199	0.182	14	$1\frac{1}{8}$ in.	
8	0.087	0.152	0.176	0.161	20	$\frac{5}{32}$ in.	+0.04in.
9	0.075	0.131	0.151	0.139	28	$\frac{1}{8}$ in.	-0.06in.
10	0.067	0.117	0.135	0.124	$\frac{1}{8}$ in.	3mm	
12	0.051	0.088	0.102	0.093	42	$\frac{1}{32}$ in.	+0.05in.

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

Tungsten carbide and diamond tooling from Eternal Tools

Eternal Tools specialize in tungsten carbide and diamond tooling for the engineer and horologist. In addition to their ever-expanding range they have just introduced a range of very fine (600 grit) diamond files in all shapes and sizes, perfect for detailed work on all hard materials and also for re-sharpening blunt cutting tools. Individual 140mm diamond files cost £5.00 each or an assorted set of ten for £44.95, while the larger 180mm diamond files cost £7.50 each or a set of five for £34.95.

To complement their diamond range they are also manufacturing diamond wheels to specification. They can be offered in 20 different shapes, most sizes and various diamond grades. One very popular wheel is a 6in. x 1/2in. x 20mm wheel designed for your bench grinder. Once easily fitted as a replacement for your normal grit wheel, tungsten carbide and High Speed Steel tools can be repeatedly sharpened with ease. At a price of £49.95, for a model engineer hobbyist this kind of wheel can be expected to last for a lifetime.

For further information Eternal Tools can be contacted on Tel: 0208 880 0974, email: enquiries@eternal-tools.co.uk and they also have a comprehensive website with secure online ordering: www.eternal-tools.co.uk

Make waterslide decals on an ink-jet printer

JetCal is a new paper that can be used to make slide-off (waterslide) decals using an ink jet printer. This revolutionary paper allows you to create your own decal design on your home PC to decorate all sorts of items, on materials such as glass, Perspex, plastic, wood, metal, pottery, painted surfaces and wax. It is therefore ideal for model makers and craftsmen, providing the means of making transfers required when painting models or putting the finishing touches to equipment which needs dials or labelling.

To make JetCal transfers, designs are generated on a PC using a standard artwork package, by scanning an existing design or by taking a digital photograph. Once the design is finalised on-screen, it is printed on JetCal paper using an ink-jet printer then cut around the edge of the design. To apply the transfer to the item, it is soaked in water for one minute to allow

it to slide from the backing paper on to the item. After application, the surface is wiped with a wet sponge and remaining water removed from the surface with a clean tissue. Unprinted areas will appear white. This process is explained further in the JetCal Instructions section of The manufacturer's web site www.thedecalpaperstore.com.

JetCal is available in packets containing ten sheets of A4 or five sheets of A3. Visit www.thedecalpaperstore.com to find out more about JetCal, How to use JetCal and Suggested Applications or e-mail questions@thedecalpaperstore.com

The Decal Paper Store, PO Box 1687, Stoke-on-Trent ST1 3TR

M.E.W. Computerised Index

A reader has suggested that some recipients of the magazine may have difficulty in reading the note which appeared on page 36 of Issue 69 regarding the computerised index for M.E.W. This index continues to be available and, as the number of published issues of the magazine increases, it becomes a more valuable tool.

The current version contains an index to all issues up to No. 68 and includes references to all articles, Quick Tips, letters

and to trade items having long term interest. A feature of the index is that it includes embedded subjects, items within an article but whose subject differs from the main object of that article.

The index is sorted by areas of interest; turning, welding, computer etc., but this can be over-ridden by the user so that it can be sorted by other criteria such as the author or chronologically. Search and print facilities are available, as is the ability for the user to edit and update the index for him or herself. For those not wishing to carry out this exercise, updates are issued every six issues, however, all updates contain the index from Issue 1, so if an update is missed, later updates will cover the missing information.

The system, whilst not requiring Windows will run on a Windows based system, any 386 standard machine or higher being adequate.

The supplied disks now also include the Lathe Changewheel Calculation program which was previously sold separately. This calculates every possible combination from the user's list of changewheels (well over 10000 for 13 changewheels).

The computerised index now costs £10, which includes post and packing within the UK. For non UK orders, please add £2.

The index can be purchased from CAHW Systems, 23 Fieldway, Berkhamsted, Herts. HP4 2NX by post only. Please make cheques payable to CAHW Systems

Welding protection from C. G. & W. Young Limited

C. G. & W. Young Limited are long-established suppliers of electric welding apparatus, making a particular feature of their eye protection equipment. This comes in two main forms, either as a LCD cartridge which will fit certain existing hand- or head-shields or as a range of full headmasks.

The 'Chameleon' cartridge is designed to fit shields which have a 4 1/4in. x 3 1/4in. (BS size) aperture and weighs only 120gm. It has a rapid 'arc to dark' switching time and a variable delay facility. It incorporates a sensitivity adjustment for use in strong sunlight and shades 9EW to 12EW can be

selected at the touch of a switch. Powered by two AAA size batteries, it achieves an average life of 500 hours, assisted by an auto-off feature which operates after 20 minutes non use.

The full headmasks are constructed around 'Translight' cartridges and are based on the latest technology, and have a larger, clearer viewing area, giving a 'true colour' image. These are also now battery powered for speed and safety, the older, slower solar powered models having been superseded by units which work ten times more quickly.

All the major operating parameters are again fully adjustable and the units are warranted for two years.

Full descriptive brochures are available on request.

C. G. & W. Young Limited, Colne Road, Twickenham, Middlesex TW2 6QQ Tel. 020 8894 5168/7767 Fax. 020 8898 1316



THE 70th MODEL ENGINEER EXHIBITION

NEWS UPDATE

The 70th. Model Engineer Exhibition will take place at Sandown Park Exhibition Centre between the 29th December 2000 and 1st January 2001

It is pleasing to be able to report that arrangements for the 70th Model Engineer Exhibition are proceeding satisfactorily. At the time of writing these notes (at the beginning of the last week in November), a substantial number of entries for the competition classes has already been received and the Loan section is also well supported. When taken together with the items which will be displayed on the Club and Society stands, it means that a goodly number of models, pieces of workshop equipment and horological items will be available for visitors to study and enjoy. My fellow Editors, Mike Crisp of *Model Engineer* and John Cundell of *Model Boats* join me in thanking all who have indicated their support for the exhibition, now being returned to the traditional format which evolved from that first Model Engineer Exhibition staged by the founder of the movement, the late Percival Marshall, back in 1907.

That support, together with that from our friends in the trade, has meant that it has been necessary to seek more space in which to accommodate the exhibition, which will now occupy the Surrey Hall, the Cobham Hall and the Eclipse Bar of the Sandown Park Exhibition Centre. In addition, our friends of the Malden & District Model Engineering Society have extended a welcome to visitors to the exhibition to join them at their nearby club headquarters. Transport is to be arranged.

Members of the Harrow and Wembley Society will be running an outdoor ground level railway track at Sandown Park (weather permitting, of course) and the Society of Model and Experimental Engineers will be actively engaged on a variety of workshop projects, using equipment most generously provided by a number of the trade exhibitors. SMEE

members will also be attempting to answer questions posed by visitors, as will the representatives of the other Clubs and Societies who will be manning their stands.

The list of these organisations who have confirmed their attendance is :- Gas Turbine Builders Association, Guildford MES, Harlington Locomotive Society, Harrow & Wembley SME, Maxitrak Owners Club, Stirling Engine Society, Ickenham & District SME, Malden & District MES, North London SME, SMEE and the Southern Federation of Model Engineering Societies.

Getting to the Exhibition

Sandown Park Exhibition Centre has 3000 free parking spaces and good road access and is located on the A307 London to Portsmouth road. If approaching from the direction of Central London, take the A3 and exit for Esher on the A309. From all other directions, join the M25 and exit at Junction 10 to follow the A3 towards London. Turn off for Esher on the A244. The route to Sandown Park is signposted.

Trains run from London Waterloo to Esher at half hourly intervals, the journey time being 21 minutes. A free bus service for rail ticket holders will run from Esher station to the exhibition, timed to connect with the trains. A return bus service will also be available.

Trade suppliers currently booked to attend:-

AB Tools
Ansa Hobbies
Bidwells
Brimarc Associates
Bruce Engineering
Carpenter & Howlett
Chalk Garden Railways
Chester UK
Chronos Limited
Classic Clock Kits
Compass House Tools
Concept EDM
Peter Dunk
EKP Supplies
Tony Green Steam Models
Hard and Software
HD Tools
W. Hobby Ltd
Home & Workshop Supplies
JB Cutting Tools
Key Solar Systems
Landseair
LA Services
LB Restoration Services
Langdon (London) Ltd.

MEC
Maxitrak
Model & College Metals
Myford
Paper 'n' Steam Galore
Peatol Machine Tools
Phoenix Promotions
Power Ball
Pro Machine Tools
Railway Correspondence & Travel Society
RD&G Tools
Ryan Tools
Shesto
Somoso Products
Starkie & Starkie Ltd
Studio Prints
Tools 2000 (Expo Drills)
Toolshop
Toolstop (Bracknell)
Tools UK
Tracy Tools
Videoline
Warren Machine Tools (Guildford) Ltd
Wilmington Engineering Supplies

GETTING STARTED IN MODEL ENGINEERING

In Part 2, Loris Goring describes the installation of his reconditioned lathe and the preparation required to bring it into operation

I had no idea that a robust lump of iron such as a Myford was anything less rigid than a frozen mammoth. In fact, the massive bed can be twisted and this is a thing that must be avoided if you want to produce accurate work. The exacting needs of a proper installation were something of a shock to me - a beginner at engineering.

No lathe will ever achieve the desired accuracy if the bed not housed on a very rigid level bench. Although a stout wooden bench can be made at home, wood moves as a result of changing temperature and humidity. Stout timbers and a metal top can minimise this and indeed, many an amateur's lathe has managed perfectly well on a wooden bench. However as my workshop has limited space, I decided that the cost of a compact new Myford Tray Top Cabinet Stand would be justified. In fact, long before the stand arrived I had played about with all variety of possible locations in the workshop, but due to other work benches I could not house it in the ideal position under a window, so the final position had to have some kind of first class lighting.

Lighting for the lathe

As we age, so our sight seems not to be as efficient as it was when we were young. As you see (Photo. 1), an extending light



1. A good light on a properly engineered extending arm is invaluable because it can be quickly positioned to illuminate the working area



2. There are a number of good headband mounted magnifiers on the market. Their advantage is that they leave both hands free.

(£25) that could be positioned directly over the tool post was purchased. Halogen lighting is good, but at around £130 from Myford rather too exotic for my fast diminishing purse.

It is worth noting that there is danger in using fluorescent lighting since this 'pulses' making it appear that the driving plate or tools in the headstock are stationary when in fact they are ready to give you a nasty injury.

For fine critical work, eyesight can be enhanced by using one of the magnifying lights on the market or Head Magnifying Glasses. I found an inexpensive one (Photo. 2), costing £19, at a model shop. It had dual magnification - 2.2x then, by slipping a second set of lenses down, a 3.3x magnification.

Safe working

Eyes are precious, so I was told that a polycarbonate mask to give full eye protection is a must when turning some types of brass which chip rather than peel off the tip of the cutting tool. Your ordinary

glasses give some protection from flying swarf, but safety glasses which have some form of side shield do a much better job. A chuck guard is also an excellent safety investment. More than one accident has occurred because a chuck key was left in the chuck and the machine has flung it out at the careless machinist.

While I detest the fact that we are becoming more and more a 'Nanny State', safety in the workshop is a vital issue. Simple measures like waiting for machinery to stop before working on it and avoiding dressing with any loose clothing that can get caught up in revolving chucks or spindles are obvious measures to take, but as someone once said, "Common sense ain't common!"

Acquiring tools

It is quite amazing how many new tools you need for a new workshop, but don't rush out and buy them at top price. Old engineers sadly pass away and often their tools are sold at greatly reduced prices by widows. Sounds morbid, but the chairmen



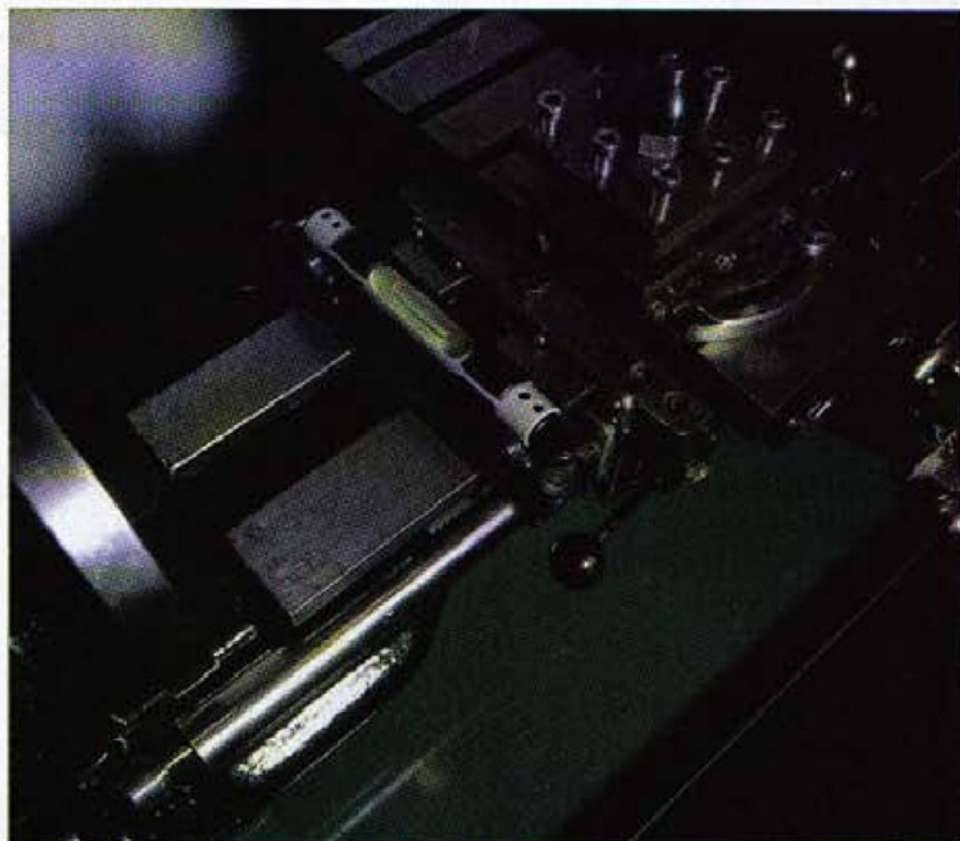
3. A simple tool rack, conveniently positioned, is a real time saver and avoids the possibility of the tools getting lost in the swarf in the machine's undertray

of model engineering societies are often asked to advise on sensible prices for tools when widows have no idea of their real value.

I made a sheet aluminium bracket and fitted it, as in **Photo. 3** to hold the tools that are constantly needed immediately to hand.

Heating the workshop

Although the joy of making things on your new lathe will blind you to the fact that it is freezing and damp in your workshop, the lathe will not like it. Therefore, put personal considerations aside and consider the best form of heating for the lathe and other machinery. While paraffin or Calor Gas (both hydrocarbon fuels) are an easy way to heat your workshop and make you comfortable, they are not the best for the lathe and tools. When hydrocarbon fuels burn they produce an equivalent weight of water vapour. This water vapour condenses on cold surfaces and rusty equipment is the result. Good ventilation will remove the vapour but also the heat, so these forms of heating are not the best. Conventional central heating or electricity are the best as both provide dry heat. I must admit that when I bought my house it was split level on a hillside and the under part was perfect for both a workshop and the central heating boiler. I'm not suggesting that you now move house, but that this was perhaps the one area where the problem of comfort for the



4. Although not cheap, a proper machine level is a worthwhile investment

lathe and myself did not need solving. Wall mounted heaters are well out of the way. Storage heaters (sometime second-hand ones) are relatively cheap and well enclosed. Free standing electric fires are not good as they can be knocked over and love wood shavings that seem to abound in workshops. They can be a fire hazard if you forget and stand too close to them while totally absorbed in your new project. Similarly, fan heaters at ground level suck in the dust that can be equally dangerous.

Levelling the lathe on its bed

Just heaving the lathe, even without a lot of its 'bolt-on bits' on to the stand was a job for two. We had inserted the levelling screws and their bolts onto the raised blocks and made sure that the blocks had their grommets inserted under them. As the blocks come down on the grommets

they prevent leakage of coolant into the cabinet below. If an old lathe is bought and dismantled from its stand for transport, the gaskets should be renewed.

The Myford manual is specific about levelling, and I ordered all the measuring and testing equipment necessary from Moore and Wright of Sheffield. They have now more than 94 years of experience in engineering precision measuring tools and I 'back Britain' as far as I can these days.

The tool I needed was the Moore and Wright ELS Engineers level (**Photo. 4**) to get the bed level in both the lengthways and crossways planes as it was adjusted on the four levelling screws. I was very surprised to find that when these screws were correctly adjusted so that the bed was perfectly level in both planes, just tightening the lock screws on top of the bolts would upset things. It took me a couple of hours to get things perfectly correct and all tightened down without disturbing the levels. In the Myford manual it describes how to turn a



5. The range of oils required to keep the lathe in good order and to aid machining



6. The Myford oil gun is designed to suit the nipples fitted to the oiling points



7. Ready to go! The refurbished and well equipped lathe would grace any workshop

test piece to check the levelling and to ensure that the chuck is holding the work correctly. My machine came with a 3-jaw chuck and things worked out well, although I understand that a 4-jaw chuck is likely to be more accurate, provided it too is in good condition.

Lubrication

Oil of one kind or another is really the life-blood of any machine, so I was not surprised to find that I needed three different types of oil (**Photo. 5**) for the Myford.

The manual does, of course, show the seventeen lubrication points, and the beginner is well advised to keep an illustration near his lathe, so that he does not forget to oil any.

The standard oils required are Esso Nuto H32 for general lubrication and Esso Febis K 68 for all the sliding surfaces. A rather expensive special Myford oil gun (**Photo. 6**) is required for the nipple oiling points and it is important to ensure that if your machine is equipped with the two drip feed oilers (which I had replaced), they feed the main headstock bearings at a slow, steady drip. As you see in the same photo, an ordinary oil can is used for the 'Nuto'.

The third can of oil was Myford 80136 Cutting Oil. This type emulsifies when water is added and it is used for cutting operations to cool the metal being worked and the cutter itself. Although you can have machines with a pumped system for the milky coolant, most small machining only requires the occasional squirt or dab from

a brush-full to keep temperatures down. I raided the bathroom for a shampoo squeeze bottle (seen right on the lathe tray in **Photo. 7**) and with a cap off an aerosol and two 5in. lengths of plastic tube, it has proved perfectly adequate for the job. Rocol do aerosol cutting spray cans of their RTD liquid, one for extreme pressure and the other a foam application.

Connecting the electricity

I am no electrician and as I enjoy life, I always use masking tape labels on any wires I dismantle, so that they go back in the same place. The lathe had originally been on a wooden bench, so the switch was of the old 'back and forth' type with 'stop' in the middle. It is vital in any workshop to have all machine tools properly earthed or 'grounded', so new wiring with the correct cross-section copper wire for the job was purchased from a proper electrical shop that advised on what should be used. You do not want any old wire that will not handle the starting load of an electric motor.

With the switch duly installed on the new cabinet and connected up I was pleased that the thing actually worked.

Getting the metal stock in

For a beginner, mild steels are cheap and cheerful and they abound. I found one

superb source at a local engineering shop, in what the proprietor called his scrap bin. Although scrap is a traded item, this bin was on a 'help yourself mate' and it was free. Model engineers in my club also unloaded their precious accumulations of metal and the gesture was much appreciated, although the better half looked aghast at the way I was rapidly turning the workshop into a scrap yard.

I was very grateful, as a newcomer, as it had never occurred to me that scrap could be such a prized item in one's life. Yellow Pages show you the metal stockists in your area, but just see what they charge! Scrap merchants are a fine source, but you usually have to do a lot of work to get the stuff you want.

At long last I had the pristine machine mounted, working and properly lit, so basically all I needed now were some lathe tools to make something from my rusty but prized scrap. While waiting to get the tools, I made the tool tray to fit under the cabinet, but it leans out only for photography! I also made a rack under an already existing shelf to hold some of the hand tools. The one cutter I had with the machine was hardly sufficient to turn out a whole candle stick, so in Part 3 I will tell you what tools I ordered.

Contacts

Precision Level:- Moore and Wright,
Sheffield Tel 0114 225 0400

LINK UP

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.

To advertise goods of a greater value, please contact our Classified Advertisement Department.

Please indicate clearly if an item is intended for Link Up.

FOR SALE

● M.E.W. Nos. 1 - 25. As new with all plants etc. Offers for lot please. Small slitting saws, 25mm dia. and smaller, 0.15 to 0.3 thick. 20 mixed for £3 or 40 mixed for £5. Tel. Colin on 01332 517439 (Derby)

● Single phase motor, ½ hp., 240V, with clutch, as new. £25. Prefer buyers to test and collect, otherwise to arrange collection. Tel. 01723 362537 (Scarborough)

● Potts' super drill grinding jig, unused £48. 240V motor, worm gearbox, 4in. shaft, final drive 46 rpm. £9. John Hammond, 96 Moorcroft Road, Moseley, Birmingham B13 8LU Tel. 0121 249 1520

WANTED

● Any information on B.C.A. Mk. 2 jig borer/miller. Tel. Colin on 01332 517439 (Derby)

● Operating manual for ACORNTOL shaper. Any information to help me repair and adjust this machine would be appreciated. Tel. Jim McGowan on 01661 822702

● Information on Boxford VSL (Variable Speed Lathe) control and speed measuring system. Tel. Pym on 01200 422257 (Lancs)

● For Westbury miller, complete Spindle Head Assembly or drawings/castings or w.h.y. Also drawings for Tinker Tool and Cutter Grinding Jig. Will copy and return with pleasure. Tel. Thomason on 01756 797261 (Skipton, N. Yorks)

● 30 notch (or 60) index plate for SAFAG II wheel cutting machine. I have a spare 12 notch plate. John Hammond, 96 Moorcroft Road, Moseley, Birmingham B13 8LU Tel. 0121 249 1520



QUICK TIPS

Drilling in the milling machine

When doing a job on a milling machine which requires a mixture of milling and drilling operations, is it really efficient to have to keep removing the collet chuck to replace it with a drill chuck?

Why not make a drill chuck arbor which will fit into a collet? Simply turn a taper to suit that of the drill chuck on a piece of material which will fit the largest convenient collet. Machine the other end as necessary to suit your collet system (e.g. threaded 20 tpi for a Clarkson chuck).

Anon

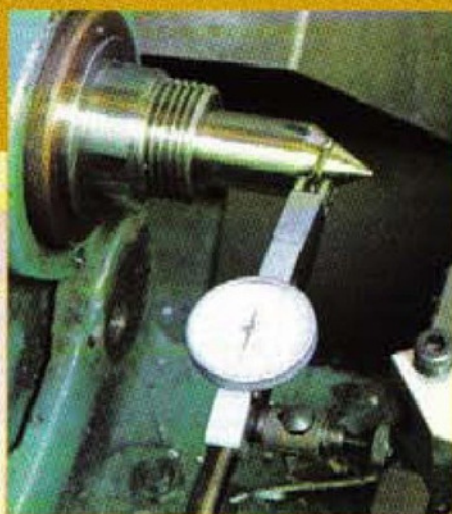
Stylus type D.T.I.s and cosine error

The traditional D.T.I. has a plunger which has a linear movement in operation. The 'Verdict' type has a stylus which describes an arc when deflected. This is unimportant for vice setting purposes where the instrument is used only as a comparator. However, come the fateful day when your 'tenths' clock has to be used to measure tenths, the stylus needs to be within 20 deg. of the surface of the work, thereby avoiding cosine error. Incidentally this is the reason why some styli have a teardrop shaped end.

'Monolith'

Lathe projects for beginners (5)

Turning Parallel - The Tailstock Effect



1. Before you undertake serious work you must be sure that both your hard and soft centres run true. Use a dial test indicator with each centre in turn mounted in the lathe's spindle, turning this by hand.

Having, in Issue 70, ensured that the lathe is set up to turn precisely parallel, the reader may now feel that it would be the end of the subject, but this is not so. It is possible that the tailstock could be off centre, resulting in work being tapered when the tailstock centre is used to support the workpiece, whether this be with the work held in the headstock chuck or mounted on the headstock centre.

Before turning a test piece to check the situation, both centres must be checked for concentricity. Place each in turn in the headstock, after having scrupulously cleaned centres and internal bore. Turn the lathe by hand and check with a dial test indicator that the centre runs true (**Photo. 1**). If, as is most likely, both run true (at least better than 0.005mm total indicator reading) all's well. If the soft centre is at fault, it can be turned in situ in the headstock; if the hardened centre is off-centre it needs grinding, not a job for the majority of home workshops and it is probably better to purchase a new one. If both are out of true, you should suspect the bore of the lathe mandrel. Hopefully it is just a small area of damage on the entry to the socket, which can be removed with a scraper.

Harold Hall now considers the influence of the lathe tailstock on parallel turning and suggests that the manufacture of a between-centres test bar as an aid to future accuracy

Many lathes have a means of moving the tailstock bodily across the axis of the machine, providing the facility of deliberately producing tapered work, though by no more than a degree or two. As this permits the centre to be out of line, it must also be used to get the centre back on the lathe's axis. If this adjustment is not available, then it will be a major fitting exercise to correct any fault and this is well beyond the scope of this series, especially as the method will vary from one lathe type to another. Even if adjustment is not provided, the test piece described below should still be produced, as it can be first used to prove that the tailstock is sufficiently accurate (the most likely case), and secondly the test piece produced will be an essential accessory later in the series.

Turning the test piece

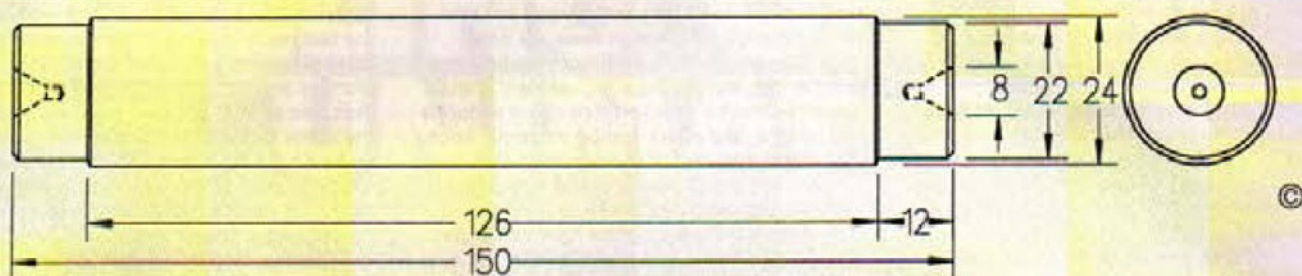
Cut a 152mm length of 25mm diameter mild steel and centre drill the ends. There are many ways of doing this and the method chosen will depend on the level of accuracy required, and of course the equipment available. For this application I would suggest the simplest, as any error present will be machined out when the part is being machined over its complete length.

If you have a 'centre square' (Ref. 1) then use this to locate the centre, but if not, the previously made 'Mini Height Gauge' can be used in the following manner as a good alternative. Set the height to 12.5mm as accurately as can be achieved. Coat both ends of the bar with marking-out fluid and place it on the surface plate or some other reasonably flat surface. Scribe a line on the end, rotate the bar about 120 degrees and scribe again. Turn a further 120 degrees and scribe a third time. If your 12.5mm was spot on then the three lines will cross in the exact centre. If, however, there was a small error, the centre of the bar will be in the centre of the small triangle produced by the lines. Centre punch the end and centre drill to about 5mm diameter on the drilling machine, making sure that the bar is accurately upright whilst being drilled. Repeat the process on the other end.

With the piece mounted in the 3-jaw chuck and the outer end supported by the tailstock centre, face the end as close to the centre as the tool being used will permit. If you have a 'half centre' then use this, even if only a drill chuck mounted version (**Photo. 4**, Issue 70 page 27). Follow this by machining the reduced diameter. If you have a tool that presents an angled leading edge, then use this as it will give a less abrupt transition between the reduced and full diameters than would a 90 deg. knife tool (see test bar drawing). Reverse the part and produce the reduced diameter on the other end, but as this time it is being held on the recently machined portion, do protect this from damage.

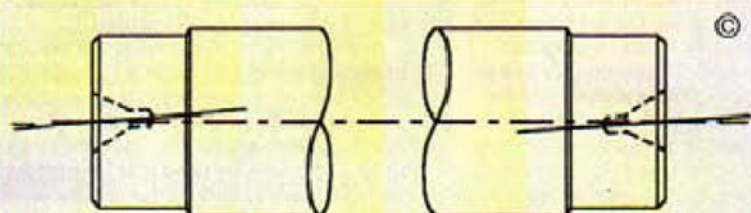
As we hope the part will have a long term application, a fact that will be understood as the series progresses, it is desirable that the centred ends are dead in line with each other. Sketch **SK. 1** shows, much exaggerated, the error that could have occurred as a result of their being drilled on the drilling machine, an error which we are trying to avoid. To eliminate this possibility, the centre drillings will now be trued on the lathe. With the part still in the chuck from the last operation, remove the tailstock centre and fit the fixed steady in a position to locate on the reduced diameter. Re-engage the centre to prevent the part moving whilst the steady arms are fixed in place. Remove the centre and, with a centre drill in the drill chuck, deepen the drilled impression to about 10mm diameter. This action will eliminate any error that may have existed in the alignment of the centre to a degree sufficient for this application. It will also remove any unmachined portion resulting from facing the end whilst using a full centre. With the first end now centred accurately, reverse the part and centre drill the second using the same sequence of operations.

Where accuracy is of extreme importance, the concentricity of your 3-jaw chuck should be considered. If an error of say more than 0.02mm total indicator reading is evident adjacent to the chuck jaws, then the 4-jaw chuck should be used, the individual jaw adjustment being employed to minimise the error, hopefully



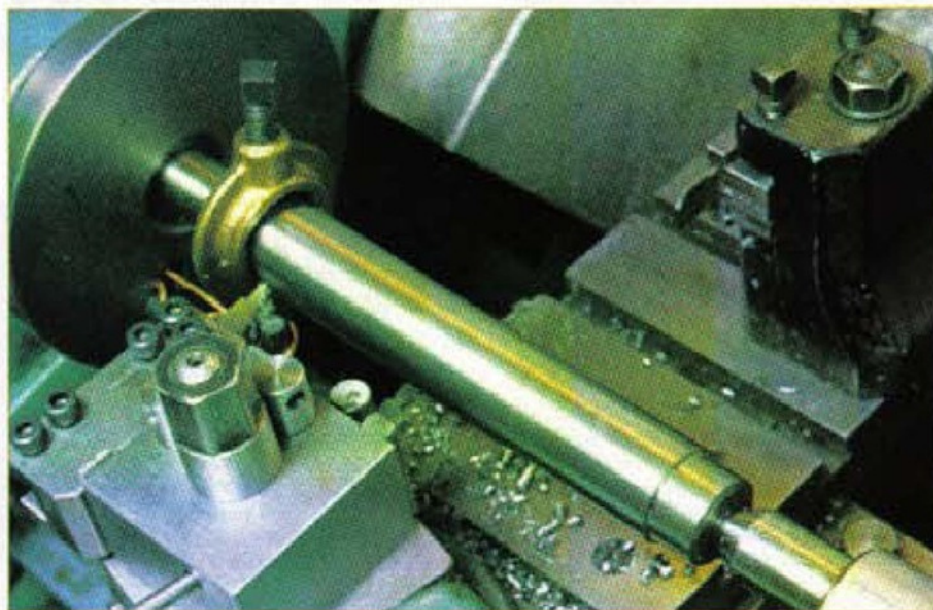
MATERIAL. 25mm DIAMETER 230M07 STEEL

Between centres parallel test bar



MISALIGNED CENTRES CAN OCCUR IF DRILLED ON THE DRILLING MACHINE.

SK1 Misaligned centres



2. Turning a test bar between centres to check that the tailstock is set accurately on the lathe axis.

to zero. Additionally, for super accuracy, rather than using a centre drill to trim the already drilled hole, it can be finally trued using a very small boring tool. This is an additional improvement as the centre drill may wander a little, especially if the barrel of the tailstock is on the loose side. In this case, unless your 3-jaw chuck is very inaccurate and/or the tailstock barrel very loose, these precautions are not essential. However, for good practice sake, you may choose to adopt them.

The part must now be located between centres so that its outside diameter can be turned along its length. Do remember that a hard centre is always fitted at the tailstock end and whilst not essential, it is normal to fit a soft centre at the headstock. Fit the driving dog on to one end of the test piece,

using some protection to prevent damage to the already machined end. Whilst turning between centres the peg on the drive plate acts against the arm of the driving dog to keep the workpiece rotating. If the part is

not round, maybe when turning a round portion on a square bar, the cut will be intermittent and the drive dog will bounce about on the drive peg. This is not ideal. With a continuous cut the problem is much less, but can still occur with light cuts. It is therefore good practice in all cases to tie the arm on the dog to the drive peg on the drive plate by some means, perhaps strong twine or copper wire.

When using centres, it is good practice to very slightly over-advance the tailstock (and I do mean very slightly) to ensure that both centres are fully home, always having first thoroughly cleaned both centres and their sockets. With this done, release the pressure and readjust to a running position, not forgetting the oil.

The part is now ready to have its outer diameter turned along its length. For this operation it is highly desirable that a fine feed is set up, making it probable that a better finish will result. It will also make the task less laborious as the part is going to be turned along its length a number of times.

Your lathe manual should quote the changewheel combinations for a range of fine feeds, use something between 0.10mm and 0.15mm, much finer than that being unnecessary. Unless you are going to do a lot of rough turning it is this feed that is best left set up on the machine. If you do not have a change wheel chart then select the three smallest gears as drivers and the three largest as driven gears. You may have to experiment to find the best order.

Fine feed quantified

If you want to calculate the feed rate it will be:- $(Dr1 \times Dr2 \times Dr3 \times \text{leadscrew pitch})$ divided by $(Dn1 \times Dn2 \times Dn3)$ where Dr are the drivers and Dn the driven. Do take note that if you have an Imperial leadscrew, leadscrew pitch is equal to 1 divided by leadscrew tpi. If you are in the fortunate position of having a lathe with a quick change gearbox then you will have the opportunity to easily experiment with



3. The test bar, turned between centres, will, after having been made to prove the tailstock's accuracy, find other uses in setting up the lathe. Treat it as a precision item and store away safely.

differing feeds. Certainly, with the round nose finishing tool, rates faster than 0.15mm are worth trying.

First using a knife tool of your choice, machine along the length with cuts of 0.1mm deep, repeating this until a constant depth cut is being taken. At this diameter 600 rpm or thereabouts is a good speed to try. No matter how careful you were at centring the part initially, it is likely to run slightly out of true to begin with, the truing of the centres described above only having made them accurate with each other and the reduced diameter ends. With the part now machined all over, replace the knife tool with the finishing tool used on previous occasions. With this, take a cut of 0.05mm depth (**Photo. 2**), and measure along its length. If already parallel, and we are looking for no more than 0.002mm difference, end to end, your lathe is already set accurately. It is, though, more likely that the tailstock will need adjusting. Inspection of the tailstock should make it obvious how this is achieved but, if not, then consult the lathe manual.

Continue to make adjustments and take further cuts of 0.05mm deep until the part becomes parallel. Now take further light cuts, endeavouring to get to a diameter of, say, 24mm $\pm$ 0.004mm. Whilst not crucial, having a simple whole number dimension for the diameter may prove beneficial when the test piece is put to use in future applications. As already mentioned in earlier parts of the series, the fine edge on the finishing tool will quite quickly deteriorate. If you make many cuts to get to this point then, edge may well require honing again.

Do remember that, during this machining sequence, the part will warm up and expand, resulting in the need to reset the tailstock from time to time. As only light cuts are being taken, temperature rise will be low, but tailstock adjustment should nevertheless be checked. For more arduous operations, the effect can be extreme, such that the tightening of the centre in the drilled end can cause localised heating, sufficient to destroy the centre. Keep checking and renewing the lubrication. You should, of course, not make adjustments whilst a cut is being taken. Also remember that a break in proceedings can cause the part to cool and contract, similarly making adjustment necessary.

During this machining operation, do not move the tailstock along the lathe bed, but make all adjustments by advancing and retracting the barrel. The reason for this is that the barrel may not be exactly parallel with the lathe's axis (remember that all components have an allowable machining tolerance, even super-precision items, so that this does not necessarily indicate a fault in the lathe's manufacture). The effect of this lack of parallelism would be that the centre would not be on the same axis if the extension of the barrel was different to that when the previous cut was taken. An important point to note is that the lathe may not turn parallel in subsequent applications if the barrel extension is different and small adjustments may need to be carried out each time a very critical item is turned. The process just carried out will though have familiarised you with the theory. In most cases, my concern is probably unfounded as the lathe will be sufficiently accurate for it

not to be a problem. The test piece will tell you. With the test piece in place and the barrel in the same position as it was when the test piece was machined, move a dial test indicator along its length with its plunger on the front edge. Deflection of the indicator should be minimal. Now carry out the same test with the barrel fully extended and with it fully home. If in both cases the indicator pointer remains essentially static along the length, the tailstock can be considered sufficiently accurate.

Without going into a lot of detail regarding its uses, one application for the test piece can be to use it for setting the top slide accurately parallel with the lathe's axis using a similar approach. This is better than turning a test piece involving a turn - measure - adjust - turn - measure - adjust approach.

Whilst there is very little to see resulting from the two articles on parallel turning, just two pieces of parallel steel, the experience and knowledge of the lathe's capabilities should be invaluable. The 'cylindrical square' may not be used that frequently, but you can use it to check your smaller squares as its accuracy will be greater than workshop grade squares. The between centres test bar seen in **Photo. 3** will though be immediately invaluable in the next part of the series. In this, it will be found possible to turn parts with next to no detectable error in diameter and length, though as will be illustrated this can only be within the capabilities of ones measuring equipment.

Reference

1. A Centre Square issue 11 page 47

REMOVING A BROKEN TAP

Raymond McMahon of Carrickfergus, Northern Ireland describes how he resolved a problem which confronts most of us at some time or another

Some time ago I was drilling and threading 50-odd 6BA holes in a steam locomotive cylinder block of cast iron. As it turned out it was rather a nasty piece of cast iron and in spite of using a lubricant and taking great care, I still ended up breaking a tap. After trying to remove it by my usual method - hoking and poking - which has some times worked in the past - this one still refused to budge. Being a steam chest bolt hole there was quite a bit of clear metal area around the tap, which meant that if it could be drilled out and the hole plugged, it could be re-threaded 6BA. The problem - how does one remove it in the first place?

In the past I have had, on occasions, to use home-made plug cutters for making timber plugs - you know the sort - wooden plugs used to cover up woodscrews which have been recessed below the surface of the timber. This gave me the idea; why not make up a hollow

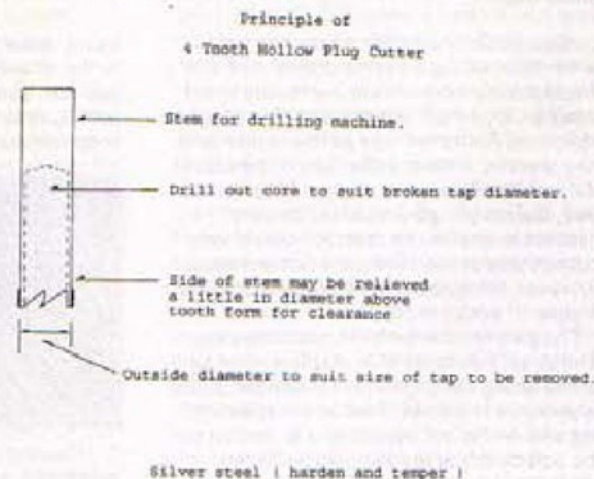
plug cutter and drill round the outside of the tap?

The method I used was as follows:- a short piece of $\frac{3}{16}$ in. dia. silver steel was selected and drilled axially with a drill equal in size to the clearance diameter of the tap and to a depth slightly more than the length of the piece of broken tap that had to be removed. I then cut across the face of the now tubular end with a junior hacksaw - two cuts at right angles. This created four segments, each of which was carefully filed in order to give a little back clearance, just like an end mill or slot drill. The cutter was hardened and tempered in the usual way, then mounted in the milling machine drilling chuck. With the cylinder block secured in the milling machine vice the broken tap was centred under the cutter.

The metal surrounding the tap was now carefully drilled out, bit by bit, taking care to clear the swarf at intervals. My first cutter shattered after a while, having been made a little too brittle, but I soon

made another and eventually the piece of broken tap came out. The enlarged hole was then fitted with a threaded plug, $\frac{7}{32}$ in. x 40, the plug itself then being drilled and threaded 6BA.

Having carried out this operation successfully, I then breathed a sigh of relief at having found a solution to what sometimes can become a nightmare problem. Thankfully, it only happens now and again.



MILLING ON THE UNIMAT 3

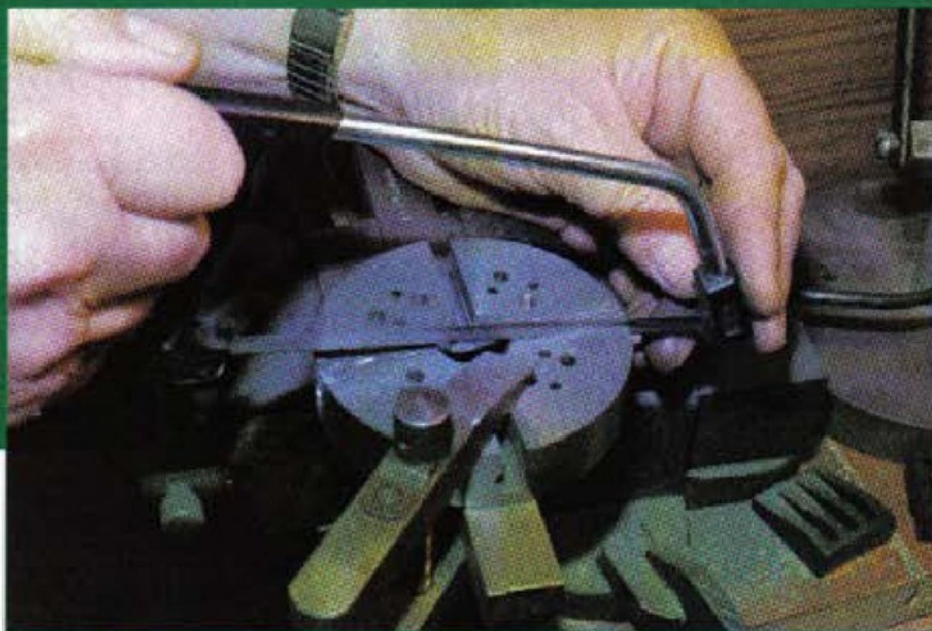
Readers frequently write to say that they do not have sufficient workshop space in which to house a milling machine or that they do not wish to spend the significant amount of money needed to acquire one. Bob Loader describes how it is possible to use the smallest of lathes to perform quite substantial milling operations

Having used my long-suffering Unimat 3 as a drilling machine and found it quite successful, it was a short step to doing the same with the milling process. As my milling is mostly odds and ends, it doesn't put too much stress on the machine, but there are factors to consider.

Taking care

First and most importantly, remember that the Unimat is a small lathe and not really designed for milling. So forget that you have ever used a Parkson, Cincinnati or Bridgeport or any such machine and get used to the idea that hacking off great lumps is a non-starter.

Where possible, make life easier for the machine by roughing out, a hacksaw, used carefully, or a file, or both will do a lot of the metal shifting and just leave the lathe to trim off the precision bit. **Photo. 1** shows a saw used to cut the sides of a slot ready for the last few hundredths to be



1. A bit of preparation work before milling

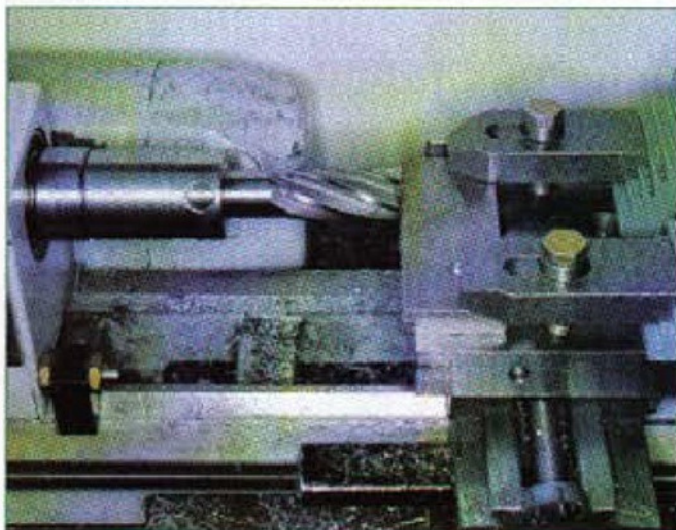
trimmed off. On the subject of slots, if a slot has to be cut, remember that two, three and possibly more, blades can be put in the hacksaw frame to cut a wider than usual slot for starters.

Because the milling process tends to put more strain on the machine than usual, remember to lock the saddle when the cut has been wound on. It is a good idea too, to put a drag on the cross-slide by half locking it; this will stop the machine jumping about so much. If a machining table is being used, it may be necessary to replace the socket screw which locks the cross-slide with a slotted one: a screwdriver will get into places

which a hexagonal key cannot - a look at **Photo. 5** will show what I mean.

Be very careful if you are tempted to use a fly cutter. They have their uses and I do use them, but only for very small special jobs; more about that later. They are an extra which is always available for small lathe, but what I always consider is the clout when the cutter hits the work. For softer materials like zinc based alloys and some aluminium alloys they are all right. Anything harder will be a bit tiresome.

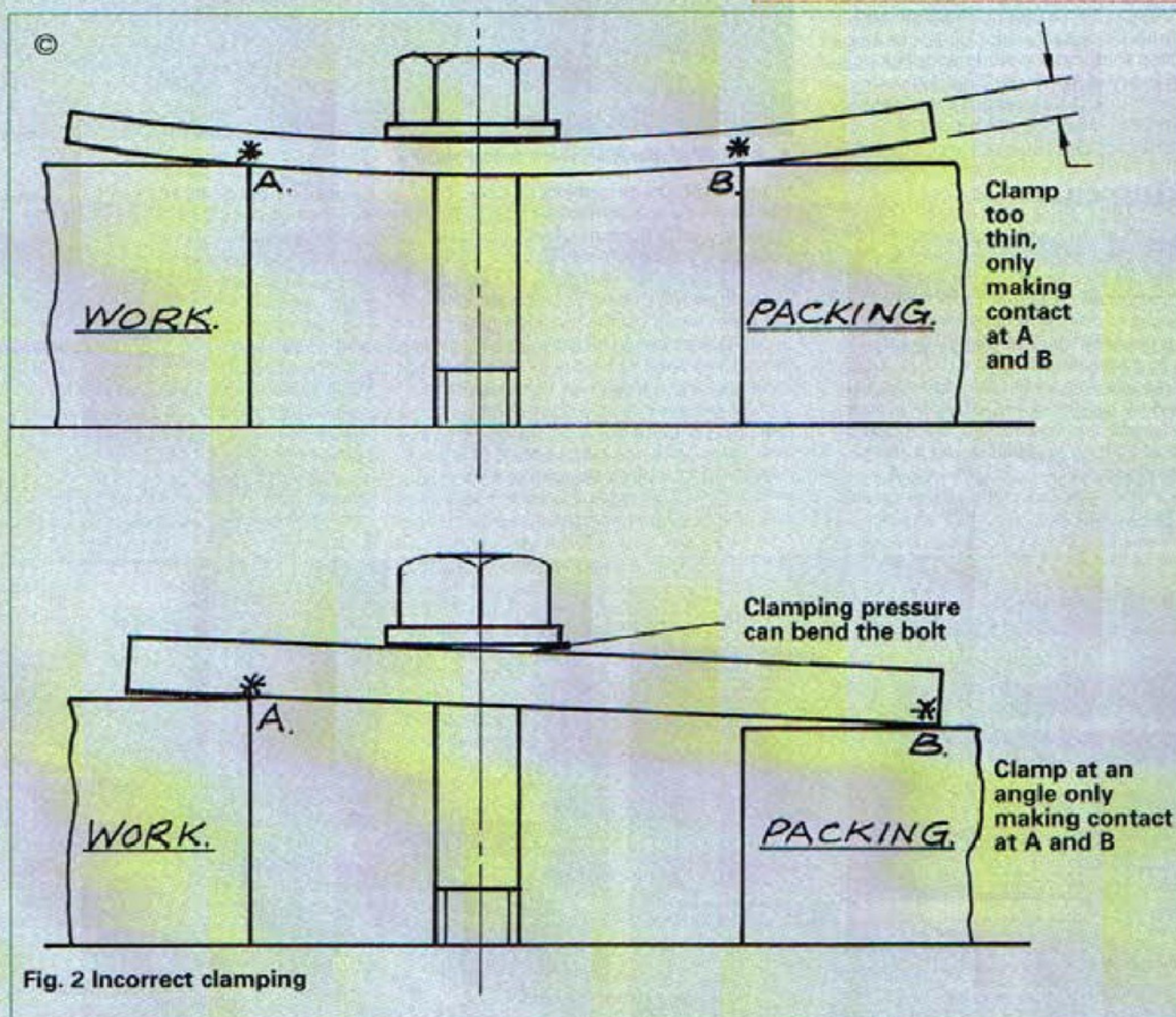
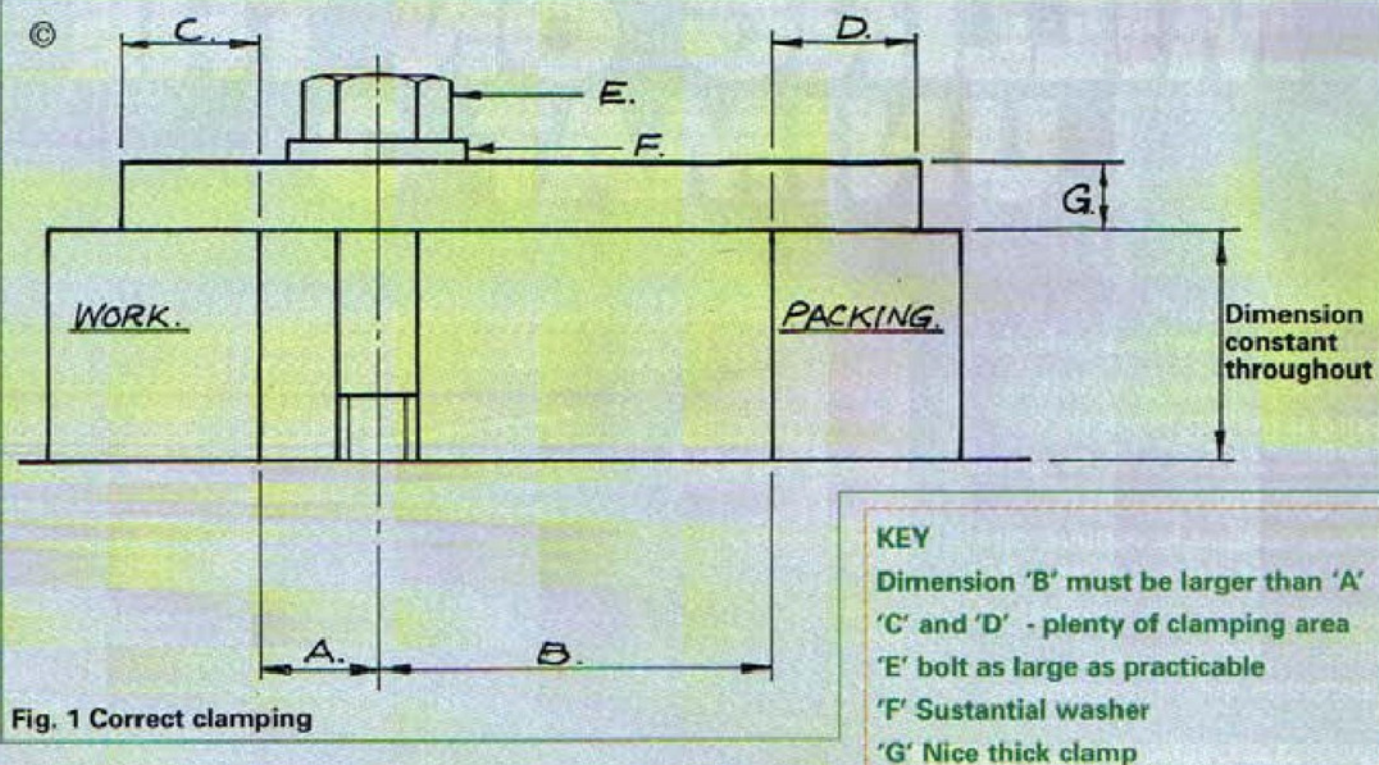
Work which has a travel of more than about 50mm will be a problem because the maximum cross-slide travel is 52mm.



2. An ideal cutter for general work



3. Finishing the slots in a four jawed chuck body



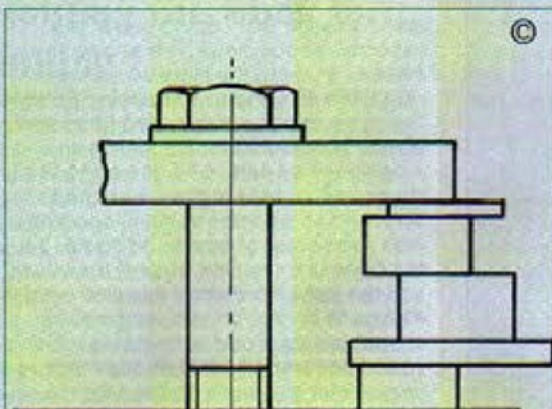


Fig. 3 Incorrect packing

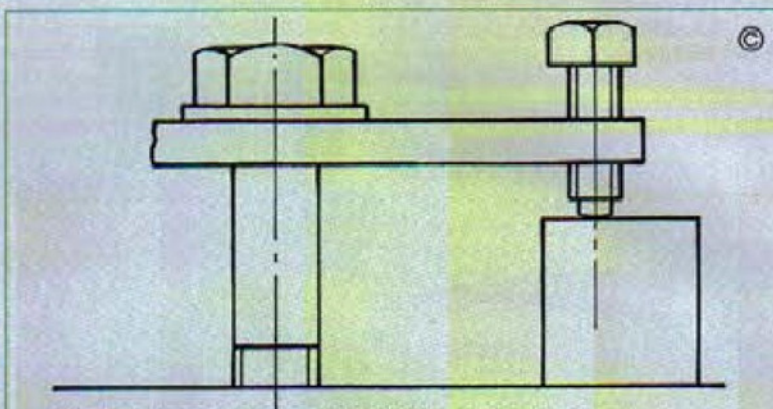


Fig. 5 Adjustable packing with set screw

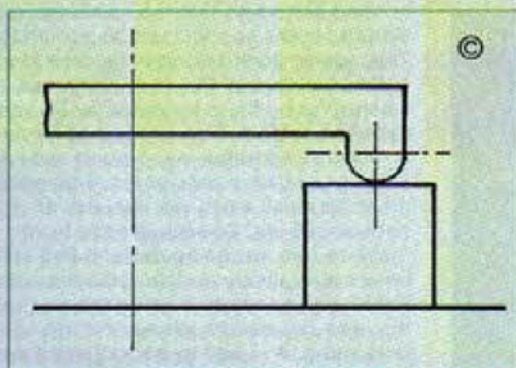


Fig. 4 Clamp with radius will allow for small variations in alignment

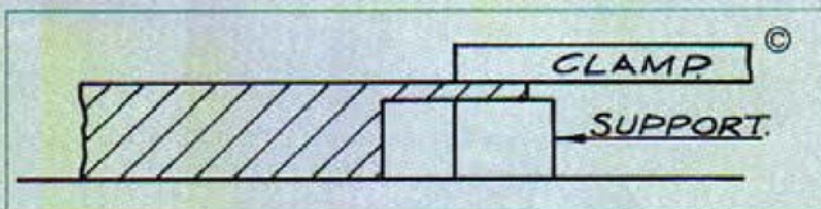


Fig. 6 Work with thin section may need support under the clamp



4. Using the larger chuck for the 9/16 in. end mill

Unless a vertical milling attachment is used, there will be no height adjustment, so one height setting will have to be enough. The setting can be varied by using packing under the work or by using a larger cutter. As this article is aimed at those who would like to use the standard machine to do all sorts, without accessories, various cutter diameters and lots of accurate packing is the answer.

Useful cutters

A selection of end mills and slot drills will do most milling jobs. Of the two, end mills are the best because they have more than two teeth. Each tooth will take a smaller slice than that of a slot drill with only two. The slice, called 'chip per tooth', is an important consideration: the smaller it is, the less effort for the machine to cut. For general use,



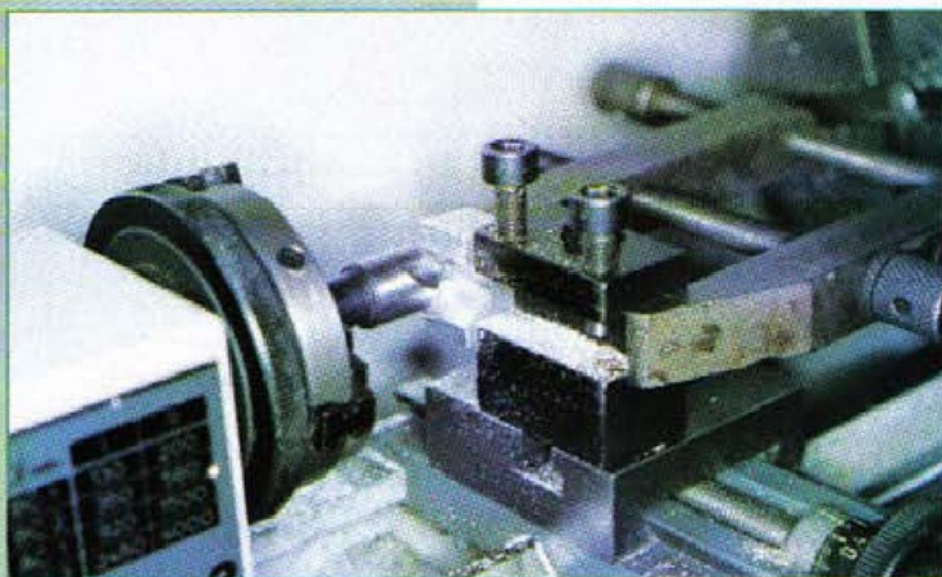
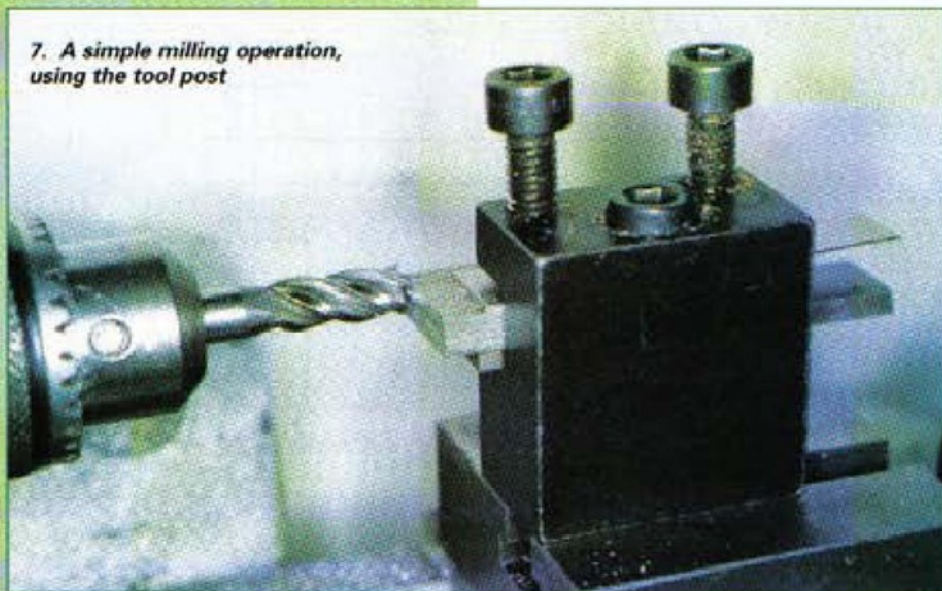
5. The milling table in position and the (not very good) drilling and milling head
cutters with helical teeth will cut better than those with straight ones, because they have side rake as well as top. For the same reason hard brass and brittle materials will do better with straight fluted cutters.
Slot drills have advantages, due to the way they cut all across the centre, which



6. The small angle plate - a very useful accessory

makes them ideal for cutting blind slots and for flat bottomed holes. The straight fluted ones can, with care, be sharpened on the face teeth which are the ones which get blunt. With a nice sharp and small grit grinding wheel it is not difficult. When I

7. A simple milling operation, using the tool post



8. Clamping to the side of the tool post to mill a vee

worked on the milling section as an apprentice, my apprentice master was always in trouble for using the small grinding wheel which the woman who did the engraving used for her cutters. It was supposed to be for the engraving cutters only. My apprentice master was a keen student of the sayings of Confucius and paid heed to the one which states "A workman who wants to do his work well

must first sharpen his tools".

For most work, the best cutter to use is an end mill with helical teeth, like the one in **Photo. 2** which also shows a holder for larger cutters which will be mentioned later. Using the lathe with standard equipment, the largest cutter which can be held in the drill chuck is 8mm. Over this size the 3-jaw chuck can be used but will not always hold without slipping. I made

an adapter so that I could use a $\frac{1}{2}$ in. capacity Jacobs chuck. It is shown in **Photo. 3** where the slots which were roughly cut in **Photo. 1** are being finished. The large chuck is a standard Black and Decker accessory and just needs an adapter with a $\frac{3}{8}$ in. UNF. thread to fit the chuck and an M14 at the other end to screw on to the lathe spindle, concentric with each other of course. In **Photo. 3** it is the piece between the back of the chuck and the lathe headstock. It is also used in **Photo. 4** to hold a $\frac{9}{16}$ in. end mill for counterboring a part, something which would be normally outside my range, a very useful and easily made adapter.

A better way of holding cutters

Some time ago, the editor suggested that I give some thought to the problem of holding cutters so that the axial and radial slipping in the chuck could be eliminated. The results were described in Issue No.53.

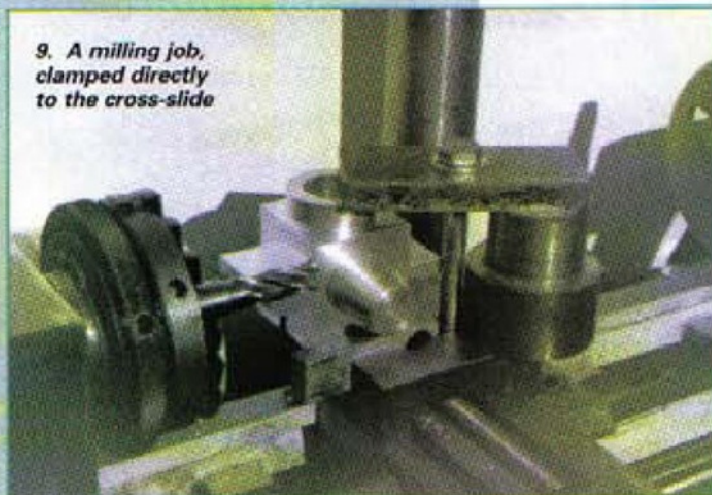
Small cutters under $\frac{1}{4}$ in. were well catered for by the ones made by Dormer called Mini Mills. They are locked by a set screw which locates in a ground slot which allows no relative movement. These are great for small work, not expensive, between £5 and £8 each in sizes from $\frac{1}{8}$ in. to $\frac{1}{4}$ in. or the equivalent. Ball ended ones are available and the others are three fluted with one flute over centre, so that they can be used for plunge cutting or bottoming. All I had to do was make a holder to fit them, the one sold by Dormer being a little too expensive for me. Like the larger one it was in Issue No.53.

The large cutter holder

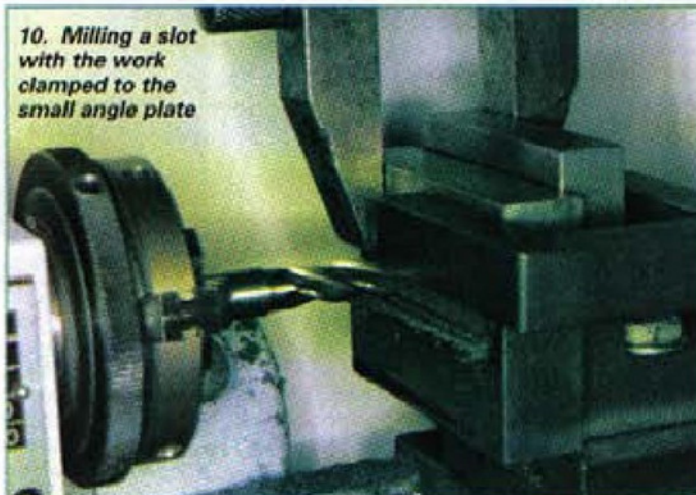
A holder for the large cutters needed some head-scratching. I chose the largest one I use regularly and made a holder for that size. The $\frac{1}{2}$ in. shank, the biggest I used, had a slot ground in the shank by methods a bit out of the ordinary.

That left a few more end mills with $\frac{3}{8}$ in. shanks, which are used a lot. These were fixed by pressing a sleeve on and filing the slot in afterwards. An alternative to the pressed-on sleeve could be silver soldering. Both methods are not such a caper as they sound and the cutters with the sleeves stood up to some heavy work.

9. A milling job, clamped directly to the cross-slide



10. Milling a slot with the work clamped to the small angle plate



Holding the work for milling

Of the things I have made for my Unimat, one of the most useful has been a milling table which can be bolted to the cross-slide, the one shown in **Photo. 5**. It is a much simplified design, with no tee slots to cut and a minimum of machining. Tables can be bought as a Unimat accessory but they cost about £30 and it is more fun to make it. There are fences to help in setting and locating work. To go with it I got a small angle plate, the one in **Photo. 6**. These can be bought as a casting in several sizes with all the faces and edges ground. All that needs to be done is to drill the holes for the bolts.

With the table and angle plate I can work out a way of milling most things I require.

Don't forget the tool post

For small work, the tool post makes an ideal miniature vice. By clamping the work in the slot where the tool fits (**Photo. 7**) and setting it square, all sorts of trimming can be done. As the photo shows, the work can be packed up to height and a soft strip over the top will stop the locking screws doing any damage. **Photo. 8** is an example of work clamped to the side of the tool post to machine a vee.

I have two other tool posts for work which will not fit the standard one. One has a larger slot, the other one a slot in a higher position and the three will do most of the milling of small parts.

Other methods

Some work can be clamped directly to the cross-slide (**Photo. 9**) or, more often, to the angle plate (**Photo. 10**) or to the milling table.

Another useful variation, not strictly a milling process, is saddle boring, a good method for boring an accurate hole in a component which cannot be swung, a component like the one in **Photo. 11**, an example of clamping directly to the cross-slide.

Like saddle boring, using a 4-jaw chuck is not really milling but will give the same result. It is a good way of truing and squaring rectangular or square work and the work does not have to be set dead true for machining. **Photo. 12** shows a typical operation; it only needs the chuck and a facing tool. My chuck is home-made and the jaws spread a little when tight, but it does the business.

Vertical slides

Although I don't own one, a vertical slide is a very useful item and solves the problem of vertical controlled movement and measurement. They are pricey; a custom made one for the Unimat with angular adjustment will cost £137 at the latest list price. If you want to go the whole hog and get a milling/drilling head it will be £350 and a co-ordinate table to fit is a further £360 odd.

I only mention the prices to give an idea of the expense to completely equip the lathe to do everything. If money is no problem, it could make more sense to invest in a small milling machine for about £500.

I once made a milling/drilling head for my Unimat, the one shown in **Photo. 5**. It was not a great success and took a long time to set up, which influenced my decision to use the lathe as a machining centre.

Clamping the work

I have mentioned clamping and aspects of it in previous articles, but only in passing and ignoring the technology. A few words and pictures will explain the fundamentals of correct clamping.

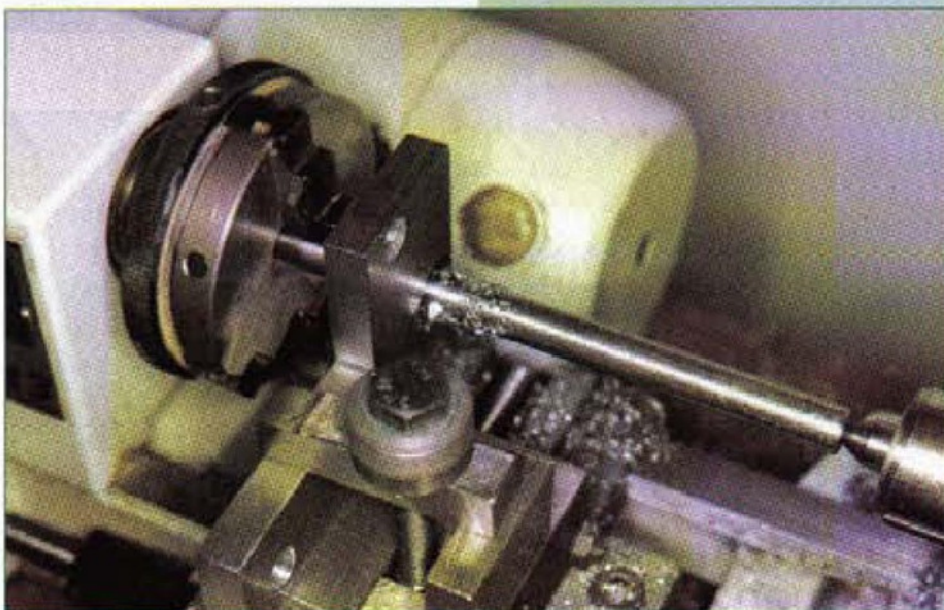
Essentials

Clamping systems depend on three things. Firstly, the clamp must be strong enough not to bend when the bolt is tightened. Secondly, it must be arranged so that the clamping force is maximised, done by the positioning of bolt, work and packing. Thirdly, the clamp should be parallel. **Fig. 1** shows correct clamping conditions with an

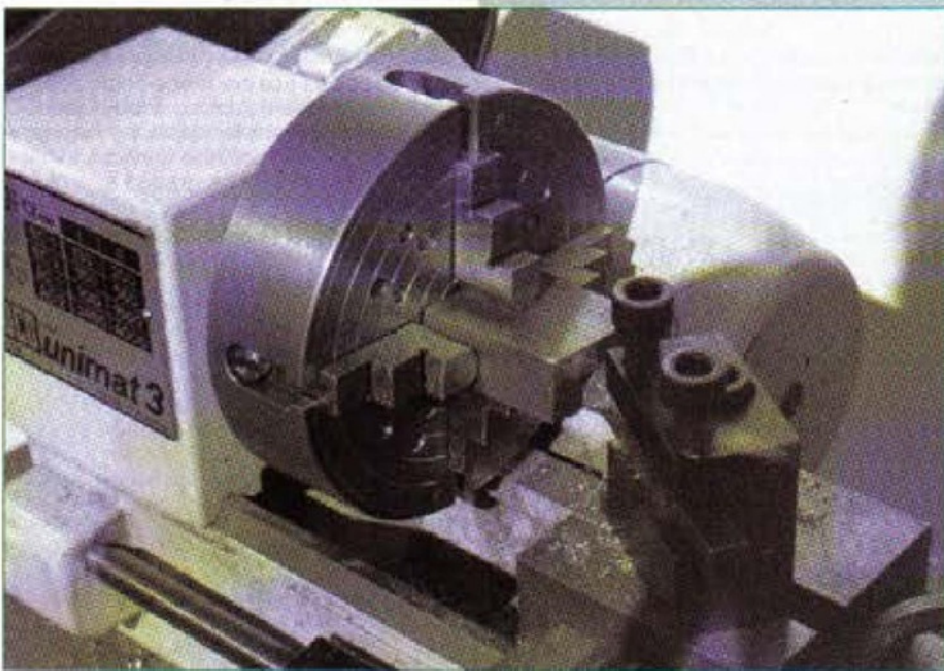
ideal set-up. **Fig. 2** shows two of the common mistakes and **Fig. 3** may cause a laugh or two, but I have seen examples almost as bad. **Figs. 4, 5, and 6** show three special cases.

There are many other custom-made clamping systems, and one I am very fond of is the one shown in **Photo. 2**. I call them 'staircase' clamps, and they are excellent. A full set of the pair of clamps and the step blocks will cost about £25, but well worth it. They are easy to adjust, strong, and just need the right bolts and tee nuts.

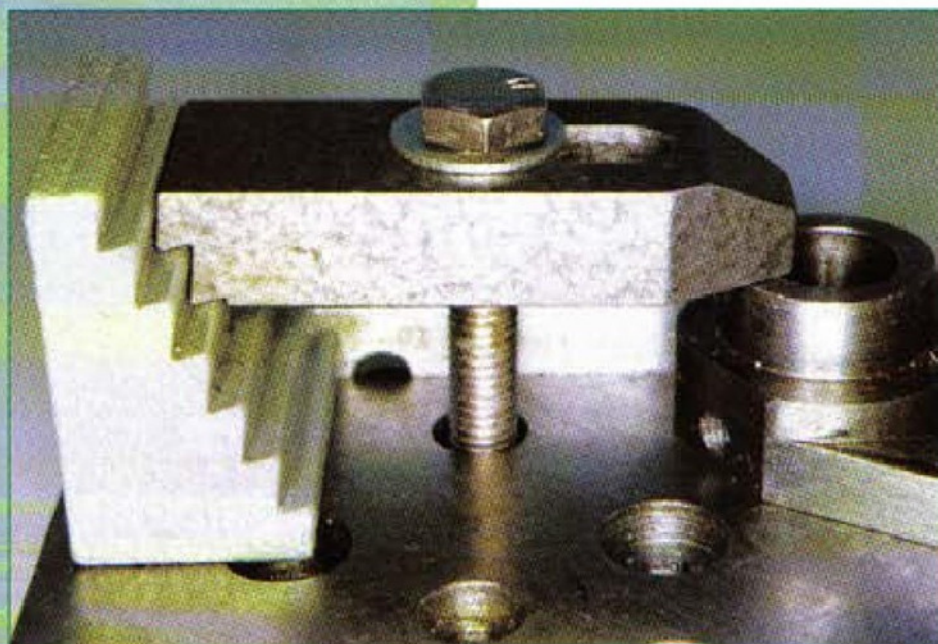
The vital thing when clamping, assuming everything is right, is the position of the bolt. It is a case of leverage and the application of it. Archimedes theorised that, given a lever long enough and rigid enough, and a firm place to stand, he could move the world. It was a slight exaggeration, but it illustrates the importance of leverage, something engineers use a lot. To summarise the clamping application, the bolt must be closer to the work than the packing and the



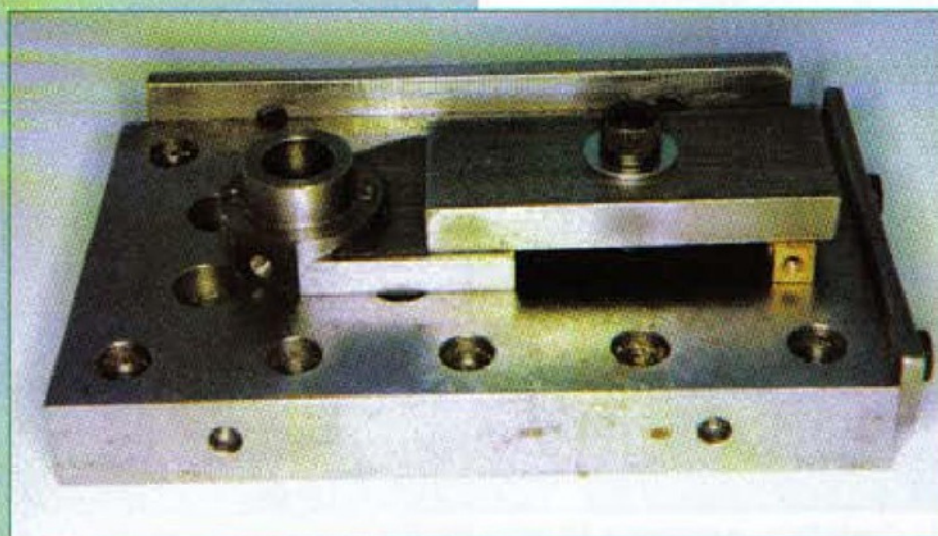
11. Saddle boring, a variation on the milling process



12. An alternative method of getting a block flat and square



13. A close look at the 'staircase' clamp and stop block



14. The milling table with a reasonably correctly clamped work piece

further the packing is from the bolt, the more clamping force there will be on the work.

Most of the other do's and don'ts are common sense. Use the right spanner. Do not overtighten - as one of my apprentice masters used to say, "You aren't anchoring the Queen Elizabeth". When using clamps with radii or set screws, like the ones in Figs. 4 and 5, protect the surface with a piece of soft material to prevent damage. Often, if the work is small, socket head screws are useful as the clamping bolts.

Photo. 13 is another, closer look at the 'staircase' clamp set-up and also an example of poor clamping, the area of work under the clamp not being enough. The set-up shown in **Photo. 14** is a little better, but the bolt should be closer to the work and the packing further from the bolt. The table is the one mentioned earlier.

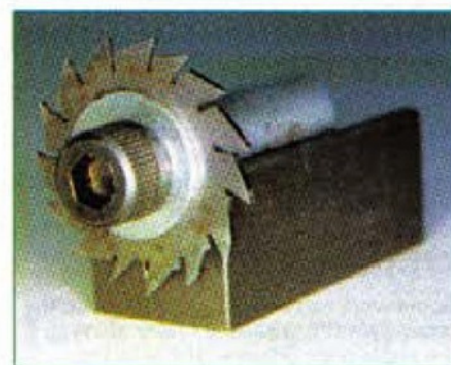
Photo. 15 shows a couple of small clamps with shapes cut off them for special work and the tee nuts which they fit. To get an idea of size, the threads in the tee nuts are $\frac{1}{4}$ in. BSF.



15. Two small clamps with tee nuts



16. A fly cutter used for cutting thin slots



17. The roughly fashioned saw

ground to shape.

Photo. 17 is of a saw I used for other slots in the same legs. It too, is home-made and looks it, but when it is whizzing round, the hideous shape of some of the teeth cannot be seen. It was one of a half dozen I made for cutting slots in wood, which is why it is so rough. It was made from gauge plate, hardened and tempered. Like the fly cutter it is on an arbor, with a large washer and locking screw.

Cutters like these need careful using on the harder metals, but can sometimes be surprisingly robust. I once got excited and accidentally wound a thin fly cutter, like the one shown, into a milling machine table. It went in $\frac{1}{16}$ in. before it broke. Hands must be kept well out of the way of such cutters and eye protection is a must because the chips fly about.

The only limit to the shapes of home-made cutters is the inventiveness and/or desperation of the user. Shapes do not have to be ground if the softer materials are to be machined. Gauge plate, silver steel or old files which have been softened will make very good cutters, only needing filing to shape and hardening and tempering.

Milling on the Unimat is not too difficult and extends the usefulness of the machine no end.

Home-made cutters

Some cutters I use are home-made ones, for those awkward jobs for which I cannot find a commercial alternative. Fly cutters are always useful because they can be all sorts of unusual shapes ground to order.

The fly cutters I use are not the sort I warned about in the introductory remarks, but specials for specific jobs and usually quite small.

I first used such cutters when I worked for a small company which, though fairly well equipped, lacked things like a cutter which would cut a 90 deg. groove fine enough to allow a 0.003in. wire to sit in, or a saw fine enough to slot 12BA screws. I still have a selection saved from those days and one of them was just right when I had to put some very thin slots in the legs of a calivider I was making, so that they would spring and clamp. **Photo. 16** shows the cutter I used. It is about 0.020in. wide and was held in an arbor in a cross-drilled hole, locked with a small cap head screw. The cutter can be made from a $\frac{1}{8}$ in. round tool bit, or as this one probably was, from a standard punch

TAPER TURNING BY OFFSET TAILSTOCK CENTRE

Doug Ball of Letchworth, Herts describes his version of a device which simplifies taper turning

Yes, it's another taper turning article. And to get the apologies over immediately, it's dimensioned in metric units. In defence, it's simple and it works.

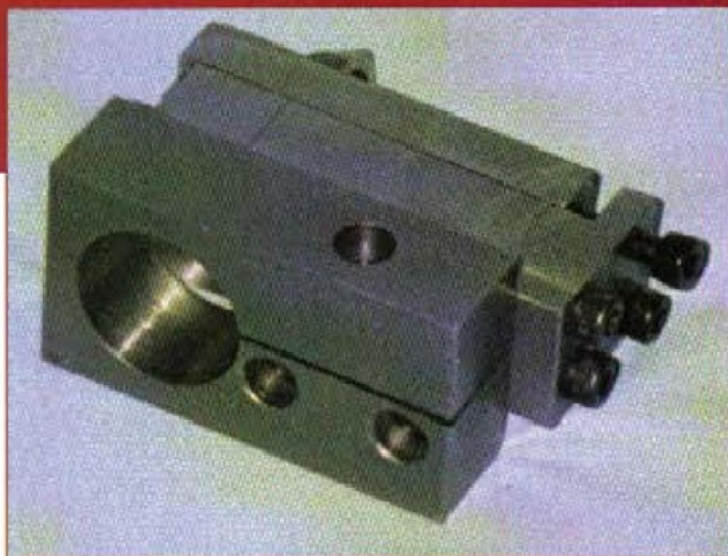
My current project is a tool & cutter grinder based upon the Derek Brooks design published in MEW. The collet tool-holding system used by Mr. Brooks has been replaced by 2MT adapters, with the grinding wheels held in 1MT adapters, so there were a lot of MT adapters to make - about 20 including spares. I've cut MT tapers before using the top slide, but the taper length is near top-slide travel limits, the handle gets in the way and, when traversing by hand, the finish is never as good as using the power feed, so a new approach was looked for.

If a Myford or similar taper turning attachment is owned, the problem is easy. Alternatively, the tailstock centre can be offset, with the trauma induced by returning it to centre when finished, so it was decided make an adjustable offset centre to fit the tailstock, and a trawl through MEW back issues found the design by Mr. Major in Issue 26.

To make an exact copy would be too easy, so the following changes were made:-

- Push/pull screws added for fine adjustment of the offset.
- Attachment clamped to tailstock barrel to prevent rotation.
- Jig for accurately aligning offset centre included.
- Plain hardened centre used to eliminate any inaccuracies introduced by a rotating centre. Incidentally, two bought rotating tailstock centres checked have total indicated runout errors of 0.03 and 0.04mm respectively.

Morse tapers vary in angle, but for the commonly used 1, 2 and 3MT the variance is slight, in fact the discrepancy is 0.00032in. per inch or 0.008mm per 25mm, less than most of us can measure - the discrepancy is less than the error in my



1. This view shows the barrel clamp arrangement

rotating tailstock centres - so it seems that a common setting for the tailstock offset is possible for the usual sizes. Taking a component length of 100mm, or 4in., the common offset becomes 2.5mm in 100mm, or 0.100in. in 4in., so setting up is easy:-

- (i) Centre drill both ends of the workpiece.
- (ii) Using a dead tailstock centre, set a dial indicator to zero against the very end of the workpiece. Take care to have the dial indicator at centre height and horizontal.
- (iii) Put in the adjustable tailstock centre and adjust across until the dial indicator reads 2.5mm, or 0.100in.

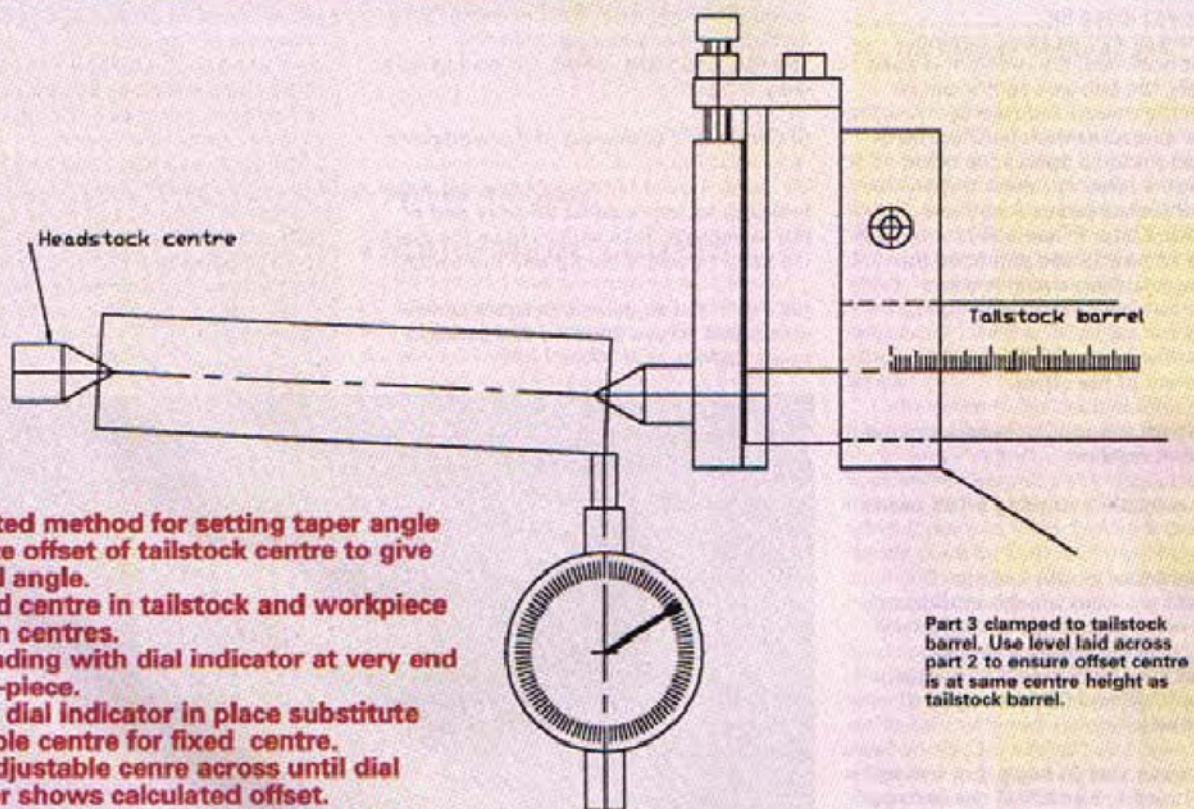
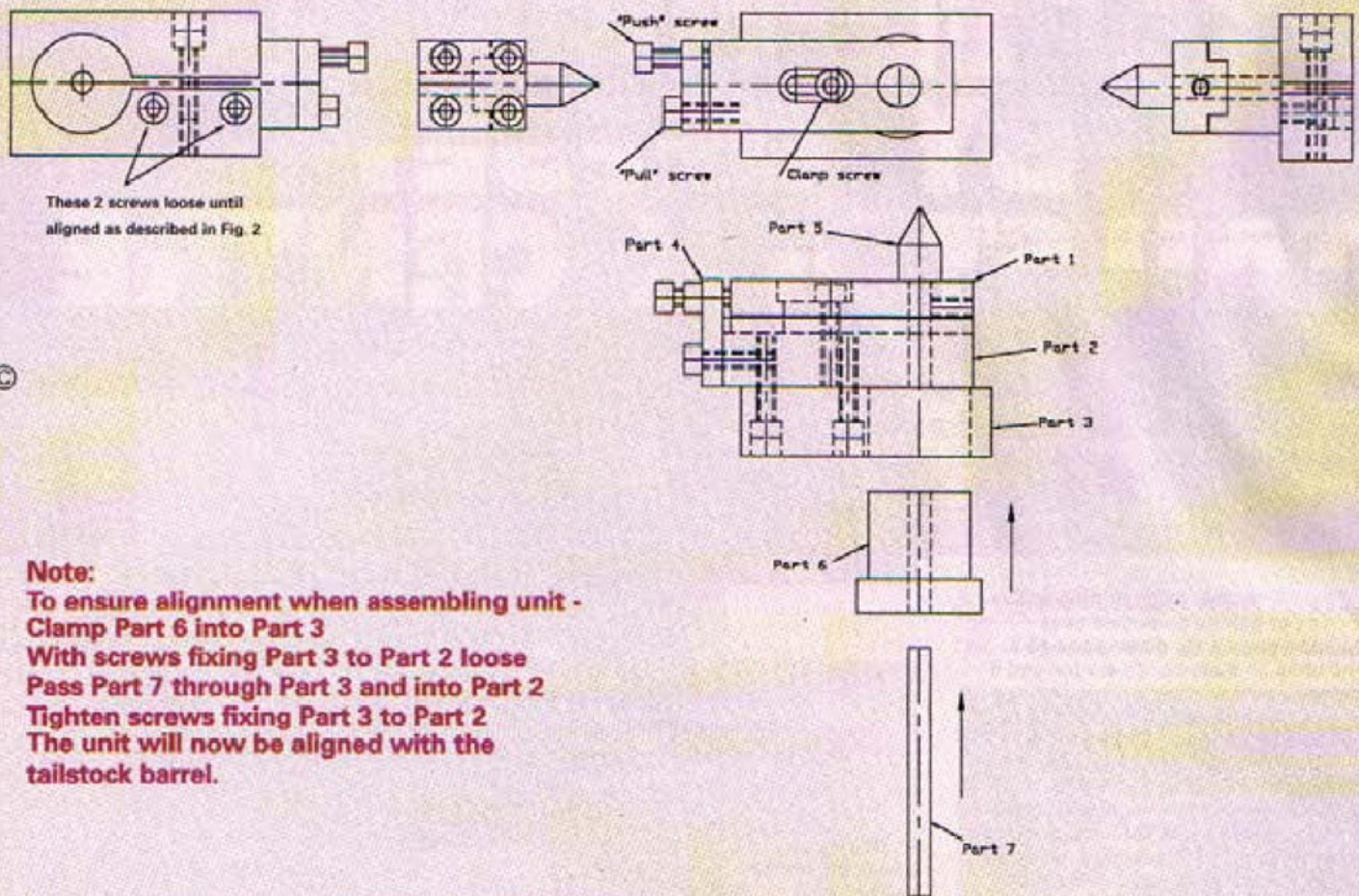
Care was taken to drill the centres to the same depth, or effective length of workpiece would vary slightly, but with an offset the centre probably rides at the big end of the centre drilling. Maybe a parallel drilled hole would be superior to a centre drilled hole, but centre drilling done with care gave accurate tapers.

It's such a simple accessory that the plan is to leave this offset centre set-up for 1, 2 or 3MT tapers, and make another if a different angle is required.

The photos and drawings will make the device easy to understand, there being nothing in the manufacture to warrant description.

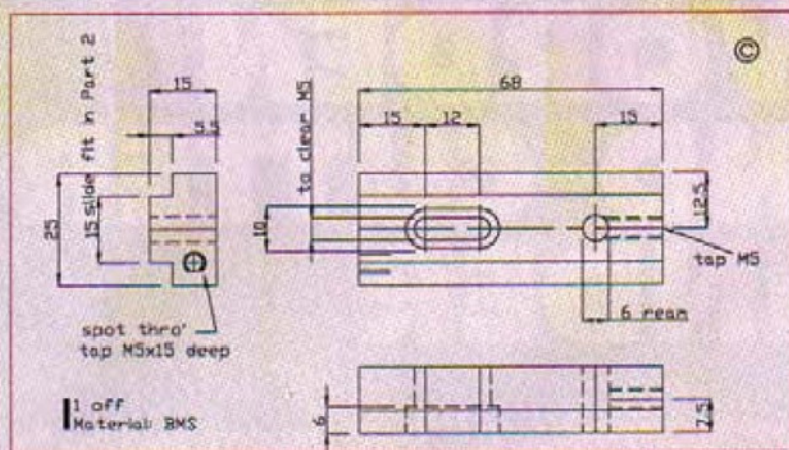


2. The offset centre device set up on the tailstock barrel

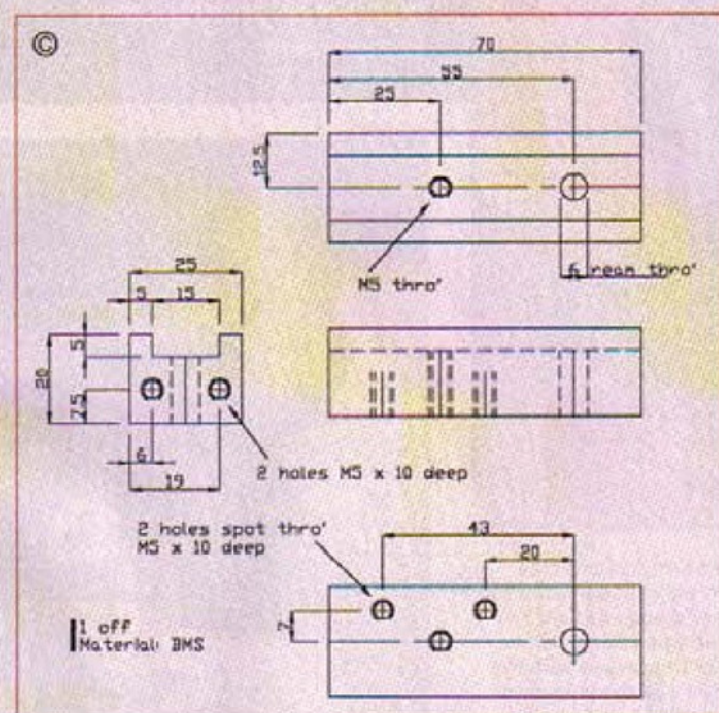
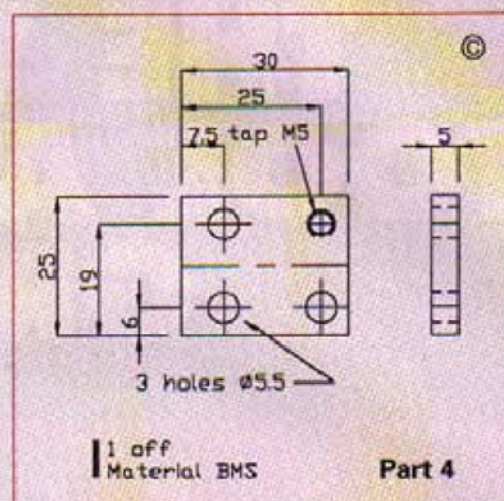


Suggested method for setting taper angle
 Calculate offset of tailstock centre to give required angle.
 Put fixed centre in tailstock and workpiece between centres.
 Take reading with dial indicator at very end of work-piece.
 Leaving dial indicator in place substitute adjustable centre for fixed centre.
 Move adjustable centre across until dial indicator shows calculated offset.
 For 1MT, 2MT and 3MT the offset is very close to 2.5mm per 100mm, or 0.100" per 4".

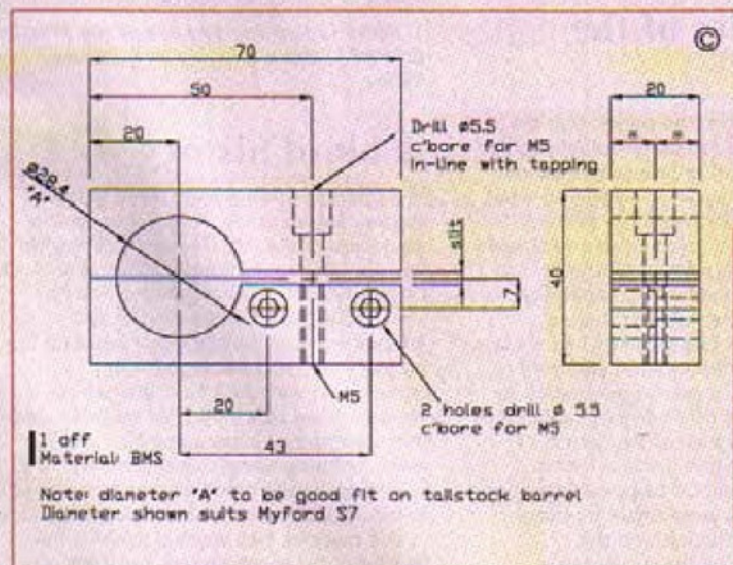
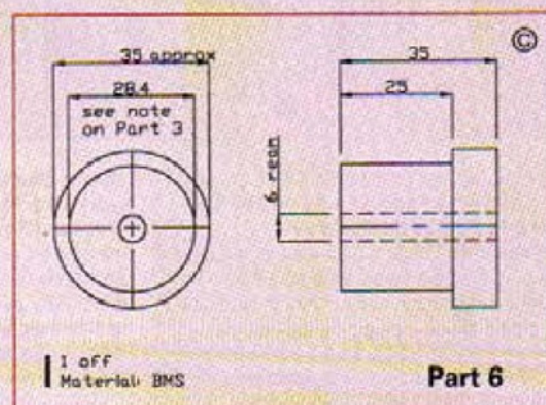
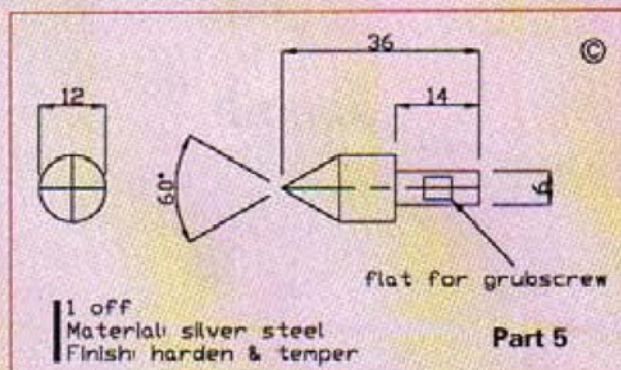
Fig.2 Setting procedure



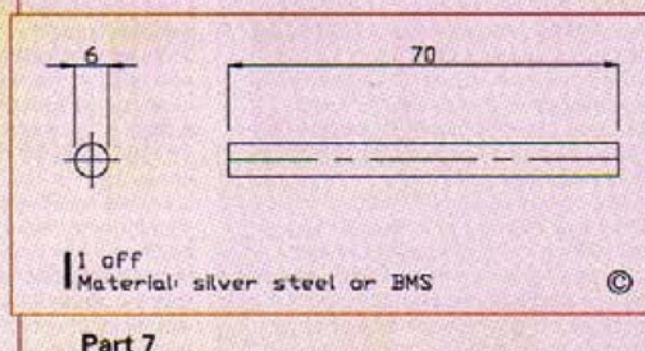
Part 1



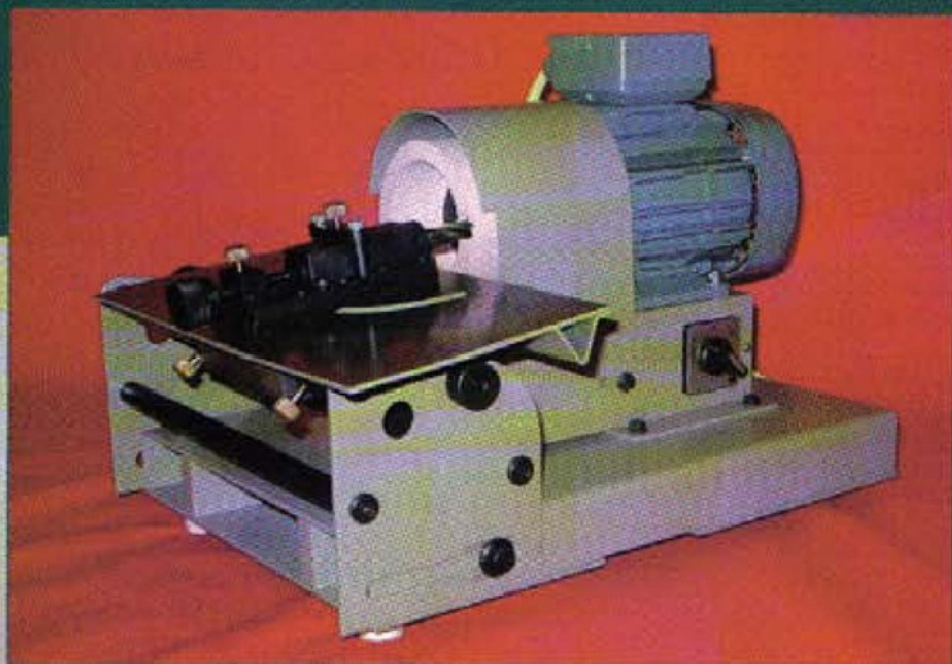
Part 2



Part 3



THE WORDEN TOOL AND CUTTER GRINDER



For some while I had been looking at the various designs of tool and cutter grinders available, some as commercial items supported by the supply of the necessary castings and materials, and others as designs published in this and other magazines. Some were extremely versatile, but quite complex to build and likely to become a life-time project in themselves. Others were based on substantial castings which would have taxed my current machine capacity to the limit, while one or two appeared to be too flimsy to guarantee a satisfactory result.

While this survey was in progress - a rather low-key process, I must admit - I met up with John Corlyon who now runs the Hemingway business from a base just outside Hull. I was telling him that Mike Chrisp of 'Model Engineer' and I would be in his neck of the woods in a few weeks time because each spring, Mike and I set up a workshop at the modellers' holiday which takes place at the Primrose Valley Holiday Village at Filey in North Yorkshire. John immediately asked us if we would like to borrow one of his Worden grinders for the week, offering to deliver and collect it while taking the opportunity to have a look at the events in progress. He has since kindly donated a material kit for one of the small tools in his catalogue as a prize for the engineering section of the exhibition which traditionally starts the week.

Each armed with a pocket full of milling cutters and lathe tools, Mike and I were

able to use the quieter moments in the workshop to explore the capabilities of the Worden (Photo. 1) and acquired an interested and enquiring audience while doing so. We were all impressed with the simplicity of operation and the sturdiness of the machine, so much so that, in the weeks that followed, we both ordered kits for our own workshops.

Capabilities of the machine

It has to be said from the outset that the Worden is designed to carry out a specified and limited range of grinding operations which, coincidentally, are in line with what I had already decided were my primary requirements. It will grind lathe and shaper tools and the cutting tips of slot drills and end mills. It has no spiralling capability, so cannot deal with the flutes of milling cutters or reamers. Giles Parkes has shown (M.E.W. Issue 64) that with an additional component or two it can be persuaded to carry out four-flute drill grinding, while the Hemingway catalogue carries details of additional kits which will add a further range of capabilities. On balance, I decided that the limitations were offset by the simplicity of construction and the likelihood of bringing the project to a successful conclusion, considering the limited amount of time I seem to be able to spend in the workshop these days.

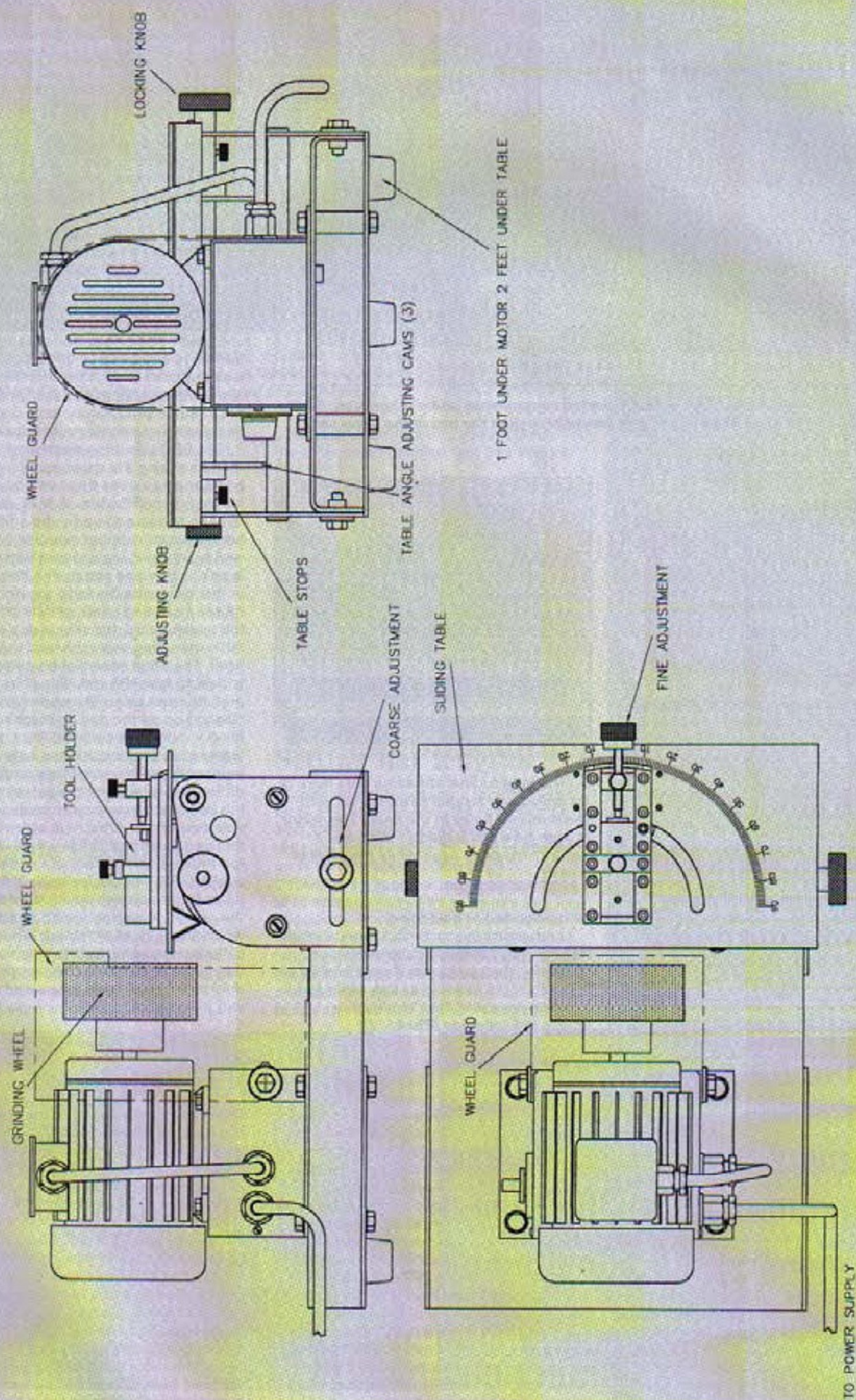
Geoff Sheppard describes the construction of a machine tool from a kit which includes a number of prefabricated components



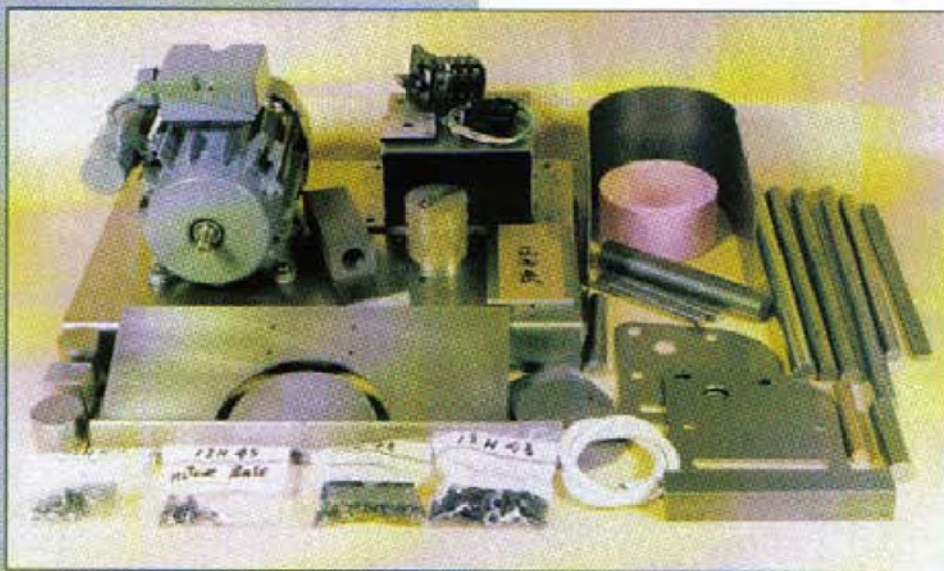
1. Mike Chrisp making use of the Worden grinder in the workshop at Primrose Valley

A bit of history

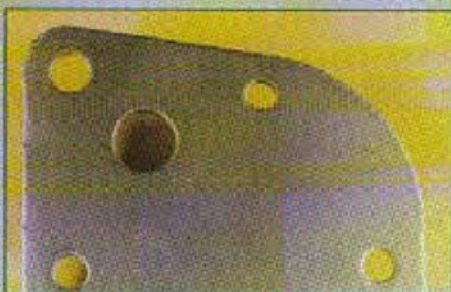
The origins of this project seem to have started, like so many useful ideas, in the workshop of the late George Thomas. He had constructed a prototype from bar stock materials and it was suggested that he should describe it, but anno domini intervened. Neil Hemingway picked up the project and 'productionised' it in conjunction with Jack Norburn, whose workshop we saw in M.E.W. Issue 41. Jack had commercial experience of manufacturing sheet metal items by CNC punching, so the machine was redesigned to incorporate structural components made in this manner. Neil wanted to call it the 'Norburn' to recognise this, but Jack preferred that it should be named after Worden Park, the spot in Leyland, Lancashire where the local model



Drawing reproduced by kind permission of Messrs. Hemingway



2. The kit is made up of a number of prefabricated components, some proprietary items and the necessary lengths of bar stock. It is essential to plan the use of the latter very carefully



3. The CNC punched sheet metal items need draw filing to clean up the edges

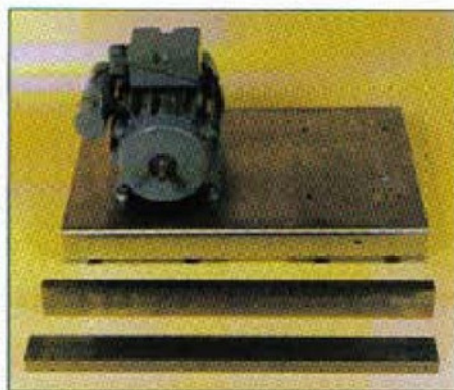


4. The edges of the curved slot in the table also need to be cleaned up. This component has a stiffening rib spot-welded to the underside. It is this which is in contact with the eccentrics while the table is being traversed.

engineering society have their railway track and he had spent many happy hours.

The kit arrives

Shortly after placing my order, John Corlyon phoned to say that he was about to despatch my kit and to check that someone would be at home to receive it. The next day, within a few minutes of the appointed hour, the door bell rang, and there was the delivery driver holding a large box. His first words were "This is very heavy, so I think it best that I put it down just where you want it. You don't want to have to shift it too often." Excellent service, I thought, and a



5. The longitudinal stiffening bars have to be drilled and tapped to match up with the punched holes in the base. The motor is seen here still bolted to the base, a security measure used while the kit is in transit

promising start to the project.

On checking the contents, I found that all was securely packed and the envelopes containing the small parts clearly labelled as to which of the assemblies they belonged.

When unpacked, they made an impressive collection (**Photo. 2**).

The planning stage

With everything safely re-stowed, a couple of evenings were spent studying the drawings and deciding how to tackle the project. As it happened, the drawings and building instructions were undergoing a major revision, and I had been supplied with a slightly out of date version. Within a few days I was sent a new set which were now in line with the modification standard of the components in the kit. While I have been building my grinder I have kept Hemingway informed of any further anomalies I have found and have made a number of suggestions for improvements to the design and manufacturing methods. It is pleasing to note that the majority of these have been incorporated in future updates.

One of the most important planning

tasks, essential for anyone embarking on this project is to identify from which piece of material each component is to be made. Any kit supplier will provide only just enough stock from which to make the parts, so it is necessary to plan the sequence of operations so that optimum use is made of each length.

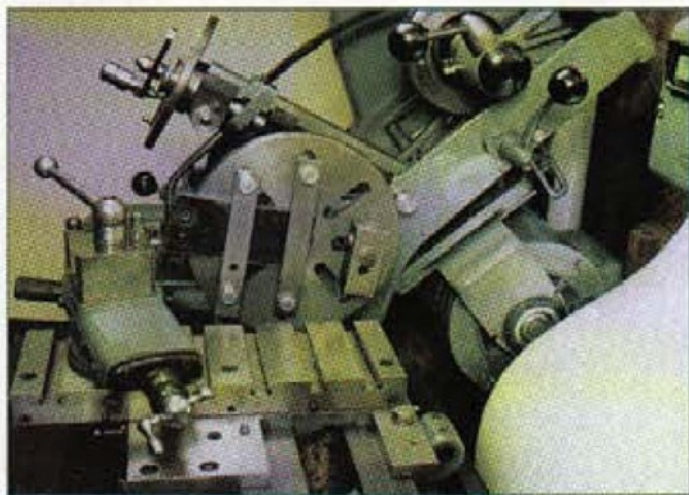
Making a start

My original intention was to make first as many of the smaller machined parts as possible, leaving the larger items safely packed away in the original container so that they would not be scattered about the workshop, taking up space and vulnerable to damage. Consequently a start was made on the tool holder slide assembly, but this strategy was promptly thrown into confusion when Mike Chrisp rang to say that he had found a small company which was prepared to powder coat the structural components of both kits at a sensible price. Some preparatory work was necessary before this could happen.

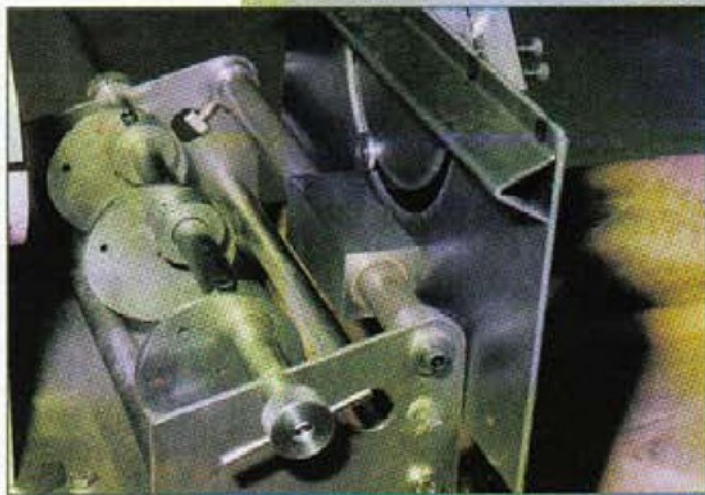
The CNC punching method of manufacturing the sheet metal components leaves them with a slightly nibbled edge (**Photos. 3 & 4**), so these have to be cleaned up by draw filing. It's not a time-consuming exercise, but one well worth carrying out carefully to ensure a satisfactory end result. The items treated in this way were the base assembly, the motor mounting plinth and its end cover, the wheel guard, the side plates of the table mounting assembly and the table itself. The other essential task was to fit the stiffening bars (**Photo. 5**) within the prefabricated base. The ends were first cleaned up on the milling machine, but filing would have sufficed. Next, the bars were set in position and the hole location marked through so that they could be drilled and tapped for the securing bolts. The bars were temporarily held in position with countersunk machine screws, the thinking being that these would not mask too much of the surface of the base during coating. The final task was to drill the holes for the screws which would secure the rubber mounting feet (doorstops) on which the unit would stand. When we collected the components after coating, they were all nicely bubble wrapped, so they could once again be packed away, and it was back to Plan A.

Tool Holder Slide Assembly

The majority of the items which make up this unit are made by straightforward drilling, tapping and plain turning. There is a bit of screwcutting and some knurling, so it is necessary to ensure that the appropriate tools are to hand. The base plate of the slide is made from a length of 2in. x 1/4in. steel, the positions of the two rows of holes being marked from the previously drilled guide bars. Before drilling, however, the material was prepared in true George Thomas fashion by carefully filing and scraping, checking regularly with engineers' blue on a surface plate. The more complex operations on this part were to create the bevel on the radiussed end and to engrave the three fiducial lines which are to be set against



6. The base of the tool holder slide assembly mounted on the face plate to allow the bevel to be turned and the fiducial lines marked. The Headstock Dividing Attachment was used to set the angle



7. The cams which set the angle of the table. The centre one is fixed to the shaft and set first, then the outer ones are located so as to support the table at the limits of travel

the engraved table scale. As suggested in the Working Instructions, this was carried out with the base set up in the lathe, strapped to the faceplate. However, instead of just relying on dividers to transfer the position of the two outer fiducial lines from the table scale, I used my Headstock Dividing Attachment (another project from the George Thomas song book) to turn the base through the appropriate angle (Photo 6). It was necessary to ensure zero backlash because two 10 deg. lines are required, one each side of centre.

All the other components in this assembly are to drawing except the two columns which support the tool holder clamp bar. I saw little point in having to drill and tap a blind 2BA hole in one end of each, then turn and thread up to a shoulder on the other. A plain clearance hole through each and a couple of longer cap head screws provide a much simpler solution.

The Table Eccentrics

The work table is supported at the desired angle by three eccentrics mounted on one bar (Photo 7). The centre one is securely fastened to the bar which is rotated by means of a knurled knob at one end and clamped in position by a knurled nut at the other. The outer eccentrics are free to rotate and slide on the bar, so are

positioned appropriately and secured after the table angle has been set by means of the centre one.

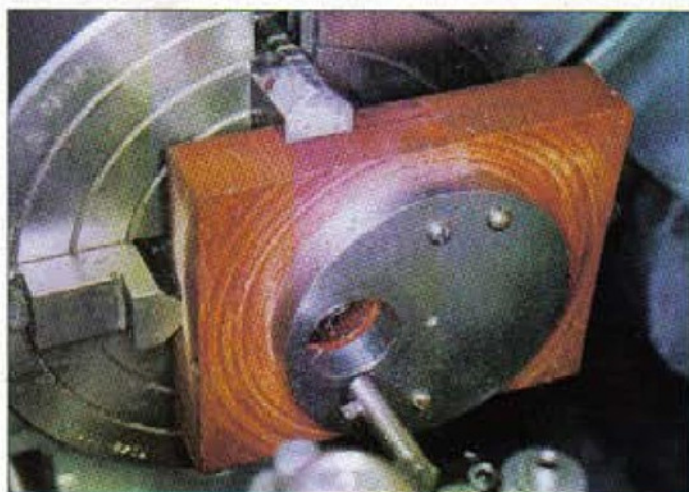
The three eccentrics are supplied pre-punched and are finished to size and bored as one unit while screwed to a suitable piece of wood (Photo 8). The spigots of the hubs to which they are attached are turned to fit after having been bored to a close sliding fit on the bar.

Experience gained while using the grinder at Primrose Valley prompted me to drill tommy-bar holes in both the bar adjustment knob and the clamping nut in order to provide better control over the angular setting and more secure clamping while not disturbing the angular position.

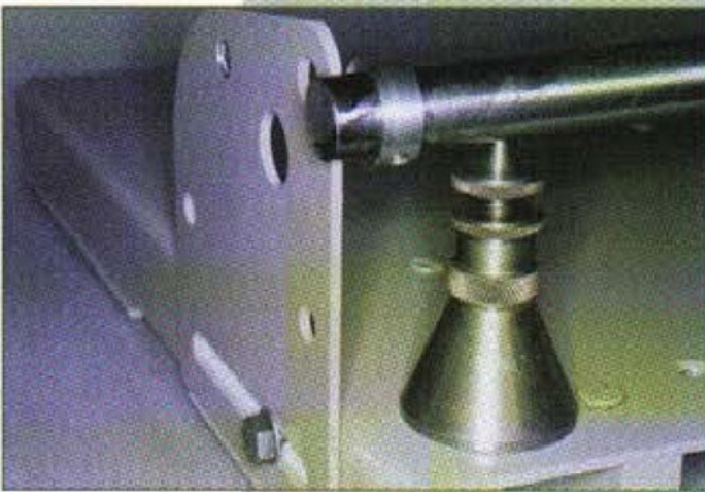
Setting bar lengths

In addition to the eccentric mounting bar there are three others fitted between the side plates. Two of these are simple distance pieces, while the third is the bar on which the table sliding block is traversed. All four are spigotted and have to be closely controlled to length over the shoulders. The procedure I used was to machine one end of each, drilling and tapping or threading as necessary, using the fixed steady for support. The other end of each was coated with marking-out fluid before the two side plates were clamped

to the base with a strip of ordinary photocopying paper interposed on each side to ensure a slight amount of clearance. The bars were then set up in turn, secured to one plate by its machined end, with the other plate positioned so as to abut against the unmachined outer diameter of the other end. A screw jack was used to stop the bar sagging under its own weight (Photo 9). Then, with either one of the table stop collars or an eccentric hub in position against the inside of the plate, a very sharp small diameter tungsten carbide scriber was used to mark the second shoulder position around the bar. Returning each bar to the lathe, it was a simple matter to finish the second end of each; working to the clearly visible scribed line. When all was assembled without the strips of paper in position, there was just enough clearance to allow coarse adjustment of the table position by sliding the whole unit, but tightening the bolts which pass through the slots ensured secure clamping. I turned up some large diameter bevelled washers to go under these bolt heads and also standardised on countersunk socket head screws, with the appropriate washers to secure the three fixed bars. The latter change is purely cosmetic, but worthwhile.



8. Boring the three eccentric plates as one unit



9. The table slide bar set up to mark the position of the second abutment face. The other three bars were treated similarly



10. A simple jig made positioning of the punches an easy task when numbering the table

The Table

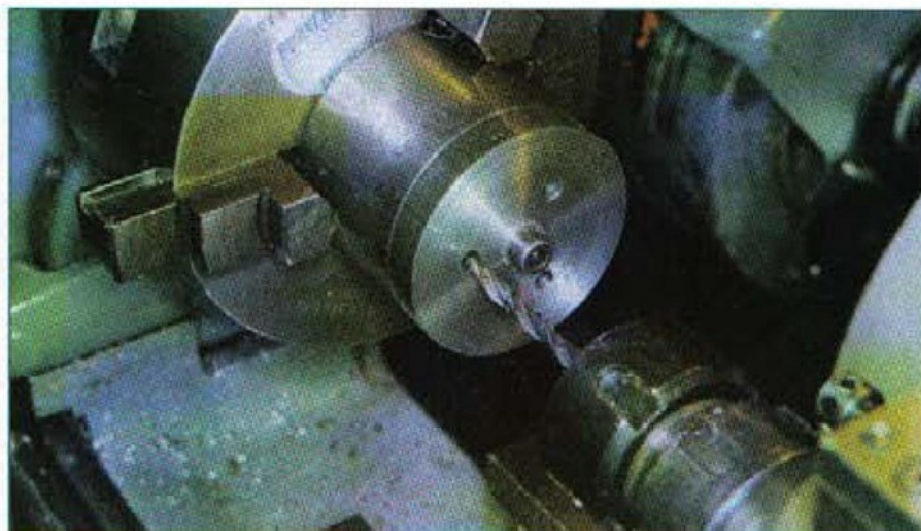
Although the table is supplied with the protractor graduations already stamped, the numbers have to be added. The Hemingway instructions suggest the manufacture of a wooden jig, but I discovered a short length of $\frac{3}{4}$ in. x $\frac{3}{4}$ in. steel angle in my odds and ends bin. This had a square internal corner which made a snug housing for the number punch, so the jig was made from this (Photo. 10). The remaining task was to attach the sliding block, care being necessary to ensure that everything was square.

Metal finishing

With all the steel components completed, the majority were treated with Metalblack solution to create a rust resistant finish before final assembly.

The Grinding Wheel Hub

Having finished the table assembly, attention turned to the motor and the hub on which the wheel is mounted. A fair degree of precision is required here because the hub must be a good fit on the motor shaft and the wheel must be properly located and secured. Hemingway have recently been beset by a few problems which affect this area because the motor supplier has changed a number of the details of its specification. In addition, the supply of square cup wheels of this size has dried up, only tapered cup wheels now being obtainable. These have a thinner section at the mounting bore location, so the length of the spigot on the hub has to be adjusted to suit. Owners of



11. The grinding wheel clamping washer is located on a short spigot turned on the hub and secured with a 2BA screw while the clamping screw holes are being drilled

machines built to the earlier standard will have to re-machine the spigot when the time comes to fit a new wheel.

In order to ensure concentricity of the hub and the wheel clamping washer, the holes for the three clamping screws were drilled while the washer was located on a very short spigot machined on the hub material (Photo. 11). This location was removed when the hub was subsequently bored to fit the motor shaft. The grinding wheel spigot and the outside diameter were turned at the same setting.

The motor and the control circuits

As supplied, my motor had its capacitor clamped to the external cooling fins, but the instructions suggested that it should be re-located within the motor mounting plinth, a hole having been provided in the end wall of the latter. Unfortunately, the capacitor proved to be far too long, so a new arrangement was sought. It could have remained in its original position, but this would have necessitated a length of six core cable between the motor junction box and the plinth mounted forward-off-reverse switch, only five core having been supplied. I could have mounted the capacitor between the upper and lower sheet metal components of the base and drilled extra cable holes in both base and plinth, but a

call to Hemingway produced a smaller capacitor of the same rating, which would go into the plinth with a bit of fiddling. As this one had no mounting stud, its strap was bolted to the underside of the top face of the plinth, making sure that the bolt heads didn't get in the way of the motor. Motors currently being supplied have an internal capacitor, so this problem shouldn't arise.

As suggested, wiring of the switching circuits was completed before fitting the components into the plinth (Photo. 12), then there was just room to get everything in (Photo. 13). All circuit connections and earthing were carefully checked with a meter before attempting to switch on.

Ready for use

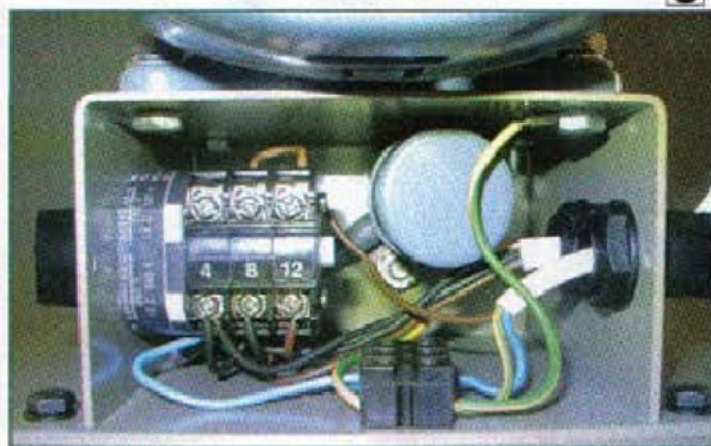
All that remained was to dress the wheel with a diamond dresser, remembering to take the machine outside to avoid covering the lathe and milling machine with abrasive dust, and it was ready for action.

This has been an interesting project because of the unconventional method of construction. I now have no excuse for trying to work with tools which do not have the keenest of cutting edges.

Supplier: Hemingway, Wadworth House, Greens Lane, Burstwick, Hull HU12 9EY
Tel./Fax. 01964 670701 E-mail: enquiry@hemingwaykits.freemove.co.uk
www.hemingwaykits.co.uk



12. A sound suggestion is to wire up the electrical components before trying to fit them in to the plinth



13. There is just enough space to get everything in and still have access to the motor mounting bolts

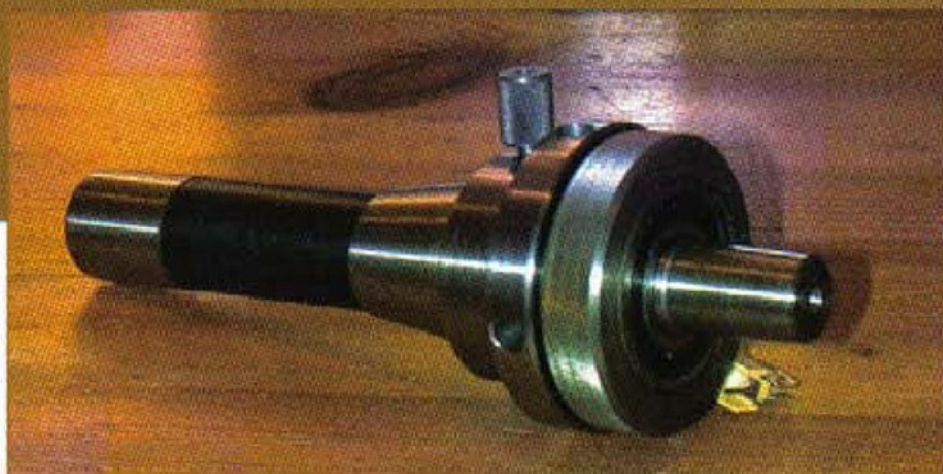
A DRILL EXTENSION

Peter Rawlinson suggests another method of maintaining alignment when more than one drill is used to create one hole.

A number of contributors have suggested solutions to the problem of maintaining alignment in the drilling machine or mill when the need arises to use a variety of drills to complete one hole. This idea for this device was suggested by Neil Munro, who asked me if I would see what could be made of it. The detail has changed somewhat from Neil's original design, but the principle is still there. It has been modified to reduce the height required and to incorporate a 'sensitive drill driver' for those small drills which only require finger pressure.

The unit (**Figure 1 and Photo. 1**) consists of an arbor which houses a sliding shaft which can be pinned in any one of four positions, thereby allowing the use of perhaps a centre drill followed by two or three lengths of drill without having to raise and lower the machine table or move the head. It also incorporates a removable capstan handle so that it may be used for guided tapping, and by fitting a bearing and cutting a keyway it has been adapted to feed micro drills. The components can be seen in **Photos 2 and 3**.

The 'Drext' (for short) is based on a standard arbor, R8, No. 3 Morse or even an MT2, to suit the machine in question, the latter not having been made but is covered on the drawings. My own requirement was for an R8 type, so this is why this particular one was made and photographed.



1. The Drill Extension unit constructed from an R8 arbor, the shaft being machined with a Jacobs No. 6 taper

Main Arbor Assembly

This basic component is, to my mind, best purchased finish machined, but can be made if so desired. There have been many excellent articles on this subject and on taper turning, so I will not cover that ground again.

The arbor is first turned down to create a spigot which will accept a previously bored and turned outer bush which will be used to take the anti-rotation pin, and this is made as a press/heat shrink fit or could perhaps be Loctited into place. It may be 'sculptured' to taste if so required. After this has been fitted, the arbor is then drilled, bored and reamed to suit the size of shaft selected, as shown in **Figs. 2 and 2A**. This does, of course, require to be accurately carried out as any variation in either concentricity or parallelism will

throw the drill off centre, and as we are extending the drill this will multiply the error. Don't forget that all R8 arbors and some Morse taper versions require a draw bar, so don't drill right through.

This item is then set up, drilled and reamed for the locking pin, working from one side to create a flat bottomed hole on the other.

Drive Shaft

This is machined from one piece of silver steel of 18mm dia. and must be a very good sliding fit in the bore created in the arbor. The two versions are shown in **Figs. 3 and 3A**. I would suggest that it is turned between centres for accuracy, and if a Jacobs taper is required for the chuck, then the top slide should be set up first so that it can then all be machined at the same setting. If a threaded chuck is to be



2. The major components of the unit



3. The detent parts

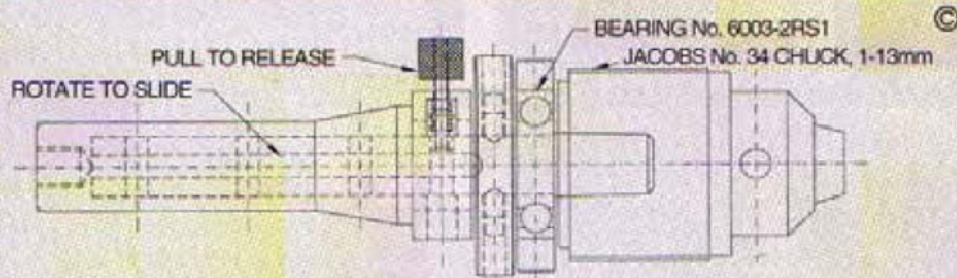


Fig. 1 Drill Extension Assembly

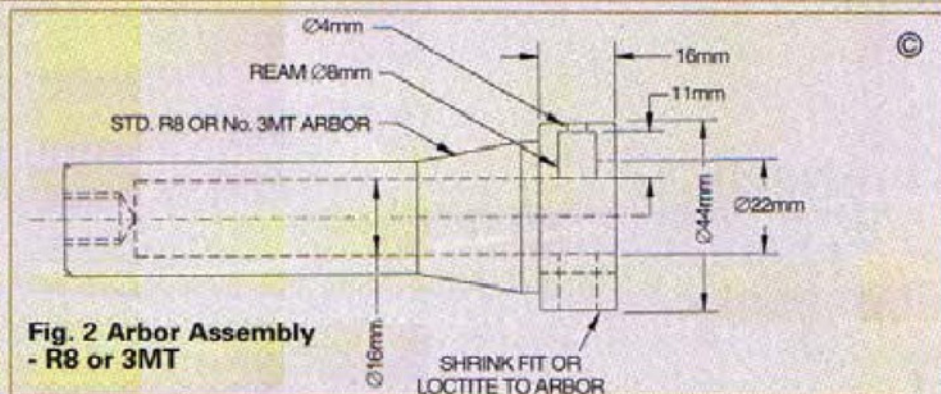


Fig. 2 Arbor Assembly - R8 or 3MT

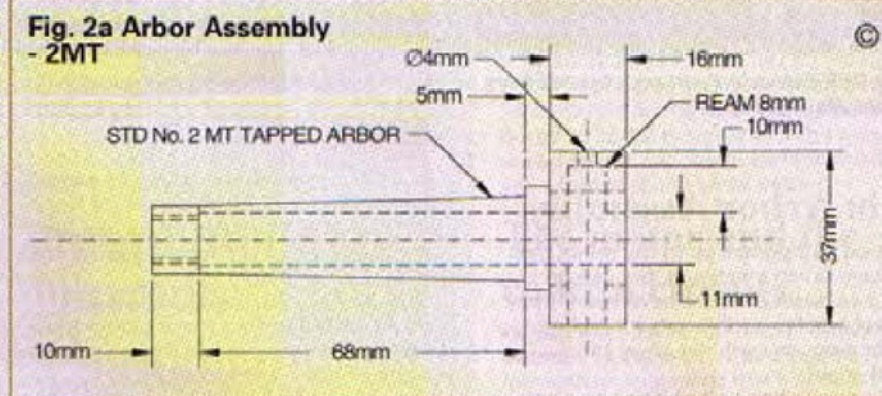


Fig. 2a Arbor Assembly - 2MT

used then the thread (usually $\frac{3}{8}$ x 24 tpi. UNF) can also be cut at this time.

Every machinist has his own way of working and his own types of tooling, so the drilling of the holes and the set-up for cutting the keyway will vary from person to person. **Photo. 4** shows my way, which will not suit everyone. The Mill/Drill Centring Device was used to set up the tool on the centre line of the shaft (see M.E.W. Issue 47, Dec. 1997). I have used a indexing head and a tailstock because this allows me to rotate the shaft as required for the holes and the key way. I also used the same basic set-up for drilling and reaming the locking pin hole in the arbor (**Photo. 5**).

Hardening

As I have said in previous articles, we do not use our tools either as hard or as frequently as the professional tool makers or machinists, so the decision on whether to harden components or not I leave to the individual. However, I feel that it would be best to harden and temper the main shaft and perhaps to case harden the pin. Through-hardening of the latter component is probably best avoided as it is in shear when driving.

Drive Discs

These are simple machining jobs as shown on **Figs. 4, 4A, 5 and 5A**, but could be reduced in diameter if smaller chucks are to be fitted. The sizes quoted are large enough to allow the Tapping Holder to pass over the chuck, allowing it

to be fitted while the unit is still in the machine. Knurling is an option and the only accurate feature is the location of the holes, which must align with those in the Tapping Holder.

Release Knob Assembly

The pin could be turned in one piece with the large diameter knurled to taste, but assembly is probably made easier by screwing the knob on when the detent, pin and spring are in position. The detent is of silver steel and should be hardened. On **Fig. 6** I have quoted a maker's number for the spring, but it is unlikely that it would be available as quantity of one, but something can usually be found in the junk box that will suit the application. The stud is simply made from 4mm steel, threaded 4BA.

Tapping Holder

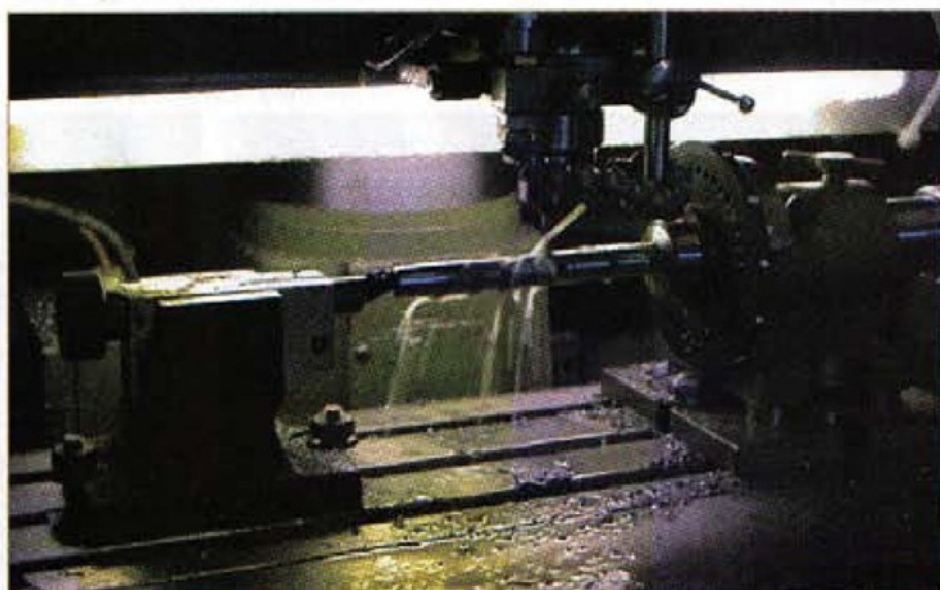
This is made from a 10mm thick disc of 100mm dia. steel (**Fig. 7**), but the size could be reduced if you are using a smaller chuck. It must be a good fit over the Tapping Disc and, of course, the handles, when, fitted must engage with the holes in this disc.

Tapping Handles

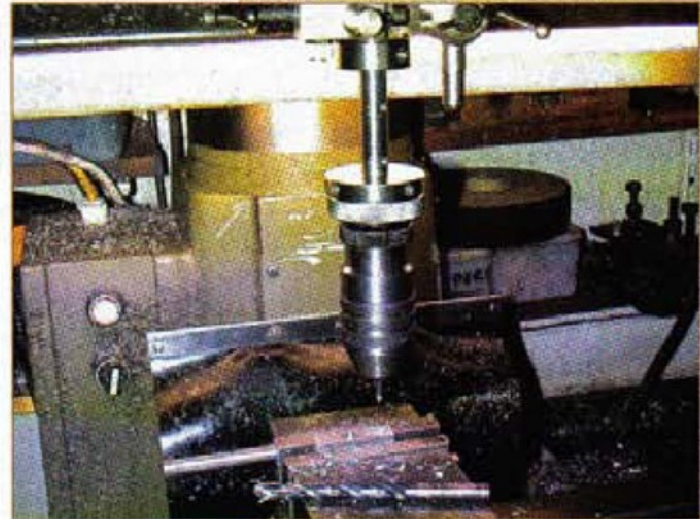
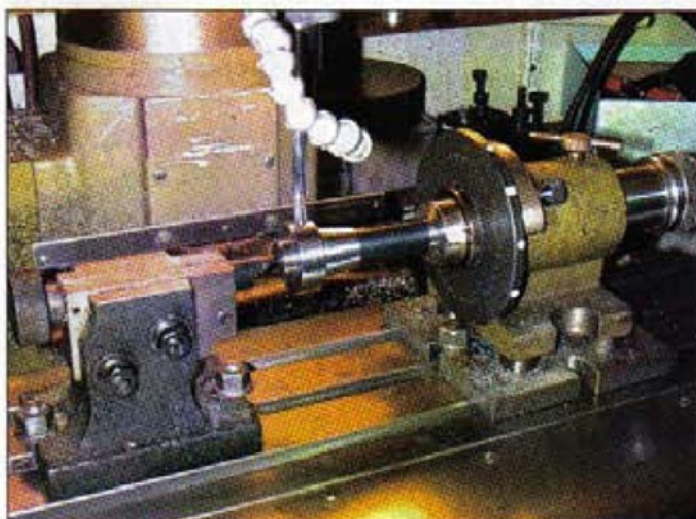
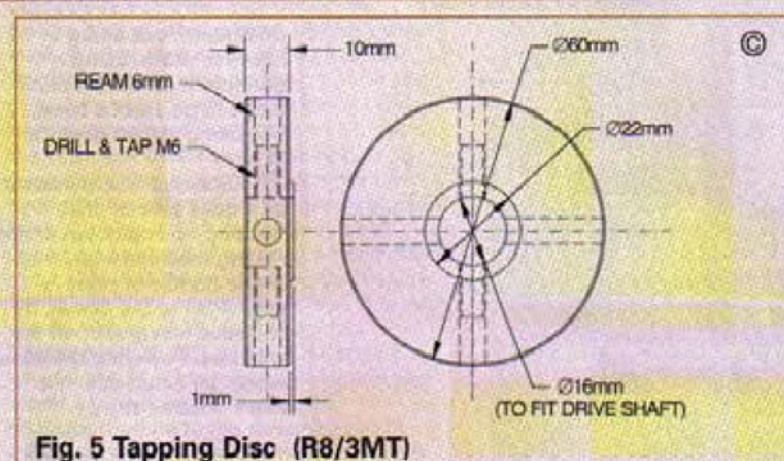
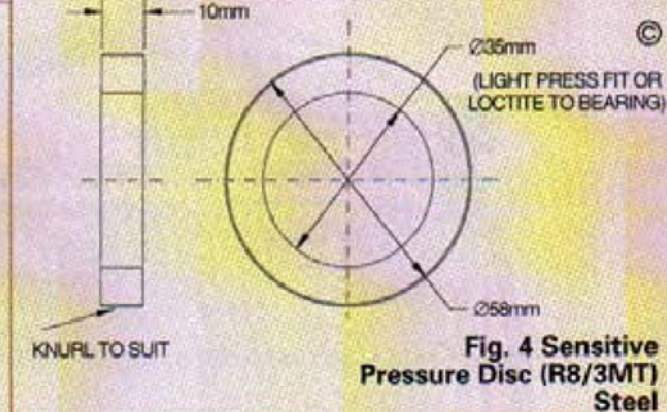
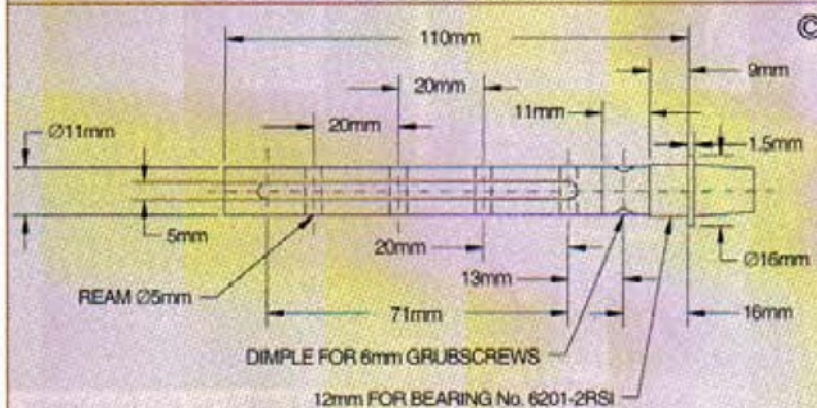
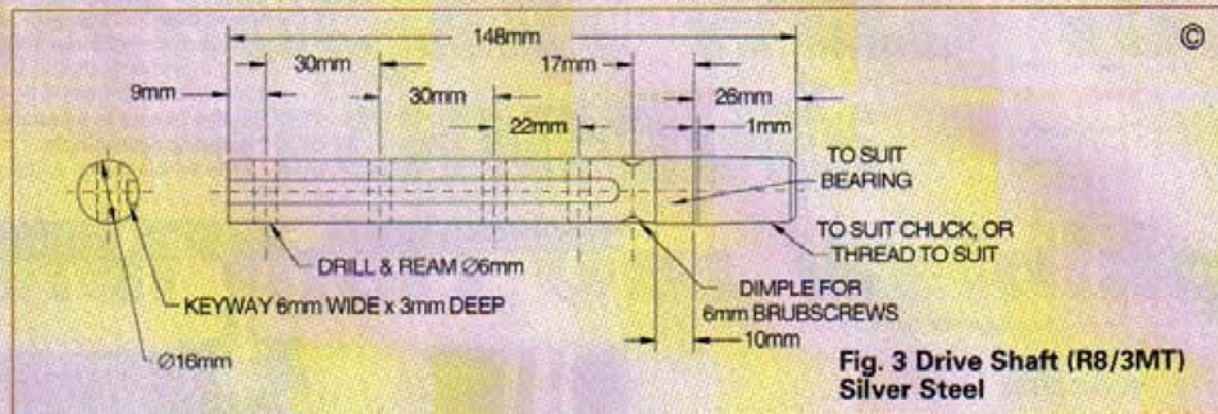
These are knurled, both to ease assembly and to ensure a good grip when in use. It would be advantageous to case harden the ends which transmit the torque.

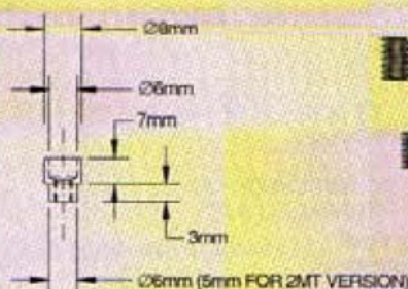
The unit in use

No problems have been encountered in its use, but do be careful when using the sensitive hand feed to keep the hands away from the release knob. **Photos. 6, 7 and 8** show three stages of drilling a hole, the milling head to workpiece distance having been set to suit the longest drill being used, with the unit in the fully closed configuration. **Photo. 9** illustrates the set-up for tapping, when the detent is located in the keyway, rather than in one of the holes. It is similarly set when using hand feed.

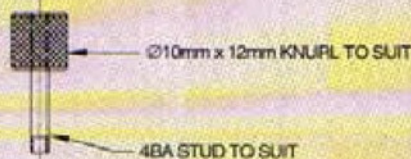


4. Machining the keyway in the shaft





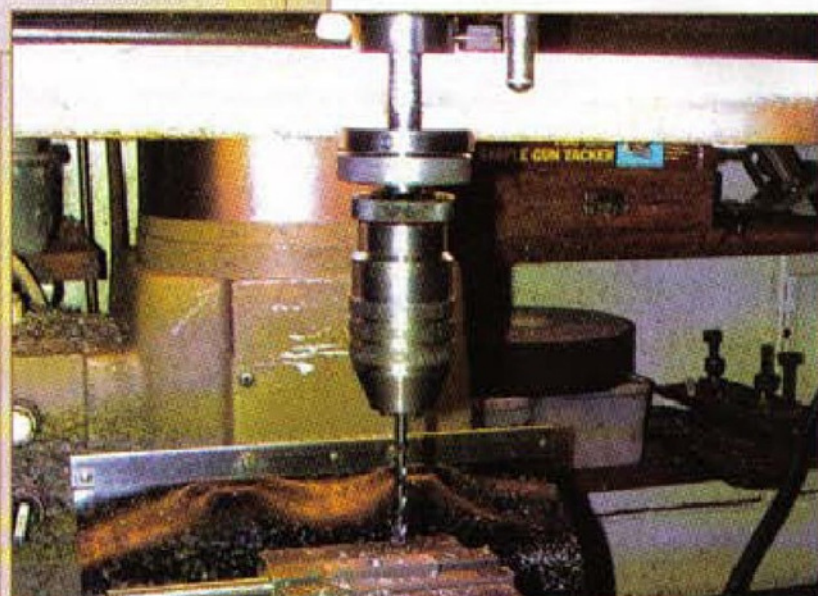
DETENT
SILVER STEEL



RELEASE KNOB

STD 'LEE' SPRING
No. LC-022BC-01

Fig. 6 Detent Assembly (RM/3MT & 2MT)



7. Partly retracted, it now accommodates a small drill

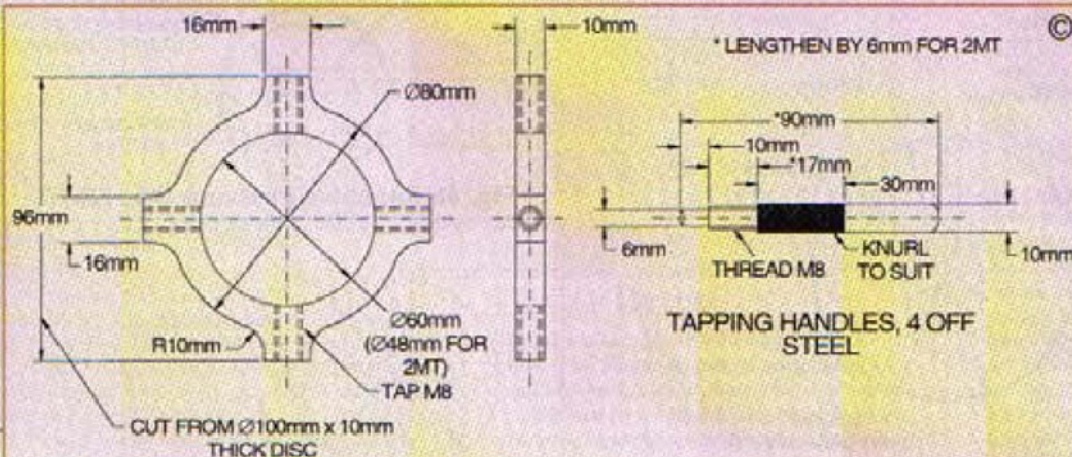


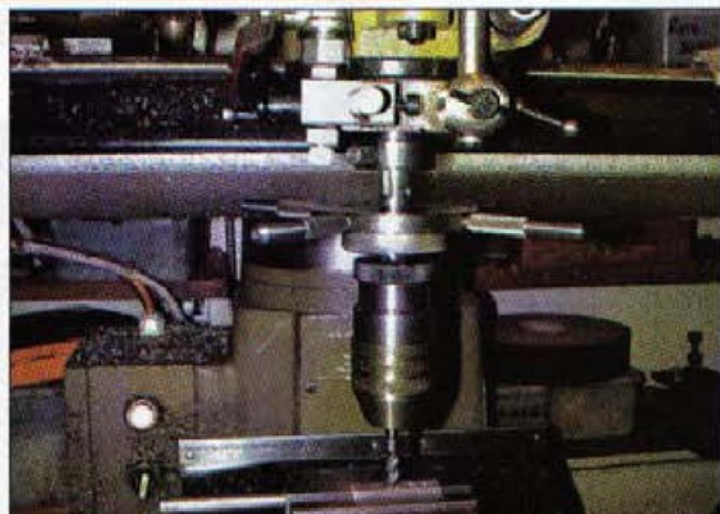
Fig. 7 Tapping Holder (R8/3MT & 2MT)

treatment, took about 6 hours to make, using a purchased R8 arbor which had a large Jacobs taper, this being turned down to 22mm.

I hope that it is of interest as it does save all that winding up and down of the milling machine knee, and as the handle of mine is very close to the bench, it will save losing skin off my knuckles. Powering the knee would be better still, but that's another story.



8. The large drill just fits when in the fully closed position



9. With the detent dropped into the keyway and the handles fitted, the hole can now be tapped

ELECTRIC ARC WELDING TECHNIQUES

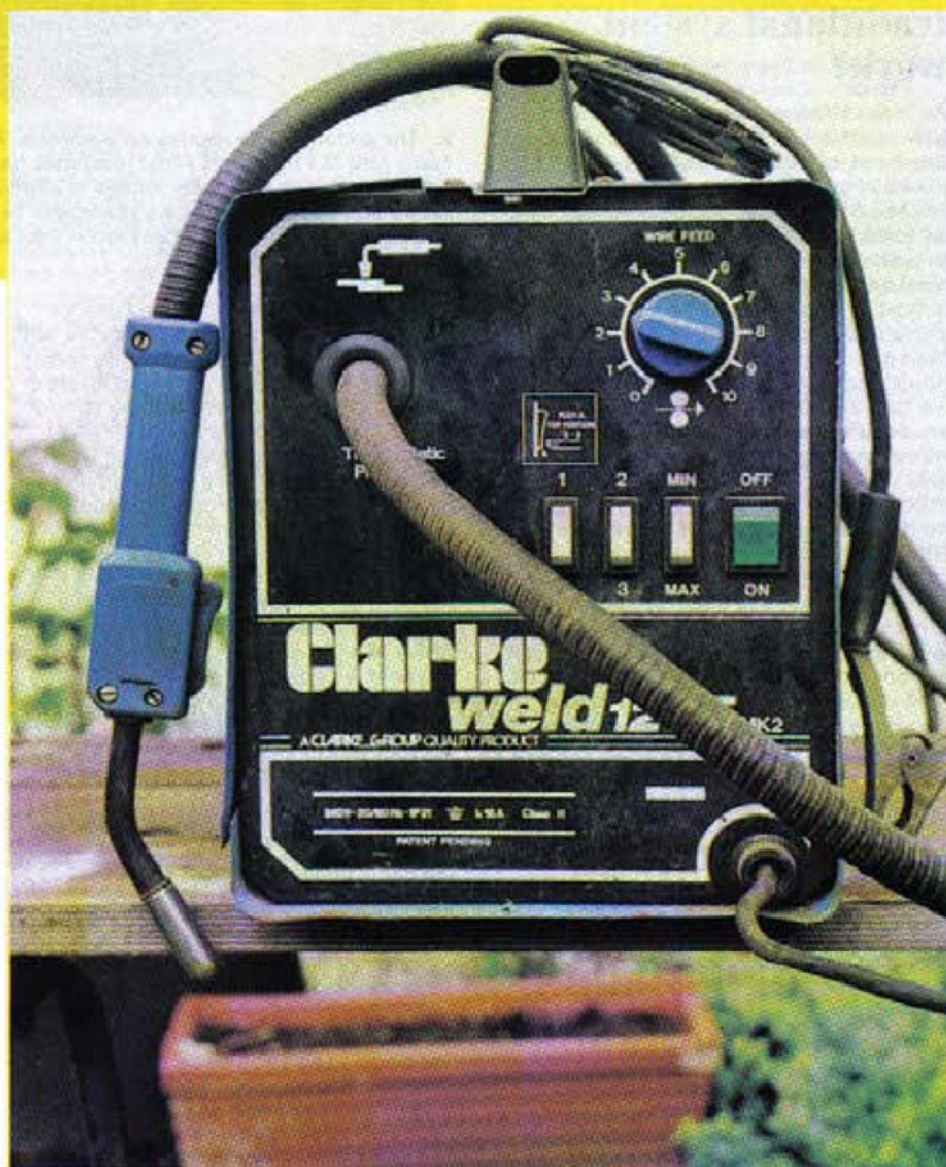
Metal Inert Gas Welding

Trevor Marlow describes the equipment and the methods used when MIG welding and suggests some advantages which the process can bring to the home workshop

In a previous article I described the attributes of simple Manual Metal Arc (MMA) or 'Stick' welding, and found that it could provide many benefits at very little cost. A slightly more complex process, 'Metal Inert Gas' or 'MIG' welding has, in recent years, attracted great popularity, largely because it offers a capability that is not usually available with the MMA welder, that of joining relatively thin sheet steel. Further popularity stems from the fact that there is little requirement for skill in making such joints. There has recently been such intense competition between the suppliers of DIY-level welding equipment that a basic MIG system has become very affordable. We can now even have systems which do not require a supply of inert gas if we so choose. It has to be said that there are some downsides to MIG welders, some things that they will not do well or at all. That said, the introduction of MIG to a workshop will usually result in increased fabrication and repair capabilities that are quite disproportionate to the modest cost. In some workshops, such as those in which there is frequent work on the restoration of older vehicles, it will be nearly impossible to do a good job in reasonable time unless there is MIG availability.

A purchase that you will never regret

Nothing in what follows is intended to detract from the benefits of using MMA welding techniques described in the previous article, those available from the MIG apparatus being complementary. For many jobs, provided the steel is more than about 2mm thick, there will be no special advantage or disadvantage in choosing to use either methods; both will do equally well. On the other hand, there are some jobs where one method will be the natural choice, and when the job involves welding material less than about 1mm in thickness, there ceases to be any uncertainty. You will do it easily with MIG



1. Familiar front-end view of typical hobby-level MIG welder, showing simple adjustment of current levels (white switches) and control for wire feed speed (blue knob).

but will be driven to distraction if you seek to do it with MMA. There are occasions when other methods (particularly Tungsten Inert Gas, or 'TIG') are better than either, but the key word is "occasional". In a workplace where a full spectrum of joining methods is immediately to hand, it will be found that either MIG or MMA will prove to be the natural choice for well over 80% of the jobs arising.

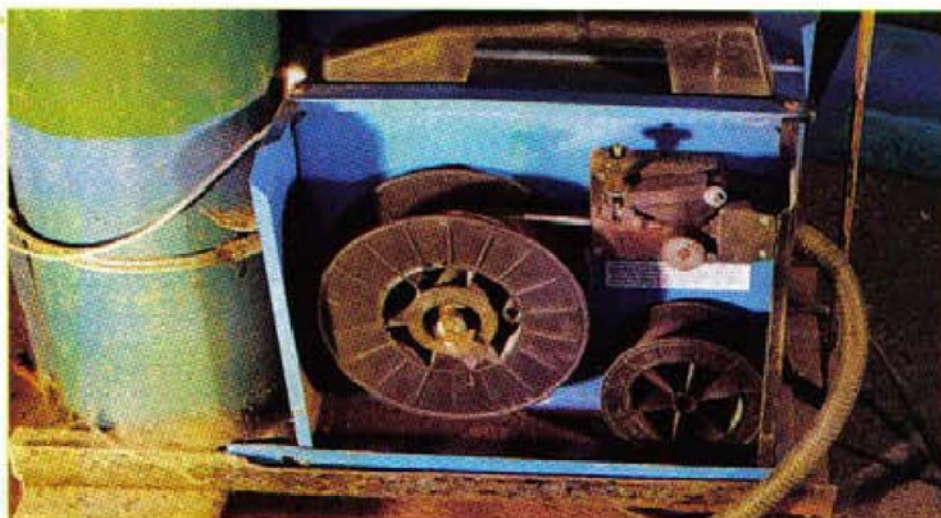
Why are MIG systems so popular?

Firstly, for straightforward jobs, MIG welders are so easy to use. A second advantage is that, unlike the MMA 'stick' process, one does not have to keep stopping to change anything. Additionally, there is no need to remove slags/fluxes from the finished MIG weld, but the recent availability of 'deslagging on cooling' MMA electrodes has somewhat negated

this advantage. The outstanding benefit however, is this ability to weld really thin sheet steel. Incredibly, it is possible, with care, to weld onto sheet steel that is clad on the other side with carpet or similar material (e.g. car internal rear wheel arches), in so doing causing so little damage to the carpet that the deterioration is not noticeable. It is even possible, in extreme circumstances, to weld onto something that isn't there any more! (That technique is based on the use of copper 'splashes', and will be described in more detail later in this article).

How does the traditional system work?

As in the MMA system, we strike an arc between the metal of the workpiece and the metal with which we wish to 'fill' the joint but, instead of using discontinuous 'sticks' of filler metal, we feed the filler as wire, from a reel. As a flux coating on the outside of the wire would flake or be scraped off by the feed system, atmospheric oxidation of the weld pool is prevented by covering it with a cloud of inert gas. This system I refer to as 'traditional' MIG. A later development, the 'no gas' variant will be described later. The welder (Photo. 1) consists essentially of a transformer to provide high amperages at safe voltages, a motor and rollers system to drive the filler wire, and a steady supply of inert gas at near-atmospheric pressure (Photo. 2). The feeds for welding current, gas supply and filler wire are conveniently bundled into a single tough umbilical. At the other end of the umbilical we have the welding torch which has a two-stage trigger system. The first finger pressure causes the start of gas flow, and at a slightly higher finger pressure current is provided to the wire. The current is supplied to the wire via sliding contact at the point just before the wire emerges from a copper tip (Photo. 3). The inert gas is guided to where it needs to be by being made to emerge through a cylindrical shroud.



2. The spool of wire locates on a spindle. The wire passes between grooved rollers and feeds into the umbilical. Most machines have sufficient spare space in this compartment to allow storage of smaller spools of aluminium or stainless. With benefit of hindsight, rather smaller gas bottles are preferable to that shown here. Because of that heavy bottle, moving this equipment more than a few feet has become an unwelcome chore, despite the castored trolley

On most MIG machines the controls have been kept as simple as possible, with the operator being able to set wire speed and to switch between preferred levels of current. Given those settings, the control mechanisms of the machine do clever things, so that if you, say, change wire speed, the amount of current supplied will change to a more appropriate value.

It is generally accepted that using MIG is totally easy, the novice operator probably being able to lay a useful weld in the first minutes of familiarisation. Despite this, there are occasions when you can only arrive at a satisfactory outcome via the use of some wheezes and dodges, these occasions usually being associated with attempting welds that aren't really feasible. As your machine loses its newness, you will also become aware that there are mildly distressing aspects of behaviour when a MIG system needs maintenance. There are similar tantrums when a MIG welder is presented with a surface

condition that is not to its liking. We will touch on these topics later in this article.

Financial outlay

You will be faced with an initial outlay and with an ongoing cost. At the bottom end of the price range, the initial figure could be as low as about £100. At the top end of the range, but still in a home workshop context, the figure might be about £400. Between £150 and £200 will provide you with a set that is unlikely to 'trip out' at normal wire speeds and current levels. Cheaper sets will usually produce welds equal to those made on the more expensive sets, but the runs of weld must be smaller, slower and less penetrative. Protracted welding sessions with a cheap set will lead to frustrating waits when the thermal switch 'trips out' to prevent damage to the windings. As to the ongoing outlay, the figure can range between virtually nothing through to some

Ongoing Cost

Region of Minimum Cost

Frequency of Use

Fig. 1

Legend: Traditional on Argon Mixture
Legend: Traditional on Carbon Dioxide
Legend: No-Gas

near-ruinous figure for a worst case. It all depends on the choices you make concerning the gas/no gas alternative, and how much use you will make of your MIG, as is explained below.

What will I get for my initial outlay?

The traditional MIG package is usually made up of the welding set, a small reel of welding wire, a face mask, a small gas bottle and a primitive gas regulator. The 'no gas' welding technology dispenses with the need for the bottle and regulator. The differences in basic initial price between the one or the other of those systems is relatively trivial. If you opt for the traditional 'inert gas' MIG, you will soon be faced with the decision whether to persevere with the Lilliputian gas bottle and rudimentary regulator, or to invest in a reasonably-sized bottle and a sufficient regulator. Most people seem to make that upgrade, sooner or later, because a small bottle is soon exhausted, whether in the short term by use or in a middle term by leakage.

Which should I choose? The traditional package or the 'no gas' model?

There isn't an automatic best choice between 'gas' and 'no gas' equipment. It all depends on a deceptively complicated relationship between **how often** you will use it, **why** you will use it, and **where** you will use it. The long term and convenient availability of an appropriate shielding gas is not totally cheap and it is not totally convenient, the need for a gas bottle being a detraction in two ways. Firstly, the rental of a cylinder and the occasional refill represents almost all the on-going cost of having a traditional MIG capability. Secondly, the presence of a substantial cylinder transforms something totally portable into something that is still portable but only with considerable effort.

Conversely, when we examine the on-going costs of the no-gas system we find that the special flux-cored wires used are many times more expensive than the straightforward MIG wire, so be careful to make sure that you are comparing like with like. A 'small' reel of traditional MIG wire will usually be much bigger than a 'small' reel of gasless wire, a strategy which allows the prices of those reels to be made broadly similar. Similarly for the larger reels of the two materials. You will get a better appreciation of this aspect by comparing the cost of depositing a set amount of weld metal. The current figures are something like those shown in **Table 1**.

Sometimes the advertised prices will include VAT, sometimes not, so be alert. Additionally, with traditional MIG you get a Kg of weld from a Kg of wire, but with the no-gas technique you get rather less because of the flux core, which must make up some fraction of the weight.

It is not difficult to visualise that the need to do a lot of no-gas welding could

Table 1

	Traditional MIG £/Kg	No-gas MIG £/Kg
On 'Small' Reels	4.9	15.5
On 'Medium' Reels	2.2	11.1
On 'Big' Reels	1.3	Not usually available

allow costs to enter the near-ruinous category. Conversely, if you hardly ever use the equipment, you will hardly ever need to buy wire, and with no costs for hiring and refilling gas bottles, the self-same gasless machine now has vanishingly small running costs! So, anticipated frequency of use is probably the paramount criterion. Other factors may influence your choice, as described elsewhere in this article, but if you will usually find it convenient to take the job to the welding machine, rather than vice versa, these are likely to be of secondary importance.

The cost of gas for use with traditional MIG will vary depending upon which gas you choose to use, whether you need to pay bottle hire charges, and how long it takes you to use the contents of a bottle. That last factor, while being related to how much welding you do, is not totally dependant on that frequency of use. If you never welded, slowly, but inevitably, the bottle would empty. It might take years, but it would happen. At the other end of the spectrum, if you needed to weld near-continuously, a typical bottle could be emptied in a day or so, the leakage factor therefore being quite trivial. If you only weld now and again, you still will have moderate on-going costs, probably due to hire charges, and certainly due to leakage. If you are using and losing gas, then clearly the unit cost of that gas is an important parameter.

As is described below, if you have opted for the traditional MIG, then when welding mild steels you are faced with a choice of gases. The cost of having those gases to hand is fairly fixed if (as is usually the case) you have to get your supplies through a major supplier.

There are other factors that should enter the gas/no gas decision process. The detail is presented below, but in round terms you can for the interim think along the lines that if you will only use the welder very occasionally, for little jobs, often in the open air, then you should opt for the "no gas" model. Conversely, if you anticipate fairly regular use, depositing a lot of metal, and usually being in one enclosed workplace, then you will be better served with traditional MIG. If you do opt for traditional MIG, you then will be well advised to closely examine the topic of gas supplies. The diagram (**Figure 1**) illustrates how ongoing costs are related to frequency of use for the various possibilities of apparatus.

Choosing your Inert Gas: an Argon mixture or Carbon Dioxide?

In addition to cost considerations, the identification of the 'best' gas for MIG welding is nowhere near as easy as might be thought because of the multiplicity of variables and the range of opinions. The



3. Where the wire emerges at the torch. In this photograph, the wire is shown prior to trimming to correct working length. You will do a lot of trimming, particularly if stitch welding, so one of the most rewarding actions is to identify a good quality pair of side cutters as set aside specifically for that purpose. Cut the wire as short as possible, to ensure that you always initiate an arc, as opposed to the hot wire syndrome.

difficulty largely hinges on the criteria by which we judge 'best':-

- ability to prevent oxidation of the weld?

- ability to achieve deep weld penetration when joining thicker materials?

- that the gas stays where it is needed? (light gases are very 'mobile')

- that the metal stays where it is needed? (i. e. doesn't spatter a lot)

- ability to support a fluid weld pool?

- that the wire becomes molten in a preferred fashion (a wire dipping into the weld pool may be preferred to metal transferring as a stream of droplets).

In addition to trying to evaluate the relative performance of a list of candidate gases (Neon, Xenon, Helium, Argon....) an unlikely event in just one lifetime, it is necessary to be aware that being 'inert' does not necessarily lead to optimum MIG performance. Small additions of other gases play an active part in the welding process.

The only thing that does seem to emerge from the debate as a hard and fast conclusion is that the 'best' gas will either be straight carbon dioxide or a complicated argon mixture. There is a range of the latter, but there is no need to overly concern yourself with the exact composition and function of the gas, just take advice from your local supplier as to which will be best for your purposes.

You can rest assured that, of the two



4. This type of gas regulator tells you how much is left in the bottle, allows you to adjust the value of the low pressure side of the system, tells you what that LP value is, and allows you to do fine adjustment to the flow rate.

main candidates, neither has some really awful downside that will render it totally useless for your needs. It's all a matter of fine tuning to get the best result at an acceptable cost - you can always change at a later date.

Remember during those discussions that the bigger the bottle, the longer it will last, but at the same time it becomes that much less portable.

You may base your choice of gas on special circumstances, perhaps you or someone in your circle of friends having access to very cheap carbon dioxide (probably from a source connected with the production of fizzy drinks. It's no coincidence that some MIG users will refer to their use of 'pub gas'!). If so, your ongoing costs for traditional MIG might be reduced to a vanishingly small amount.

If you chose to seek the opinions of experienced users, you will probably hear quite a lot of criticism about carbon dioxide, but little against the argon mixtures, except of course concerning their cost. That about says it all. To have first class gas performance, opt for the argon mixture. Then, if you end up using your MIG fairly frequently, but not near-continuously, your ongoing costs will be something like a couple of £'s a week.

Preliminary Setting-Up

In the initial setting-up of a new machine the operator will set the roller pressure which serves to feed the wire. That usually is a one-off adjustment, maybe never reset for years on end. It is deemed wise to have the roller pressure set just tight enough that you normally do not get slippage between wire and roller, but will allow slippage if something prevents easy feeding. Almost always, that 'something' is

sticking of the wire up at the working end: it happens for instance when you don't leave sufficient gap between torch and workpiece. Because you have established the 'slip if necessary' condition, you should not get any big tangles or damage down at the wire feed region.

As to setting up for regulation of gas flow rate, it all depends on what sort of regulator you possess. The simplest regulators have to be reset for each welding session, because there is only one control and it serves both for turning the supply on and off as well as providing adjustment of the rate of gas flow. A more up-market regulator (Photo. 4) has on/off and a separate control for rate of flow, so the setting of rate of gas flow can be a once-off adjustment if you so choose. You may however find that it is wise to close off the flow adjuster after each welding session because, by observation of the pressures indicated on the various dials over the several days after a welding session, you may arrive at the conclusion that the on/off seal at the flow rate controller is better than the on/off seal at the bottle neck. By shutting down both you set up an extra stage of pressure differential that helps conserve your precious gases. It is also very worthwhile, when making the connections to a new bottle, make sure that all joints are gastight. Train yourself to shut down your gases after each welding session, no matter how short the period before you expect to resume operations. In addition to knowing that you are making reasonable effort to contain your ongoing costs, you should be spared the pain of coming back to an empty bottle. Remember also that the gas valve at the torch is very rudimentary, serving its primary purpose and no more.

'Floating ball' or 'floating bobbin' flow

indicators can be awfully prone to sticking, a fact of life that there isn't a lot you can do about except to ensure that the viewing tube is vertical. Stuck bobbins can usually be freed by a light tap on the side of the viewing tube, but very occasionally they can be a bit more troublesome and you then will have to do some dismantling and prudent cleaning. The flow rate indicator is still worth having, despite such problems, since it removes the subjectivity of judging flow rate by the loudness of hiss as the gas emerges from the end of the torch. A numerical value for flow rate will be suggested by the manufacturer of the set, a figure which is easy to forget if the equipment is used only infrequently, so it is a good idea to stick a reminder label in the vicinity of the flow meter. Another useful label, in that instance of the tie-on luggage variety, should be hung around the neck of the bottle, reminding you of the most recent advice from your gas supplier as to where you now go to exchange the bottles.

Recurring problems: their causes and cures

As one of the principal attractions of MIG welding is that it doesn't require high skill and you can start making good welds almost immediately, it also means that there is not a lot for you to forget if you do not need to use the equipment for a while. Hence, when you do resume welding, you tend to do so as capably as previously. Over time, however, you are almost certain to experience problems, either caused by wear and tear of the equipment, or by lack of recognition that an apparently simple task is deceptively difficult. The equipment may be 'playing up' because of inadequate preparation of the surface of the workpiece.

Among the most common of problems is that where, on pulling the actuating trigger, nothing happens. Almost always, the cause is lack of power, either due to simple oversight on your part or in consequence of the high amperage demand from your mains supply having blown a fuse or something similar. The best guide is the illuminated on/off switch on the front of the machine. If that isn't lit, you will probably have a simple supply problem. If it is lit, then you are suffering from something that will take a bit more sorting.

Perhaps next most common problem is that where wire is propelled through the tip of the welding torch, but does not make an arc on the workpiece. About half such occurrences are because you missed! Your aim is such that the wire has missed the objective and is feeding into free space. You can immediately recognise this because, in addition to the lack of an arc, there is no simultaneous feeling of 'kickback' on the torch due to the wire coming up against the workpiece. There are other common errors where you don't get an arc, but in those instances the wire comes in contact with the workpiece but is not melted. The workpiece is reluctant to move, the wire still wants to come out of the torch, something has to give, so you feel the wire-driving force fed back through the torch.

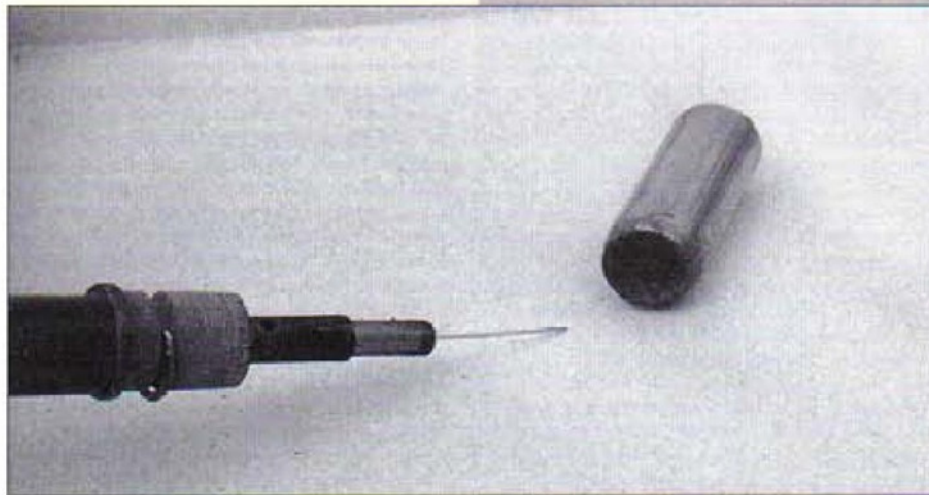
Missing the workpiece is often directly

related to how clearly you can see what you are doing. It is often overlooked that if you need to wear spectacles for reading, then you need (behind the mask, of course) to wear similar spectacles for welding. If you cannot see with total clarity at the working distance, it will degrade your spatial perception. If you can afford a liquid crystal mask (the type which is darkened by the arc, usually costing £100 to £200), it should allow you to have totally clear vision, but be warned that those masks can have their own occasional frustrating downsides, one such being that incident sunlight or a nearby workshop light can be enough to switch the mask to darkened mode. It usually happens, of course, that it switches just as you are positioning yourself prior to welding, so your vision is now totally obscured. Clever solutions, such as positioning yourself where there are no incident sunbeams are not always available since sometimes you have to take the welder to the workpiece rather than taking the workpiece to the welder. All the 'headband-held' type of masks (a category into which most liquid crystal masks fall) can make things very difficult when you try to get into the best position to do an awkward weld, e.g. as encountered when fitting replacement sills to a car. All things considered, the best strategy often turns out to be to use the simple hand-held mask that came with the welder, perhaps in conjunction with a couple of small but intense spotlights with which you illuminate the region where you are about to weld. As well as making it easy to see what you are doing before you start welding it also ensures far better vision even while you are welding. Keeping the mask close to the face gives the added benefit of minimising reflections from the inside-mask surface of the welding lens.

Another contribution to making life easy is to identify a nearby object that can be used as a steady for either the torch or the hand that holds it, perhaps positioning something for just that purpose. One old favourite that can be used on a workbench or other flat surface is the familiar Nippy vise. Because of its broad base and substantial mass, and jaws perfect for holding something like a piece of dowelling, it enables you to precisely position your 'steady' wherever you choose to put it. Similarly, a welders' clamp can be used as a steady, sets of such clamps being dirt cheap and oh-so-useful.

Surface preparation

Returning now to the causes of 'kickback' experienced when feeding the wire. Firstly, if you try to start welding with the wire actually touching the workpiece and the machine is set to low amperage, you do not always have the necessary conditions to establish an arc, so all that happens is that hot wire feeds out of the torch. More usually, the classic cause of kickback is simply that you haven't remembered to connect the earth clamp to the workpiece. Variations on the theme are that you have connected onto something that isn't, electrically, part of the workpiece, or the earth clamp cannot make contact because of rust or paint. If you are sure that you have a good connection at your earth



5. The tip of the torch with the gas shroud pulled off its retention spring. Gas emerges from holes just prior to the location for the screw-in tip. The gas shrouds collect internal spatter, which causes deterioration of the uniformity of local flow of the emerging gas, and can in extremis cause the shroud to attain welding voltage. Remedy: have a few spare shrouds to hand, so that you can simply substitute a fresh one, rather than needing to break off for a despatching

clamp, and yet you still get kickback, it almost certainly means that your feeding wire has abutted against a surface that, while generally appearing clean and bright, will at the position of wire contact, not allow electrical conduction of sufficient amperage to establish the arc. Almost always, the culprit turns out to be a minute area of rust or paint, often indicative that your workpiece poses extra problems re surface preparation. What in normal conditions would be adequate is, on that particular surface, not enough. (See 'tubercles' in the following paragraphs).

Considering preparation, we should remember that wire brushes are only marginally useful for removing rust. For us, the more effective tools, by a long way, are our old friends the small angle grinder and the miniature hand-held belt sander, driven by either compressed air or electricity. Both score high marks because they remove rust with greater ease than other equipment and they generally allow far better access. Belt sanders are now available which use 13mm belts, the cost of which has dropped significantly relative to the other widths in use. Although the small electrically driven units do seem to have a finite life, for convenience of use and economy, the best strategy appears to be to stick with the 13mm electric model and accept that you will need to buy a new one periodically. Purchase replacement belts in bulk at a fraction of the local shop cost from one of the postal suppliers, perhaps also investing in a few of the twisted-wire cup brushes that fit your angle grinder to take advantage of post-free order level offers. You will find that these remove paint and similar materials with a Terminator-like efficiency. Finally, if you are going to encounter fiddly work, with tight recesses that deny access even to the snout of the 13mm belt machine, consider the benefits of a miniature electric drill (e.g. Dremel or Minicraft) driving a diamond-impregnated point or burr - just think of the small spaces your dentist has to work in when preparing a tooth for filling. Incidentally he may be willing to give you some used burs which are no longer suitable for his purposes, but

which will suit yours admirably.

The task can call for a little patience, and might well be impractical on bigger jobs, but the advantage is that you can on any contour of surface. Using a miniature (about 20mm diameter) grinding wheel in the same drill can also provide special advantages, both in preparation of surfaces and in the subsequent dressing of any welds that require it.

With adequate surface preparation, you should experience very few further problems when MIG welding. Rather, the MIG machine should deposit weld metal where you want it and when you want it, accompanied only by the gentle whine of the wire-feed motor and an arc noise that can range from a gentle splashing through to something not unlike frying bacon.

However, instead of the gentle whine of the wire-feed motor you may become aware of a rather frantic and halting delivery, probably accompanied by the staccato rattle of relays seeking a rest position. At the same time, you may experience a hint of the 'kickback' phenomenon at the torch, with the arc flickering on and off in rapid and unpredictable fashion. All this suggests the fact that you still haven't got your surface preparation to the state where the delivered wire is always presented with a 100% metal surface. Almost invariably, the cause is that your surface has been long-term rusted, and that rusting process has not been uniform resulting in local 'tubercles' where the rusting process has been particularly vigorous. Removal of the general thickness of rust means that you are left with an array of rust-filled pits set in an otherwise bright metal surface. Those regions have lower electrical conductivity than the general surface, a condition which immediately throws the MIG control system into a degree of disarray, hence the halting and chattering. The simplest thing to do in these circumstances is, obviously, to re-grind the surface to sufficient depth that you remove all the rust-filled pits. If, however, such further grinding isn't practicable (you may have nothing left to weld onto!) one solution is to grit-blast the pits rust-free.

This process is very effective at removing rust without significant removal of metal if undertaken with care, but does require access to the appropriate facilities. If blasting is impractical or unavailable, there is still a way to prevent the halting and stuttering without further surface preparation, and that is via an almost imperceptible modification to your welding technique. This relies on the fact that once you have a weld pool, then obviously that pool provides excellent electrical conductivity to the workpiece. Hence, you can deposit more metal into that pool without difficulty, but there would be no value in that phenomenon if you could only continue to deposit metal in the one place. Fortunately, if you bias the deposition process towards one side of the weld pool, that side becomes a leading edge, allowing you to advance in a direction dictated by those further additions of metal. The only downside to the technique is that, in seeking to always remain within the weld pool, you will tend to put rather more metal into the weld than you would otherwise prefer. By concentrating attention on making the deposition point very near the leading edge, you will, after a little practice, find the technique to be an outright winner.

Problems in welding on a good surface

If you start to experience the halting, stuttering, kickback etc. when you are seeking to weld metal that has an immaculate surface, the cause may usually be traced back to the condition of the bore of the copper tip at the 'working end' of the welding torch (Photo. 5). That tip serves a dual purpose: to guide the wire as it emerges from the welding torch and to provide a supply point for the high current that will convert that emerging wire to weld metal. The latter task subjects the tip to a hard life, and after a period of time the bore will no longer be a snug fit to the wire. That degradation does not mean however that the welder becomes inoperative. Rather, it means that you lose some of the consistency of electrical contact between the wire and the tip, and consequently lose some of the smoothness of operation. Taking about 10 seconds to change the tip, at a cost of about a £1, will restore the pleasure of welding and avoid the degradation of the finish of the weld.

Rapid degradation of tips due to a damp workshop

Since a copper tip has a hard life at the best of times, it is clear that the situation will not be helped by any presence of an abrasive on the surface of the wire. That however is exactly what happens if the wire is allowed to start rusting, a phenomenon experienced in many workshops. Once a reel of wire has started to rust, all you can do is to seek to minimise your losses. Sometimes, you may find that the early rusting is confined to the outer turns on the reel, so you can throw that material away and get away with minimal financial loss, but if you search in vain for pristine material, your penalty will increase, particularly if you are using flux

cored material. The best course of action, by far, is to prevent the rusting ever happening. There are all manner of prevention strategies, such as storing the bulk of your wire in the airing cupboard until you need it, by sprinkling 'Vapour Phase Inhibitor' powder in the reel compartment, having the reel feed out of a plastic bag, or perhaps lining the base of the wire reel compartment with trays of those blue desiccator crystals. Choose whichever method is effective and easiest for you.

Wire Feed problems

Sometimes, for rather ill-defined reasons, the wire will not feed easily to and through the torch, causing either slippage at the feeder bobbins or worse, tangles and bends in unfed wire. There isn't a standard cure, because there isn't a standard cause, but the common feature of almost all such events is that the wire 'downstream' of the drive rollers or in the umbilical is being directed around too many tight curves, in one way or another. The remedy lies in ensuring that all feed is as straight as possible, through a liner tube that is in good condition. A low-friction wire feed tube may help (Photo. 6).

Welding Aluminium

It is quite possible, using appropriate wire and **pure** argon, to use your MIG to weld aluminium. It cannot however be claimed to be an entirely appropriate method, for a variety of reasons. In the first instance, the MIG method does not lend itself to those careful manipulations of the molten pool that allow you to end up with good fusion to the parent materials, there also being a tendency to deposit too much metal. You can make good aluminium welds with MIG, but it cannot be seen as the preferred method. Given the choice, you would almost certainly opt to use an alternating current TIG system.

Material loosely described as 'aluminium' is almost certain to be an alloy, predominantly of aluminium but with a very important minor content of other metals. While you may be able to make a satisfactory join or repair in your 'aluminium', the final properties of the welded area may be inferior to those of the parent metals, with a range of deleterious consequences (particularly a reduced range of elasticity) combining to make the end product unfit for its intended function.

Welding Stainless Steels

Again, using appropriate wire and (preferably pure) argon, it is possible to use your MIG to weld stainless steels. To be more exact, it is possible to weld satisfactorily the majority of the austenitic stainless steels - those which are readily identifiable from their cousins (martensitic and ferritic stainless steels) by having little or no response when offered to a permanent magnet.

Attempts to weld the stainless steels that **do** respond to a magnet will usually result in a weld that looks good, without it being at all obvious that some parts of the weld or adjacent material are now very brittle. Such welds should never be trusted to sustain any load, even a trivial one, as

they can fail catastrophically without any warning. Be wise: unless and until you have special information to the contrary, regard any 'magnetic response' stainless steels items as not reliably weldable.

The MIG welds on the 'no magnetic response' (austenitic) stainless steels can be entirely satisfactory for any reasonable purpose. If however, as happens in some high-tech industries, you need to seek the highest levels of weld quality, then the codes and local experts will deem MIG welding to be not good enough.

You might be tempted, if possessing a reel of stainless wire but no pure argon, and only needing to make an occasional weld in stainless, to make do with other gases in your possession. If you do, then to a degree you may be successful and to a degree you will fail. The use of the non-pure gases will cause various degrees of degradation of the properties of the welded region which may exhibit rusting in a damp workshop, whereas a similar weld made under pure argon should remain pristine for an indefinite period. Of these non-preferred gases, carbon dioxide is likely to be found to be particularly deleterious to the subsequent corrosion resistance. For any jobs where you are not constrained by the thickness factor, but where you haven't the ideal gas, and you happen to also possess an MMA machine, you would probably better job with this, using the appropriate austenitic rods.

Spot welding with MIG

Spot welders that work from your MIG set are obtainable, but there are a number of factors to consider before making a purchase. You may arrive at the conclusion that you could put the money towards something more useful. Will the amount of use it is likely to get compensate for the fact that the accessory will clutter up your workshop between jobs? Give thought also to the fact that a spot weld is not examinable, and that the only way you can assess the strength of such welds involves their destruction. Consider how often you are prevented from using a spot welder because of access difficulties. Finally, decide if you could make better joints by simply pre-drilling holes in one of the sheets. You may find, however, that this is one of the few occasions where MIG welding can be a little ... quirky. Your aim will be to fill the hole with weld metal, after getting good fusion to the backsheet and all around the periphery of the hole. There is a tendency for the arc to establish all around the hole, failing to fuse at the back surface, and droplets of melting wire seem to go anywhere but where you want them. The edges of the pre-drilled hole will eventually melt with the result that the hole just gets bigger! With a little practice you will get around the problem and will then make superb welds. For a start, drop the amperage and wire feed rate and make a fillet weld around the rim of the hole and work from there.

Welding Cobwebs

As described earlier, one of the biggest attractions of the MIG is that it allows easy welding of thin sheet steel, material less

than a millimetre in thickness. Sometimes however, particularly if you restore classic, vintage or veteran cars, you will need to weld materials that are far thinner, until in extremis, there is nothing there at all, the result of atmospheric corrosion.

Preparation of such materials always presents a bit of a dilemma. In getting it clean enough to avoid the stuttering and halting problem, tools that will remove rust effectively will almost inevitably remove a significant fraction of your remaining metal (that is, if there is any). In trying to avoid one problem you exacerbate another because the material can become molten full through-thickness and will simply fall away.

The first useful trick is to seek to remove all rust, but not remove any metal. The user-friendly 13mm belt devices allow you to get down to the general surface and the miniature electric drill and the diamond-impregnated point or burr will deal with the rust-filled pits, which must be cleaned.

One of the earliest experiences during a 'cobweb repair' is that, despite being set for lowest amperage, the arc melts right through the workpiece, allowing the unmelted wire to continue on its own merry way through the hole. One remedy here relies on the fact that a short duration of welding can be sufficient to allow good deposition of a tad of weld metal, while at the same time not putting in sufficient local heat to cause melt-through. So, instead of laying down continuous welds such as one would do on thick material, you lay down your weld metal as a sequence of stitches. It is very useful to utilise the local elastic stiffness provided by the last stitch to get over the problem that some regions of sheet cannot be fully held together by welders clamps. By lightly tapping around the location of the last stitch you can plastically deform the metal in such fashion that the sheets are drawn fully together at the location of the next stitch. Proceeding in that fashion leads to the end result that the finished job has tidy seams. If you need to repair an old car by this method, be warned that the MOT rules contain demands for 'continuous' welds. One way to comply with such requirements is to add intermediate stitches so that eventually they fully overlap, and thus provide the required continuity. Arguably, in situations where there is no such mandatory requirement, the middle way is best, i.e. put in enough stitches to create sufficient strength, but do not proceed to continuity, thus avoiding the same magnitudes of residual stress or deformation.

A second way to make continuous



6. When purchasing your first batch of replacement copper tips, it is a good idea to purchase a low friction wire feed tube. Fasten it to the carrying handle of the welding set so that when you need it, months or years later, you will know exactly where it is.

welds on cobweb material is to increase the gas flow, so that instead of just providing an inert atmosphere, it provides significant forced cooling (provided someone else is paying for the gas!).

Sometimes, you will come up against the seemingly impossible task of welding metal that isn't there, most having been lost by corrosion. It is usually best to replace those missing sections, but for one reason or another such replacement may not be practicable. All need not be lost in such circumstances. The trick is to provide a non-bonding collection surface on to which to 'splat' the molten weld metal in such a way that it builds up to be a surface. Merging the edges of that new surface with the remaining edges of the parent metal creates one big surface, completing your repair. Clearly, you would not seek to replace a big sheet by this technique, but for small areas it is a winner.

An ideal non-bonding collection material, widely and cheaply available is the copper tubing used for plumbing and central heating installations, the copper being formed into the shape of collection surface required for the particular task, e.g. you would use a flat collection surface behind a flat sheet. A pithy generic term for one of these copper collection surfaces is a 'splash' and anyone doing lots of cobweb repairs will, over course of time, accumulate a collection of special tools to do special jobs, pieces of copper folded and beaten to provide snug fits into corners, along edges and so on. You then

ensure that there is electrical connection between the pieces of the different metals, and then proceed to deposit metal at the edges of the remaining sound steel, the copper acting as backstop and receiver. You continue with that deposition until, in the case of the flat sheet, all the edges join, i.e., you have built up your own little sheet to replace what was missing. You will find that, besides accumulating your own collection of special 'splashes', you will create simple devices to facilitate the particular repair, as the occasion demands. For instance, **Figure 2** illustrates how simple rollers and other guides can be used to enable cobweb repairs of cylindrical sections.

The large circle represents the cylinder under repair. The two smaller circles are rollers or sliders. The rectangle at the base is the non-bonding deposition surface (copper 'splash'). During the repair, the cylinder is rotated slowly (manually) while at the same time weld metal is deposited at that appropriate position where the retreating edge of the workpiece material is sliding across the working surface of the copper splash. The deposited metal forms a new retreating edge, and the procedure is continued, depositing overlapping lines of weld onto the previous lines until the eventual arrival of the other side of the original hole. Joining the two edges completes the repair. It will often be found that the easiest way to create the neatest end product is to make these deposition lines circumferentially on the cylinder.

Such a repair technique is made easy and practicable only by the control of deposition special to the MIG process. MIG equipment does what it is designed to do superbly well, and for many tasks in the home workshop there just isn't any good alternative. Anyone thinking that they really cannot afford a hobby level MIG has probably not fully appreciated the direct savings made possible by that new ability to repair and fabricate and the value of the enhanced capabilities and techniques. I hope that these notes will help you make your decision as to whether you ought to make such a purchase.

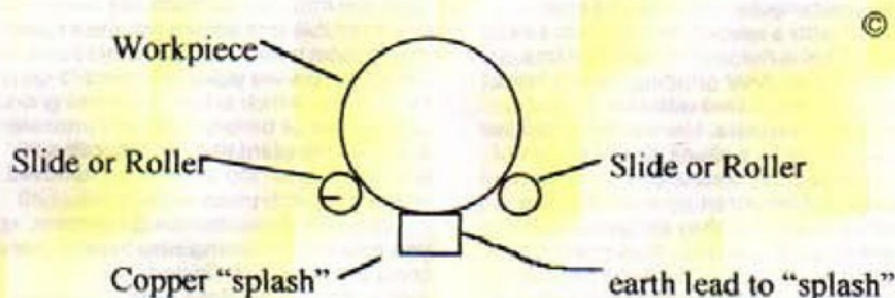
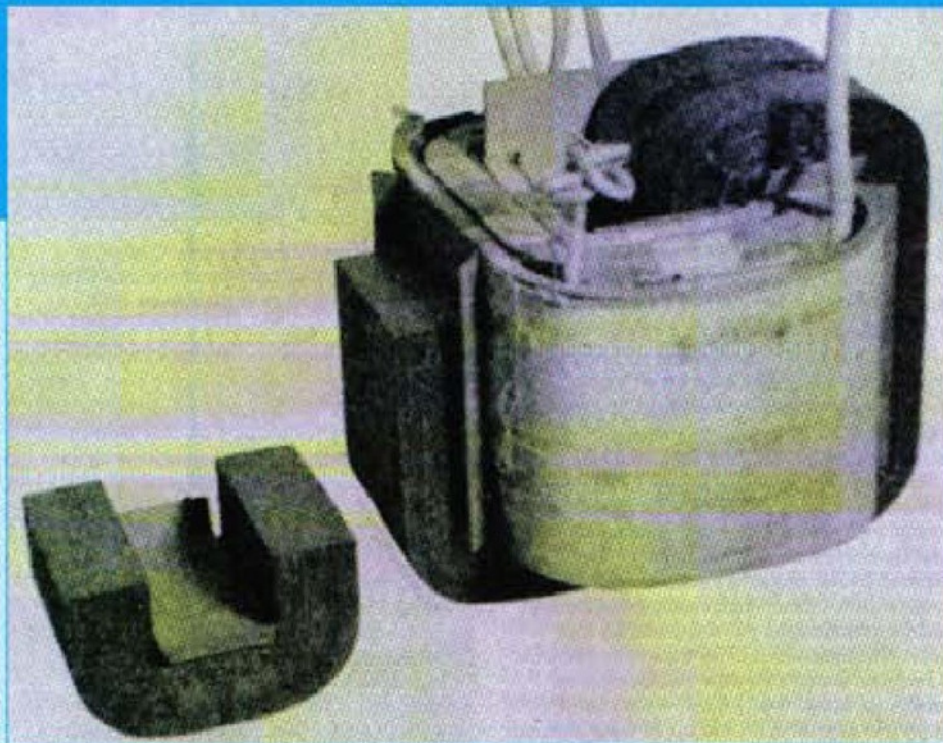


Fig. 2

ELECTROMAGNETIC DEVICES - Part 6



In this instalment, Tony Claridge discusses the detail of transformer design theory and looks at some aspects of construction

What is a transformer? If you have read the previous articles in this series you will know that it consists of an iron core round which is wound a primary winding which is connected to an AC supply, and with one or more additional windings also wrapped round the core. When an alternating voltage is applied to the primary winding this causes an alternating magnetic field to be set up in the core and this in turn produces alternating voltages in the secondary windings. If a load is connected to the secondary windings and current thus flows in them, this tends to suppress the magnetic field and when this happens additional current flows in the primary winding so as to maintain the field substantially constant.

The main use of transformers is to change the voltage of the incoming supply to one which is better suited to the intended application. There is another use which comes as a bonus and is sometimes important. A transformer provides electrical isolation between the incoming supply and the transformer's output.

The Core

Cores come in various forms and, with the exception of sintered ferrite ones which are used almost exclusively for high frequency applications, they are made of thin sheets of iron alloyed with up to 4% of silicon. For reasons which will be explained shortly, laminations have an

electrically insulating coating on one side. Many years ago flour was used for this purpose, sprayed as flour paste and baked on. I shall never forget my early days as an apprentice in a fitting and machine shop training school which was next door to where this took place. Being wartime, with severe food rationing, you may imagine the effect of the all-day smell of freshly baked bread upon thirty or so permanently hungry adolescent boys!

Silicon iron has a coarse crystalline structure and can be sheared easily. By cold rolling, its magnetic properties can be enhanced along the direction of rolling at the expense of reduced properties transversely. Core topology is sometimes chosen to exploit this directional property.

Photo. 1 shows a partly assembled transformer which uses a form of construction with what are called 'C cores'. The iron, in the form of a ribbon, is wound onto a rectangular mandrel and then bonded with a special resin to form a solid shape. This is then cut in two by a thin abrasive disc. After grinding the cut faces, they can be re-united with little loss of magnetic properties. Usually they are used in pairs to make a shape similar to that of the stamped-out laminations shown in **Figure 1**. After inserting them into the winding assembly, they are strapped together using the same taping strap method which is used on large cartons.

With conventional, flat laminations it is necessary to assemble these one by one (alternately from each side to avoid having

an air gap in the magnetic circuit). Unlike the C-core type it is possible to make a thicker stack and thus increase the power available from a given size of lamination. Incidentally, it is very rare to have coils on both sides of a simple two limb core. This is because of something called leakage inductance, which we will come to later.

Currently fashionable for small electronic power supply transformers is the toroidal transformer. This has a ring-shaped core which may be formed as a coil of iron ribbon or as a stack of washers. By having the windings on the outside it is easier to get rid of the heat which they generate, and another advantage is that because of their 'homogenous' shape, there is very little stray field to interfere with electronic components close by. However, it is difficult to make solid attachment to the heavy core without imposing stresses on the windings, so this form of construction tends to be limited to small sizes. The real killer for the amateur constructor is that, unless the number of turns is small, winding becomes impractical without a special coil winding machine which is about as complicated as a sewing machine, to which it bears a slight resemblance. I was involved in bringing a machine of this type into service about fifty years ago and it took a long time to learn how to use it.

The Initial Design Stage

For our purposes we mostly have to start by taking an existing transformer and adapting it for our purposes. Old radios and TV sets often yield useful components since the iron core is practically indestructible and sometimes the original mains input winding is perfectly sound. Scrap microwave ovens contain a large transformer which is ideal for making a spot welder or battery charger. Fortunately it is fairly standard that the secondary windings are on top and can be removed to make room for new ones.

Before we begin the design process, you may be wondering why transformer cores are always laminated. The explanation is that if we used solid iron the core would constitute a single turn, short-circuited winding and would have a

large current circulating round it. Apart from anything else it would get very hot. This effect is called 'eddy current' and it is the bane of all electromagnetic designs. Once you are aware of it however, it is not too difficult to avoid it. While we are on the subject it is important to avoid forming any short-circuited loops round the core. For example, where clamping bolts go through holes in the corners of the laminations they must be insulated at least at one end. An insulating washer under the head and an insulating sleeve or a layer of insulating tape along the bolt's length is all that is necessary.

We can now proceed to the design process, assuming that we are building from scratch. An early step is to calculate the volts per turn. However, if you are able to use a cannibalised transformer with a healthy primary winding, it is easy to measure this parameter. All you need is a voltmeter and a length of flex. For the sizes we are interested in, the volts per turn will lie in the range of 0.1 to 0.5. Depending on the ranges on your voltmeter, wind a few turns round the centre leg of the core, taking care that both ends of the wire come out at the same side. With proper respect for the incoming mains supply, connect the supply to the primary winding, having previously connected your voltmeter to the ends of the flex, and read the voltage. As an example, let us suppose that there are 10 turns of flex on the core and the voltage reading is 3.5 volts. Then the volts per turn is 0.35.

However, we will go through the design process from scratch. The transformer which we will design has the following specification:-

Input 240 volts, 50 Hz single phase

Output 24 volts, 10 amps. at FLUPF.

This needs some explanation. The input is the normal UK mains supply (shortly to become 230 volts). 'FLUPF' means full load, unity power factor. This means that the output voltage is to be the specified value with the transformer delivering 10 amps into a resistive load. It makes a difference if the load current is not in phase with the voltage. We will deal with this later. In the specification for power distribution transformers it is usual to quote the no-load secondary voltage rather than the full load figure.

Based on an educated guess, we will begin with a stack of laminations of the dimensions shown in **Figure 2**, the stack measuring 30mm thick. Because of the insulating coating on the laminations and the inability to squeeze the stack completely flat, the amount of iron in the stack is normally reckoned to be 95% of the actual stack thickness. The area of the centre limb round which the coils are wound is thus:-

$$30 \times 30 \times 0.95 = 855\text{mm}^2 \text{ or } 0.000855\text{m}^2$$

Choosing a flux density of 1.2 tesla, we can now use the following expression to calculate the volts per turn.

$$\frac{V}{T} = 4 \times 1.11 \times B \times A_i \times f$$

Where B = flux density
A_i = iron area
f = frequency

Remembering that the voltage induced in each turn of a coil is derived from the rate of change of the flux linked with each turn, this formula is explained thus:-

In the course of one supply cycle the flux rises to its peak level and then descends to zero before carrying out a similar excursion through the negative half cycle. Its total travel is thus four times the maximum flux. The total flux is the peak flux density multiplied by the core cross-sectional area. The time taken is one supply cycle and instead of dividing the total flux change by this time we multiply by the frequency, which amounts to the same thing. Lastly we come to the 1.11. The volts per turn we have calculated so far is an average value, and we need a different measure.

Because much of our usage of voltage and current involves the square of the quantity, e.g. I²R, we need a factor which reflects the value of this squared, which is called the 'root mean square', usually abbreviated to 'RMS'. The mathematical process to derive both the average and the RMS values for a sine wave entails the use of the Calculus, though they can be evaluated in half a page of working out. For those who want to get straight to the answer, the average value of a sine wave equals twice the peak value divided by π . The RMS value is the peak value divided by the square root of 2.

The term 'form factor' is used to denote the ratio between the RMS and the average values. In this case the form factor turns out to be 1.11, so by adding this to the basic formula for volts per turn we get the answer in volts RMS.

Putting the known figures into the equation, and choosing 1.2 tesla as the peak flux density, we get:-

$$\frac{V}{T} = 4 \times 1.11 \times 1.2 \times 0.000855 \times 50 = 0.2278$$

Next we make the number of turns on the primary winding to be:-

$$\frac{240}{0.2278} = 1054$$

It may be that there will be a small adjustment to this figure as the design proceeds, but not by very much. The next stage is to choose a size of wire. For this we make a preliminary choice based on current density. Working with metric sizes, 0.71mm diameter (0.767 over enamel) looks a likely choice. An area of 0.3959mm² gives a current density for a primary current of 1.05 amps of 2.65 amps/mm² which sounds about right. (A secondary current of 10 amps corresponds to 1 amp in the primary since the input/output voltage ratio is ten to one. A bit extra is added on to allow for magnetising current and iron loss). Now, will it fit into the core window?

The window is 70mm long, but we need to have a small clearance to be sure that the pairs of laminations (the 'E' and 'I' s) can abut one another fully. Then we assume bobbin flanges of 1.5mm thickness and a further 1mm or so for the curled-up edges of the interlayer paper. The width for the wire is thus:-

$$70 - 1 - 3 - 2 = 64\text{mm}$$

The maximum turns per layer is thus:-

$$\frac{64}{0.767} = 83 \text{ plus; say } 82$$

The number of layers becomes

$$\frac{1054}{82} = 12.8$$

We end up with 13 layers of 81 turns each.

Next comes the build-up to see if the primary winding occupies about half the window's space. Since the amp.turns on the two windings are almost exactly the same, the primary should take up about half the space available. We will use paper of 0.1mm thickness between layers, but because the winding never lies completely flat, especially on a rectangular bobbin, the build-up is based on an assumed 0.13mm thickness to make a suitable allowance for this. It is good practice to allow for a bit of sticky tape to anchor the flex which is soldered to the winding wire (remember the earlier article about making coils?) and perhaps put on a couple of layers of paper to provide a smooth base for the wire. The primary winding's build-up is then:-

Initial paper layers	0.26
13 x 0.767 wire	9.97
12 x 0.13 paper	1.56
Total	11.79mm

Don't be misled by the apparent precision of working to two figures after the decimal point. Its not really that accurate. Call the build-up 11.8mm

Now, as a precaution against a transformer fault connecting the mains to a low voltage secondary output, which would be hazardous, good practice is to add an earth screen between primary and secondary windings; then any primary fault can reach the secondary only via a connection to earth which will eliminate any risk of electrocution. This is not an essential feature, but I strongly recommend it. It has another benefit for transformers in sensitive electronic equipment. A route for mains-borne interference is via capacitive coupling between the primary and secondary windings. An earth screen gets rid of this possibility. It is important that the screen, which ideally is made of copper foil, though aluminium is fine as long as there is a good earth connection to it, forms a complete **BUT NOT SHORT-CIRCUITED** turn. It must be suitably insulated from the windings, especially the primary one. Five layers of paper below the screen and the same above is usually suitable. A short overlap of one of the paper layers into the foil will prevent the formation of a shorted turn. The build-up of this element is:-

5 x 0.13 paper	0.65
1 x 0.10 foil	0.10
5 x 0.13 paper	0.65
Total	1.40

Finally we come to the secondary winding. The volts per turn are the same as on the primary winding, so the number of turns is:-

$$N_s = \frac{24}{0.2278} = 105.36$$

Now clearly we can't deal in fractions of

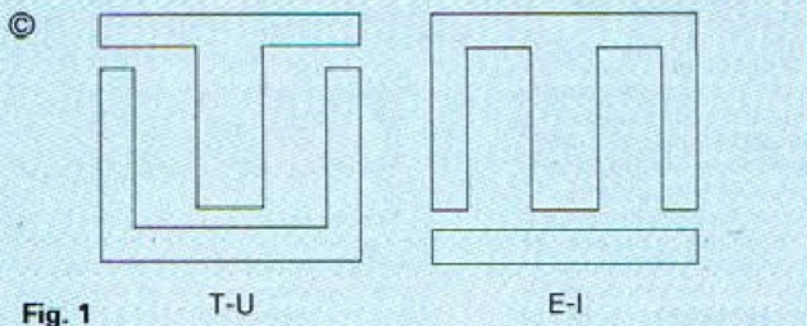


Fig. 1

T-U

E-I

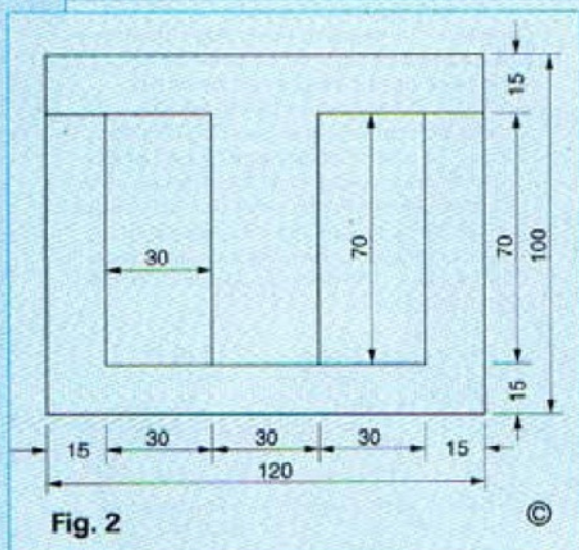


Fig. 2

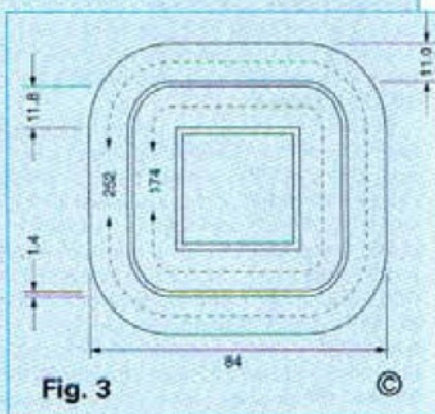


Fig. 3

a turn (though if the end connection is brought out on the opposite side of the core to the start this amounts to a half turn). However we have yet to make allowance for the volt drop in both windings due to their resistance, so we can make a guess at how much this will be and increase the number of secondary turns accordingly. For this transformer an allowance of 3% is a fair guess so we will settle on $1.03 \times 105.36 = 108.5$. So we could use the tip above to provide exactly the right number of turns if my guess of 3% voltage drop is correct! Now we have to choose a wire size.

With the better cooling possible on the outside winding we can afford to let the current density be a little higher than for the primary. 2.0mm diameter is about right. With a CSA of $3,14159\text{mm}^2$ we get 3.18 amps/mm² which should be adequate. However the tension needed to persuade this thick wire to lie on top of the primary winding may be a problem. There are several solutions. We could use a flat foil of 0.05mm thickness by 60mm wide. This would be easier to get to lie flat and at 3.0mm CSA would be OK especially since heat flow would be better than with round wire. Another method would be to use two or three wires of smaller size in parallel. However, if this route were chosen, it would be important to keep the separate wires close together turn by turn, otherwise tiny differences in the voltages induced in each strand would cause substantial circulating currents to occur between the strands. Finally, we could put the secondary winding on the bobbin first so that it wouldn't put the comparatively fragile primary winding under stress. For the time being let us assume that all will be well and go ahead with the 2.0/2.092 enamelled wire.

$$\text{Turns per layer can be } \frac{64}{2.092} = 30.6$$

so that we need four layers which would each have 27 or 28 turns. Lets forget the half turn for now. Its not that important! This seems to be an easy fit. Next we will look at the build-up. Note that I have assumed thicker paper between layers because of the wire being so much larger.

4 x 2.092 wire	8.37
3 x 0.1 paper	0.40
Total	8.77

Allowing for the wire's reluctance to lie flat, the true build-up will be a bit more than this; let us guess at 11mm.

Now we can tot up the whole build-up.

Clearance between core and bobbin ID,
- say 0.5mm each side
Bobbin tube thickness, - say 1.5mm

So:-	Clearance	0.5
	Bobbin wall	1.5
	Primary winding	11.8
	Screen	1.4
	Secondary winding	11.0
	Total	26.2mm

The window is 30mm deep, so we have just enough space to wrap a few layers of paper or tape on top to protect the winding from accidental knocks. Don't put too much on though, as we don't want to add thermal insulation and retard the

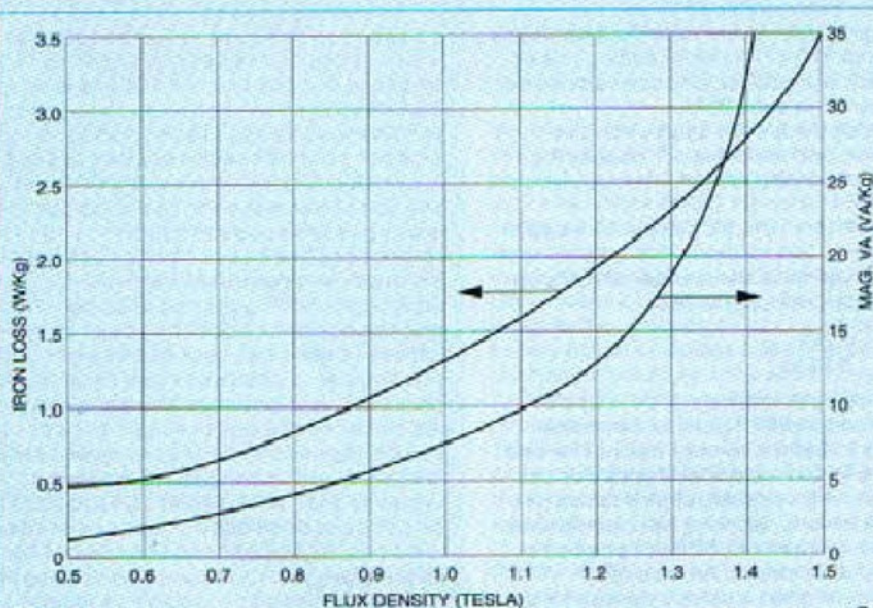


Fig. 4

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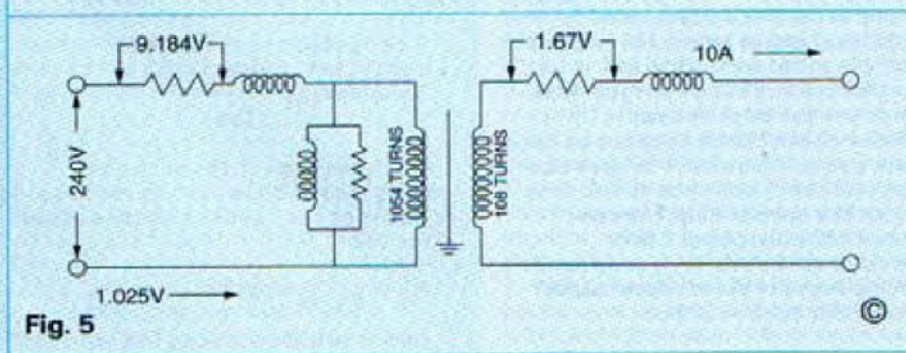


Fig. 5

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escape of heat from the windings.

Our next task is to estimate the windings' resistances. We have no need to be over-precise about the arithmetic because the actual value varies with the temperature, and we don't know what that is. It isn't even constant across the windings. **Figure 3** shows a cross-section of the coil assembly. For each winding the length of the mean turn (LMT) is the perimeter of the bobbin plus the circumference of a circle of radius equal to the mean radius of the 'corners' of the winding.

From **Figure 3** we can see that the length of the primary mean turn (LMT) is 174mm. The total wire length is thus $1054 \times 0.174 = 183\text{m}$. At 20 deg. C, wire of 0.71mm diameter has a resistance of 0.0436 ohms/m. The primary winding's resistance is thus $183 \times 0.0436 = 8\text{ ohms}$. However, a likely operating temperature is 50 deg. C and since the temperature coefficient of copper is 0.004 we have to multiply the 'cold' resistance by $1 + (30 \times 0.004) = 1.12$. Thus the effective resistance of the primary winding is $8 \times 1.12 = 8.96\text{ ohms}$.

Using the same procedure for the secondary winding, we get:-

LMT = 252 mm
Wire length = $108 \times 0.252 = 27.2\text{m}$

Resistance at 20 deg. C = $27.2 \times 0.0055 = 0.149\text{ ohms}$
Resistance at 50 deg. C = $0.119 \times 1.12 = 0.168\text{ ohms}$.

The other factors which we need to evaluate are the magnetising current and the iron loss. You will recall that the initial guess was that these would cause an increase of 5% in the primary current. We can now see how accurate this guess was.

Data sheets for the different core alloys are usually published in the form of graphs of total iron loss in watts per unit weight against the working flux density. Graphs of magnetising volt.amps per unit weight are also published against flux density. Although it doesn't affect this design, it should be noted that the loss and the magnetising volt.amps rise with supply frequency. The curves for Stalloy in laminations of 0.35mm thickness are shown in **Figure 4**. From these we can see that at our chosen flux density of 1.2 tesla, the iron loss is 1.8 watts/Kg, and the magnetising volt.amps is 13.2VA/Kg.

You don't need me to tell you how to work out the weight of the core. Just multiply the area of one pair of laminations by the stack thickness to arrive at the iron volume, and then multiply by the density of iron, which is 7860Kg/cubic metre, or 7.86 g/cc, to arrive at a more convenient number. I make it 1.75 Kg so that the iron loss works out to $1.75 \times 1.8 = 3.15\text{ watts}$ and the magnetising volt.amps comes to $1.75 \times 13.2 = 23.1\text{ VA}$. The iron loss is clearly negligible in term of a primary current of an amp or so, and the magnetising current is only

$$\frac{23.1}{240} = 0.0096\text{ amps.}$$

Since this current is 90 degrees behind the load current (look back at the phasor diagram to see this) we can ignore this as far as the effect on the primary current is concerned. From the start I knew that

these effects would be negligible, but I have gone through the calculations because iron loss and magnetising VA are not always trivial, and it is wise to check up on their magnitude.

There are two more calculations which we can now make. First is the drop in voltage which results from some of the nominal voltage being used up in overcoming the resistances of the two windings. It is not too hard to see how this happens by means of an 'equivalent circuit'. This is drawn to combine an imaginary perfect transformer with the various resistances and inductances which are present in the real world. All the diagram does is to show these factors as being external to the transformer. **Figure 5** shows the diagram for our transformer. There are some items on it which we haven't dealt with yet. They are there for completeness, but the things they represent have no effect on our transformer. They will be explained later.

It may be helpful to think of the resistances as causing a drop in voltage in the same way that steam loses some of its pressure in passing along a pipe. In the case of steam, the pressure drop is proportional to the square of the flow; with electricity the voltage drop is linearly proportional, i.e. is given by current times resistance.

The other thing we need to check on is the likely temperature rise in the windings due to the I^2R loss in the two windings. We have just worked out that the primary current is barely increased at all by the magnetising and iron loss currents, so we can calculate the loss as:-

$$I^2 \times 8.96 = 8.96\text{ watts}$$

For the secondary winding, the same calculation is:-

$$10^2 \times 0.1672 = 16.72\text{ watts}$$

The winding assembly thus has to dissipate 25.7 watts. Remember that this is a figure which depends on the actual winding temperature, which may be quite different from the assumed value, and will not even be constant across the whole winding. Thermal calculations, and consequently heat generation figures are pretty rough but are good enough for our purposes. It's a different matter on large transformers for power distribution systems. Every manufacturer has his set of formulae which have been tried and tested.

There are lots of methods for estimating the temperature rise in windings. A lot depends on the extent to which the heat is radiated or carried away by convection. The first depends on the temperature of the transformer's surroundings, while the opportunity for strong convection currents is important to the convection process. We have to dispose of 26 watts or thereabouts, and we have a coil surface area of roughly 200cm², taking into account only the face of the winding and discounting heat which escapes through the bobbin. This gives us a figure of about 0.13 watts per square centimetre. This, combined with the chosen current densities seems to indicate a temperature rise in the range of 30 to 40 degrees, so having satisfied ourselves that the

temperature rise is not excessive, we will leave it at that.

Now let us turn again to **Figure 5**. It depicts a perfect transformer with all the imperfections (such as winding resistances) shown separately. To explain what each part represents, we have both windings' resistances and also their leakage inductances. These are due to the small amount of magnetic flux which links with one winding but not with the other. We can ignore them in our study. The resistor and inductor connected across the primary winding are there to represent the magnetising VA and the iron loss. We found earlier that they are insignificant in our transformer. Remembering that our 'perfect' transformer in the diagram will have voltage ratios and amp.turn ratios exactly in accordance with the turns ratio, we can now work out how our transformer will behave.

We can choose which parameter(s) are to be fixed. We will choose the secondary current and the supply voltage of 240V. With the secondary current of 10 amps the primary current will be:-

$$10 \times \frac{108}{1054} = 1.025\text{amps}$$

Next we calculate the voltage drop in the primary winding which is:-

$$1.025 \times 8.96 = 9.184\text{ volts.}$$

Thus the voltage at the primary winding is $240 - 9.184 = 230.82$.

Using our precise primary/secondary ratios, the secondary voltage is given by:-

$$230.82 \times \frac{108}{1054} = 23.65$$

Next we have to deduct the voltage lost in the secondary winding, which is $10 \times 0.133 = 1.67\text{ volts}$. Our full-load secondary voltage is thus:-

$$23.65 - 1.67 = 22.0$$

If this is not acceptable, we can choose either or both of two solutions. We can reduce the number of primary turns, which would raise the flux density slightly. Since the winding has only 230 or so volts to produce flux, we could decrease the primary turns to about $230 \times 1054 = 1010$. 240

We could also raise the number of secondary turns slightly. Or we could do both. You will know the process as 'trial and error' but status-conscious engineers call it 'iteration'.

Because there are more turns on the primary winding, it is possible to make smaller changes in output voltage by changing this winding rather than the secondary. A useful trick, which I used to use frequently is to put taps on the primary windings at steps of 5% at one end and just one at 2½% at the other, giving a wide range of adjustment with a small number of taps.

This instalment has gone into considerable detail in the design process, mainly to show the underlying principles. For a good many applications it is not necessary to go into such detail. In the next article I will clear up the parts I skipped over this time and make a start on electric motors.



SCRIBE A LINE

Varnishing brass

From Philip Amos, Mosman, Australia

In Issue 69 of M.E.W. Dr. W. B. Amos enquires about protecting a brass finish. Perhaps the following may be helpful.

Brass, either cast or wrought, can be polished to a high lustre and a most attractive finish. However, the oxygen, carbon dioxide and water vapour in the air cause the surface to tarnish and so the appearance soon becomes less satisfactory. The tarnishing process can be delayed by varnishing the product after polishing, and this will preserve the lustre for quite some time, but eventually the brass will tarnish. This is probably due to the varnish coating not being impervious; as the solvent evaporates it leaves some porosity in the coating.

Commercially these days the varnish commonly used is polyester. As this material is readily available in the market place in pressure pack spray cans, it is a very easy means of treating brass items.

Nevertheless it would seem that in earlier times the varnishing of brass items provided more effective protection than is currently achieved. For example, I have a microscope presented to a medical practitioner by grateful patients when he left Kent in 1877 for New Zealand. This instrument is not in pristine condition, but is certainly in very fair order after a life of 120 years.

If one refers to Charles Holtzapffel's book "Turning and Mechanical Manipulation" Volume 3 first published in 1850 (reprinted 1993) at page 1395 there is a recipe for "Lacker for brass" comprising "shell lac and spirits of wine", and at page 1406 there are detailed instructions for its application. This information probably represents the normal practice at the time when my microscope was made.

The problem of porosity is largely overcome if a 2 Part varnish, such as epoxy, is used as this does not dry by evaporation of a solvent, but hardens by the interaction of the two components. Most such varnishes are fairly thick - suitable for brushing but probably not for spraying. The use of thinners to reduce the viscosity of course violates the advantage of non-evaporation, and can produce porosity again. I have not encountered spraying epoxy varnishes so I cannot determine whether such are available to yield a coherent poreless coating.

From Tony Claridge, Derby

In the 1950's I worked with a member of the Royal Microscope Society. I recall watching him carry out the varnishing of a brass tube which was part of a microscope he was restoring. So far as I recall, the procedure was something like this:-

1. The coating was shellac dissolved in methylated spirits and of a consistency about the same as very thin oil.
2. The process was carried out over a methylated spirit lamp, and the tube had been prepared by circumferential rubbing with very fine emery paper. It was not polished further, but it was not touched by my friend's fingers; he held it by the ends, which were not to be lacquered.
3. The tube was warmed above, not in, the flame, which was from a burner about an inch in diameter. The varnish was applied with a small paint brush and the tube rotated gently to ensure an even spread. It was not applied all at once.
4. I have an impression that the flame was used chiefly to evaporate the spirit and cause the shellac to dry in place. Clearly the heat must have been too low to

damage the shellac itself.

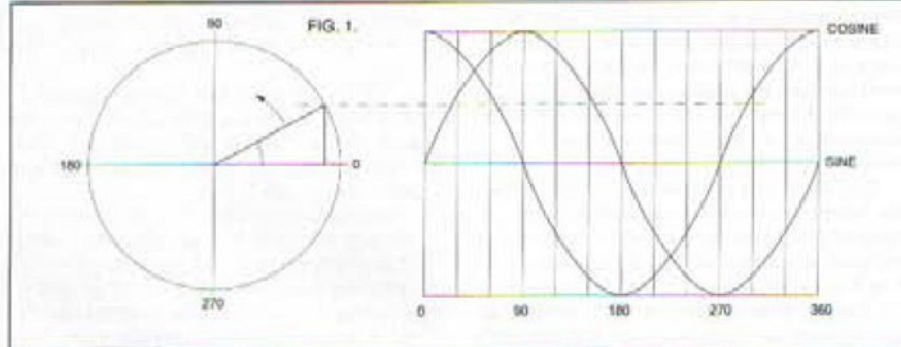
5. Afterwards the tube was stood on end for a few hours. I used the instrument of which it was a part for about a year afterwards, and there seemed to be no deterioration on the coating

From Gerry Collins, Chairman, Stationary Engine Committee, The Society of Model and Experimental Engineers, London

I read with interest two letters in Scribe a Line (M.E.W. November 2000.) It is many years since I spent some time in a clock and watch repairer's workshop. As a youngster, one of the jobs I was given was the polishing and lacquering of brass pendulum bobs. After removing all the old lacquer with solvent, the brass was polished with a cotton polishing mop mounted on a double-ended polisher, the mop being charged with polishing compound which came in stick form. Once I was satisfied with the polish, the bob was given a final polish with a clean dry cloth and then lacquered with ordinary brass lacquer applied by brush. It was important NOT to touch the bob with your fingers once you had given the final buff up with the polishing cloth. All these materials can be obtained from the Axminster Power Tool Co. and are listed in their catalogue (usual disclaimer). The lacquer dries very quickly and was not sprayed as it would start drying before it reached the work and give a mottled finish. It may be that in the intervening years products have been developed that can be sprayed but unless you have large areas to cover brushing will be just as good. I have, at a pinch, lacquered small components using clear nail varnish although this does not always satisfactory if heat is involved (copper steam pipes for example). For family harmony it is best to get permission from the lady of the house first unless you are a lady model engineer, in which case you have your own.

The other letter that caught my eye was the one from Brian Padgett of Clifton. When David Urwick passed away in 1984 his collection of Stirling engines was left to a great friend together with a large amount of technical information and correspondence. Due to constraints on space six engines were placed with the Society (with his widow's permission) for safe keeping.

The society has a large collection of models including work from such well known model engineers as LBSC, K. N. Harris, Tom Walshaw, E. T. Westbury and many others. The collection is the responsibility of the Stationary Engine Committee, somewhat of a misnomer as the collection contains model locomotives, tooling, and clocks as well as steam, hot-air and I.C. engines. The name goes back to the early days of the Society when the collection consisted of a few stationary engines. As the collection grew, the Committee's name remained the same. The Society is always pleased to consider donations or bequests from model



ERRATUM

We apologise for errors which occurred in our article on Electromagnetic Devices Part 5 in the last issue (No. 70) on page 51 Figure 1 and page 53 Table 1 (shown in order.)

Correct formulae for Table 1

$$\sqrt{\left[\frac{1}{11} + \frac{1}{2}\sin\theta - \frac{2}{1.3\pi}\cos2\theta - \frac{2}{3.5\pi}\cos4\theta\right]}$$

$$\sqrt{\frac{8}{\pi^2}\left[\sin\theta - \frac{1}{9}\sin3\theta + \frac{1}{25}\sin5\theta - \frac{1}{49}\sin7\theta\right]}$$

$$\sqrt{\frac{2\sqrt{3}}{\pi}\left[\cos\theta - \frac{1}{5}\cos5\theta + \frac{1}{7}\cos7\theta - \frac{1}{11}\cos11\theta\right]}$$

engineers who want to be assured that their models will be cared for and looked after in the future. They do not have to be members of the Society. It is a sad fact that many models built by model engineers, especially those with no family, end up in the antique trade unloved and uncared for and just a means of making a few more pounds. Examples from the collection are shown at major exhibitions throughout the country, giving ideas and encouragement to model engineers of the present and the future. I feel sure the builders would want this to continue.

Vacuum chucks

From Doug Baker, Scarborough, Western Australia

In response to an article on vacuum chucks in Issue 68 of Model Engineers' Workshop magazine, I feel it necessary to voice my concerns and a warning to your readers regarding the configuration of this chuck and in doing so, offer some alternatives.

The focus of my concern is the use of a vacuum cleaner as the mode of obtaining a vacuum for this chuck. While I have no doubt that the use of a vacuum cleaner will work, vacuum cleaners, be they industrial or domestic, are not designed to operate in this applied manner.

In Philip's article he made reference to using a 'Shop Vac' of 850 watts and there lies the first problem. This type of cleaner relies on the air that is sucked by the fan creating the vacuum to cool the electric motor. In the event one blocks the airflow off, as has been done when the pipe is coupled to the chuck, heat will build up in the motor and eventually cause the motor to burn out. In the worst case scenario the cleaner will catch fire.

The article does make reference to dry grinding, however there was no warning not to use a grinder or milling machine that uses coolant. It may be obvious to most that using coolant with this type of suction will cause the coolant to find its way through to the electric motor.

Finally, grinding dust as a generalised statement is metal in a powder form. This dust is extremely invasive and aggressive to moving parts and it doesn't socialise that well with 220 volts either. It is my opinion that there should be a maze trap with a little oil in the bottom (known as a scrubber) to trap any dust that may find its way down the suction line. I recognise that some shop vacs do have a filter within the works to stop this type of ingress. Be that as it may, it still does not overcome the previously mentioned hazards.

Timber, because of its instability, will continuously move due to ambient conditions. What may be working fine today may not be tomorrow. In Australia we are subjected to huge temperature changes - 0 deg. in winter to 45 deg. in summer is not uncommon, coupled with very high humidity.

Philip also recommends the use of 'O' rings as the method of sealing the work face. With my vacuum chuck I use a rubber sheet called dental dam. This is a very thin inexpensive material, readily available from any dental supply house. I place the rubber sheet on the work face and lay it flat ensuring that there are no wrinkles, and apply the vacuum. When the rubber is held in position by the vacuum, I then place the job on the rubber and, using a felt tip pen, mark around the perimeter of the job onto the rubber. By removing the job one can clearly see where the job is going to be held in position by the holes in the work face. I then prick the rubber using a scriber at the all the available ports that are inside the

perimeter. When this has been done, the job can be returned to the marked area and, within seconds, the job will be held firm. During the set-up procedure, leave the vacuum pump running, so that the rubber sheet cannot move.

I have also found that ordinary typing paper will do the same job as a seal, similar to the aforementioned system. With paper, all one has to do is place the paper on the work face and, without pricking any holes, apply the vacuum. Paper, being porous will allow an air flow through at a restricted rate and, in turn, hold the job. If you use this method, because of the coefficient of friction, paper versus rubber, the paper may not hold as well and you can cause the job to slide.

If you go to the trouble of manufacturing a chuck I recommend that it is built entirely of metal. It may take a little longer, but it is well worth the effort. A vacuum chuck is a very useful tool to have in the workshop; as Philip has rightly highlighted, some jobs cannot be held in any other way. If you are machining plastic sheet, carbon, any non-ferrous metal, indeed anything that is flat and can't be held in a conventional manner, then a vacuum chuck is the answer. Vacuum chucks are also ideal for production work. Some faculties of industry make a mould of the irregular job they wish to machine and drill holes in the holding face, so when the job is sat in the cradle, the vacuum holds it in position during the machining operation.

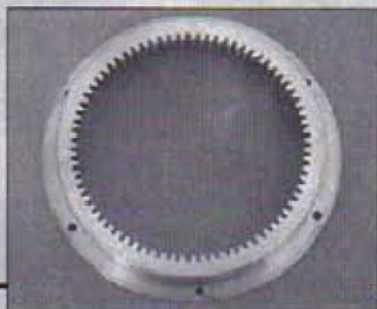
Once you own a vacuum pump there is almost a never-ending list of projects that one can become involved in. Just to mention a few; - form moulding, lost wax casting, GPR casting, furnaces, freeze drying, cleaning small components such as watches, making mirrors. The list really goes on and on.

IN OUR NEXT ISSUE

Coming up in Issue No. 72 will be

SIMPLE GEAR SHAPING

George Dimelow describes a simple method of producing gears for light duties



MILLING MACHINE KNEE MOTORISATION

Peter Rawlinson tell how he reduced the effort required to use his milling machine



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