

No.125

MAY 2007

MODEL ENGINEERS' WORKSHOP

THE PRACTICAL HOBBY MAGAZINE

**UNIMAT
PROFILE
TURNING
ATTACHMENT**

**HOROLOGY
Making
Gear
Cutters**

**MYFORD
Simple
taper
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7-9 September 2007



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ENGINEER
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CNC

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WARRANTY



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Spindle speed r.p.m.	180 - 3000
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Tool holder	MT 2Optional MT3 or SK 30
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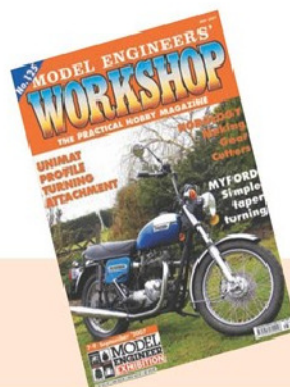
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Dave Fenner's Triumph Bonneville looks great after fitting new wheel rims. See page 24 for full details.

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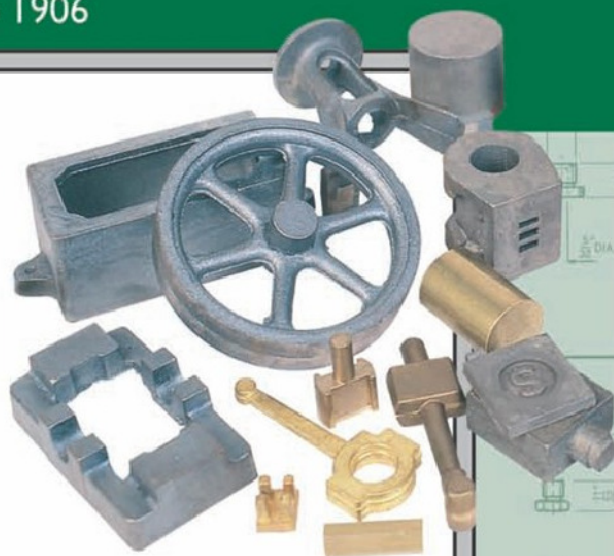


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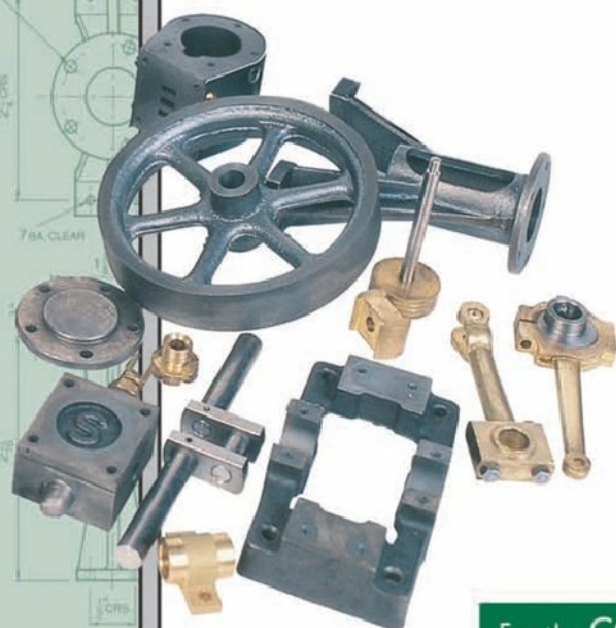
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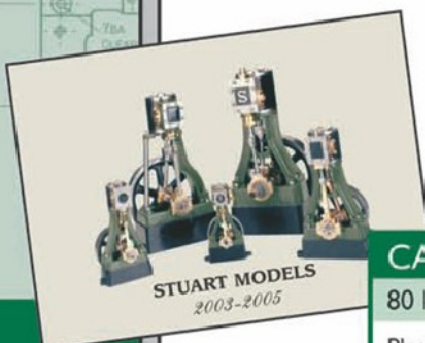
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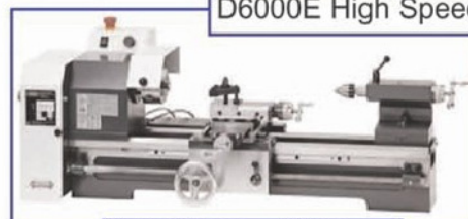
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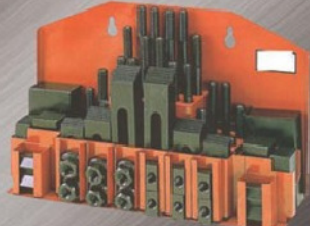
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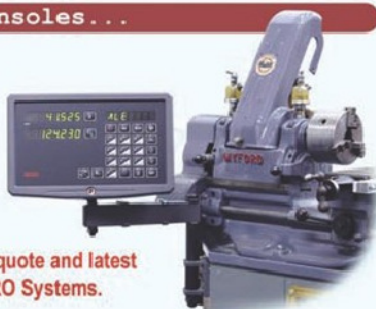


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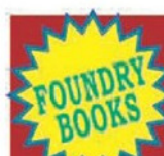
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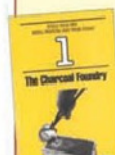
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Metalcasting - appropriate technology in the small foundry • Hurst • £19.60

An excellent book aimed at those wanting to start serious metal melting on a commercial, or semi-commercial basis. Intended as a guide to aid workers in third world countries, and containing one heck of a lot of information on all aspects of foundry work. It will be of interest to anyone thinking of trying to cast from their own patterns. 227 page paperback full of photos, drawings and diagrams.



The Charcoal Foundry • £7.70

First book in a Dave Gingery series on making your own machine tools, this book explains the basics of pattern making and molding in very clear and simple language, plus gives instructions for making a simple charcoal fired furnace capable of melting brass and aluminium. Tremendous first book on foundrywork.



Making Crucibles • Gingery • £8.50

We have sold thousands of books on making your own furnace, but all of these books assume you will purchase a crucible for use with the furnace. Most of these books were written by Dave Gingery, and now Dave's son Vince has now written a book on making your own crucibles. Two methods are described - both depend on making molds, but differ as to how these are used. Either way looks straightforward, and a lot of fun. Covers making the clay for the crucible, firing it etc, and making crucible tongs. Excellent instruction. 117 photos and drawings. Paperback.



Lost Wax Casting • Feinburg • £14.30

Given the interest in the subject it is surprising there are so few books on the techniques of Lost Wax Casting; in fact for years this has been the only one. It is very good, but intending purchasers should be aware that it was written to assist Aid workers in the Third World in setting up local craft industries. So in the so called 'advanced' countries may choose not to use cow dung as the clay binding agent, but take it from us that, as long as you make allowance for such instructions, this is a very sound book on the subject - as well as the only one (we think). 74 pages. Well illustrated with drawings and photos. Paperback.



Wood Pattern-Making • McCaslin • £12.70

Here you get the secrets of good pattern making. This book comes in two parts: bench work and lathe work. In the first you get basic information on precision woodworking, but then it gets really useful. You learn how to make patterns so that you can cast a surface plate, clamp, bracket, pedestal, bell-crank, toolrest, steady rest, tailstock, gear case, cylinder head, water jacket, piston, handwheel, flywheel and a host of other interesting shapes. As you go along you are shown how to make the necessary cores, and how to pour complex castings. You get dimensioned drawings, demonstrations of how a mold is rammed up, and much, much more. All heavily illustrated. The "How to Make Sections" are amongst the clearest we have seen. There are a fair few pattern-making books around. This is one of the best (otherwise we wouldn't sell it). Buy a copy! 296 pages. Paperback.



Secrets of Green Sand Casting • 1903 • £10.05

A foundryman will tell you that you cannot learn green (or wet) sand molding from a book and he is probably right, but this book comes close to revealing the secrets. Covers every aspect of good molding for successful results, and we mean EVERY aspect. Most of the information is on a larger scale than the home foundryman might need, but the techniques are the same. 174 pages jam packed with information and drawings. Paperback.



Melting and Casting Aluminium

• 1925 • Anderson • £10.15

Very good technical book on mixing, melting and casting aluminium, including special moulding techniques etc. Probably too advanced for everyday use in the home foundry, but an excellent addition to your foundry book shelf! 251 illustrated pages. Paperback.

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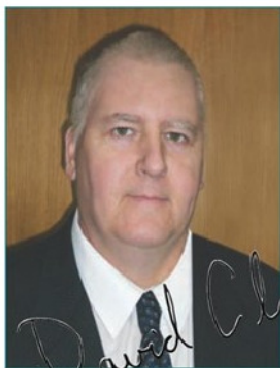
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First, some of you tried to phone me about issue 124. The phone number printed in the magazine was correct. There was a fault on the line from Wednesday 11th until Saturday 14th April which resulted in callers being given the message "you have dialled an incorrect number. Sorry about this but it was out of my control. The few people that did manage to get through to give comments on issue 124 have been very positive. Please feel free to write to me at Berwick House or phone me direct with your comments good or bad and tell me what you would like to see in **MEW** or what you think needs improving.

Increase in number of issues

In line with my taking over as Editor, it has been decided to increase the number of issues of **Model Engineers' Workshop** to twelve issues a year. This means that towards the autumn, there will be a couple of issues that will be on the newsagents' shelves for only three weeks. It would be a good idea to subscribe to **Model Engineers' Workshop** to avoid missing an issue. You can pay for 3 issues by 3 monthly direct debit (UK only), save money and get a free copy of Harold Hall's book, **Tool And Cutter Sharpening**. This is an excellent little book and makes great bedtime reading as well as being useful in the workshop. Subscription information is on page 56. Overseas subscribers contact +44 (0)1689 899 200.

Model Engineers' Plans service

The Model Engineers' Plans Service web site has gone live and can be found at www.myhobbystore.com where you can purchase plans for workshop equipment as well as locomotives, traction engines, steam engines and internal combustion engines. I have just checked the tool drawings out and apart from one saw bench plan they are all under £10 each (plus postage). This sounds like very good value for money. Have a look today, you might find that next project online.

Email address error

It has been pointed out that the email address for Roger Dewsbury in Scribe A Line issue 124 was incorrect. It should be ian@knutton.co.za and not as printed.

ON THE EDITOR'S BENCH

Model Engineer and Model Engineers' Workshop Website

Work is progressing on the combined website for MEW and ME. I will bring you more news as soon as I hear about it. It is hoped to offer forums where you can all discuss your latest project or get help and advice from other web users. Love it or it loathe the Internet is here to stay. It can be a great place to find useful tools and equipment. Most of the advertisers in Model Engineers' Workshop have their own website where you can browse for that tool you want.

Buying items on Ebay

Ebay is also a very good source of second-hand (and new) tools. You have to be careful and make sure you buy from a seller with good feedback, preferably someone who has been a member of Ebay for at least a year or more. There are some secrets to finding items on Ebay. Also you have to be sure that you don't pay too much.

I wanted the book Building 'Minnie' by L C Mason. I searched on "Mason Traction". Several items were available three of which were the book I wanted. Two of these books were listed in the category toys>steam. One was listed in Books, Comics & Magazines > Non-Fiction Books > Instructional. The last book was the one to bid on. Anything listed in Toys>steam usually goes for silly money. I placed a snipe bid (see www.hammersnipe.com) for a reasonable amount and waited a few days for the auction to end. The result was, I won the book for 99P. The books in Toys>steam went for about £18 each. George Thomas's books go for silly money on Ebay but some at least are still available new from TEE Publishing. Alec Farmer's book on boiler making consistently sells for £50 or more on Ebay in toys>steam. In other categories it probably won't reach a quarter of that value.

Ebay is a great source of taps, dies, end mills and slot drills. Recently, I needed a 4in. X 1/4in. X 1in. bore side and face cutter. I found a brand new one for £6 in a *Buy It Now* auction. I dread to think what the new price would be. Now, I am not saying go to Ebay and buy all your tools from there. What I am saying is treat Ebay like any other supplier, search around and find what you want at the best price and then save your money for the really expensive bits of tooling that

you can only find at the regular suppliers. The one word of warning I would give you about Ebay is be wary of new Myford items. There is at least one seller who makes copies of Myford items in China and sells them on Ebay. Quality can be very different from the genuine Myford item. I know to my cost.

Harrogate Exhibition

As I write this, Harrogate is two weeks away. I am looking forward to my visit as, (so I am told) Harrogate is one of the bigger exhibitions. Hopefully I will have met a lot of readers there and you will have given me feedback about **MEW**. There will be a full show report in **MEW** issue 126.

A new life for old model aircraft engines

I thought long and hard about printing this article, I even thought about passing it over to **Model Engineer**. Then I thought no, it is relevant to **Model Engineers' Workshop** from the diamond lapping aspect of the article. Tell me whether I made the right decision to include it in **Model Engineers' Workshop**? Yes, I know I could have changed the title to diamond lapping but that would be cheating.

Wheel rebuilding

Also in this issue is an article on rebuilding motorbike wheels. While this may not appeal to everyone, let me know what you think about this sort of article. It is interesting that if a motorbike picture appears on the cover of **Model Engineers' Workshop** the circulation goes up. Does this mean you are all hiding in your workshops rebuilding motorbikes or do people buy the magazine by mistake?

Readers' Tips wanted

Please send your readers tips to me for inclusion in the magazine. Help your fellow readers and you could win a book from the Workshop Practice series.

Future articles

The article bank is very good but new contributors are always required. Please email me for contributors' notes or send an SAE requesting contributors' notes to the Berwick House address.



1. This set of three dividing plates, each with 6 rings of holes, give 18 different hole numbers.

DIVIDING IN THE WORKSHOP

Harold Hall takes a look at dividing.

The term dividing can be applied to many characteristics, length, angle, volume, weight, even potential (voltage) dividers, etc. However, in the engineering workshop the term applies almost entirely to dividing a circle. In the home workshop its uses are likely to be many and varied though three

applications probably account for 99% of all dividing undertaken. These are the production of gears, the engraving of dials and drilling holes on a pitch circle diameter (PCD).

The methods for achieving the correct angular divisions split mainly into three processes. The use of a dividing head, a

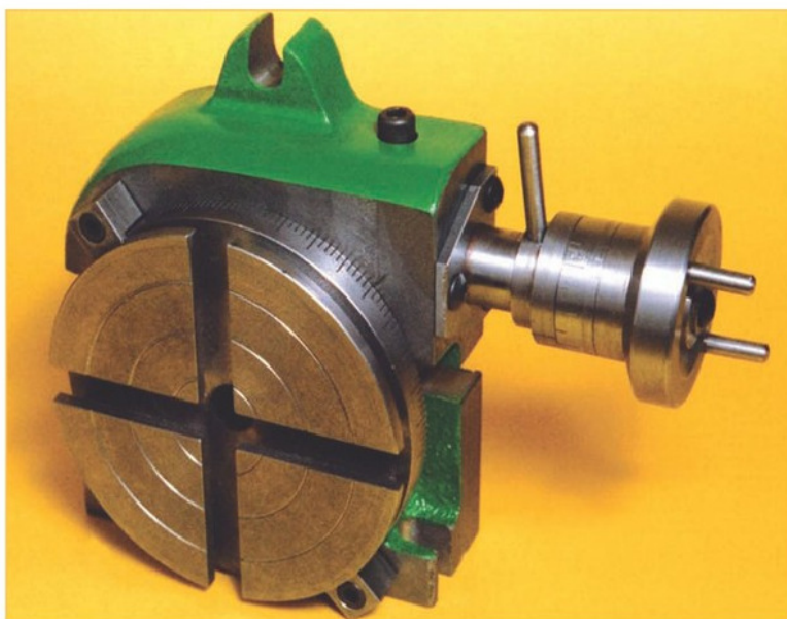
rotary table, or working out the X and Y co-ordinates for use with a compound table and using its leadscrew dials. I use the term dividing head loosely as this applies to any situation where the angle of rotation is controlled by holes placed round a circle on a device known as a dividing plate. **Photo 1** shows a set of three plates. Alternatively the teeth on a gear wheel can be used. A rotary table consists of a round tee slotted table that is rotated by means of a worm driving a wormwheel mounted on its rear, **photo 2**. The worm-driving handle incorporates a dial to enable the table to be rotated by fairly precise amounts, rather like the dials on a lathe or milling machine leadscrew.

A fully-fledged dividing head will often have a worm and wormwheel between the dividing plate and the workpiece and the input hand wheel on a rotary table can often be fitted with a dividing plate. The demarcation between the two is therefore blurred. In the home workshop though, I think it is true to say that most rotary tables are not fitted with dividing plates so for the sake of this article we will keep to the definition in the previous paragraph. Where a rotary table is fitted with a dividing plate then any reference to a dividing head will be equally applicable to the rotary table.

The mathematics

Before we get down to the methods of producing the workpiece it will be necessary to establish the set up required to achieve it. The newcomer may think this is a straightforward calculation and not worthy of comment. The process though, is much more complex than most will envisage.

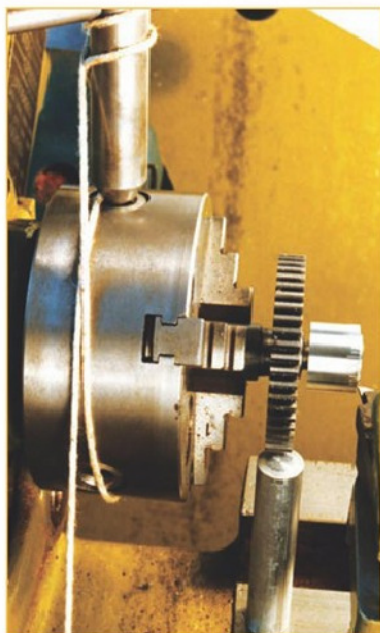
It would be easy to fall into the trap of considering that if one needed sixty divisions this would be six degrees between each making it an easy process. Whilst this is the case, it most certainly is not so for very many situations. Consider creating a dial having 125 divisions for use with an eight threads per inch (TPI) leadscrew requiring an angle between



2. A rotary table can be used where the number of divisions can be easily achieved using the dials provided.



3. An indirect dividing head where the dividing plate is coupled to the spindle via a worm and wormwheel.



4. A simple method of achieving the divisions on a small dial. The short length of aluminium on the lathe bed sets the position at each gear tooth.

divisions of 2.88 degrees. If our dividing head (or rotary table) has a 60:1 worm and wormwheel ratio and is fitted with a 60 hole dividing plate (or the dial on a rotary table is calibrated with 60 divisions) then each position will be equal to a rotation of 0.1 degree. As a very small error may be permissible on the final division, let us consider using an angle of 2.9 degrees. This will equate to 29 holes on the division plate or divisions on the rotary table (having made the point regarding the rotary table I will now cease to refer to it).

One hundred and twenty-four divisions at 2.9 degrees will amount to 359.6 degrees giving a final division of 0.4 deg., obviously far too great an error. Had the error been very much smaller, say a final division of 2.8 degrees then just possibly it may have been liveable with.

Taking now the requirement for a 127-tooth gear, as used in an imperial to metric conversion on the changewheels for an imperial lathe. In this case the required angle between each division is 2.8346456. Using 28 holes on the division plate would be the nearest but as a gear is being produced, any error at all will be unacceptable so I will not pursue the example.

Whilst the above may be extreme, very many applications will fall into the same degree of complication so the situation cannot be glossed over. Other divisions though, will be much simpler. One hundred divisions, as required on a dial for a 10 TPI leadscrew, would require 3.6 degrees per division. This can easily be accommodated by indexing 36 holes on a sixty-hole division plate.

How many holes

The above examples serve to show that it is necessary to choose a dividing plate that will enable a requirement to be achieved exactly. Whilst it is possible to change the



5. Another method of making the divisions on a dial using a marked strip of paper on the chuck's backplate.



6. A dividing head set up for direct dividing, that is, division plate mounted onto the head spindle.

plate on a dividing head, the calibration of a rotary table will be fixed and so provides much less scope for providing divisions as required.

Let us consider the 60:1 ratio worm with a 60-hole plate further. To rotate the output of the dividing head one full revolution, the worm will need to rotate 60 times. As the plate has 60 holes this will result in the



7. A dividing head set up for direct dividing but using a gear to set the divisions.

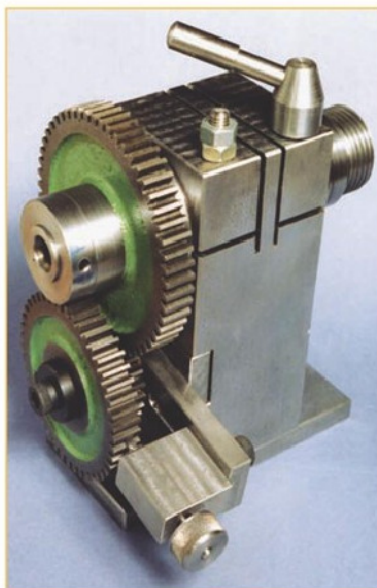
setting device passing 60 x 60 holes, that is 3600. Any whole number that divides exactly into this is an achievable division. Taking an easy example, say 40 divisions, this will require the setting device to pass 3600/40 holes per division, that is 80 holes, being one full turn plus 20 holes.

Whilst 3600 is a relatively large number, the number of possible divisions is quite small and are all what one might call

The Table

- This shows the number of complete turns plus the number of additional holes on the division plate for all possible divisions, up to 186, plus a few of the more important higher numbers. It is only applicable with a 60:1 worm and wormwheel ratio and dividing plates having the following divisions. 27, 29, 31, 32, 34, 38, 42, 46, 60, 66, 78.
- A few divisions are possible using only full turns without the need for a particular dividing plate. These are as follows.

Divisions	Turns	Divisions	Turns	Divisions	Turns
2	30	6	10	20	3
3	20	10	6	30	2
4	15	12	5	60	1
5	12	15	4		



8. A simple dividing head but using a gear train to increase the number of divisions possible.

simple numbers. These are 2, 3, 4, 5, 6, 8, 10, 12, 15, 18, 20, 24, 30, 36, 40, 45, 50, 60, 72, 80, 90, 100, 120, 150, 180, 200, 240, 300, 360, 450, 600, 720, 800, 1200, 1800 and 3600.

Knowing the dividing head ratio together with the number of holes on the dividing plate, it will be easy to determine if the division required is achievable. However, you are likely to have a set of dividing plates (or gears) that could result in a lot of calculations, albeit simple, until a suitable dividing plate is found, or maybe not found. Referring to a prepared chart will help avoid the chore in many instances.

On some occasions the published charts may not cover your requirements, or you may not have all the plates quoted but have others. In this case you will have to resort to calculation. As already mentioned the ratio (R) times the number of holes (H) divided by the number of divisions required (D) must be a whole number (W), that is $(R \times H) / D = W$. This is a simple calculation if one has R, H and D but what if attempting to work out the number of holes (H) required on the dividing plate (or, as will be seen, a gear being used as an alternative). In this case we have two unknowns (W and H) making the process appear less than straightforward. However, the value for W can be any number providing it is whole.

Let us consider the requirement for 57 divisions in which the formula will read $W = (60 \times H) / 57$. The values for R and D, 60 and 57 in this example, should be simplified to their smallest values, reading $W = (20 \times H) / 19$ (that is dividing both by 3). From this it can easily be seen that W will be whole providing H is 19 or any multiple of this, 19, 38, 57, etc. The published chart suggests 57 being achieved with a 38-division plate.

Having established the dividing plate to be used, it will be necessary to calculate the number of holes traversed for one division. In this case the number of holes for a complete revolution of the workpiece will be $60 \times 38 = 2280$ and the number of holes

9. A typical use of a dividing head, cutting a gear.



per division will be $2280 / 57 = 40$. Forty holes will be achieved by one complete turn plus 2 holes. See line 57 in the table.

Whilst 60 is a common ratio, 40 and 90 are also common, (40 is very common for commercial dividing heads) the dividing head illustrated in Photo 3 can be fitted with a wide range of wormwheels. Possibilities are therefore much greater than any published tables and calculation cannot be avoided.

Division plate errors minimised

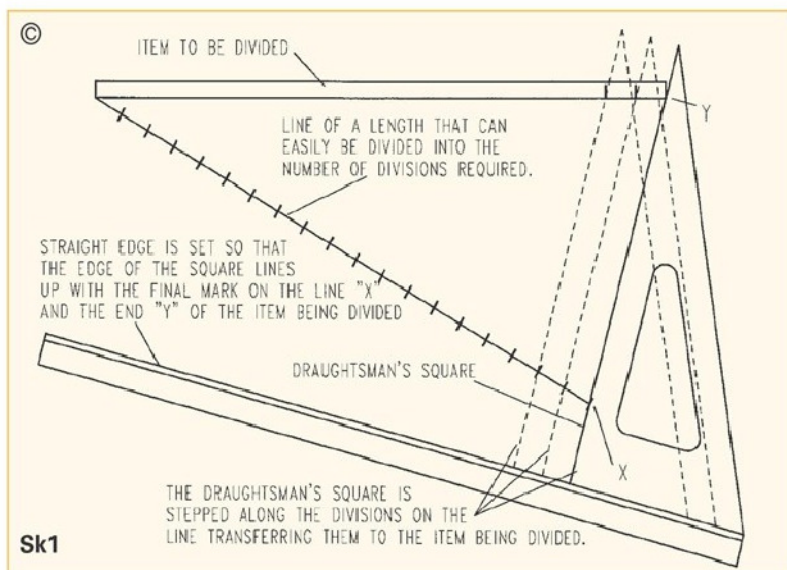
Whilst not a calculation that the reader will be called to carry out, the following illustrates how a worm and wormwheel configuration considerably reduces the effect of any division plate errors. The extent will no doubt come as a surprise to the uninitiated.

Consider a division plate with 18 holes theoretically spaced at 20 degrees ($360/18$), but having an error of 1 degree on the 12th hole, that is spaced at 19 and 21 degrees between its adjacent holes. If now attempting 9 divisions (40 degree spacing) and using a dividing head with a 60:1 ratio, the arm on the dividing head will have to pass $120 [(60 \times 18) / 9]$ holes per division. This is 6 turns plus 12 holes for the first division.

In this example, that is, $(6 \times 360) + (11 \times 20) + (1 \times 19)$ degrees, that is 2399 degrees and for the next division $(6 \times 360) + (11 \times 20) + (1 \times 21)$ degrees, that is 2401 degrees. As the worm/ wormwheel arrangement reduces the rotation by a factor of sixty the angles at the workpiece will be 39.984 degrees $[2399 / 60]$ and 40.016 degrees $[2401 / 60]$. From this it can be seen that the second division will be accurately placed as it compensates for the error in the first, $(39.984 + 40.016 = 80)$ but the ± 1 degree error between the two on the division plate has been reduced to 0.016 degree, 1/60th that on the dividing plate. The value of 1/60th is no coincidence but will always be by the same factor as the worm/ wormwheel ratio. This feature is a great help when wishing to improve on the accuracy of a home made dividing plate by using it to make a second, or from that even a third if you are after super precision, but I doubt the need for this.

Making the divisions

Whilst using a dividing head will, in most cases, be the ideal, other equipment is often used. The reasons for this can be many and varied, but will most often be because either a dividing head is not available or that the project is simple and more easily set up using some other method. Typical of this would be when needing to make three divisions on an



Dividing

A Number of divisions

B Number of complete turns

C Number of additional holes on quoted division plate

A	B	C										
		27	29	31	32	34	38	42	46	60	66	78
7	8	-	-	-	-	-	24	-	-	-	-	-
8	7	-	-	-	16	17	19	21	23	30	33	39
9	6	18	-	-	-	-	28	-	40	44	52	-
11	5	-	-	-	-	-	-	-	-	30	-	-
13	4	-	-	-	-	-	-	-	-	-	48	-
14	4	-	-	-	-	-	12	-	-	-	-	-
16	3	-	-	-	24	-	-	-	-	45	-	-
17	3	-	-	-	-	18	-	-	-	-	-	-
18	3	9	-	-	-	-	14	-	20	22	26	-
19	3	-	-	-	-	6	-	-	-	-	-	-
21	2	-	-	-	-	-	36	-	-	-	-	-
22	2	-	-	-	-	-	-	-	-	48	-	-
23	2	-	-	-	-	-	-	28	-	-	-	-
24	2	-	-	-	16	17	19	21	23	30	33	39
25	2	-	-	-	-	-	-	-	24	-	-	-
26	2	-	-	-	-	-	-	-	-	-	24	-
27	2	6	-	-	-	-	-	-	-	-	-	-
28	2	-	-	-	-	-	6	-	-	-	-	-
29	2	-	2	-	-	-	-	-	-	-	-	-
31	1	-	-	29	-	-	-	-	-	-	-	-
32	1	-	-	-	28	-	-	-	-	-	-	-
33	1	-	-	-	-	-	-	-	-	54	-	-
34	1	-	-	-	26	-	-	-	-	-	-	-
35	1	-	-	-	-	-	30	-	-	-	-	-
36	1	18	-	-	-	-	28	-	40	44	52	-
38	1	-	-	-	-	22	-	-	-	-	-	-
39	1	-	-	-	-	-	-	-	-	-	42	-
40	1	-	-	-	16	17	9	21	23	30	33	39
42	1	-	-	-	-	-	18	-	-	-	-	-
44	1	-	-	-	-	-	-	-	-	24	-	-
45	1	9	-	-	-	-	14	-	20	22	26	-
46	1	-	-	-	-	-	-	14	-	-	-	-
48	1	-	-	-	-	-	8	-	-	-	15	-
50	1	-	-	-	-	-	-	-	-	12	-	-
51	1	-	-	-	-	-	6	-	-	-	-	-
52	1	-	-	-	-	-	-	-	-	-	12	-
54	1	3	-	-	-	-	-	-	-	-	-	-
55	1	-	-	-	-	-	-	-	-	6	-	-
56	1	-	-	-	-	-	-	3	-	-	-	-
57	1	-	-	-	-	-	2	-	-	-	-	-
58	1	-	1	-	-	-	-	-	-	-	-	-
62	0	-	-	30	-	-	-	-	-	-	-	-
63	0	-	-	-	-	-	-	40	-	-	-	-
64	0	-	-	-	30	-	-	-	-	-	-	-
65	0	-	-	-	-	-	-	-	-	72	-	-
66	0	-	-	-	-	-	-	-	-	60	-	-
68	0	-	-	-	-	30	-	-	-	-	-	-
69	0	-	-	-	-	-	-	40	-	-	-	-
70	0	-	-	-	-	-	-	36	-	-	-	-
72	0	-	-	-	-	-	-	35	-	50	55	65
75	0	-	-	-	-	-	-	-	48	-	-	-
76	0	-	-	-	-	30	-	-	-	-	-	-
78	0	-	-	-	-	-	-	-	-	60	-	-
80	0	-	-	-	24	-	-	-	-	45	-	-
81	0	20	-	-	-	-	-	-	-	-	-	-
84	0	-	-	-	-	-	-	30	-	-	-	-
85	0	-	-	-	-	24	-	-	-	-	-	-
87	0	-	20	-	-	-	-	-	-	-	-	-
88	0	-	-	-	-	-	-	-	-	45	-	-
90	0	18	-	-	-	-	-	28	-	40	44	52
92	0	-	-	-	-	-	-	-	30	-	-	-
93	0	-	-	20	-	-	-	-	-	-	-	-
95	0	-	-	-	-	-	24	-	-	-	-	-
96	0	-	-	-	20	-	-	-	-	-	-	-
99	0	-	-	-	-	-	-	-	-	40	-	-
100	0	-	-	-	-	-	-	-	-	36	-	-
102	0	-	-	-	-	20	-	-	-	-	-	-
104	0	-	-	-	-	-	-	-	-	-	45	-
105	0	-	-	-	-	-	-	24	-	-	-	-
108	0	15	-	-	-	-	-	-	-	-	-	-
110	0	-	-	-	-	-	-	-	-	-	36	-
114	0	-	-	-	-	-	20	-	-	-	-	-
115	0	-	-	-	-	-	-	-	24	-	-	-
116	0	-	15	-	-	-	-	-	-	-	-	-
117	0	-	-	-	-	-	-	-	-	-	40	-
120	0	-	-	-	16	17	19	21	23	30	33	39
124	0	-	-	15	-	-	-	-	-	-	-	-
126	0	-	-	-	-	-	20	-	-	-	-	-
128	0	-	-	-	15	-	-	-	-	-	-	-
130	0	-	-	-	-	-	-	-	-	-	36	-
132	0	-	-	-	-	-	-	-	-	30	-	-
135	0	12	-	-	-	-	-	-	-	-	-	-
136	0	-	-	-	-	15	-	-	-	-	-	-
138	0	-	-	-	-	-	-	20	-	-	-	-
140	0	-	-	-	-	-	18	-	-	-	-	-
144	0	-	-	-	-	-	-	-	25	-	-	-
145	0	-	12	-	-	-	-	-	-	-	-	-
150	0	-	-	-	-	-	-	-	24	-	-	-
152	0	-	-	-	-	15	-	-	-	-	-	-
155	0	-	-	12	-	-	-	-	-	-	-	-
156	0	-	-	-	-	-	-	-	-	-	30	-
160	0	-	-	-	12	-	-	-	-	-	-	-
162	0	10	-	-	-	-	-	-	-	-	-	-
165	0	-	-	-	-	-	-	-	-	24	-	-
168	0	-	-	-	-	-	15	-	-	-	-	-
170	0	-	-	-	-	12	-	-	-	-	-	-
174	0	-	10	-	-	-	-	-	-	-	-	-
180	0	9	-	-	-	-	14	-	20	22	26	-
184	0	-	-	-	-	-	-	15	-	-	-	-
186	0	-	-	10	-	-	-	-	-	-	-	-
200	0	-	-	-	-	-	-	-	18	-	-	-
240	0	-	-	-	8	-	-	-	-	15	-	-
300	0	-	-	-	-	-	-	-	-	12	-	-
360	0	-	-	-	-	-	7	-	10	11	13	-

item in the three-jaw chuck. In this case, placing a piece of packing between the bed of the lathe and each chuck jaw in turn would be accurate enough for most applications and certainly much quicker than setting up a dividing head.

An extension to this idea is to include a gearwheel into the set up and use this in a similar way to the previous example, see **photo 4**. Using a weight on the end of a piece of string attached to the chuck, as seen in the photograph, would keep the packing in place whilst the operation of cutting a dial is carried out.

A rather similar idea, but one having no limitation as to the number of divisions other than a practical maximum, is to wrap around the back plate, a strip of paper suitably marked with the divisions required. This may seem a simple idea but the space between each marking when in the flat is likely to be a complex value. Say with a 100mm diameter backplate the circumference would be 314.1592654mm. Dividing this into any number would result in a value that would be difficult to work with. Fortunately, there is a simple way out of the problem.

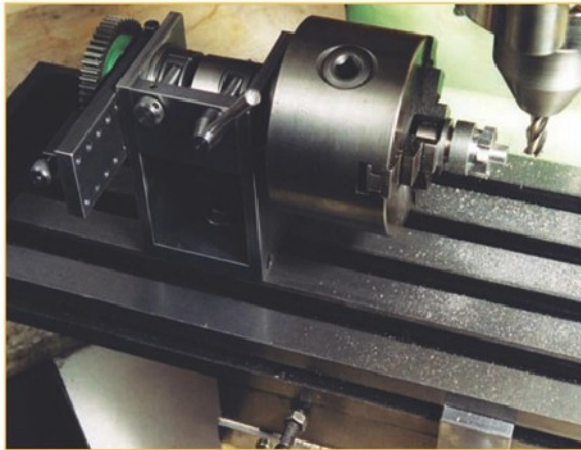
Wrap your strip of paper, a little on the long side, closely round the periphery of the chuck and carefully cut through both with a sharp knife at the overlap. You will now have your 314.1592654mm long strip of paper. Fix this down on a piece of paper and on this draw a line at an angle to the strip of paper and starting from one end of it. For example, say you wanted 19 divisions mark the line at 285mm (19 x 15) and mark this off at 15mm increments. Using a straight edge and a draughtsman's square as illustrated in **Sk.1**, transfer the divisions to the strip of paper that will now be accurately divided. Fix the strip to the chuck and use this to achieve the required result. **Photo 5** shows a dial being cut in this way. The process in **Sk.1** is a rare occurrence in the workshop for dividing length.

All the methods above have one major problem. That is, there is no method of securely locking the spindle. With only a little care this should not present a problem for the tasks shown being undertaken. For more arduous tasks though, such as machining a hexagon on a turned item, it would be a non-starter. Because of this, even though the system can easily cope with any number, it would

not be suitable for cutting that gear for which you do not have a suitable dividing plate. There is though, a simple way out.

Mount a disc onto the faceplate and using a suitably divided paper strip round the outer edge of the faceplate, you will enable the disc to be marked for making a dividing plate. The positions can be made using an automatic centre punch mounted on the top slide, or with a small drilling spindle. This process should make a dividing plate accurate enough for most applications. If used via a worm/wormwheel rather than direct division, the improvement in accuracy, as described above, would certainly make it adequate.

Typically, a 150mm diameter faceplate marked with 127 divisions for making a dividing plate for cutting an imperial to metric conversion gear will result in divisions almost 4mm wide, so a fair degree of accuracy should be achievable. An important requirement is that the dividing plate mounting must be concentric with the ring of holes, otherwise there will be more divisions on one 180 degree segment than the other. The bore must therefore be made at the same time as the hole positions are marked out.



10. The simpler task of cutting a ratchet.

The bullwheel

Many home workshop owners have added to the above methods of using the lathe mandrel by using a plunger engaging with the bullwheel or a gear mounted on the rear end of the mandrel. Using the bullwheel is limited by the number of teeth on the gear and if this is not a convenient number, may make it a non-starter for most applications. These will typically be the machining of hexagons and squares on components already in the chuck, having been machined there. Even though this idea has been around for many years, to my knowledge, few if any lathe manufacturers have included it in their machines. Interestingly though, Myford have now provided the bullwheel dividing feature using a 60 tooth gear in their latest version of the series 7, see MEW issue 94 page 23. The bullwheel is the gear fixed to the lathe mandrel as part of the back gear assembly.

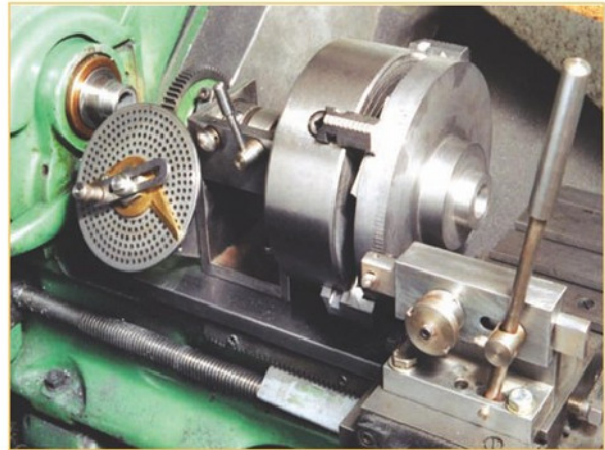
Mandrel mounted gear

Mounting a gear on the rear end of the mandrel will prove more adaptable as any of the lathes change gears can be used, providing a wide range of possibilities. Using a dividing plate will expand the possibilities even further, and if made in the workshop as described above, and later in the article, there will be no limit other than an upper one. The likely method for mounting the gear, or dividing plate, would be to use an expanding mandrel to grip the internal bore of the lathe's mandrel as illustrated in **Sk.2**.

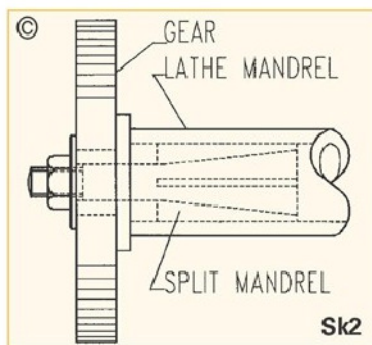
Backplate dividing

A relatively common method, much used in the past, is to drill the periphery of the chuck's back plate with a series of holes to provide its own inherent dividing plate. As there would be only one ring of holes this limits the range of divisions available.

All three of the above methods will require some attachment to carry a locating plunger and whilst the principle will be the same the mechanics of doing this will vary from lathe to lathe. For this reason I cannot propose a design but many examples have featured in **MEW**. (Ref. 1).



11. Using a dividing head mounted on a lathe bed.



Dividing heads

Commercially available dividing heads, even from the economy end of the market, are likely to be too expensive for the vast majority of home workshop owners, especially taking into account the limited use it will probably get. For this reason I will illustrate the article with two simple dividing heads I have made and which have featured in past issues of **MEW**. (Ref. 2). Other designs have also been published in the magazine. (Ref. 3).

Universal dividing heads provide three levels of division, direct, indirect, or differential. Direct dividing is where the division plate, or gear, is directly fitted to the dividing head spindle, **photo 6** and **photo 7** being examples. Indirect is where a worm and wormwheel is interposed between the division plate, or gear, and the dividing head spindle, as in **photo 3**.

Differential dividing heads are almost entirely a commercial product though I have seen one home workshop item. (Ref. 4). In these the output spindle is driven from the crank handle via the worm and wormwheel in the normal way. However, a gear train from the rear end of the dividing head spindle is arranged to rotate the dividing plate itself by a small amount as a result varying slightly the input from the crank handle from the chosen hole to hole value. By choosing a suitable gear chain, divisions can be obtained which are not obtainable by the normal process. The mathematics of this is quite complex and recourse to published figures would be the obvious route. In any case these should be provided with the dividing head when purchased.

Direct dividing using the lathe change gears (**photo 7**) between 20 and 70 teeth and in increments of 5 would appear to

give a good range of possibilities. It will though, only give 2 through to 15 and the complete number of teeth on each gear, 20, 25, 30, etc. One feature that can be provided where gears are used is that the plunger can be made as a fork so that it can either locate between adjacent teeth or across a single tooth. This effectively doubles the number of divisions for each gear. Typically, a 40-tooth gear provides 80 divisions.

The range can be extended appreciably by using direct mounted dividing plates as in **photo 6**. In addition to simplicity, direct dividing has the advantage of virtually zero backlash providing the plunger assembly is close fitting.

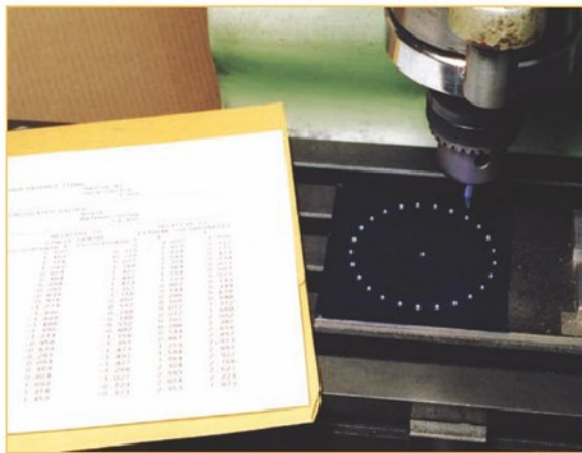
Commercially available indirect dividing heads come with a fixed worm / wormwheel ratio. However, the setup in **photo 3**, using a lathe changewheel, has adjustment for the pitch between gear and worm, permitting the gear to be changed over a range of sizes. This gives a wider range of worm / wormwheel ratios and recourse to the formula given previously will be necessary as the tables published with this article only apply to a 60:1 ratio.

Conventional differential dividing heads can have their gear chain coupled to a gear on the end of a milling machine table lead screw, rather than its own dividing plate. This causes the dividing head to rotate with leadscrew rotation so that a spiral will be cut in the workpiece as the table is traversed. The ratio of the gear chain will control the helix angle. This is a subject that is beyond the scope of this article. (Ref. 5).

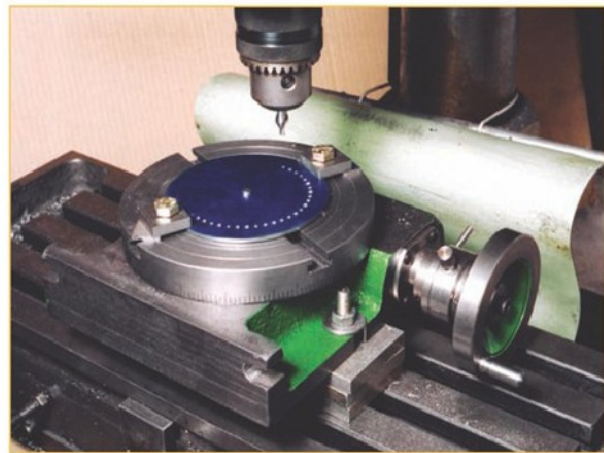
Referring now to **photo 8** showing a pair of gears providing the divisions. These two gears amount to a reduction in angular movement between the dividing device (gear or plate) and the dividing head spindle in the same way as a worm and wormwheel. However, the ratio with a worm and wormwheel will always be a whole number, 40:1, 60:1, etc. With two spur gears though the result may be complex. Typically, for example, gears of 55 and 35 teeth will have a ratio 11:7. Whether this is usable will depend on the number of positions on the dividing device.

Some more Mathematics

We are now moving into a depth of complication that is greater than can be



12. Placing holes on a PCD using their X and Y co-ordinates. This method will enable any number of holes, up to a maximum value, to be positioned.



13. Placing holes on a PCD using a rotary table. Possible divisions will be limited by what can be read off its dial accurately. Note the locating peg in the centre to ensure concentricity with the plates eventual mounting.

fully covered in this article. However, the following should give an indication as to what is possible. One important point to make is not to attempt to work out the values in decimal terms as this can so easily shroud the meaning of the answer so do stick to fractional form.

Example 1

Consider a set up with a 30 tooth dividing gear and a 60/20-tooth gear chain, which is 3:1. The formula is therefore number of holes passed for one rotation of the dividing head output which is $30 \times (60/20) = 90$ holes. This will enable the 30-tooth wheel to give divisions of 2, 3, 5, 6, 9, 10, 15, 18, 30, 45 and 90. Nine, 18, 45 and 90 are additional to the numbers possible with the 30-tooth gear used direct.

Example 2

Consider a set up with a 40 tooth dividing gear and a 55/20-tooth gear chain that is 11:4.

The number of holes passed for one rotation of the dividing head output is therefore $40 \times (55/20) = 110$ holes. The point to note here is that even though the ratio is 11:4 it still results in a whole number for the number of holes.

Example 3

For this example I am suggesting a six-tooth gear as it simplifies the explanation. I do know that in practice a six-tooth gear is largely unworkable though of course you could have a six hole dividing plate. Consider a set up with a six-tooth dividing gear and a 55/20 gear chain, again 11:4. The number of holes passed for one rotation of the dividing head output is therefore $6 \times (11/4) = 16\frac{1}{2}$ holes. With an answer of $16\frac{1}{2}$ holes the setup would appear to be worthless, as no number will divide into this, this is not so. If in this case the output is allowed to rotate another full turn then this results in 33 holes passed.

Whilst this will only give divisions of 3, 11 and 33, 33 is a number that may be difficult to obtain with other available methods. To prove if the divisions on the second pass fall between those of the first let us do some more calculation. To save

space I have minimised the detail. You may like to write it down in full to be confident regarding this.

Thirty-three divisions will require intervals of $360/33$ degrees, that is 10.91 degrees. 16th division made will be made at 2 turns plus 4 holes that is $\{2 \times 6\} + 4 = 16$ holes. 17th division made will be made at 2 turns plus 5 holes that is $\{2 \times 6\} + 5 = 17$ holes. 33rd division made will be made at 5 turns plus 3 holes that is $\{5 \times 6\} + 3 = 33$ holes.

Input rotation at the 16th division = $\{2 \times 360\} + \{4 \times 60\} = 960$ degrees
Input rotation at the 17th division = $\{2 \times 360\} + \{5 \times 60\} = 1020$ degrees
Input rotation at the 33rd division = $\{5 \times 360\} + \{3 \times 60\} = 1980$ degrees

Using the worm/wormwheel ratio of 11:4
Output rotation at the 16th division = $\{960 \times 4\}/11 = 349.09$ degrees, that is $360 - 10.91$
Output rotation at the 17th division = $\{1020 \times 4\}/11 = 370.91$ degrees, that is $360 + 10.91$
Output rotation at the 33rd division = $\{1980 \times 4\}/11 = 720.00$ degrees, that is $360 + 360$ degrees. In terms of final position this can be considered as $360 + 0$

This shows that the 33rd division made will fall exactly between the 16th and 17th divisions made. Note here the division numbers given relate to the order they are made and not the position in which they fall on the finished component. See Sk.3.

As a final example, a 50 tooth input gear coupled to a 35/30 tooth gear chain will result in $58\frac{1}{3}$ holes being passed for a single turn output from the dividing head. Three full turns at the dividing head output will result in 175 holes passed. The same principles as in the previous example will still apply.

These examples, which show only a minute fraction of those possible, do, I hope, give an indication of the range of possibilities with this set up, and as a result enable you to go down this avenue knowing that it is possible.

Some applications

Before briefly illustrating some actual applications, one aspect of the dividing operation needs to be described. Consider

using a 66-hole division plate on a dividing head with a 60:1 ratio. To make 33 divisions, this will require 1 full turn of the dividing arm plus 54 holes, as given on the table published. The one full turn will present no problem but how does one count the 54 holes. Doing this 33 times without making an error seems very difficult. Photo 6 shows that the dividing plate has a device mounted on its face consisting of two brass fingers. These can be rotated, one against the other, so that the space between them amounts to the number of holes to be traversed, 54 in this example. The fingers can then be locked together (see the small screw and clamp plate) to maintain this setting.

The fingers can be rotated together on the dividing plate face, but some inbuilt friction ensures that they do not move once set for each division. With one finger against the plunger the first division is made. Then the fingers are rotated so that the other finger is against the plunger prior to this being disengaged, before rotating it one full turn plus 54 holes. (Editors note. The fingers must span 54 holes + 1 = 55 holes. The reason for this is that you have to take into account that the indexing pin occupies one hole.)

In the example in photo 6 the dividing plate with fingers are together rotated by the number of holes for the division, the plunger being stationary. The process is repeated for each division required. In the case of an indirect dividing head, (photo 3) the plate and fingers remain stationary and the arm on which the plunger is mounted is rotated, otherwise the process is the same.

Gear cutting

This can be carried out on the lathe and for many years before milling machines became widely available, it was the way it would be done. This necessitated a milling spindle to be set up on the lathe, which made it a lengthy project. Some engineers do still adopt this method. If a milling machine were available then using this, as in photo 9, would in most cases be a much easier option.

Not quite a gear, but a ratchet is being cut in photo 10. Note that a single gear is used to control the spacing required.

Rather than count the number of teeth traversed at each division during the process, counting and marking the gear in some way prior to mounting it on the head will be easier and less prone to errors.

When carrying out machining operations as in the above two cases, relying on the indent on the dividing plate to keep the component in place is a non-starter. For this purpose dividing heads are provided with a method of locking their spindle to prevent rotation. In **photo 10**, the small lever to the left of the chuck is used for this purpose.

Dial cutting

Dials can most often be more easily made on the lathe as the top and cross slides will enable depth and length of line to be controlled with ease. Earlier **photos 4** and **5** are examples. However, with a dividing head giving a wider range of possible divisions, this will often be the only option, albeit mounted on the lathe bed rather than on the milling machine table. With the dividing head mounted in this way the top and cross slides can still be used as above. **Photo 11** shows basically this set up but a line engraving tool is being used to control the length of the line rather than the top slide.

The dividing head in this photograph is made with its centre height equal to the lathes centre height so that the tailstock could be used to support a component if necessary. Commercial dividing heads are frequently supplied with a tailstock or one is available as an option.

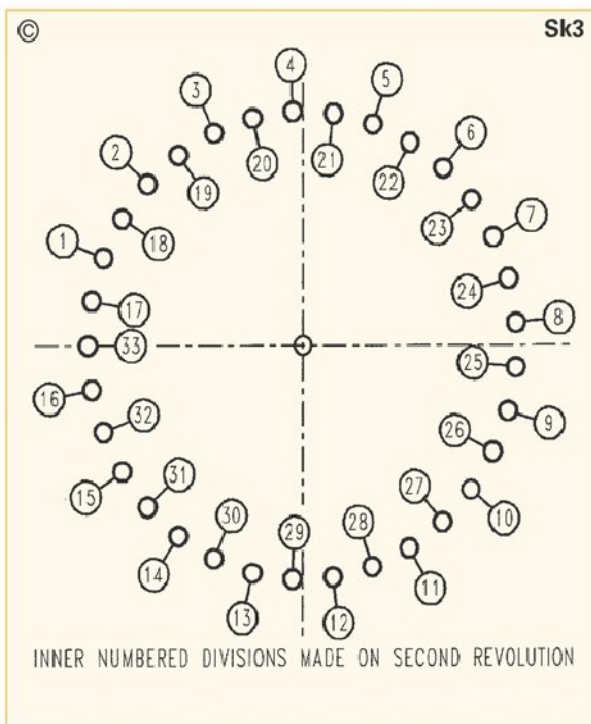
Backlash

Consideration must be given to the backlash inherent in the dividing head assembly. If you ignore the backlash, divisions will come out irregularly spaced. Because of this, the workpiece or the device holding it must be restrained by hand and in the same direction each time to take up the backlash consistently. As an alternative the method of a string and a weight, as can be seen on **photo 4**, could be considered.

Holes on a PCD

The need for placing holes on a PCD is likely to be very varied. Typically, from just a small number of holes for a cylinder head on a steam engine, to a much larger number when making a dividing plate. Three methods can be adopted, the use of a rotary table, the dividing head, or using the X and Y co-ordinates of each hole to place each one using a compound table and its leadscrew dials.

The advantage of the latter method is that there is no limit to the number of holes that can be produced other than an upper maximum. It can therefore be used to produce a dividing plate to whatever number is required. Its advantage is that it will also produce a plate to a reasonably high level of accuracy. On the down side



though there is a large amount of calculation to carry out and the task of making the divisions needs to be carried out with extreme care else an error will likely result. If like me your leadscrew is 8 TPI, 0.125in. per revolution, it will be even more fraught with possible errors than a 10 TPI leadscrew.

Having worked out the co-ordinates, convert them to total number of leadscrew turns plus dial reading for each hole and note on your table of values. Do not attempt to do this mentally at each hole. Don't position a hole relative to the previous value. If you do, one error will then be perpetuated on all the positions that follow. **Photo 12** shows me making a dividing plate with my calculations on the machine table, these having been worked out using a computer spread sheet (Ref. 6). It may be visible that I did not take my advice at the commencement of this paragraph and give that advice from the experience I had attempting to work out dial readings on the run.

Rotary tables

As commented earlier in the article, the demarcation between rotary tables and dividing heads is not that precise and most of the above operations could be adapted to the rotary table. Most rotary tables can be vertically mounted, that is with their axis horizontal as in the case of a dividing head. The differing method for holding the workpiece can be a problem but methods have been adopted for mounting a chuck so that overcomes that problem. It must though be concentric with the table's axis.

The major problem is due to the absence of a dividing plate assembly on most tables. This results in all dividing having to be done using its calibrations. Using it for making gears is possible as can be seen by the front cover of **MEW** issue 91. Whilst this may not be that arduous for small numbers of teeth,

especially if the number divides nicely into 360 degrees, it would for me be a questionable operation for anything more complex. Perhaps my level of concentration is diminishing with age.

Rotary tables where dividing is the task, are more suited to operations such as placing holes on a PCD. **Photo 13** shows another example of a dividing plate being made and this is much more straightforward than the method of using the X and Y co-ordinates above. However, unless the number of divisions results in exact dial readings it really is a non-starter. There is no hope if you need to work to say five and a little bit divisions. This results in only a relatively small number of values being possible, which compares badly with using X and Y co-ordinates where every value is possible.

Another method

Another method for placing holes on a PCD is by the use of CAD. These programs provide facilities for placing marks on a PCD with ease and print out with surprising accuracy and in a matter of only a minute or two overall. The print out can then be overlaid on a piece of sheet steel and centre punched through the paper sheet and then drilled. If a dividing plate, do not forget to include the centre of circle in the computer print out, as concentricity is vital. If all other approaches to acquiring a plate with the divisions required fail, this is certainly a method worth attempting. If you do not have access to a computer then it is such a simple exercise that you should not be that embarrassed to ask a friend who has access to a CAD program.

I hope I have provided some useful details that will help you have success with your dividing projects.



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2. *A Failed Attempt*, **MEW** issue 53 Page 43. *Milling Projects for Beginners 5*, **MEW** issue 88 page 26.
3. *A Small Dividing Head*, **MEW** issue 29 page 38. *A Unique Dividing Head*, **MEW** issue 38 page 44.
4. A home workshop produced differential dividing head, **MEW** issue 57 front cover.
5. *The History of the Milling machine*, **MEW** issue 23 page 61, **photos 7b and 7c**.
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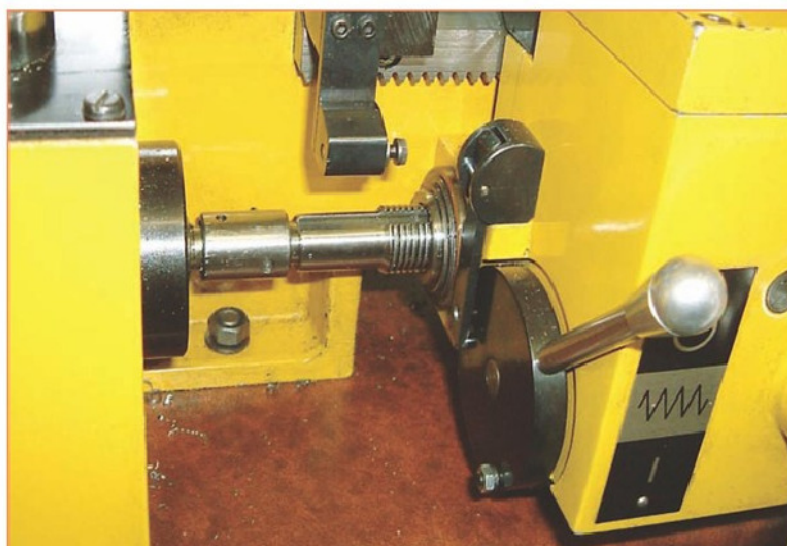
AN AUTOMATIC CARRIAGE STOP FOR THE PRAZIMAT LATHE

Jim Whetren comes to a stop.

My first lathe was a Cowell ME 90, which was later followed by a Drummond flat bed in a search for greater capacity. Both of these lathes feature a dog clutch on the lead screw to enable the power traverse to be disengaged automatically at a preset stop. This was found to be a most useful feature.

I then went to a modern machine and replaced the Drummond with a Prazimat DLZ, which has an adjustable carriage stop, but no means of automatically releasing the clutch. I use the stop all the time and to make life easier, I have replaced one of the securing Allen screws with a handle. It is now a simple matter to position the stop without the use of tools.

Having been inspired by the article in MEW issue 96 page 30 by Peter Foyle, and the description of a similar system by the late J Radford in his book, I decided it was time to try and resolve the problem with the Prazimat (after 18 years!). What follows is the device I came up with. As can be seen in photo 1, it is quite simple and requires little work or modification to the lathe. I made a start with the most complicated bit.



1. The completed stop.

end before finally tightening the vice. Light cuts were taken with the same end-mill until the new surface ended just past the 2mm cross-holes. This extra cut is to provide clearance for the trigger to operate.

10mm long compression springs placed in the holes, the trigger is pressed down on to the springs to allow the pivot pin to be pushed through, securing everything. The constant pressure of the springs should hold everything in place.

The pivot block Fig. 1

This was made from a stub of 25mm diameter FCMS. I used round stock because I didn't have any square big enough. As it turned out, I am pleased with the final appearance and would use round stock again.

The stub was mounted sideways in the four-jaw chuck and a facing cut was taken to a depth of 5mm. The piece was then turned around with the machined face held square against one of the chuck jaws. Another facing cut was taken to a depth of about 3mm so this face was just level with the previously machined face. The location of the 2mm Dia. pivot hole was marked out and the hole drilled.

The piece was then mounted in the milling machine vice, seated on the larger face and the 10mm slot was cut to 7mm depth with an end-mill. The piece was marked out for the two holes in the centre of the slot and transferred to the drilling machine where a 3mm hole was drilled right through the centre position and then opened up to 5mm for a depth of 6mm. The second 5mm hole was then drilled to the same depth. It was then back to the mill where the piece was again mounted on the large face but this time a 1.5mm drill was pushed just under the rounded

The trigger Fig. 2

This is made from a piece of 10mm x 4mm BMS flat, cut to length and squared off to 65mm long. In the centre of the bar, 57mm from one end, mark out and drill the 5mm hole. When complete, file a 30deg. bevel on the bar leaving a small flat portion on the end. Turn the piece over and scribe a line across the width 12.5mm from the opposite end and mill a shallow V groove to lock against the pivot pin, which is just a piece of 2mm Dia. Stock, cut to length and the ends rounded off.

The Pivot Block is now placed on the ledge above the clutch cam where it will probably be found that unevenness in the casting prevents both flat faces seating. Simply file a chamfer on the corner of the block until both faces seat fully. With the block level with the end of the ledge, spot through the 3mm hole to mark the end of the apron and drill tapping size for the M3 thread to a depth of 6mm. Although access is restricted, it is quite easy to drill the alloy casting with a hand drill, keeping everything square by sighting against the lead-screw. A 'T' handle tap wrench will sort out the tapping of the thread.

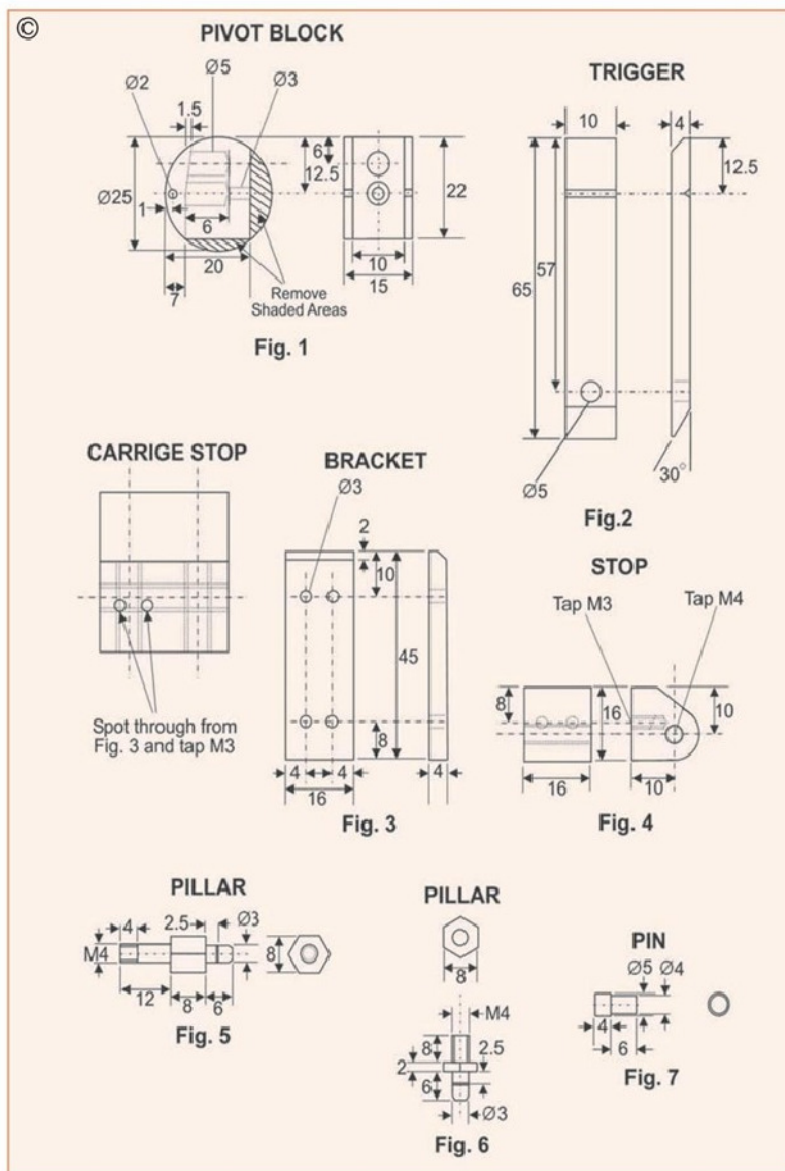
The block may now be mounted with an M3 Allen screw. With two 5mm Dia. x

The bracket Fig. 3

Take a piece of 16mm x 4mm BMS, cut and square off to 45mm long and file a 2mm chamfer on one end which will become the top outer edge. Mark out and drill the four 3mm clearance holes, then align the chamfered end of the bracket square to the left hand outer edge of the lower portion of the carriage stop block, chamfer outwards and spot through the two 3mm holes. Drill the holes in the stop tapping size to a depth of 6mm and tap M3. This is then fitted to the carriage stop with 2 off M3 Allen screws

The stop Fig. 4

This is a 16mm x 16mm cube of BMS squared up on all faces. Clamp the square end of the bracket to the bottom of the block, with the chamfer side of the bracket towards the block. Spot through the two holes and drill tapping size to a depth of 6mm and tap M3. On the face at right angles to the M3 holes, mark out as in Fig. 4 and drill and tap through for the M4 thread fine adjustment screw. This screw is an M4 socket head cap screw 20mm long with the top of the head rounded slightly.



The screw is fitted into the stop with a locknut. The profile shape is for appearance sake and is left to the user's choice. The Stop is secured with two M3 Allen screws.

Pillars Fig. 5 & Fig. 6

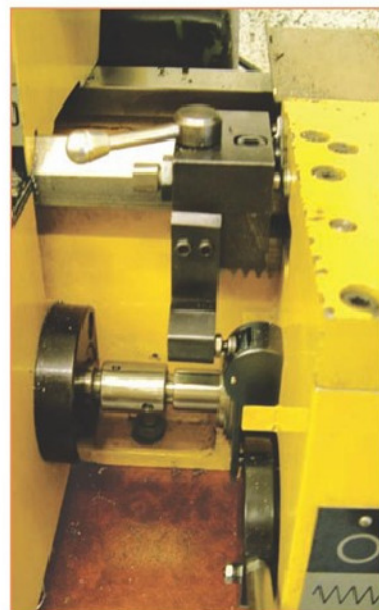
The pillar in Fig. 5, replaces the stop pin fitted to the bottom of the clutch cam. It is a simple turning job from 8mm FCMS hexagon bar as per the sketch Fig. 5. The flat on the top should be horizontal when fitted and should contact the bottom of the apron as the detent ball engages with the cam in the disengaged position. It is secured with a nut and a spring washer.

The second Pillar is another turning from 8mm hexagon as per the sketch Fig. 6. This pillar replaces the front left outer M4 screw securing the bottom cover to the apron. After fitting the pillars, a small 21SWG tension spring, 11mm long is hooked over the pillars, keeping the cam in the disengaged position.

Pin Fig. 7

This is turned from 5mm dia. Silver steel as per Fig. 7 and hardened. The pin is located by placing the cam in its engaged position and spotting through the 5mm hole in the trigger to make a mark in the blackening of the cam. I thought this would be the easy bit, wrong, the cam is casehardened. I found that with perseverance, a TC drill, (masonry drill) used at a slow speed with no lubricant, the drill could penetrate to its full diameter for about half a millimetre, I then changed to a HSS drill which made short work of drilling to a depth of 8mm. The pin is pushed into the cam with a touch of adhesive.

We are now ready for a test. The stop adjuster screw is run out so that the trigger is released just before the carriage hits the stop and the lock nut tightened. Using the calibrated collar on the carriage handwheel set to zero when hard against the stop, a dry run with the lathe switched off saw the clutch disengage when the saddle was half a millimetre from hitting the stop.



2. The carriage feed engaged.

Another test under power using the fastest traverse speed saw the feed disengage a lot closer to the stop. I presume this difference is due to friction in the drive components of the clutch when under power. Nevertheless, the system provides a reliable means of stopping the feedscrew drive prior to contacting the carriage stop. I just wish I had bothered to pursue the matter sooner.

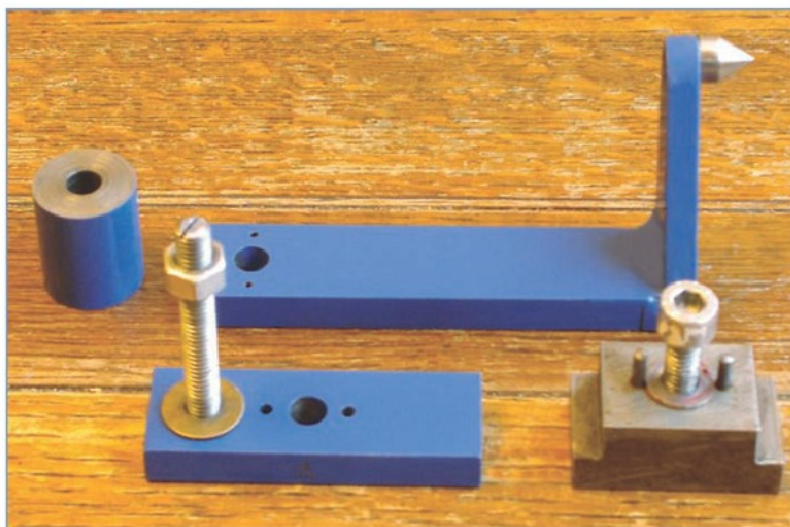
One final thing, when everything is seen to be working, the trigger is case-hardened at both ends, in particular the 5mm hole and the face which the stop screw contacts. You could of course make the trigger from gauge plate and then harden and temper it.



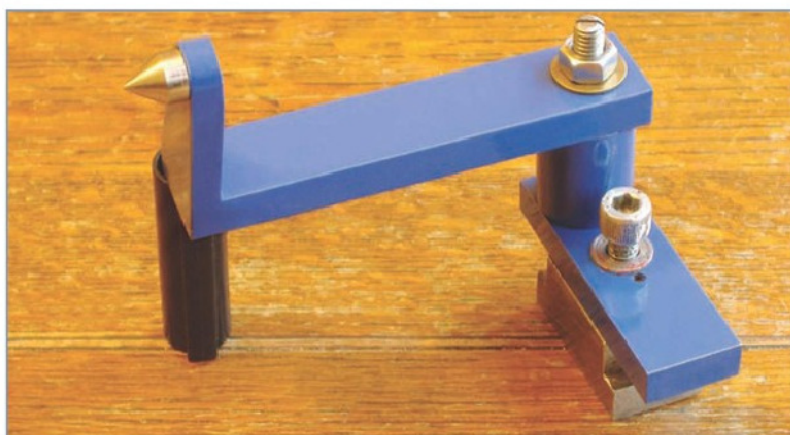
3. The carriage feed disengaged.

A SIMPLE APPROACH TO TAPER TURNING

Chris Smith goes off on a tangent.



1. The components of the auxiliary tailstock.



2. The auxiliary tailstock assembled.

Most engineers at some point need to turn an accurate taper, but do not have the facilities or the time to set the lathe up for taper turning. Having used the old method over the years of setting the compound-slide up to an already made taper and never being quite happy about the results, I came up with the

following idea, which involved the making of a few simple parts, which are as follows:

1. Clock gauge holder
2. Sine bar.
3. Auxiliary tailstock.
4. Twelve inches of half inch round silver steel centred at both ends.

Clock gauge holder

This is made from 13mm square mild steel bar, and was made to fit a spare clock gauge that I had. The sizes are not critical, only that when clamped in the tool holder the clock gauge sensor is at centre height. The two pieces of the holder are just welded together where shown on **drawing 1**.

The sine-bar

The sine bar was made from what I could find laying about my workshop. All the sizes are shown in metric, for ease of drawing, but it will be noticed that the 254mm dimension is exactly ten inches, and was made to this dimension for a reason that will become apparent later. The rollers are made from 20mm bright bar and welded in place. To get the rollers to stay in the right place while they were being welded, a piece of angle iron was cut and secured by a small clamp, to the sixteen millimetre bar 10mm from the centre lines of the rollers. This angle iron is only to hold the roller in place while it is being welded, and there is no further need for it afterwards. Two angles are shown on the drawing but only one is really needed. The knurled 6mm screw has up to now not been necessary, but may be need one day, this will be explained later. The 6mm plate for holding the sine bar into the tool holder is held in place by M5 Allen cap screws. (**Drawing 2**)

Auxiliary tailstock

When cutting tapers the compound slide is used, so the normal tailstock gets in the way, and although I managed to turn a couple tapers with out a centre, there was too much hanging out of the chuck to be able to take a reasonable cut. The following is what I came up with to solve this problem, **drawing 3** and **photos 1** and **2**.

The T-piece is made to fit into the bed of my Myford lathe. Other lathes of the same make, may have machining tolerances, which may need the T-piece to be finely tuned to each lathe bed. The centre holder is roughly cut to shape, and the hole for the centre left un-drilled. The base is then welded to the upright centre holder, across the underneath and up both sides, but not across the top. Cut a Vee out of the underneath before welding, as the underneath needs to finish up flat. The welds on the sides can be left proud.

Fit all the parts together and put onto the bed of the lathe, on the chuck side of the carriage. A centre drill is now put into the chuck, and the bed clamp of the centre holder nipped up so that it just slides on the bed, when the carriage is pushed against it. It may need a packing between the bed clamp, and the carriage in order too make sure of a flat push. Using the carriage, push up to the centre drill, and centre the work, finish drilling through with a 5mm drill. The centre itself is made from silver steel, and turned to give a press fit. After hardening and tempering press the centre in, using a piece of copper or aluminium with a hole in it to prevent damage to the centre point. The centre holder is then cut and filed to the finished shape. When in use, the centre holder just



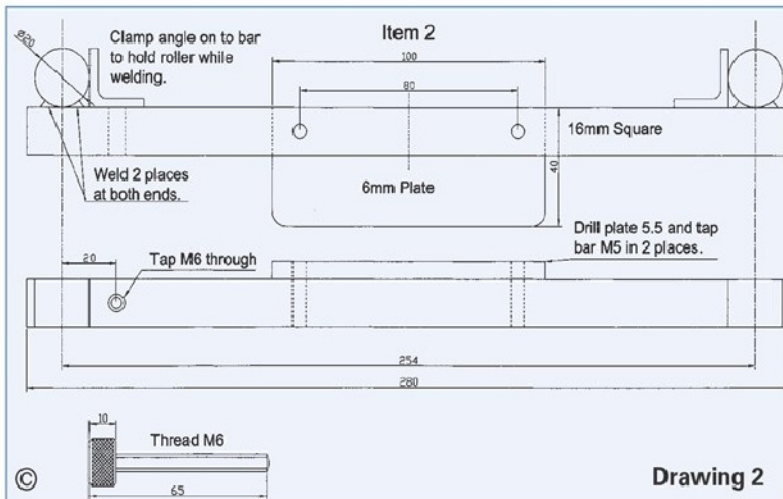
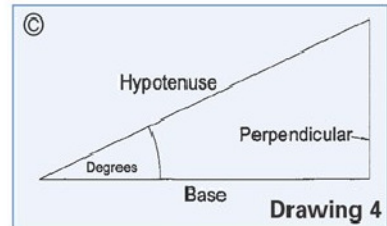
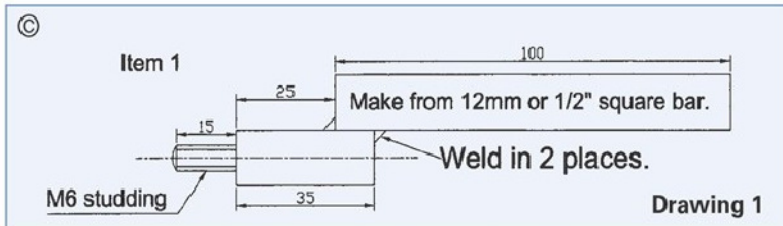
3. Clocking the bar to ensure tailstock and top slide are set true.



4. Setting the sine bar true with the centres bar.



5. The sine bar and cross slide with packing in place.



takes). The taper is two triangles, each one either side of the centre line of the circle, the one below the centre line is the mirror image of the one above, this is the reason why the spacer is only half the perpendicular. The length of the base is what we choose to make it, if working on inches of taper per inch the base line will be one inch, if working on inches of taper per foot then the base line will become one foot. Only one half of the taper (the top triangle) is needed when calculating the spacer thickness. The sine bar always represents the hypotenuse of the triangle, so as the angle gets steeper the base line gets shorter, this may need to be looked at closer when calculating the spacer thickness.

Table 1 shows Morse taper data, in the range of sizes that may be encountered in a small workshop. Other tapers are calculated in the same way. Looking at No. 2 Morse taper, which has a taper of 0.04995 inches per inch, which means that if the base is ten inches long the perpendicular will be 0.4995 inches. Using formula (3)

Table 1

Morse taper Number	Taper per Foot	Taper per Inch	Small end in inches	Length in inches
0	0.62460	0.05205	0.2520	2.03125
1	0.59858	0.04988	0.369	2.15625
2	0.59941	0.04995	0.572	2.609375
3	0.60235	0.05019	0.778	3.250
4	0.62326	0.05193	1.020	4.125

clears the cross slide, allowing the cut to be applied without disturbing the centre.

Calculations

Next we have to calculate the thickness of the spacer, which is to be used in conjunction with the sine bar.

Tapers all relate to the degrees in a circle. There are 360deg. in a circle, each degree contains 60 minutes and each minute contains 60 seconds. This is how trigonometry tables express parts of one degree, but if you have a scientific calculator, parts of one degree are shown as a decimal. The tables used are Natural

sine, Natural cosine and Natural tangent and the formulas are put down as follows:

(1)

Perpendicular = Sine
Hypotenuse

(2)

Base = cosine
Hypotenuse

(3)

Perpendicular = Tangent
Base

The hypotenuse is the radius of the circle, (and the path that the sine bar

$\frac{\text{Perpendicular}}{\text{Base}} = \text{Tangent}$

$0.04995/1 = 0.04995 \text{ tangent}$
which is 2.8595deg.

By now using the formula (1) the spacer thickness can be calculated.

$\frac{\text{Perpendicular}}{\text{Hypotenuse}} = \text{Sine}$

$\text{Perpendicular}/10 = 0.049887$
this is the sine for 2.8595deg.

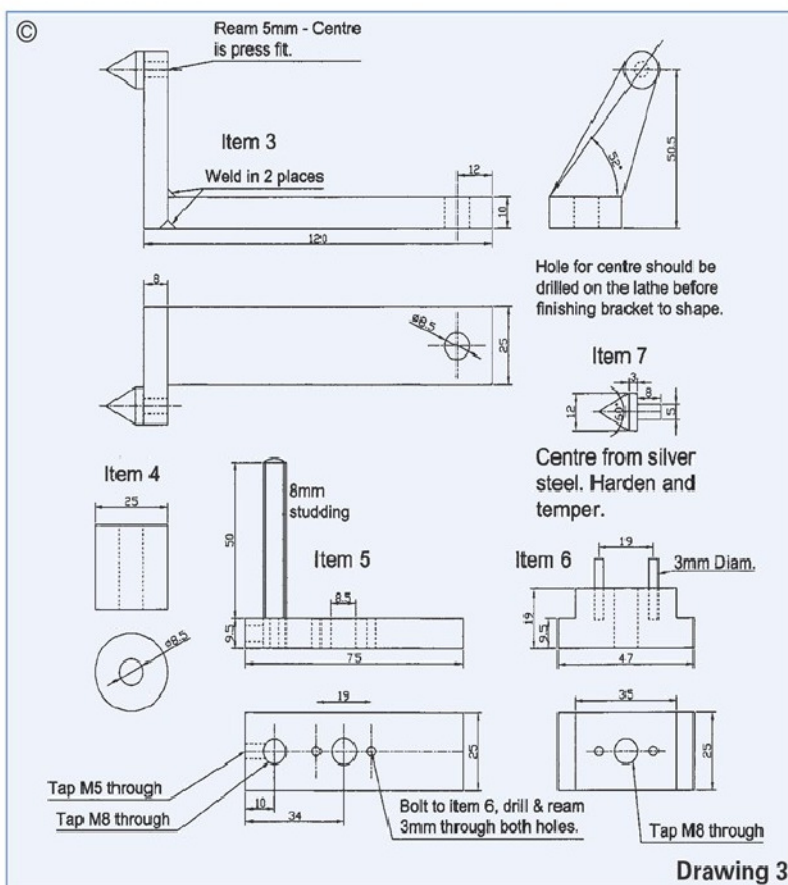
$10 \times 0.049887 = 0.49887$ this is the perpendicular, which when divided by two gives the spacer thickness of 0.249435 inches. This just demonstrates that the slight loss of base length as the sine bar moves in an arc, makes very little difference, and that the spacer size can be taken straight from the Tables at $0.04995 \times 10 = 0.4995$ $0.4995 / 2 = 0.24975$ both ways arrive at the same figure, with a spacer of 0.250 inches being used.



6. Turning a Morse taper.



7. Some finished tapers.



To cut a taper, which has a 7deg. angle, what will be the spacer thickness? The angle of half the taper is 3.5 deg. and the sine bar rollers are spaced at ten inches. The two known quantities are the hypotenuse and the angle of 3.5 deg. The other one required, is the perpendicular. So from the three formulas, number (1) is the one we want.

$\text{Perpendicular} = \text{Sine Hypotenuse}$
 $\text{Perpendicular}/10 = 0.061049$
 this is the sine for 3.5 deg.

The Sine number for 3.5 deg. is taken from the trigonometry tables or a calculator.

$0.061049 \times 10 = 0.61049$ inches this is the perpendicular and the spacer thickness.

Preparation and setting up for taper turning

The work is taken to the stage where it is ready for taper turning, and then removed from the lathe. A twelve-inch length of 0.5in. diameter silver steel centred at both ends is placed between the lathe centres, (a carrier is not needed). The clock gauge is held in the tool post, and with the lathe stationary, the clock gauge is run down the full length of the silver steel, this is to check, and set, the tailstock parallel to the bed of the lathe, adjusting if necessary. (Photo 3). Do the same with the compound slide, winding it the full travel and set it so there is no deviation on the clock gauge. Put the sine bar into the tool holder and bring both the sine bar rollers to rest on the silver steel bar, tighten up the tool holder. (Photo 4). Wind the sine bar away from the silver steel bar, slacken the compound slide, hold the right size spacer under the headstock end roller, and with the use of the cross slide, gently turn till the right hand roller touches the silver steel bar, tighten up the compound slide, and recheck. (Photo 5). To turn external tapers, the spacer is placed under headstock end roller, for internal tapers, place under the tailstock end roller. The compound slide is now set to the correct angle to turn a No2 Morse taper. The knurled screw has been made, in case the taper needs at some point to be set with feeler gauges. The screw is brought to rest on the silver steel bar and then with the compound slide slackened off screwed in till the correct gap is obtained between roller and silver steel.

The work can now be put back in the lathe ready for finishing, and set up using the auxiliary centre. The entire taper turning is carried out with the compound slide, and when turning a No2 Morse taper, the compound slide has just enough travel. (Photo 6). When working on larger tapers they will need cutting in two stages. Some finished tapers are shown in photo 7.



WHEELBUILDING DIY STYLE



1. The rebuilt wheels highlighted the need for attention elsewhere.

Dave Fenner renews the wheel rims on his ageing Bonneville.

rounded wheel rim. **Photos 2, 3 and 4** illustrate making the parts, and the finished jig. I also used a piece of aluminium tube about 3in. diameter to ensure that the hub sat squarely on the jig base.

The second jig was built up from offcuts of one-inch square steel tube, forming a fork arrangement with clamps to locate the axle, and allow the wheel to be rotated.

Dismantling

After removing the front wheel I also photographed it face on (**photo 5**) and also prepared a sketch to give a clear record of the spoke-lacing pattern, **diagram 1**. The sketch was made to cover about half the circumference, and included the position of the valve. A small centre pop was also made in the hub radially in line with the valve as a positioning aid for later rebuilding. The brake disc was then removed, as this would be skimmed. The bare wheel was now set up in jig 1. Initially the arms were swung clear and the nuts run down below the level of the rim. The arms were then moved inwards so that the threaded rods just contacted the rim and the bolts tightened to lock them in position. The three nuts were then screwed up to just contact the rim. The heights were then checked and adjusted until all were equal. This may be seen in **photo 6**. This height was then noted. It was then possible to proceed with further disassembly.

I recalled many years ago finding that bicycle spokes came in very useful for parts of control line model aircraft, and thought it might be an idea to try to unscrew, rather than butcher, the spokes with an angle grinder. Thinking that thirty years of exposure and corrosion might raise a few problems, I chose not to use my shiny new spoke key, but carved up the gadget shown in **photo 7** from an offcut of $\frac{1}{2}$ in. AF hex steel bar. Surprisingly, it worked and all front wheel spokes came away without damage. (The rear was another story, and the gadget fractured on the second spoke. Angle grinder to the rescue.)

Brake disc

The intention was mentioned earlier of skimming the brake discs. Originally the discs had been plated, however at the front, the chrome had worn through in a non-uniform manner. This meant that when riding and braking, a slight cyclic variation in brake effect could be detected. Modern bikes often have their brake discs located on bobbins, which I believe is

Background

Some months ago, it was mentioned that I had acquired a 1977 Triumph Bonneville (**photo 1**) from Alan Rohers who runs Lanivet Motors at the other end of the country, near Bodmin in Cornwall. As I expect to have this machine for a number of years to come, I indulged in a fairly comprehensive strip down and rebuild over the winter months. Various jobs have been tackled, including replacing the valves and guides, and undertaking a rebore on the engine, with assistance from Alex Fairbairn, prior to rebuilding with plus 0.020in. pistons.

Thirty years after manufacture, it is probably asking a bit much for the chrome to be in perfect condition. In reality it actually was not too bad but I decided that, in the first instance, the wheel rims should be replaced. I had earlier obtained various engine parts from Ray Fisher's Britbits Company. For rims and spokes though, he referred me to Dave Benn who runs Brickwood Wheel Builders. On his advice, I checked the existing rim specification and also the spoke gauge and lengths for both wheels, before posting off the order for these. He had advised that there would be a two to three week lead-time, as they buy in the rims as unchromed blanks. They then polish, form the dimples and then punch the holes for the spokes. After this, the rim is sent to a specialist plating company to be chromed. The punching angles are specific to the wheel in question and thus each is produced to order. Dave makes no pretensions to using modern CNC technology. His punching machine is of an older but more versatile type so that on occasion he receives requests to do work that larger companies with more modern equipment are unable to undertake. A couple of weeks later, a large box arrived by carrier, containing the rims, stainless steel spokes and a spoke key.

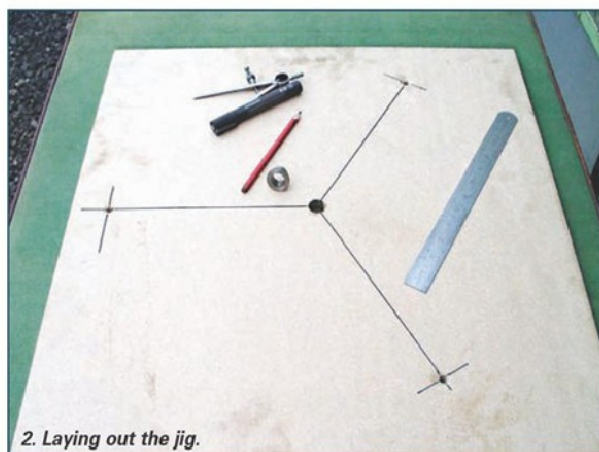
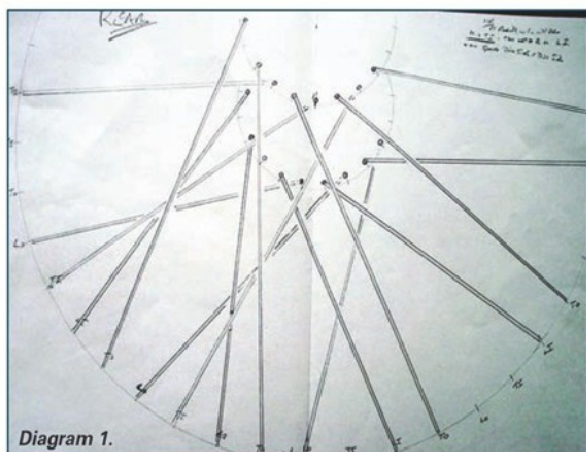
Preparatory work

Before embarking on this project, I had never built a motorcycle wheel, although I had, many years ago, built up a cycle wheel. One friend recommended that I consult the excellent Haynes book *"The Vintage Motor cyclist's Workshop"* by Radco, which gives good advice on the topic. I had also taken the opportunity to do a bit of brain picking when talking to Dave Benn. Two jigs were prepared. The first was set up before dismantling the old wheel to establish the rim offset and ensure reasonable concentricity at the initial build. The second allows the assembled wheel to be rotated, checked

for true running and corrected for errors in swash and concentricity.

Jigs

The first jig is built to the teachings of Radco, and is basically a sheet of 19mm MDF on which the wheel can be placed. A hole is bored centrally through, either to be a close fit on the axle, or fitted with a bush to give fairly accurate positioning. Three arms are prepared, cut drilled and tapped to carry lengths of threaded rod. The arms are attached to the base by bolts from the underside. On each length of rod is screwed a "nut" of sufficient size to support the



intended to allow slight movement sideways, thus correcting swash discrepancy. This technique was not thought of in 1977, so the discs are each retained by four bolts, which pass through and clamp up the elements of the hubs. As when machining car discs, it is important to ensure that the disc is held on the correct location diameter and perhaps more importantly with the location face suitably positioned. It is also necessary to

check what minimum thickness is specified after machining.

As a brief digression, it may be noted that if a brake disc is machined with perfectly uniform thickness, but with a swash error, then the effect in use, will be to move the pads back further. The symptom that will then result is greater (perhaps excessive) handle or pedal movement when the brakes are applied.

Here, I chose to use the three jaw chuck tightened on the internal diameter of the now cleaned location face, and pulled this face hard up to the chuck by means of a length of threaded rod passing through the headstock. The tie bar parts rescued from the scrap bin are shown in **photo 8**. This

set up may be seen in **photo 9**. Having now ensured that the work could not move and was running true, work was started to clean up the front face. Having completed this, and without disturbing the job, the rear face was also tidied up with the removal of just a few thous of metal. Following this sequence would ensure that there was no thickness variation around the disc. To get to the rear face, I unearthed a tool welded up some time ago to carry out the same operation on car brakes. The second part of the skimming operation is shown in **photo 10**.

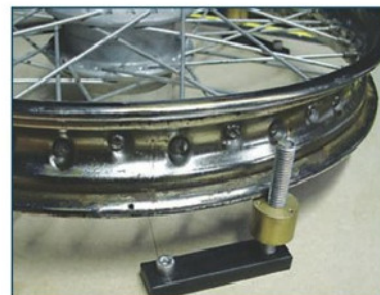
In the amateur shop this will probably always be a two stage process, however in a professional recon shop, I have seen a



3. Drilling the arm.



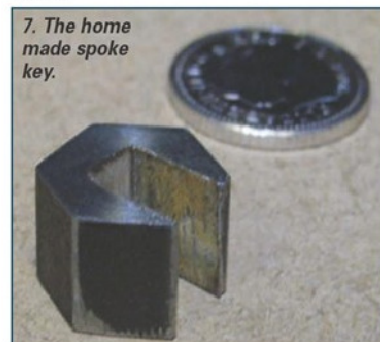
4. The completed jig.



6. Jig 1 adjusted to accommodate old wheel.



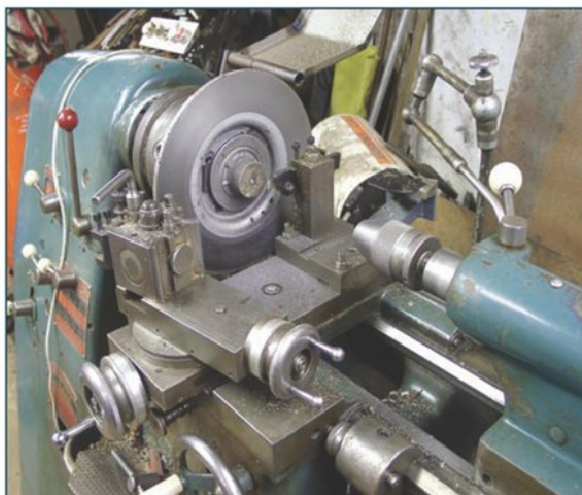
5. Showing the lacing pattern.



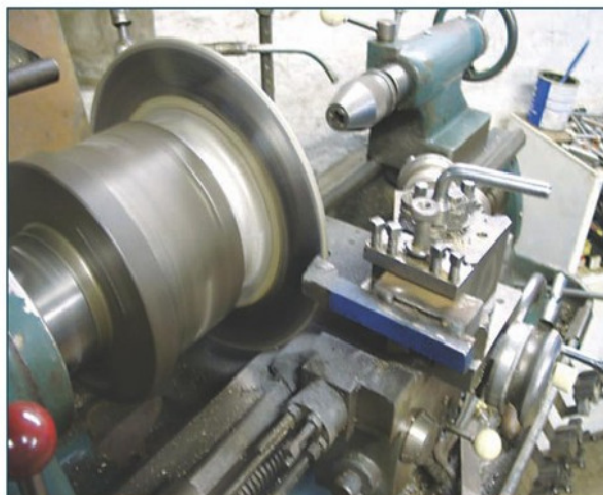
7. The home made spoke key.



8. Tie bar assembly to retain disc in chuck.



9. Set up showing disc held in chuck with screwed rod retention.



10. Skimming the rear face of the disc.



11. Spokes fitted to the hub.



12. Hub, rim and spokes assembled in the jig.

purpose built lathe with provision for two tools to reface both sides of a disc simultaneously.

Back to the wheel

Faced now with a bare hub, it was a much easier job to clean off the old paint, corrosion deposits and general grime. Being made of aluminium alloy, it was first given a coat of etch primer then primer and metallic silver topcoat. My next thought was to place this in the Radco jig and lace up the spokes according to the sketch and photo. The reality is that you cannot do the job this way round due to the clearance needed below the hub for pushing each spoke into its allotted hole, so the initial procedure was "hold it in the air and feed in spokes until the arm gets tired, then put it down, then repeat". A better arrangement came to mind and is shown in **photo 11**. Eventually all spokes were in place and the hub and spokes could then be positioned in the jig (**photo 12**). There was then a bit of fiddling to get the spokes into their positions in the rim and the rim located on the height control

nuts, and abutting the threaded rod. Again repeated reference to the sketch ensured that it went together correctly.

It was then a case of progressively tightening (slight tension only at this stage) the spoke nipples using a screwdriver modified for the job, whilst at

the same time ensuring that the height was not upset. Here, the dimension noted previously served as a double check. The wheel was then transferred to the fork jig, and two pieces of strip material clamped in place to give indications of concentricity and swash errors. This set up is illustrated in **photo 13**. Adjustment then continued tightening and slackening as necessary until the wheel was running within about fifteen thou. And all the spokes emitted a satisfactory "zing" when tapped.

The final part of the metalwork was to trim off the excess length of the spokes back to flush with the nipples. This was done with a Minitool and cutting disc. It was then possible to fit a new rim tape, followed by the tyre and tube.



13. The wheel in the fork jig with plates clamped to aid setting.

Suppliers

Britbits 185 Barrack Road, Christchurch, Dorset, BH23 2AT Tel 01202 483 675
Brickwood Wheel Builders, Old Brickwood Farm, West Grimstead, Salisbury, Wilts, SP5 3RN Tel. 01722 712701

HYDRAULICS

Mike Houghton takes a brief look at basic pneumatics and hydraulics, with reference to the home workshop and surplus industrial equipment that might find its way there. Please read the earlier pneumatics article in MEW issue 123 first.

The name "hydraulics" derives from the Greek hydraulikos meaning "water organ". More generally, hydraulics is now considered a part of fluid power engineering. The hydraulics under review here are those concerned with mineral oil, or synthetic substitutes. (Phosphate esters, glycol mixtures or even water in oil emulsions or micro emulsions). Mineral oil is very convenient because its viscosity is much higher than air, which reduces leakage even at very high pressures, and of course, it is a lubricant, reducing wear on moving parts, pumps, valves and cylinders.

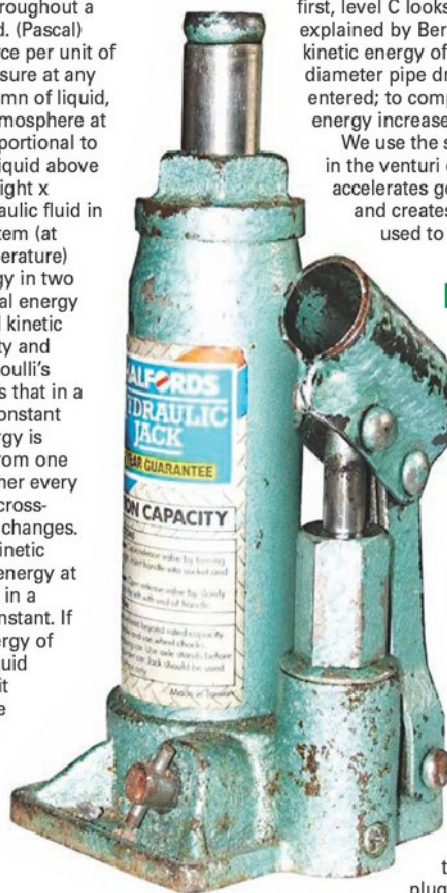
Differences from air (pneumatics)

The major difference between Hydraulics and Pneumatics is the almost complete absence of change in volume of a hydraulic fluid with change in pressure. (Actually it's about a 1% volume decrease per 100-bar increase in pressure). If you have ever had air in the hydraulic braking circuit of your car you will know how even a small quantity of air in the hydraulic fluid will cause a soft pedal response and dramatically worsen braking efficiency. This is because air entrained in the hydraulic circuit is so much more compressible than oil. Of course, when you bleed the brakes to remove the air, the braking performance returns. Hydraulic circuits generally operate at pressures far higher than pneumatics, so the absence of leakage is important and the higher pressures have consequences for the design of any valves that may be used to control hydraulic circuits. Whilst Pneumatic systems are "once through", the expanded air being released to the atmosphere, Hydraulic circuits are closed. All the low-pressure fluid is returned to a tank once it has been used. It is then reused, probably after filtration. The cleanliness of hydraulic fluid is very vital to reduce wear on the closely fitting components in pumps, valves and cylinders, so good filtration is very important. Hydraulic fluids are much denser than air. The density of water is approx. 1000Kg/M³, lubricating oil is about 860 Kg/M³ and air 1.2 Kg/M³ at room temperature and atmospheric pressure.

Basic hydraulics

Liquids have no shape of their own. They adopt the shape of the bottom of the container they occupy. Pressure is

transmitted throughout a confined liquid. (Pascal) Pressure is force per unit of area. The pressure at any point in a column of liquid, open to the atmosphere at the top, is proportional to the height of liquid above that point. (Height x density). Hydraulic fluid in a working system (at constant temperature) contains energy in two forms, potential energy (Pressure) and kinetic energy (Density and velocity). Bernoulli's principle states that in a system with constant flow rate, energy is transformed from one form to the other every time the pipe cross-sectional area changes. The sums of kinetic and pressure energy at various points in a system are constant. If the kinetic energy of the flowing liquid decreases, as it must when the pipe becomes larger and the velocity decreases, the liquid pressure will increase to compensate. Consider dia. 1.



1. 2 tonne Bottle Jack.

Fluid in the bottom of the very large water reservoir A (a lake) has a pressure at its outlet to the pipe E equal to the height of liquid in A and has no pressure where it exits the horizontal pipe E. The pipeline E is of uniform diameter except for a short section of larger diameter below the vertical standpipe C. The level of water in the three open vertical standpipes B, C, D indicates the pressure of water in the pipe E. Level D is lower than B and is in turn lower than A because of frictional losses in the pipe as the water flows through it. (Pressure drop, ΔP) At first, level C looks to be too high, but is explained by Bernoulli's principle. The kinetic energy of the water in the small diameter pipe drops as the wider pipe is entered; to compensate its potential energy increases.

We use the same effect, in reverse, in the venturi of a carburettor. Air accelerates going through a venturi and creates a vacuum that can be used to suck up liquid fuel.

Pressure drop

Pressure drop, ΔP , occurs in all hydraulic circuits where the fluid is moving. ΔP is caused by a number of factors that restrict fluid flow. If the flow is laminar (streamlined), the pressure drop is smaller than if the flow becomes turbulent. High liquid velocities, abrupt changes in pipeline diameter and lower fluid viscosity, can cause turbulence. All control valves introduce a pressure drop and it's important to size them correctly. Orifice plugs can be deliberately placed in circuits to generate a ΔP , if required.

Metric Units

Two triangles, diagrams 2 and 3 can be useful to remember the relationships between Force, F; Pressure, P and Area, A; Force = Pressure x Area etc
In metric Units: -
F = Newtons (N)
P = bar (1 bar = 10N/cm²)
A = cm²
In the second Triangle we relate Speed, S; Flow rate, Q; and Area, A.
Flow Rate = Speed x Area
In metric units
Q = cubic centimetres/minute (cm³/min)
S = centimetres/minute (cm/min)
A = square centimetres. (cm²)
Note: 1 bar pressure is 14.7psi

Diagram 2

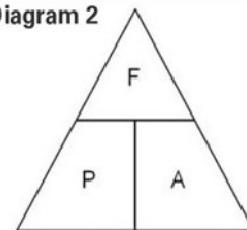
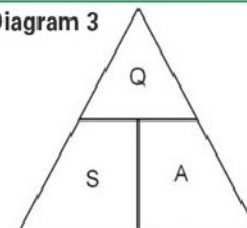


Diagram 3



2. 12 tonne pipe bender.



3. Cylinder press.

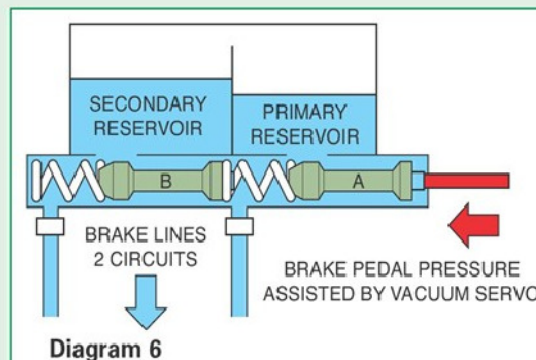
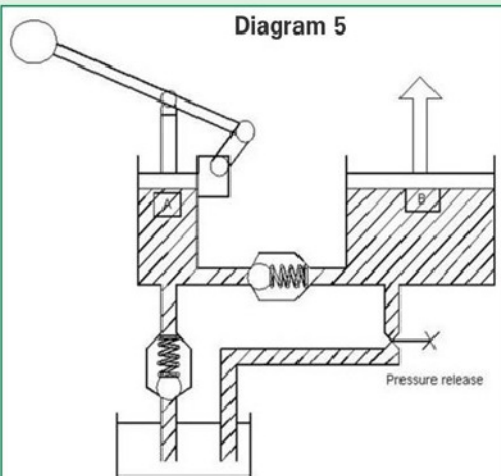
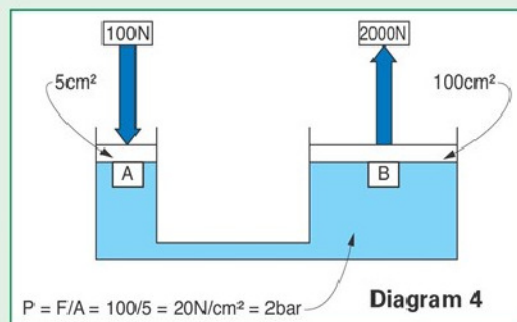
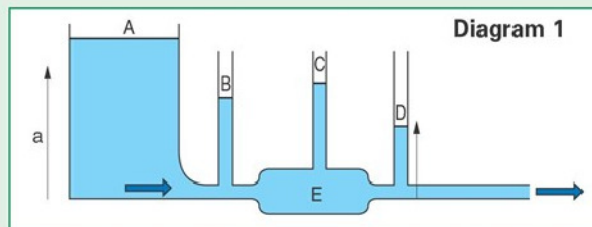
Mechanical advantage and simple cylinders

Imagine two hydraulic cylinders with closely fitting pistons of different diameters connected by a pipe as shown in **Diagram 4**. Cylinder A has an area of 5 cm² and cylinder B 100 cm². The mechanical advantage is 20. A force of 100N applied to piston A creates a pressure of 2bar in the fluid and a force of 2000N to the piston B.

Our simple example is very close to the hydraulic car jack you probably have in your garage. **Photo 1** shows a basic 2 tonne car jack, sometimes called a bottle jack. In this instance the smaller cylinder is

10.7mm dia. and the larger one 22mm dia. The smaller cylinder (ram) stroke is 24mm (max) so delivers about 8.07cm³ of oil to the larger cylinder per stroke, raising the larger piston 1.16 cm. The maximum lift (stroke) of the larger piston is 125mm. The bottle casting contains the oil reservoir and the stroke of the larger piston is limited by an oil return hole that is exposed when the piston is fully extended. Hence you cannot pump the larger piston out of its cylinder. The mechanical advantage provided by the two pistons is small (22/10.7) but is amplified by the use of a 450mm long bar and a 30mm pivot to ram distance. Adding 2 simple non-return valves (check valves) and a manual return valve completes this simple hydraulic circuit. See **Diagram 5**.

I'm told that new EU regulations require overpressure relief; this is not included in my diagram. There are many variations on this simple circuit that may find their way into our workshop world. The car trolley jack is a similar arrangement, but on wheels and with the hydraulic cylinder mounted horizontally. The pallet truck uses the same basic principles to lift a pallet and its load off the floor and very effective they are too. The humble car jack can be adapted to other tasks in the Home Workshop. In some ways it's more versatile than a bench vice, but has to be used along with some form of frame to complete the press. Most bottle jacks are designed to be used vertically. They can be used: -





4. Adapted bottle jack.

1. As a metal bending press, see **photo 2**, a 12 tonne pipe bender, which is a beefed up version of a bottle jack in a frame with pre-formed pipe bending tools.
2. For pressing bearings into housings, see **photo 3**, using a separate hydraulic cylinder pushing downward. The hand operated primary cylinder isn't shown here. The two cylinders are connected by the black flexible hydraulic hose.
3. For broaching keyways and square holes in pulleys, hand wheels etc using a push rather than a pull broach.
4. For lifting heavy stuff off the floor with an S shaped adaptation. See **photo 4**. Many heavier duty hydraulic lifting devices employ two rams (pistons) to pump on the downward and upward strokes of the handle. My 1 tonne engine lifter is shown here lifting a small Centec 2A mill on its industrial stand. See **photo 5**. As you can see, it's basically a hydraulic cylinder pushing up an adjustable length jib with a hook and rope attached. **Photo 6** shows a close up of the two rams employed on this lifter. This gives a lifting force on both the up and down strokes of the operating handle and hence provides a faster lift. Engine lifters are very useful for shifting workshop machines, but they do need a lot of floor space for their legs. For stability the load must be located between their legs, which are wheeled. In the case of this Centec lift, the machine was lifted off the floor and planks placed across the lifters legs, the machine was lowered so some of its weight was on the planks, then the whole lot moved to its new position with the aid of toe bars and levers. Final positioning was done on rollers, as the space available was limited. When I finally sold this mill, the same engine lifter was used to lift it horizontally onto a flat bed low loader.

Brake Systems

Automotive brake systems are pretty familiar to most

of us and are examples of single acting cylinders, but with many added extras. **Diagram 6** is a highly simplified version of a brake "Master Cylinder" which is mechanically operated by your brake pedal. As you can see there is one cylinder but two pistons, two oil reservoirs and two braking circuits. The two spring-loaded pistons A and B transmit braking pressure from the foot brake pedal to the two hydraulic circuits. For security these braking circuits are crossed, i.e. the front left operates with the rear right and the front right operates with the rear left. Should one of the circuits fail by developing a leak, the other circuit should still work, but with less effective braking. Most Master Cylinders now have servo assistance to reduce brake pedal pressures, essential for disk brakes, heavier vehicles and drivers wearing high heels. The servo vacuum is taken from the inlet engine vacuum through a one-way valve and operates on a large diameter diaphragm. Under non-braking conditions, the vacuum is applied to both sides of the diaphragm. On applying brake pedal pressure, air is admitted to one side of the diaphragm and the vacuum helps suck the brake pedal inward as you push on the pedal. If you have a vehicle with a turbo there will be no engine inlet vacuum so a separate electric vacuum pump has to be provided. It might be worth looking for these at auto parts re-claimers?

The complications of the hydraulic braking system don't end there however. The hydraulic braking pressure is normally distributed unequally to front and rear brakes. Usually 70:30. A proportioning valve is used to achieve this ratio and if disk brakes are used on all the vehicle wheels, they usually have smaller bore pistons and cylinders on the rear wheels. Normally the rear brakes are applied a fraction of a second before the front to assist in straight line braking, using a

hydraulic metering valve that applies pressure to the front disk brakes after the circuit pressure has risen above a threshold value.

To add a further dimension to this description, remember that Advanced Braking Systems (ABS) sometimes called anti-lock braking systems are now common and mandatory in the EC. ABS systems impose hydraulic valves with solenoid control between the master cylinder output hydraulic lines and the brake cylinders.

These systems are computer based and monitor the speed of each wheel with a pick-up coil so that the computer can rapidly modulate (turn on and off) the braking force applied to each wheel should any wheel start to lock up in a steering and braking situation. (ABS



6. Detail of two rams on engine lifter.

only operates above a minimum speed). Modern ABS units have all these functions integrated into one small unit and these will be available at a breakers yard near you, for experimentation purposes of course. Google 'Bosch ABS' for more information. The first commercial ABS systems came from Dunlop, not Bosch, but were all hydraulic, as electronics were not as well developed in the 1950's.

Yet another complication in this automotive hydraulic story is the introduction of Electronic Stability Control (ESC). (Remember the Mercedes A series and the ELK Test?) ESC systems add to ABS control by sensing the acceleration or deceleration and yaw of the vehicle and feeding this data into a computer that controls the ABS unit solenoid valves.

Disk brakes

Most automotive disk brake systems are now a single hydraulic cylinder/ piston for each wheel, pushing two or more friction pads onto a cast iron disc. Apparently 90% of these disks now come from China! The cylinder is mounted in a calliper, which has some sideways movement to allow it to centralise on the disk. The disc piston diameter (50 to 90mm) is much greater than that of the master cylinder so the distance the friction material, the pads, travel has to be very small. Cast Iron is used for the discs because it retains its strength even when very hot, red hot in fact.

Mobile plant hydraulics

The classic example of applied hydraulics seen on a road or a building site near you is the "JCB", or backhoe in US parlance. See **Photo 7**. These familiar mobile machines make extensive use of hydraulics to control and precisely operate their hydraulic cylinders in their front buckets for material removal, their rear buckets for digging trenches, hydraulic outrigger legs to stabilise the machine and for steering the vehicle. These are complex



5. Engine lifter.



7. JCB type earth mover.

hydraulic machines, as the following basic description of some of their features will show. The general principles described below also apply to bigger earthmovers, many tracked vehicles, some mobile cranes and a lot of agricultural equipment. (Combine harvesters etc.)

Control valves

Hydraulic control valves tend to be spool types rather than poppet valves. (See the

earlier Pneumatics article for the reasons why.) Consider my simple **diagram 7** of a centre-off spool valve. This is a 4 port 3 position spool valve shown in its centre off position, where ports T (Tank) P (Pressure) and A and B ports are not connected. Pushing the spool to the left connects P to A and B to T. Pushing the spool to the right, past the centre not connected position, connects A to T and B to P. The symbol for this arrangement is **diagram 8**. I have added springs to the spool valve to cause it to be normally in the central

position, and an operating lever. The three central compartments of the valve diagram describe the three possible valve positions. I have illustrated a closed centre valve, but open centre valves also exist.

A typical application of a closed centre valve might be as **diagram 9**. The blue lines indicate hydraulic oil returning to the tank and the red lines hydraulic oil under pressure. In my drawing a motor driven pump draws hydraulic fluid from the tank through a filter F. The relief valve R directs any excess Hydraulic fluid back to the Tank. I have drawn the spool valve in its central position and the double acting cylinder is in an intermediate position. The fluid drawn in green is not moving and is trapped by the spool valve. In this position the cylinder could support a considerable load without moving, e.g. one of the hydraulic legs of the JCB. If the cylinder were full of air this would not be the case due to the difference in compressibility. When the spool valve is displaced to the left or right the hydraulic cylinder will extend or contract with low-pressure oil being returned to the tank.

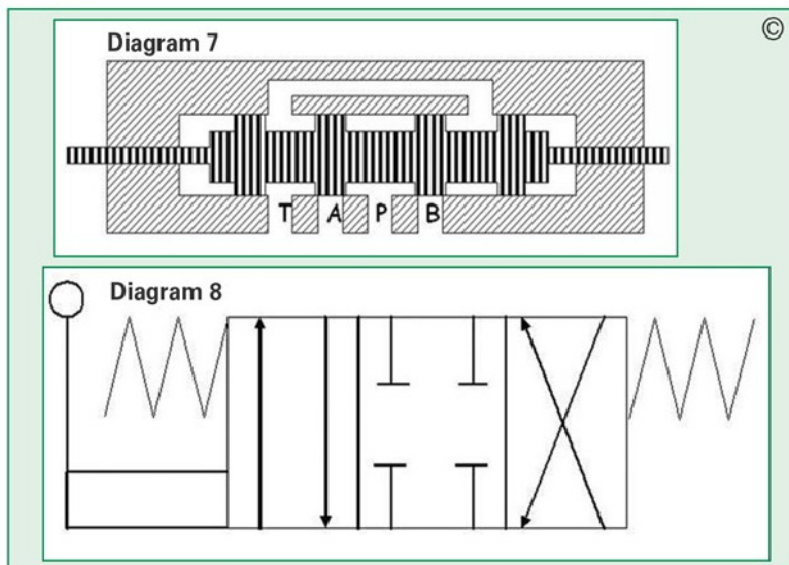
My drawing has several flaws. In our JCB there would be several hydraulic cylinders and control valves operating independently of each other, but sharing the same motorised pump. Allowing the pump to dump unwanted pressurised hydraulic fluid back to the tank via the relief valve is a waste of energy, (hotter oil) and would be overcome by fitting a variable displacement pump that adjusts its output volume to meet the hydraulic demand. Our JCB engine revs up when a bucket is working hard.

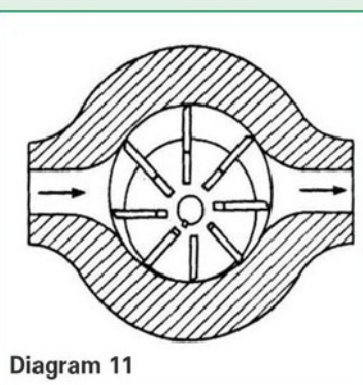
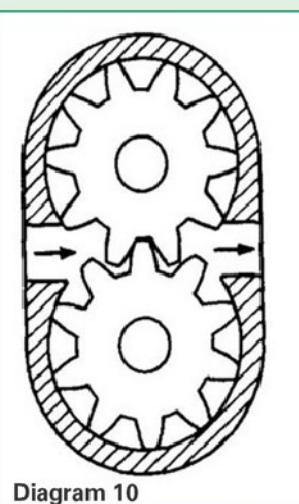
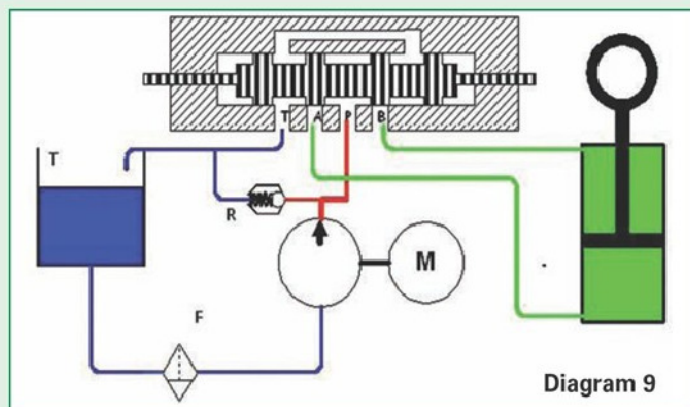
Solenoid valves

Spool valves, of which there are many different types, are often operated by solenoids. This particularly applies if some form of computer control is required and, or the valve is to be remotely operated. Remember the ABS unit earlier. Hydraulic valves are often called upon to operate in a sequence and some form of computer control is ideal for this. Solenoids have a few disadvantages, one of which is the available force to pull or push of about 10kg max. In a powerful hydraulic system with perhaps 170 bar (2500psi) and a flow rate of 80 litres per minute, it's usual to use a pilot solenoid valve. The pilot can be a separate smaller solenoid operated valve sending hydraulic fluid to operate a larger valve, but more than likely the two valves will be integrated into one, with a cost saving. To cut down on pipe work and save cost, many modular valves are often combined into a manifold. Google "CETOP modular valve". Where a spool valve cannot handle the flow required, a pilot operated cartridge valve might be used. Google "pilot operated cartridge valve".

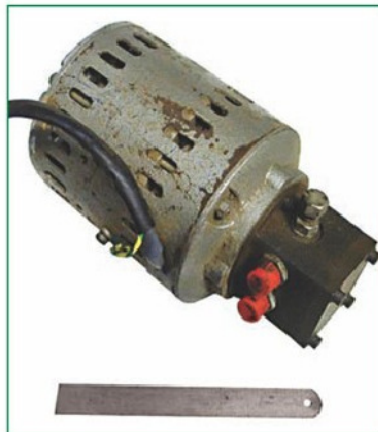
Hydraulic pumps - Gear type

Photo 8 is a small electrically driven hydraulic gear pump. It has internal pressure relief via the chromed adjuster on the top of the gear pump block. The 6in. rule gives an indication of size. **Diagram 10**





shows a simplified drawing of a gear pump. This unit has very closely meshing gears with small clearances between them and the outer case. Input oil travels between the gear teeth and the outer pump casing. This type of pump is suitable for output pressures up to about 180Bar or 18Mpa. It is relatively insensitive to dirt, cheap to manufacture and is reliable. In order to prevent cavitation (see later) the pressure on the suction side should not be less than about 0.2bar below atmospheric. (20kPa). Some gear pumps have three meshed gear wheels delivering twice the capacity of the two wheel variety.



8. Electrically driven gear pump.

Gear pumps come in two varieties. External, shown above, and internal where one smaller driven gear wheel runs inside the other, both still rotate, but in the same direction this time and a crescent shaped separator is added between the two gears. Google "internal gear pump" or "Gerotor" if you would like more details. The internal gear type has been used in automotive engines to pump lubricant. Normally engine oil pumps use a simplified rotor design (Gerotor) and no crescent shaped separator. This is a low-pressure design, maybe 5-bar max. It isn't usually possible to vary the output of a gear pump, except by slowing the drive down or fitting a variable over-pressure relief valve.

Hydraulic pumps - Vane type

Vane pumps are suitable for discharge pressures up to about 200bar. **Diagram 11** shows a simplified vane pump. The advantage of a vane pump is that the oil delivery is pulse free and quiet. By moving the pump body relative to the rotor centre, the output of the pump can be varied from zero (concentric) to maximum. (eccentric). The design shown here is unbalanced because the pressure on the outlet side of the pump presses the rotating assembly towards the inlet side with a massive force. Adding more inlet and outlet ports across different diameters allows these pressures

to be balanced out and make life easier for the bearings. Google "balanced vane pump" should you like to read more details. The design of the vanes used in these pumps is considerably more complex than my simplified diagram shows. The vanes have to be pressed outward against the pump case to prevent leakage around the vane ends. One might expect a small spring, but because of the high pressures involved, a small piston under each vane, supplied with oil at the outlet pressure, is actually used to force each vane outward. Our simple vane pump has suddenly got a lot more complex!

Hydraulic Pumps - Piston Motors

For hydraulic pressures above 250bar, piston motors are most commonly employed. Several types are used, all are multi-piston. 5,7,9 and 11 pistons seem common. **Diagram 12** shows a simplified axial piston pump with rotating swash plate. The swash plate is driven by a shaft and the angle of the swash plate determines the length of stroke of the pistons. This type of pump can be driven in both directions but cannot be used as a hydraulic Motor. **Diagram 13** shows a similar axial piston pump with a rotating barrel that can serve as a pump or a motor. The swash plate is static but can be varied in angle to adjust the pump stroke and output. The yellow end plate is static and contains all the inlet and outlet ports. V is a vent for the pump case. My **diagrams 12** and **13** are very simplified. Although I have shown only one piston several will actually be present, usually an odd number.

These motors are beautifully constructed and given a supply of clean fluid will last a very long time.

To achieve greater pump stroke length variation, bent axis piston pumps can be used. Google for more information or refer to the resources list at the end of the article. Piston pumps have the highest volumetric efficiency, over 98%, and can be used at the highest pressures.

Pump control

In many situations, hydraulic pumps are only required to deliver their maximum pressure and flow on demand. By varying the pump stroke, perhaps by varying the swash plate angle, a servomechanism can adjust the pump output according to demand. Should an engine drive the pump, as with our JCB, a further feedback loop will be required to control the engine throttle. Many complex pumps incorporate pressure sensing or load sensing systems, which I won't go into here.

Actuation cylinders

Our JCB utilises several hydraulic cylinders and pistons. These will all have some form of deceleration of the piston as they approach the end of their travel. In the pneumatics article, I described cylinder cushioning to stop the piston slamming into the cylinder ends. The hydraulic

version is similar, with extensions to the piston ends covering ports close to the end of the travel. Oil can then only escape via a small orifice, this causes a backpressure on the piston and it is decelerated. The system works in reverse to limit acceleration away from the end position.

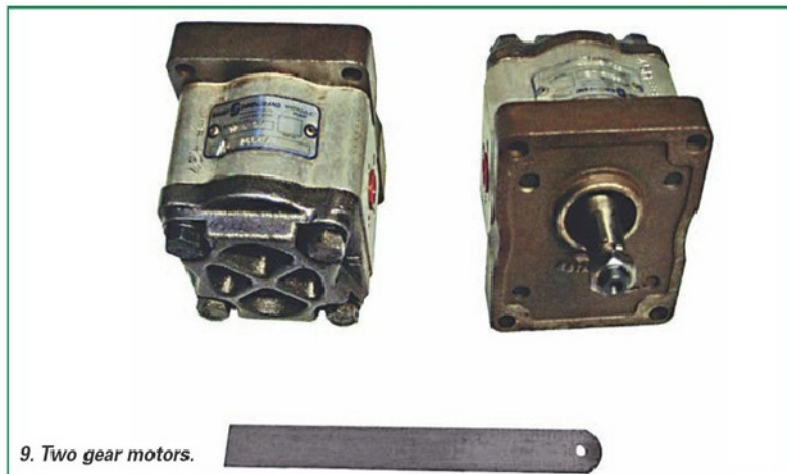
The high working pressures of these actuation cylinders has lead to the development of very advanced seals for all the moving parts. Cylinders and piston rods are invariably ground, thick chrome plated and then ground again to ensure a mirror surface finish and excellent concentricity. We can benefit from these materials being commercially available (or second user). I have recently obtained some new chromed hydraulic bar to use as bed bars on my Quorn tool and cutter grinder in the hope that they will be corrosion resistant and overcome "stiction" (stick-slip) for which this machine is infamous.

Hydraulic motors

Photo 9 shows a pair of gear motors. They are each rated at over 10hp (7.46kW) despite their small size. There is a 6in. ruler in the bottom of the picture for size comparison. Gear and vane pumps and some piston pumps can operate equally well as hydraulic motors. The power available from a physically very small motor is amazing and explains why they are sometimes seen incorporated in loco bogies. They are also very controllable and reversible.

Radial piston motors are commonly used in winches because they can deliver very high torques at low rpm, often without the need for a gearbox. Generally, the greater the number of pistons, the greater the torque. The arrangement of pistons and cylinders is similar to a radial aero engine. Google "radial piston motor" to get more details. The same design can also act as a hydraulic pump. Internal radial piston motors also exist and are used in high power, high torque applications. Google if you want to read more. Connecting a large capacity motor to a smaller capacity pump is a useful method of bringing about a speed reduction. The relationship between the various units of power and torque are as follows. Power = pressure x flow rate

To convert from SI units (Pascal, time in seconds and flow in cubic metres) to more



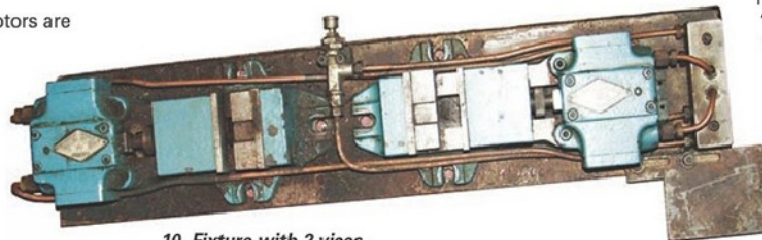
9. Two gear motors.

useful units (pressure in bar and flow rate in litres per minute) becomes: - Power, Kw = (pressure x flow rate) / 600
Torque, Nm = force x distance

The pressure intensifier

Connecting two pistons of different diameters together provides a neat way of increasing hydraulic pressure. **Diagram 14**, operation of valves A, B, C and D.

Step 1) allows the high-pressure cylinder to be filled with oil from the motor driven pump and oil displaced from the low pressure



10. Fixture with 2 vices.

cylinder to be returned to the Oil Tank. Then step 2) Switching the valves allows the low pressure cylinder to push the high pressure piston down, delivering high pressure oil to the point of use. In smaller intensifiers, all these valves are integrated into the pump unit and operate automatically. Pressures up to 3,000 bar are possible from commercial units. Smaller size intensifiers are used to provide clamping pressures for hydraulic vices and hold down clamps or cylinders, during machining. Industry uses these for speed of clamping and unclamping and to preset clamping forces, (less damage to the work piece). **Photo 10** shows a pair of

small vices from a milling machine table. These are actually pneumatic but they could equally be hydraulic. Each vice has 2 pistons and cylinders operating a cam.

It is possible to operate an intensifier with compressed air driving the low-pressure side rather than hydraulic oil. See my later section on air / hydraulics.

Effects of temperature on hydraulic fluids

Low temperatures cause hydraulic fluids to become more viscous and eventually "freeze". The temperature where the fluid fails to flow under gravity is called the Pour Point. Think of a

hydraulically operated tree harvesting machine in a Scandinavian or Siberian forest. These tracked all terrain machines bear hug the tree trunk, cut it off at ground level, move the trunk to a

horizontal position, remove the side branches and cut the trunk into lengths all in a continuous, swift operation. Nighttime temperatures might easily fall below -40C, that's -40F as well, yet the operating temperature of the hydraulic fluid might exceed 100C during the day when it's working. Quite a demanding specification for the hydraulic fluid! A similar temperature range might be experienced by an aircraft hydraulic fluid, low temperatures at high altitude and high temperatures during landing and take off.

The viscosity of the fluid, its thickness, drops as the temperature rises, and rises as the temperature falls towards the pour

Diagram 12

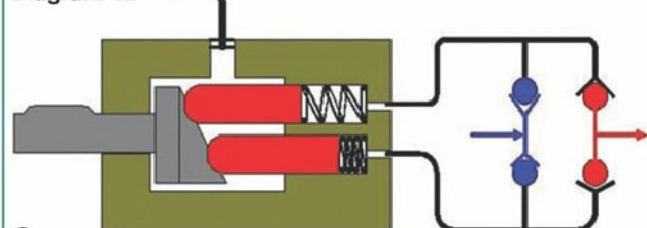
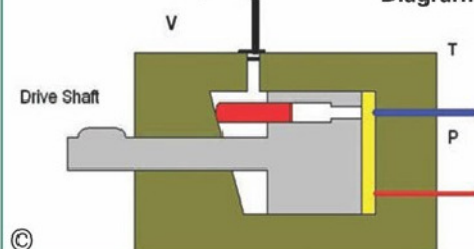
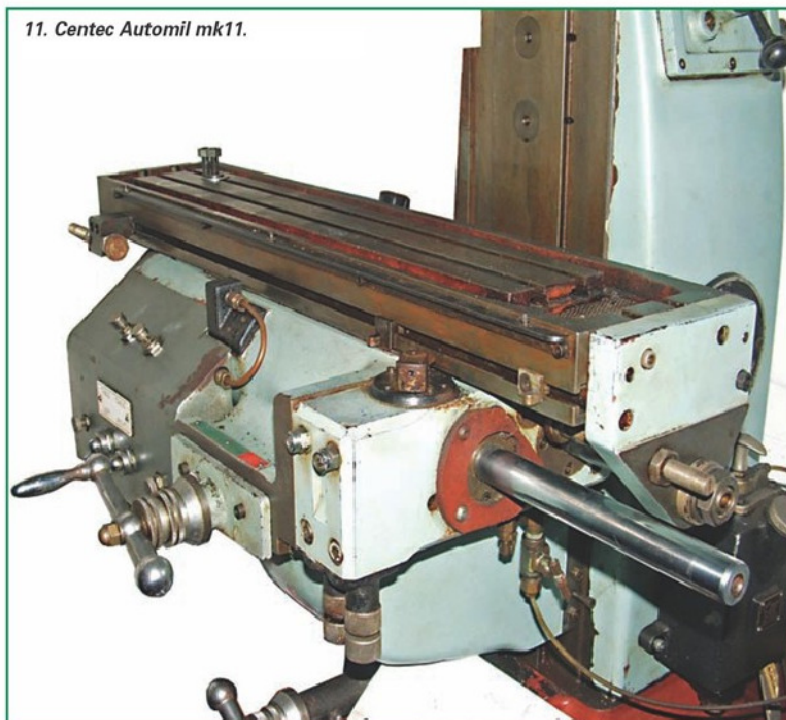


Diagram 13



11. Centec Automil mk11.



point. Its Viscosity Index (VI) describes the way a fluid's viscosity varies with temperature. VI is calculated from measurements of viscosity at 40C and 100C. The higher the VI the flatter the viscosities vs. temperature curve. Some Hydraulic control valves have temperature compensation to allow for change in viscosity with temperature.

There has been a worldwide adoption of ISO viscosity grades, displacing the old SAE system for engine and gear oils. Remember when you bought SAE 20W 50 multi-grade engine oil for the family banger? The thermal expansion, change of volume with temperature, of hydraulic fluids is small, but significant. When closed down and inactive, Hydraulic systems left in the sun, can generate massive pressures and some hydraulic cylinders have automatic over pressure relief.

Cavitation

A very undesirable phenomenon in hydraulic systems is cavitation of the hydraulic fluid. It's usually seen in the suction parts of a pump where a vacuum is created and minute particles of low-pressure gas are produced. When these gases enter the pump, they implode, with the creation of very high temperatures (1000C). Cavitation can damage the hydraulic fluid additives (polymers) and cause rapid erosion of the hydraulic components. Assuming correct sizing of the pump inlet pipe work, blocked filters starving the inlet to a pump are often a source of cavitation.

The effect of pressure on hydraulic fluids

Surprisingly, very high hydraulic pressures can cause hydraulic oils to turn to a solid.

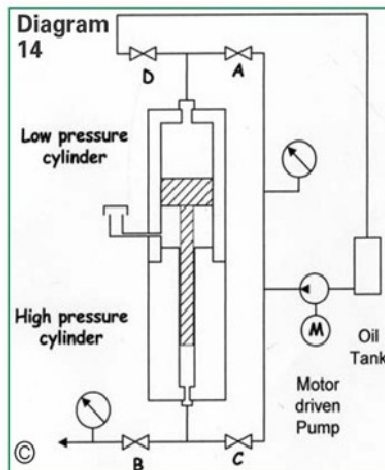
This is a problem likely to be seen in pressure intensifiers where pressures over 1000bar might be generated. Moral: always use the correct hydraulic oil.

Pneumatic/hydraulic systems

Compressed air is often used to create hydraulic pressure where the cost of a Hydraulic pump cannot be justified. A piston with air on one side and hydraulic fluid on the other, rather like the pressure intensifier above, can be used to create the hydraulic pressure. Control of the hydraulic circuit is easier and more precise than a pneumatic one. An example of this is my 1960's Centec Automil, **photo 11**, which has the table X-axis movement controlled in both directions by a pair of hydraulic cylinders driven by compressed air. You can see one of the chromed cylinders with its cover removed in my photo. Adjustable hydraulic oil flow restrictors control the rate of table travel. The table travel distance is controlled by adjustable stops that switch a hydraulic rotary valve. The closing of air bleeds controls automatic reversal to the right or left. See **photo 11** for some of these features.

Hydraulic pipe, flexible hoses and fittings

In view of the very considerable pressures and consequently hazards involved, it's best to play safe and get pipe, hose and fittings that are correct for your intended maximum pressure and temperature. Consult an expert before you start. Fabric reinforced hoses should be avoided. There are many schedules for hydraulic hoses and pipe. Both hoses and pipes are specified by their outside diameter, the



wall thickness varies with their pressure rating. Standard threads that don't have 100% engagement of the thread will just leak and leaks are dangerous and potentially a fire risk.

In summary

This has been a very hurried run through a very large subject. I have omitted a lot but I hope it has sparked your interest to learn more and keep your eye out for hydraulic or pneumatic stuff that you could give a new life to in your home workshop. Any comments or questions to mikehaughton@btinternet.com



More reading

A Practical Engineer's handbook HYDRAULICS by G.Tutt. ISBN 1-901672-21-2 Kamtech Publishing
A practical Engineer's Handbook PNEUMATICS by S.Sands ISBN 1-901672-22-0 Kamtech Publishing
Hydraulics and Pneumatics A Technician's Guide by A.Parr ISBN 0-7506-4419-2 Elsevier
Vickers Industrial Hydraulics Manual ISBN 0-9634162-0-0 Vickers
Hydraulics Fundamentals of Service ISBN 0-86691-256-7 John Deere

On the Web

For general reading have a look at the on-line encyclopaedia WIKIPEDIA.
<http://en.wikipedia.org/wiki/Hydraulic>
<http://en.wikipedia.org/wiki/Pneumatic>
 For ISO and BS schematics of hydraulic and pneumatic components try
http://www.roytech.co.uk/Useful_Tables/Drawing/Hyd_Pnue_symbols.html
<http://www.airlinehyd.com/KnowledgeCenter/Symbols.asp>
 For hydraulic oil viscosity try
<http://www.hydraulicsupermarket.com/tempvisc.html>
 Many of the major manufacturers and distributors maintain good websites. You can often download catalogues etc. Parker, Norgren, Bosch, Rexroth, Vickers, Spiraxsarco, Hypro, Festo, HAC etc etc.

MYFORD VM-E CNC CONVERSION ③



1. The milling machine complete with fabricated cover testing a CNC routine on some MDF.

It is now a few months on from the work described in the articles beginning in MEW 118. I have finished the electronically controlled "manual" drive to the three axes and there is a cover to the belt drive on top of the mill, **photo 1** although this is awaiting its topcoat of Myford blue. In the course of this work, I have come across a couple of points which were not initially obvious and which might be usefully shared with anyone using similar components.

If you have read the earlier articles, you may remember that I had based my work on Dick Stephen's write-up of his conversion of the X-3 mill. Unlike him, however, I used Arc Euro stepper motors and drivers because, among other reasons, they were cheaper than the Gecko drives he described. All went well with the CNC side and I was getting a bit cocky about this newly sampled area called electronics. I had assembled the components for the electronic control box to provide "manual" movement of the three axes and was a bit put out when on switching on, there was random movement of the appropriate axis rather than the smooth control which I had witnessed when visiting Dick's workshop. A few checks revealed that nothing obvious was wrong but the randomness seemed to suggest that the direction signal was not being reliably received or was subject to a bit of interference. The first step, therefore, was to look at the cable connecting the box with the stepper drivers. Multicore screened cable is not very easily sourced in small lengths but

Maplin offer a range which seemed to have enough current capacity (0.25A/core) for the signal which I thought was being created or the current drawn by the rotary encoder (less than 100milliamps). I had used six-core cable, as in the original article, with one core each for the step signals to each axis and a common direction core. The other two cores were for +5V and ground.

Faced with the problems described above I decided to separate the three direction signals by using an eight core cable with eight-pin DIN connectors. Eight core screened cable was not available so I purchased some twenty-five core and doubled up eight pairs in order to give me a good margin on current capacity. At this point, I think I can hear the electronically competent among you guffawing. All went well with the assembly but the signal was still random.

The next stage was to by-pass as much cabling and switching as possible and connect the output of the manual control board directly to the step and direction inputs of one of the motor drivers. There was no improvement and given that the drivers and motors were working happily in CNC mode, I concluded that the problem must rest with the manual control unit itself. Telephone conversations with Dick Stephen's and Tony Jeffree suggested that the circuit, which was working for the Gecko drivers, might be giving an output signal current at the low end of what was required.

Diagram 1 shows the circuit diagram for the control circuit taken from the original article. The 7490 integrated circuit in the

Peter Edwards discusses some of the benefits of hindsight.

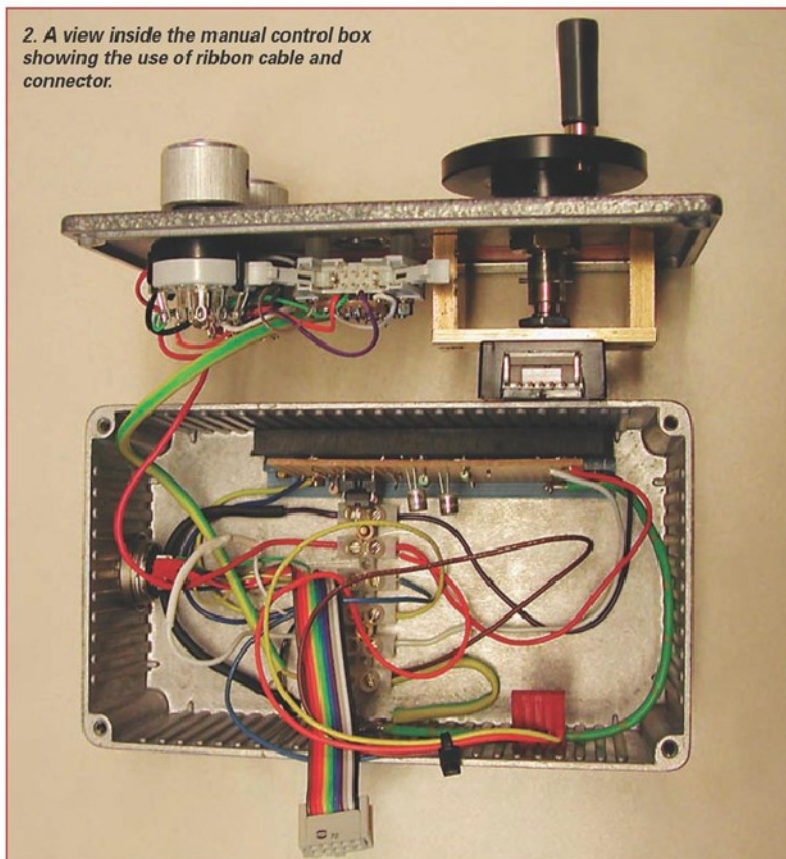
centre was omitted as the Arc Euro stepper motor drivers have selectable levels of micro stepping and that, together with the 2.5 mm pitch of the leadscrews, would give a fine enough control for my needs. If you should be using this chip, however, you will need the input marked in dashed line to terminal 1. This was lost at some stage in the production of the original article.

Channels A and B, in the diagram, carry the signals from the rotary encoder which result from moving the hand wheel clockwise or counter clockwise. The LS7184 chip then converts these into direction and clock pulses, which are output from pins 7 and 8. A 2N2907A transistor then amplifies each of these pulses before being available as Direction and Basic Clock (amount of rotation) outputs. These go to the stepper motor drivers via a selector switch, which directs them to the driver for the desired axis. Resistance R2 controls the current level of the output signal. You will see that it was designed as 1K, which with the 5V available would give a maximum of 5mA output. This was apparently adequate for the Gecko drives although at the low end of their requirement. It turned out to be insufficient for the Arc Euro drivers. Dropping the value of R2 to 300 ohms made a proportionate increase in the output current, which was sufficient to have the drivers and motors behaving as they should. In fact I lowered R2 to 100 ohms, which produced an output still well within the rated level for the transistor and gave a bit of margin for the drivers. Some time after writing the above, I was looking back at an earlier edition of MEW (Number 108). I noticed that Brian Thompson had described this characteristic of the Arc Euro driver in his article on gear hobbing.

The need for repeatedly opening up the box that contains the manual control meant that I needed to do something to tidy up the wiring inside. I eventually used a ten-way ribbon cable, and an IDC socket and connector from Radiospares. (**Photo 2**) This made it simple to detach the box lid with the switches and encoder from the rest of the case that holds the circuit board and other bits. I also connected things so that both the direction and clock step cables were led through the axis selector switch. There were ample ways for this on the switch originally specified.

The second rotary switch in Dick's design was for selecting the high and low ratio for the drive to the motors. I did not use this facility as I mentioned above and have used this switch position for an on/off control for the 5V supply to the circuit in the manual box. Thus it is only energised

2. A view inside the manual control box showing the use of ribbon cable and connector.



when I am using the manual control and can be isolated when the mill is in CNC mode. **Photo 3** shows the layout of the manual controls. There is a similar on/ off switch for the supply to the DeskCNC board in the main cabinet, which isolates that section when I am using the machine for "manual" milling.

There is one final cautionary note. Western Digital, as listed in Dick's article, supply very reasonably priced rotary encoders and LS 7184 chips. Their

website is detailed but orders from UK must be faxed, phoned or mailed. They set a high premium on speedy supply and the default carrier for my first order was an express service. This would be fine for domestic USA delivery but very costly transatlantic. The goods arrived within 24 hours of dispatch but the carriage cost was similar to the cost of the goods. It is worth phoning the order and discussing alternative delivery methods as I did on a later occasion.

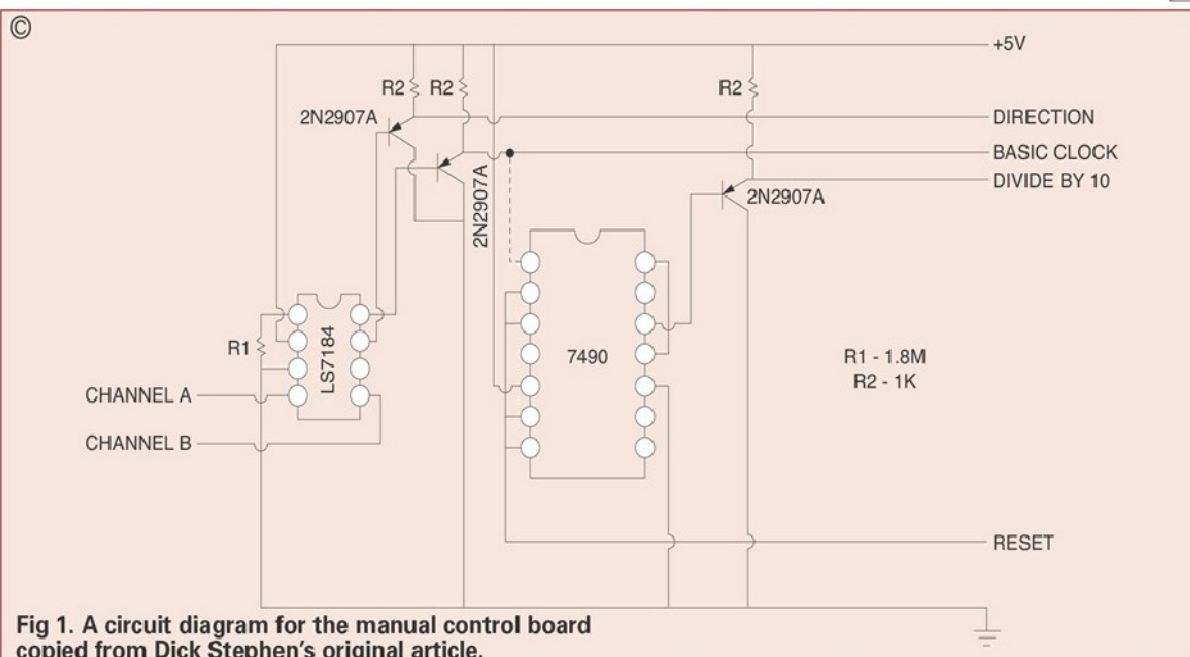


3. The manual controls.

As I continue on my journey of discovery into CNC (I have cut trials in a lot of MDF board in the process) I find it is mostly a forward progression and I hope that the notes in this article will be of assistance to anyone engaged in something similar using the same components.

Postscript

Readers of the articles may have recognised the tool post, which is in use in some of the lathe shots. It is based on the design, which A.N.Eastwood described in Model Engineer 4236 and 4238. I have found it provides a very rigid mounting, easy swapping of tools and the facility to make additional tool holders cheaply. Thanks, Mr Eastwood.



MAKING CYCLOIDAL PINION CUTTERS

Bill Morris gets ticking in his workshop.

Background - getting into clocks

In truth, my hobby is making items of workshop equipment and writing about the experience, but from time to time, I have felt the need to make some sort of artefact that is easily recognizable to the non-addict as a worthwhile end result of owning a workshop. For some reason, locomotive chassis do not cut the mustard and most people, including my wife, do not think that they enhance a mantelpiece or hall table. Clocks, however, are in a different category and so in 1994 I completed my first clock, a Model Engineer Jubilee clock, as amended by John Wilding. For the first time, wife and daughters exhibited some interest in my hobby, to the extent that one daughter demanded to have the clock following my demise. As it was not (and is not) imminent, and as my other daughter also wanted the clock, I made a copy the following year.

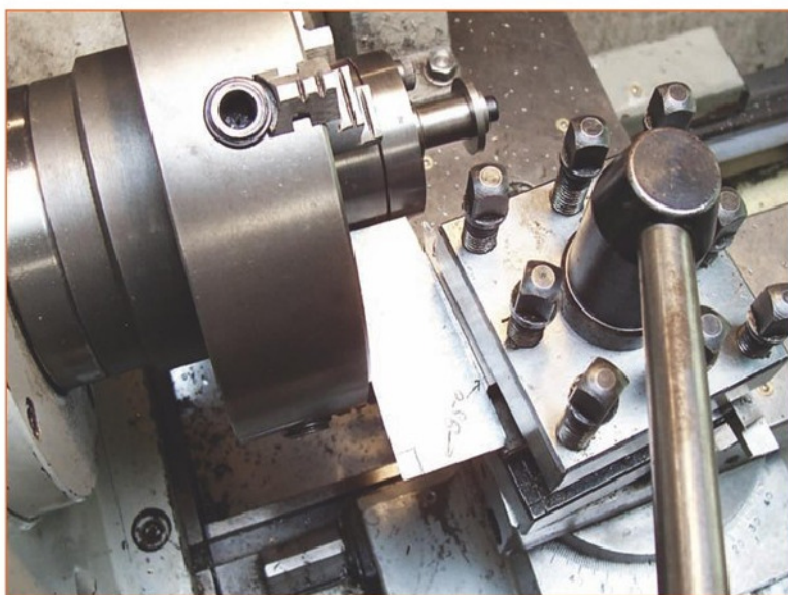
Cutting the gears posed some problems for me as I was not then much good at very small work, understood nothing about gear cutters and did not possess any, though I did have a reasonably well constructed George Thomas dividing head. I also had a short length of 2½in. diameter oil-hardening steel bar so I set about making a Eureka device with which to back off the cutters, scaling it up somewhat so I could use the steel that I already had. Nearly all the articles I have been able to find in **Model Engineer** and **Model Engineers' Workshop** refer to involute form gear teeth and so I made involute cutters. At the time, I was quite pleased with the results although on re-

examining them recently I was struck by the poor finish on the relieved parts of the cutter teeth and by the stubbiness of the involute teeth, which seem out of place in a clock. I was also in some doubt as to whether the sides of the teeth actually had any relief worth talking about, as the cutters were far from free cutting.

"Lay" people who admire my clocks do not realize quite how crudely engineered a clock can be and still run. Eighteenth and nineteenth century clock makers used a variety of rules of thumb to decide on the form of the gear teeth and a great many of their products are still going strong. For many engineering products, constancy of velocity ratio is important. For example, in the chain of gears that link the spindle of a lathe to its leadscrew when cutting threads, if the ratio of the input of the chain to its output varied as the gears went around, then there would be (and usually are) cyclical errors in the resulting screw thread. Involute gear teeth are tolerant of errors of spacing of the wheels but in clocks, friction is the enemy to be avoided. Constant velocity ratio is also important, but practical teeth do not have this, so that there is acceleration and slipping at the beginning of contact and deceleration at the end. In most engineering mechanisms, pinions (the gears with few teeth) drive the wheels, whereas in clocks, the wheels for the most part drive the pinions. In this application, a cycloidal tooth form is preferable, mainly to do with frictional considerations and acceleration as teeth begin their engagement with each other. Interested readers can find a fuller explanation in W O Davis's standard text.

From involute hobs to cycloidal cutters

In 1999, emboldened by my previous experience, I built Peter Heimann's regulator long case clock. This has Module 0.6 wheels driving lantern pinions and so I felt able to invest in one of Thornton's superb wheel cutters. It proved a good investment as the clock runs very freely and, with its compensated Invar pendulum keeps a constant rate to a few seconds a month. By 2003 I felt ready to tackle Dick Stephen's Ferris Wheel clock, which, Dick gives fair warning, is not a beginner's clock. Had I not just completed a beefed-up Jacob's gear hobbing machine, I would not have been able to attempt the clock, as I would have needed a total of four new cycloidal cutters at a current price of about £58 each, an expenditure that my wife would not countenance - unless paid for by MEW earnings! As it was, I "simply" had to produce two hobs, one to cut the 0.3 Module gears and one to do the 0.4 Module ones. Essentially, this meant cutting two worms of the correct pitches with an Acme (straight-sided) thread form. The resulting gear teeth are of involute form and the clock is nevertheless very free running though not a great



1. Adjusting the flank angle.

timekeeper. However, with the bit now firmly between my teeth, I am constructing a copy of an eighteenth century English

bracket clock and I want the results not only to work but to look right, so I needed three Module 0.6 cutters for the pinions of

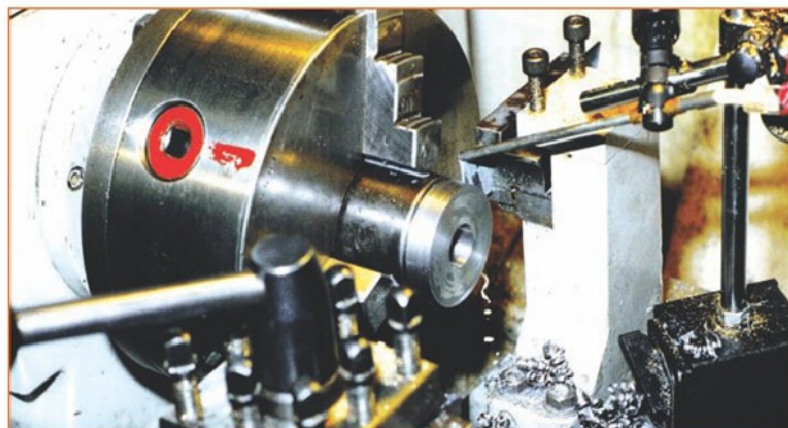
6, 7 and 8 teeth. With my wife no more sympathetic to my buying them than before, I have had to make them myself. There are very few recent articles in **MEW** or **ME** about making cycloidal cutters, other than a section in Don Unwin's article, which gives dimensions for "full Ogive" cutter teeth. The article is a little light on form relieving the cutter teeth, so those who have been put off from the delightful experience of making a clock by the cost of the cutters might welcome an account of my experiences.

Making the cutters resolves itself into two problems: achieving the correct tooth form; and achieving an approximation to the correct backing off, so that the correct tooth form is maintained even after several sharpenings. Heat treatment turned out to be less of a problem than I anticipated. Much of what follows draws heavily on W.O.Davis's little classic, *Gears for Small Mechanisms* and, since I do not propose to go any further into the theory of cycloidal tooth forms and why they are desirable, I recommend that interested readers borrow or buy a copy of this little book. I will however, give sufficient information for the reader to make his own pinion cutters to a selected module pitch and a selected number of teeth.

Definitions

For those new to clocks, a pinion is a gear wheel with a small number of teeth or leaves, usually between six and twelve. A separate cutter is needed for each tooth number. A wheel has a relatively large number of teeth, typically more than forty, and a single cutter suffices for all numbers of teeth. The module, M , is the pitch circle diameter in mm divided by the number of teeth, so the pitch circle diameter (PCD) is the module multiplied by the number of teeth. For example, a six-tooth pinion of 0.6 Module has a pitch circle diameter of $0.6 \times 6 = 3.6$ mm. The addendum is that part of the tooth that lies outside the PCD and the dedendum is the part that lies inside the PCD. For British standards, which are in turn based on Swiss standards, the dedendum parts of the teeth are straight, radial, and easy to form and polish, so we can concentrate on the more difficult addendum parts of the teeth.

While all the dimensions can be calculated, it is perhaps more instructive for the beginner to make a large scale

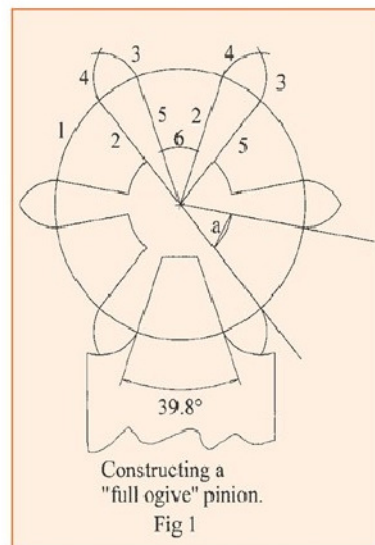


2. Doing some hefty parting off.

drawing, say, about thirty times normal size. I will describe this process first, staying with the six-tooth Module 0.6 example. Reference to **Table 1** gives the dimensions (p.42) that Thornton's quote, which is slightly modified from BS 978-Part 2-1952. The values given are for Module 1 and have to be multiplied by the module number for smaller or larger sizes. To give the beginner some idea of sizes, by the time you get down to Module 0.3, gears start to look and feel like watch parts while Module 1.0 appear in pretty hefty clocks. Module 0.6 seems to be about right for long-case "grandfather" or "floor" clocks, relatively easy to handle with only a pair of hobby magnifying glasses to help.

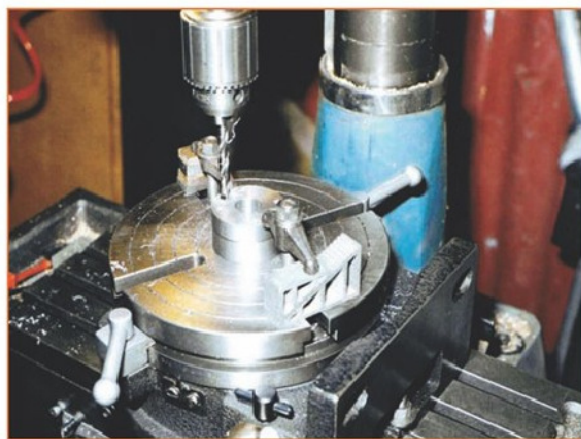
An example

We have already established that the PCD is 3.6 mm, so, referring to **Figure 1**, we can start by drawing a pitch circle $3.6 \times 30 = 108$ mm diameter (1). Since we do not actually cut gear teeth, but the spaces between them, we need to draw two adjacent teeth. There are $360/6 = 60$ degrees between adjacent teeth, so the next step is to draw two radii, sixty degrees apart (2). From **Table 1**, the addendum radius is $1.05 \times \text{Module}$ and, scaled up thirty times, this gives us $1.05 \times 0.6 \times 30 = 18.7$. Using this as a radius, draw arcs centred on where the radii cross the pitch circle (3) and two further arcs from where the first arcs cross the pitch circle (4). Now draw lines from the pitch

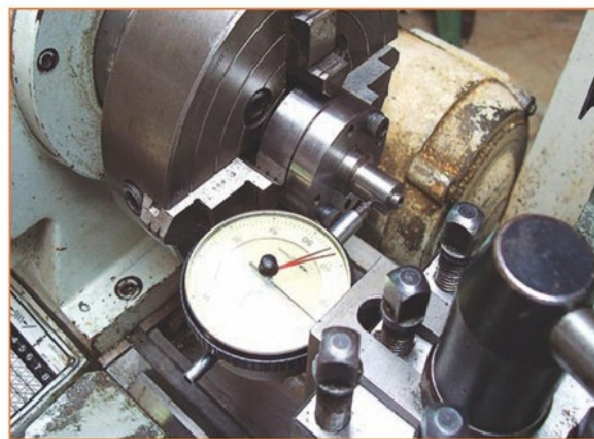


circle centre to where the first pair of arcs crossed the pitch circle (5). The dedendum flanks are radial, so we have already drawn them. It remains only to draw the bottom of the tooth space (6). The dedendum is $1.75 \times M = 1.05$ for a six tooth pinion and we need to subtract this from the pitch circle radius of $3.6/2 = 1.8$. This gives us the radius, $1.8 - 1.05 = 0.75$ of the bottom of the tooth space. Scaling up by a factor of 30 gives us 22.5.

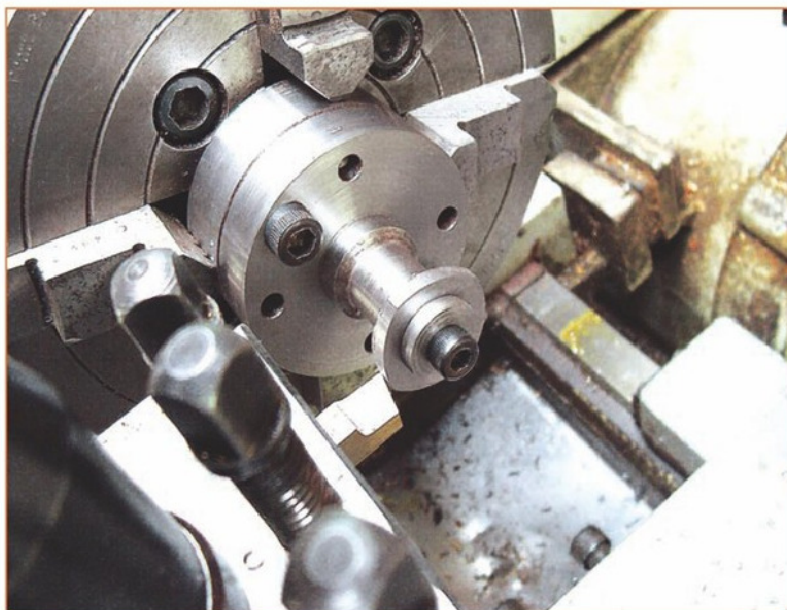
The upper part of **Figure 1** shows the development of the tooth space and the



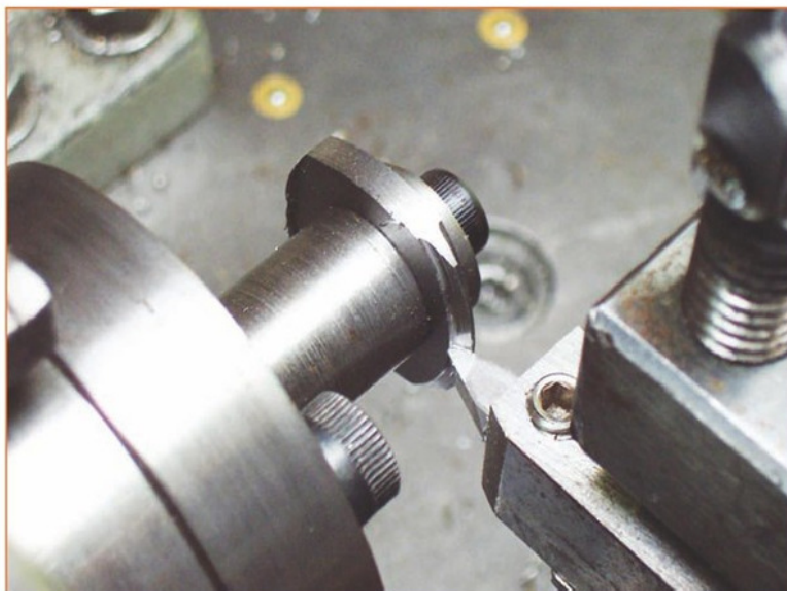
3. Jig-drilling the holes.



4. Setting over with the DTI.



5. Forming the lobe periphery.

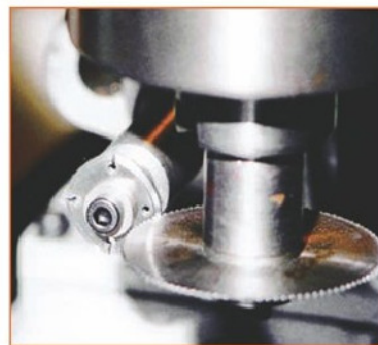


6. The completed flanks.



7. Drilling the stress-relief holes.

bottom part gives an idea of the cutter form that shapes it. The end is made flat, since nothing touches the bottom of the tooth gap and this was the form of eighteenth century pinions and wheels.



8. Slitting the faces.

You could if you wanted take all the cutter dimensions off the scaled drawing or let your CAD program do it for you, but it is scarcely worth the trouble, as the table gives all the dimensions you need. Note that for 10 to 16 leaves, Thornton's use $\frac{1}{3}$ rd ogive, in which the radius is set at $\frac{1}{3}$ rd of the leaf thickness. This is rather more difficult to set out. Happily, you don't need to, but I have shown the process for a twelve-leaf pinion in Figure 2 to show what is meant by $\frac{1}{3}$ rd ogive. The term "ogive" probably came from the usage of medieval masons. Next time you look at the arch of a gothic window, think of clocks.

I hope it is now becoming clear that the problem of tooth form has further resolved itself into making a cutter that has a straight tip, straight flanks of known angles and lengths, blending into known root radii. The cutter itself can be formed with a single point vee-shaped tool with the correct flank angles and a correctly formed radius at the tip. We could do one tool for each tooth number or, since most of us will have tediously to form the radius by hand, we can do one for 6 teeth and one for 10 teeth and swing the tool around to do the cutters with the smaller flank angles, (photo 1).

Radiusing the tool tip

To make the single point tool, I found it convenient to use 5 mm square HSS tool steel, which comes in easy-to-handle 100 mm lengths at a quite reasonable price, (NZ\$5.60 or about £2.20). There is less grinding and radiusing to do than with larger sections and you can make a tool from each end before cutting them off to insert in a home made tool holder, which is convenient for initially setting square to the lathe's axis. So, start by grinding sharp vees of the correct flank angles on each end of the tool, taking care to keep the flank angles symmetrical about the axis of the tool to make later tool setting easy. A side clearance angle of about 4 degrees seems a fairly good compromise. If you have a tool and cutter grinder such as a Quorn, this is easy to do. It probably can be done free hand without a tool grinder, but most people might use a combination of fences and sheet-metal templates to get the angles right. Bear in mind that even the rulers and protractors used by eighteenth century craftsmen were nothing like as good as the ones available to us and their gears still ran!

For the mathematically inclined, a side clearance angle of 4 degrees, approaching the minimum for steel, results in a front clearance angle of $\tan^{-1}(\tan \text{ side clearance angle} / \sin \text{ included point semi-angle})$. For a six-tooth cutter, this gives $\tan^{-1}(\tan 4 / \sin 20) = 11$ degrees, about right for turning steel, while for a twelve-tooth cutter, the result for the front clearance angle is a somewhat high 24 degrees.

If you haven't access to a tool and cutter grinder, one way to achieve the side clearance angles might be to drill an 8.5 mm hole through a piece of 12 mm square stock and file, face or mill a facet at 4 degrees on one face, as shown in Figure 3, with a tapped hole for a grub screw to hold the HSS blank in place. A fence held by a tool maker's clamp on to the table of an off-hand grinder will see to it that the flank angles are achieved and held,



9. Removing the back of a tooth.

grinding against the face of the wheel, (I know we're not supposed to use the face, but we all do it). Then comes the tedious part, radiusing the end so that it is of the correct radius and blends smoothly and symmetrically into the flanks. The best way to do it for a good result in my view is very slowly.

Without a T and C grinder, and even with one in my case, you need a radius template and the sizes we want are in the case of the 0.6 module, non-standard, so we have to make our own. Sticking with the 0.6 Mod example, the addendum radius for 6 to 8 teeth is $1.05 \times 0.6 = 0.63$, or a diameter of 1.26 mm. It so happens that 1.25 mm drills are available from Meadows and Passmore, so we can drill a hole of this diameter close to the edge of a bit of thin brass sheet and then carefully file the hole in half. For 10 to 16 teeth, the addendum radius is $0.82 \times 0.6 = 0.492$ or a diameter of 0.982. Drills of 0.98 mm are also available, though at a price of £3.20. In the nature of things, such templates, looking as they do like scraps of brass, tend to get lost, as I found had happened when I came to write this article, so scribe the radius on and put them in the drawer

with your radius, screw and feeler gauges.

The tip of the tool then has to be painstakingly rounded to the template and, since putting on tools are not yet readily available, I suggest using a fine slip stone or, better still, a fine diamond lap. Within reason, you need as much magnification as you can get, at the least a strong hand lens of about 10X or, even better, a low power microscope. If you have made Dick Stephen's centring microscope, you can use that, but whatever way you choose, you will need to arrange for light to come from underneath, as in the little light box shown in Figure 4. Even if it takes you a whole morning to get it right, it's worth it, as the shape of the addenda of all the pinion teeth of those tooth counts you will ever cut will depend on that one tool. The next stage is to make the cutter blanks.

Cutter blanks

It is easiest for the amateur to make these out of round silver steel and 25mm diameter is a suitable size, roughly the same as for commercial cutters in the 0.4 to 1.0 Module range. They could of course



10. A hardened and tempered finished cutter.

be laboriously sawn out of 3mm gauge plate. Start by drilling a central hole followed by a 7 mm machine reamer if you have one or otherwise a homemade toolmaker's reamer. Then face and part off several slices just over 3mm thick. It helps with subsequent operations if you face the other side so all the discs are a uniform 3mm thick with a good and parallel finish on each face. I used a surface grinder. A bell chuck or turner's cement (rosin/bees' wax mixture) or perhaps even superglue, are other solutions that will allow the blanks to be held for a light, facing cut. We now have to digress to make a relatively simple turning fixture that will allow us to produce a four-lobed "disc" and hence a four-toothed form-relieved cutter. Six teeth are also possible, but I have not tried and the commercial cutters, with their twelve teeth, are produced by different means. The Eureka device also backs off twelve teeth, but it is much harder to make.

The relieving fixture

a) General arrangement

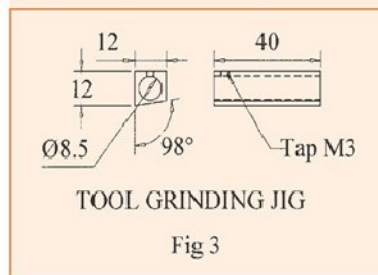
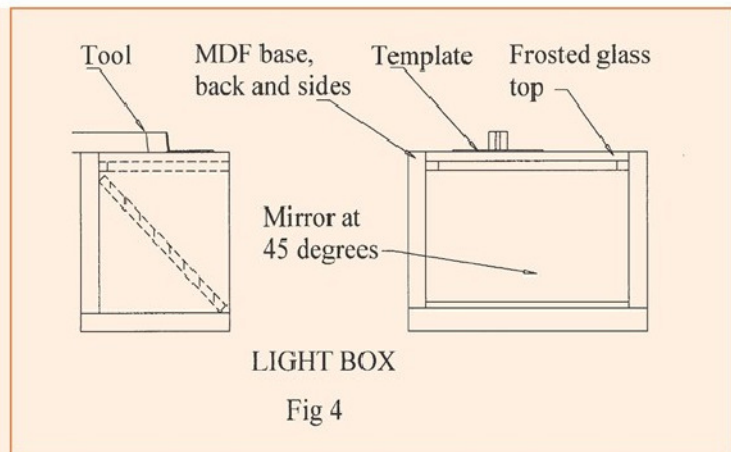
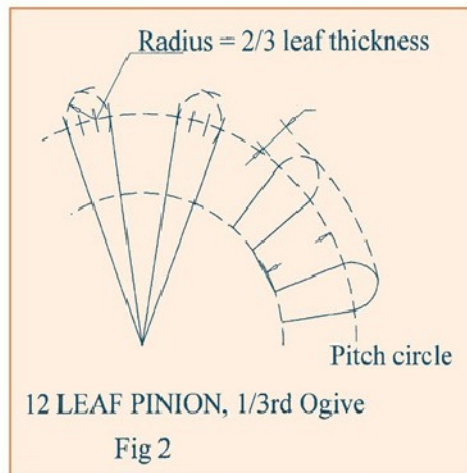
(Figure 5)

The base, 1 is held in the four-jaw chuck to allow it to be offset. The indexing plate, 2 bears an arbor, 3. The arbor extends through the indexing plate as a spigot so that dowel pin, 4 locates and indexes the plate. The plate is held solidly in its indexed position by two screws, 5. The cutter blank is held on a register at the end of the arbor by washer 6 and screw, 7.

In use, the base is held in the four-jaw chuck, offset by an amount calculated to give not only front clearance but also adequate side clearance, about which more later. Referring to figure 6, a cut is taken on the periphery of the blank to form a lobe and the indexing plate is then rotated 90 degrees. Further lobes are formed until they meet at points, the location of the future tooth tips, to give a four lobed shape. The radiused tool so carefully prepared previously, is then fed a calculated amount into each side of the blank to form the side cutting faces, again indexing the blank each time. Two saw cuts are made through the apices of the lobes into drilled stress relief holes to complete the formation of each tooth and the completed cutter can then be hardened in water and tempered in a domestic oven,



11. Cutting a 12-leaf pinion.



followed by honing of the radial faces. The dimensions of the relieving fixture are given as examples. I used what I had got and so can you.

b) The arbor

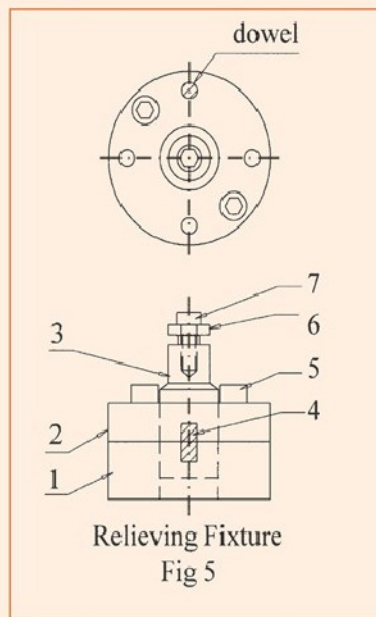
(Figure 7)

You might as well start with this, as it will come in useful as a gauge for further machining operations. Take a skim over a 50 mm length of 20 mm mild steel round bar, drill and tap M5. Carefully turn and face the register that will locate the cutter blank, reduce to 14 mm diameter over a 16 mm length as shown in **Figure 7** and part off at about 50 mm long.

c) The indexing plate and base

(Figures 8 and 9)

Chuck a piece of mild steel bar about 54 mm diameter, face the end, drill to 19 mm (conveniently about ¾ inch) and carefully bore out the hole to a snug fit on the 20 mm diameter of the arbor. Then part off (**photo 2**) or saw off a 12 mm slice and face the other side. Do the same for another slice, this time a little thicker than your four-jaw chuck jaws are high. This will become the base. Using the arbor to align them, make a sandwich and carefully centre them, preferably by using a dial indicator, and clamp them to a rotary table as shown in **photo 3**. Then drill four equally-spaced holes 4.9 mm diameter on a 42 mm diameter pitch circle, more or less, three of them passing nearly through the indexing plate and the other one through the indexing plate and nearly through the base. (You can go all the way through if you put a thick piece of plate on the top of



the rotary table). At 45 degrees to one pair of these holes, drill a further two at 5 mm almost all the way through indexing plate and base.

Remove the sandwich and open it in order to complete the drilling of the holes all the way through and counter-sink the edges of all holes to remove burrs. Then clamp the sandwich together again with the arbor, the 4.9 mm holes in the index plate and the base lined up so you can ream the holes to 5 mm through the base and into the index plate. Repeat this for the other three holes. Glue with Loctite or similar a 12 mm-long dowel pin into the base, leaving about 6 mm projecting from the top and making sure the end is well rounded. With any luck at all, you should then find that with the arbor in place, you can index through the four positions without anything jamming. If you have achieved this happy state you will still have a pair of 5 mm holes going all the way through when in fact you need two pairs, so index through ninety degrees and jig drill another pair through the base. You then tap the four unoccupied holes M6 and open out the pair in the index plate to 7 mm. Make sure you open out the correct pair!

After removing all the burrs, all that remains to do is to glue the arbor into the index plate, leaving a spigot about 12 mm

long projecting from the underside.

Almost any old washer will do to secure the cutter blank to the arbor, but it is nice to make a special one about 3 mm thick and 15 mm diameter for the M5 securing screw. It is easy to index in the wrong direction and waste time, so a final refinement is to make a punch mark on the edge of the base opposite the dowel pin (but not where a chuck jaw may hide it) and to stamp numbers from 1 to 4 on the edge of the indexing plate opposite the index holes.

Clearance angles

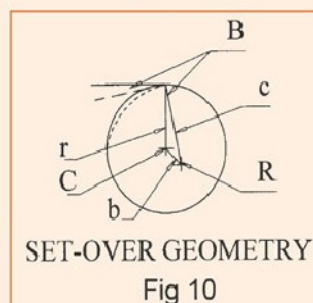
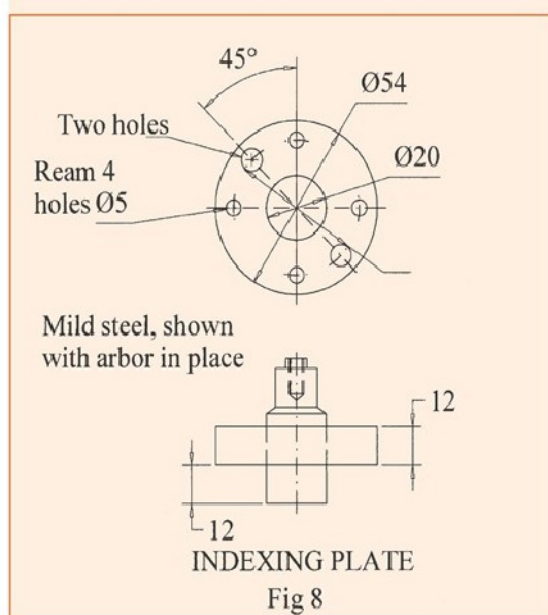
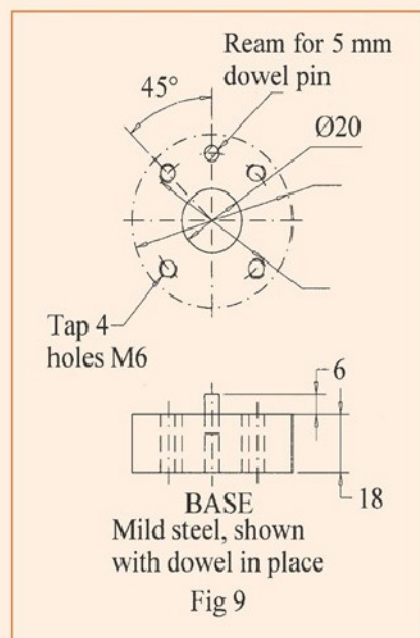
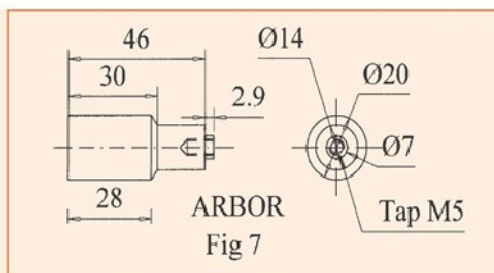
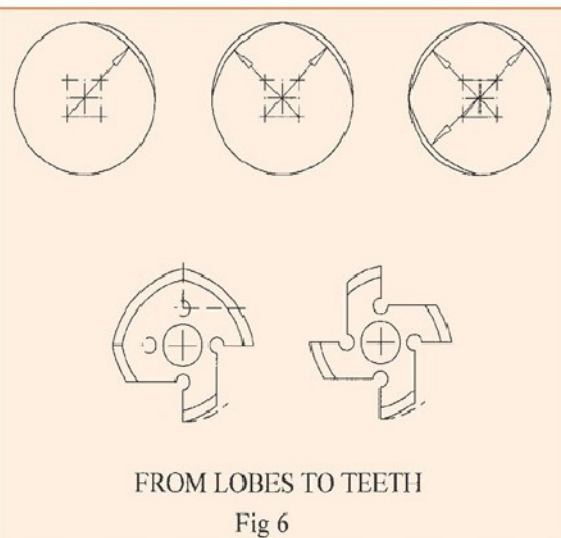
As described above under setting over, the blank is bolted to the arbor and the whole device set over to form four eccentric lobes. The intersection of the lobes will eventually form the tips of the teeth. You will recall that the dedenda are straight, radial lines, formed by the tip of the cutter. The relief is at a minimum here on the radial sides of the cutter teeth. The amount of setting over will determine the amount of relief at the tooth tip and this amount has to be adequate to allow sufficient relief at the sides of the teeth without weakening the tooth tip too much. W.O. Davis gives 18 degrees as near the practical maximum tip relief and 2.5 degrees as near the practical minimum for the side clearance. The side clearance is the really important one for us amateurs, as if there is not enough there will be rubbing and smearing of the work-piece finish, while if there is too much front clearance, barring disasters the cutter simply needs re-sharpening more often.

For those who are shy of maths, in **Table 2** I give suggested clearance angles that seem good compromises for pinion leaf numbers from 6 to 16. For those who wish to do the maths for themselves, something that is very easy with a modern pocket calculator, let us follow Davis and call the half-included angle of the tooth α (alpha), the front clearance angle β (beta) and the side clearance angle γ (gamma).

Then: $\tan \gamma = \tan \beta \times \sin \alpha$ and $\tan \beta = \tan \gamma / \sin \alpha$ and the side clearance angle γ itself is: $\tan^{-1} (\tan \beta \times \sin \alpha)$ (1)

What you feed into your calculator for the side clearance angle is usually:

"Shift, tan, (, tan, front clearance angle value, x, half included angle value,), ="



As examples, suppose we chose a front clearance angle of 12 degrees for an 8-leaf pinion whose included dedendum angle is 30 degrees. We find the minimum side clearance angle is a healthy 3.1 degrees, but for a 16-leaf pinion, even if we select a front clearance angle of 20 degrees, we find the side clearance angle is verging on the inadequate, at 2.5 degrees.

How much set-over?

In figure 10, I show the geometry of the set-over, or offset, with the first lobe, shown dotted, struck from R, which is joined to the centre C of the blank circle by the line b, set at 135 degrees to the radius r. Two tangents are shown forming an angle B (which is the front clearance angle as well as the angle

between r and c). The full line is tangent to the blank and the dotted line is tangent to the lobe (note the convention of using capital letters for the angles and lower case letters for the sides "opposite" the angles).

The centre angle C is $90 + 45 = 135$ degrees and B is the chosen clearance angle, so the angle R must be $180 - 135 - B$, or $45 - B$.

$$\text{Now } r/\sin R = b/\sin B$$

$$\text{So } b = r \times \sin B/\sin (45 - B) \quad (2)$$

We know the values of r, B and R, so we can calculate the offset b. In Table 2, I give the results for 25mm diameter cutters with the clearance angles shown, and equation (2) will allow you to calculate it, within

limits, for a cutter of any diameter and front clearance.

Forming the cutter teeth

a) The tips

First centre the relieving fixture in the four-jaw chuck with a dial test indicator, set the DTI to zero and then move the fixture over until the DTI shows the desired value, (photo 4). If your DTI won't cover the range you can wind out your cross slide the desired amount and move the fixture until it is re-zeroed. High accuracy is not needed. Make sure that your cutter blanks are free from burrs but on no account round or chamfer the edges or you will not easily be able to get the correct tooth

thickness. Mount a blank securely and then with a freshly sharpened tool, form the first lobe on the circumference. When you think you might have formed a lobe on approaching a quarter of the circumference, zero the cross slide thimble, index the fixture and form the second lobe to the same cross slide setting. Alternate between the two lobes until they meet. Then index round and do the other two lobes at the same setting, (photo 5). You are then ready to form the all-important flanks.

b) The flanks

Assuming for the moment that the included angle of the single-point tool we are going to use is the correct one for the leaf number, we need to know how much cut we need to apply to achieve the correct tip thickness or width. We know what the in-feed will be, simply the sum of the addendum and the dedendum, or tooth height in table 1, but to get the right tooth-tip width we need to do some more sums. Returning to figure 1 for a moment, we can calculate the value of the chord "a" - it is the sine of half the included angle (the flank angle) multiplied by the diameter - and we can get the diameter at this point by deducting twice the dedendum from the PCD, or:

tooth tip width = sin flank angle x (PCD - 2 x dedendum).

For your convenience, I have added the tooth tip thickness to table 1. Remember to multiply all values (except angular ones) by the chosen Module.

Knowing the tip width, we can deduct this from the blank thickness, halve the result and feed the tool in for that amount on each side. Let's call it "the side cut". First set the tool at the correct angle to the lathe axis, advance the tool until its tip just scrapes a very fine shaving from a lobe, wind it away from the work piece and advance the tool using the cross slide by the amount of the tooth height shown in Table 1, not forgetting to multiply by your chosen Module value (and by 2 if your cross slide index tells you by how much the diameter gets reduced). Then bring up the tool to the front flank of the blank until it just begins to shave the corner and lock the saddle. Using the top slide slowly apply the calculated side cut and then index around until all the front flanks have been done. Repeat the process on the back as in photo 6, (a posed photograph taken long after the event), and you should then have a correctly formed cutter blank with the correct tip width. If you are going to err, do so on the side of having the width of the cutter tip a little on the large side. This will result in a wider tooth space on the pinion that it cuts. A too narrow tooth space may prevent the pinion engaging properly with its wheel.

I don't know of any easy method of checking you've got it correct while it is in place on the fixture. Don Unwin gives a method using feeler gauges set to the addendum radius and a micrometer, but to me the method seems to lack "feel". You can attempt directly to measure the tip width with a micrometer, reducing the gap little by little until the edges of anvil and spindle face just "skid" off the tip. This seems to be accurate to about 0.05 mm or so. I am not sure how good it is for the micrometer.

TABLE 1 - PINION CUTTER DIMENSIONS

Number of leaves	6	7	8	10	12	16
Pitch circle diam	6	7	8	10	12	16
Outside diam pinion	7.71	8.71	9.71	11.61	13.61	17.61
Root diam pinion	2.5	3.3	4.2	5.9	7.8	11.8
Leaf thickness	1.05	1.05	1.05	1.25	1.25	1.25
Addendum radius	1.05	1.05	1.05	0.82	0.82	0.82
Addendum form	Full ogive	Full ogive	Full ogive	1/3rd ogive	1/3rd ogive	1/3rd ogive
Angle of cutter flank	20	17	15	10.75	9	6.75
Addendum	0.855	0.855	0.855	0.805	0.805	0.805
Dedendum	1.75	1.85	1.90	2.05	2.1	2.1
Tooth height	2.605	2.705	2.755	2.855	2.905	2.905
Cutter tooth tip width	0.855	0.965	1.087	1.100	1.220	1.387

Multiply values by Module to obtain dimensions

TABLE 2 - PINION CUTTER CLEARANCE ANGLES

Number of leaves	6	7	8	10	12	16
Half included angle	20	17	15	10.75	9	6.75
Front clearance angle	12	12	12	18	18	20
Side clearance angle	4.15	3.6	3.1	3.6	2.9	2.5
Offset mm, 25 mm cutter	4.77	4.77	4.77	8.51	8.51	10.12

For cutters that have the same addendum radius but different leaf numbers, the tool can be rotated using simple templates before putting on the cuts. For example, if you make a tool for a 6 tooth M 0.6 cutter you can also use it to form 7 and 8 tooth cutters by rotating it 3 and 5 degrees respectively so as to reduce the cutter flank angles.

c) The faces

There are various ways of forming the radial faces. If you can index your lathe spindle and drill from the cross slide, you can drill four holes on radii that pass from the lobe points to the centre. I mounted the blanks on a mandrel in my rotary table and drilled the holes that way, (photo 7). I then set the top edge of a slitting saw at the centre height of my George Thomas dividing head and used this to form the faces of the teeth, (photo 8), followed by indexing a further 45 degrees to remove material in front of the faces, (photo 9). Bear in mind before doing this which side of the radial saw cut is on the centre line so that you do not produce little triangles of waste that bear the radial faces. Using a slitting saw gave a finish that was almost ready to use, but first had to come hardening and tempering. Figure 11 is a dimensioned drawing of the finished article.

Hardening and tempering

Since you cannot tell just by looking at the cutters their Module or tooth number, it is worthwhile at this stage to engrave or lightly stamp this information on one of their faces. Hardening parts of this size is relatively easy. If of silver steel, bring to a bright red heat and quench in cold water, if of gauge plate, quench in oil. When you do quench, don't just flip the part into the water or oil but make sure that it enters edge first to minimize chances of warping. Polish the faces with some 400 grit emery

paper glued to a flat strip of wood (or even better, 1/4in. Paxoline) and temper to a "dark straw" colour, which is lighter than "golden yellow" and much lighter than "brown". One might almost say that one is aiming for the merest hint of yellow, rather difficult to judge from photo 10. The books say the tempering temperature is around 240 Celsius, just within the range of the domestic oven, which I am allowed to use. Check the tempering colour first with a piece of scrap material so that you get it right first time for the cutters, as repeated re-heating to hardening temperature adversely affects the grain structure of the cutting edges. If you wish, you can carefully hone the faces on a fine oilstone or touch them up on a tool and cutter grinder. Whichever way you chose, make sure that the faces of the teeth stay radial so that the correct form is maintained through at least a few sharpenings.

Cutting speeds

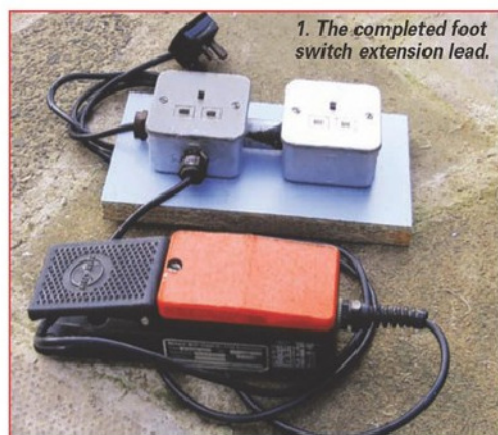
Thornton's suggest a rotational speed for cutting carbon steel pinions with their HSS cutters that translates to roughly 20 metres/minute, so we should probably halve that rate for our new carbon (silver) steel cutters, say about 130 rpm if of 25 mm diameter. It is wise to have a good stream of soluble oil rather than a dribble. Photo 11 shows a twelve-leaf Module 0.6 pinion in the process of being formed.

I am very well aware that there are some people who flee from anything that looks like a formula, but the Editor (Dave Fenner) expressed a wish that some theory should be included and I have done the best I can with my limited mathematical skills, while aiming to inform and to include information that is not easily found elsewhere. I hope those who fear maths will find that the tables will help them out, as they have only to multiply numbers by the chosen Module. If I have made errors, I hope that they will be pointed out as kindly as possible. I am happy, too, to be contacted by e-mail at engineer@clear.net.nz

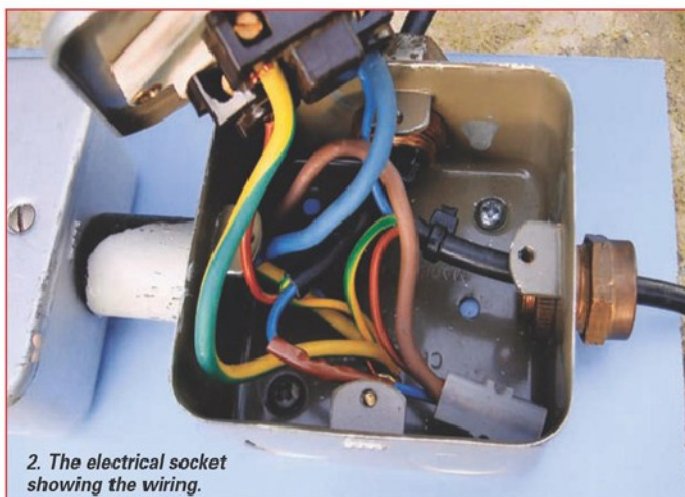


ELECTRICAL SAFETY IN THE HOME WORKSHOP

Ted Fletcher puts his foot down safely.



1. The completed foot switch extension lead.



2. The electrical socket showing the wiring.

Like so many other model engineers, I carry out jobs in my home workshop in a manner which the Health and Safety Authority would frown upon. For example, I have a DIY bench top circular saw without any form of NO-VOLT RELEASE and I am not very happy with the position of the on/ off switch either, should it be needed in an emergency. I go to auto jumbles, car boot sales and best of all amateur radio rally's and often pick up electrical and electronic gadgets, which might be useful in the workshop. Last summer I bought two foot-operated

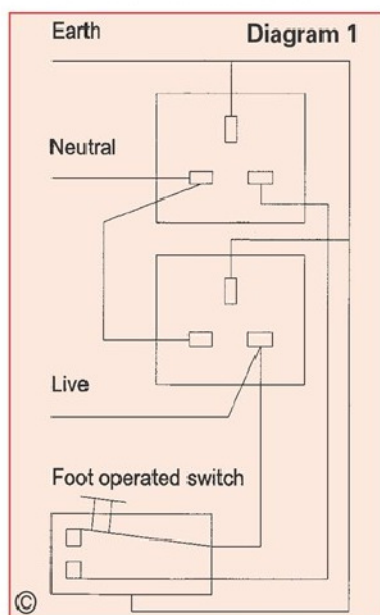
switches for £1.50 each intending to wire one into my bench drill circuit. I have had one or two exciting moments when drilling sheet steel. Then I had a better idea, why not make it portable, **photo 1**, and then I could use it on other pieces of workshop equipment as and when required, for example my saw bench or planer.

The arrangement consists of two short pieces of 3 core flex, two single 13 amp metal clad socket outlets mounted on a piece of chip board at one end, and a 13 amp plug on the other (similar to an extension lead). The other piece of flex has the foot operated switch connected to it at one end and the 13 amp metal socket outlets to the other end, as follows. The blue wire from the 13 amp mains PLUG is connected to the NEUTRAL terminal of both 13 amp socket outlets as normal, the green/ yellow earths are connected to the earth terminal within the metal boxes and to the earth terminals of both 13 amp socket outlets. One brown LIVE goes directly to the foot-operated switch (via the 13 amp metal socket outlet box) and to the other socket outlet live terminal. See **diagram 1**.

What I actually did was to connect the BROWN from the mains flex to the BROWN of the foot switch flex together in the metal box using one piece of a strip connector (chocolate block), I also put a piece of BROWN sleeving over the blue wire of the foot switch (**photo 2**) for identification purposes only and connected it into the 13 amp socket LIVE terminal in a simple series circuit, **diagram 1**. For reasons of electrical safety in all 240 volt mains electrical wiring, all single pole switches, (which the foot switch actually is), must break the live conductor only, NEVER THE NEUTRAL. The other socket

outlet as described above is connected, so that it is energised or alive all the time, as is in all extension leads. This socket is where I plug my workshop vacuum cleaner in, so that before starting woodworking, the cleaner is switched on, and irrespective of whether the saw or planer is in operation, the cleaner is working, see **photo 3**. For convenience of identification I gave the socket outlet that is controlled by the foot switch a spray over with a grey paint aerosol.

Now I operate the drill, planer, saw or what ever, with the satisfaction of knowing that should anything untoward take place, all I have to do is move away and the motor will stop, but the vacuum cleaner will continue running.



3. The foot switch in use on the saw bench.

A SOLDERING IRON CONTROLLER

Ted Fletcher stops his bits being eaten away.



Fed up with burnt soldering iron tips, **photo 1**, I decided that I should do something about it. I intended to make the following arrangement exclusively for a small 15-watt soldering iron, not using a 13-amp socket outlet at all. I got started, and then had yet another idea, why not make the arrangement flexible? Then any soldering iron, large or small could be controlled, hence the 13 amp socket outlet. As most readers will know, when a soldering iron is in intermittent use the copper bit/tip soon burns away, then needs cleaning and re-tinning, unless the iron is frequently unplugged from the electricity supply, which is a nuisance.

When the iron is in the "tick over" mode the energy applied to the element is reduced, so there is less likelihood of the iron tip being burnt. Then, if full power can easily and quickly be re-applied as required, the bit will be saved and the iron will be hot when needed. A low voltage foot operated switch fitted with a 3.5mm plug, (as used by audio typists), can be used, together with a 12 volt dc relay, a diode, a low voltage dc power supply unit (ex computer printer or similar) to control an electric soldering iron. When one's foot

is placed on the foot-operated switch, the iron receives full mains voltage via the low voltage relay, but when pressure is removed, a diode is placed in the 240-volt mains circuit. With the diode in the circuit, only one half wave of the 240 volts mains supply, (which is considerably less than full mains voltage) is applied to the iron element. This arrangement avoids overheating the iron and burning of the copper bit. This is how some vacuum cleaner and domestic hair dryers obtain their 2 speeds. It does not matter which way round the diode is connected.

The relay

The miniature relay, which I used, has 3 contacts; a common contact, one open contact and one closed contact as well as a single pole change over (c/o), something like a two-way switch.

A pair of the contacts, the common and one other, which are closed even when the relay is not energised, are known as normally closed (n/c). Conversely the other is, normally open (n/o). All are related to how you would find a relay on the shelf in the stores with no electrical connection at all. When electricity is connected to the relay coil the contacts change over. I have used a pair of contacts, which are (n/o), so that when the foot switch is operated the relay becomes energised, the (n/o) contacts then close, full mains voltage is applied to the iron element and maximum heat is available.

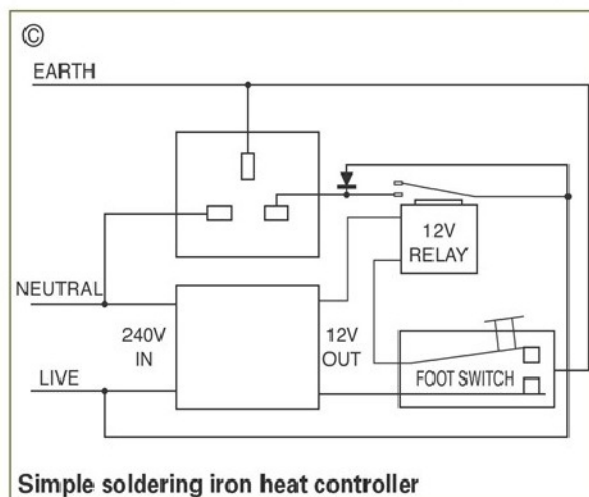
Construction details

Obtain a printer or similar transformer, a relay, a 13-amp socket outlet, a 3.5mm

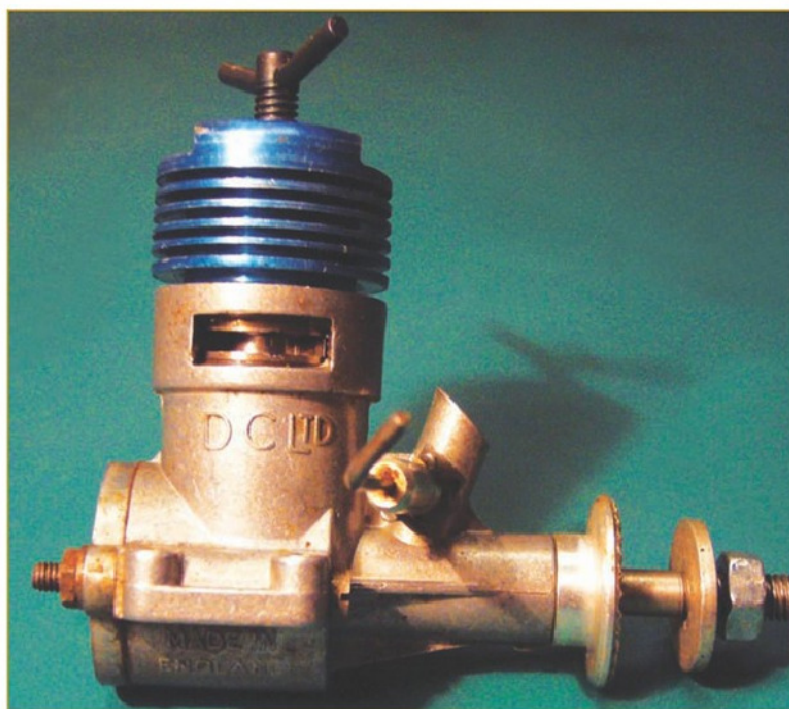
socket and a metal box with a lid, large enough to accommodate all three. Cut a hole in the box lid to accommodate your 13-amp socket, also drill a 6.5mm hole in the box for the 3.5mm socket. The relay and transformer are held in place using a glue gun. Your layout might be different to mine, but providing you follow the circuit diagram all will be OK. The BROWN wire (which is the live lead from the mains) is connected via a block connector to the one end of the diode, (either way round), together with two other wires. One wire is connected to the transformer input, the other to the common or centre terminal of the contacts. The other wire is to be connected to the normally open contact.

The BLUE (neutral) is connected in the normal manner to the terminal marked N in the socket outlet, together with a wire connected to the transformer. The GREEN / YELLOW is connected to earth the metal work.

For a simple final test, connect the box 13amp plug into a socket and connect a reading lamp to the box. If all is correct the lamp should be dim and pressing the foot switch should make the light shine at its full brilliance. The actual mechanics I will leave to the readers, other than to say I made the hole in the thick aluminium plate for the 13 amp socket outlet, using a 4-jaw chuck. **Photo 2** shows the final product. A piece of scrap "Handy Angle" or "Dexion" makes a useful soldering iron stand. Almost any 1 amp, 400-volt diode will be OK for this workshop project. (IN 5004) Speed control boards from failed a washing machine have lots of good electronic components ready for reuse. The relay, transformer, metal box and 3.5mm socket, as the car dealer would say, are all pre owned, the transformer coming from a discarded printer.



A NEW LIFE FOR OLD MODEL AIRCRAFT ENGINES



1. Initially purchased as a non-runner for £5, after reboring, this British diesel became a treasured and useful addition to my collection.

As a schoolboy, I spent many hours gazing at the treasures displayed in the local model shop window. Among the kit boxes, the built up boats and aeroplanes on show were the latest range of diesel and glow plug engines. Oh how I wanted one of those gleaming metal jewels,

almost all of them British made, but my pocket money only covered the cost of one or two rubber powered models.

In later years I was able to fly internal combustion powered model aircraft but most of the engines were foreign made so I felt somewhat cheated, and, determined to chase my boy hood dreams decided to keep

Alan Johnson laps his cylinders into shape.

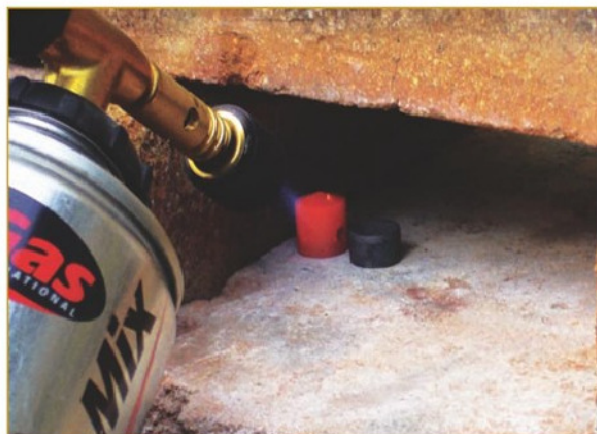
an eye out for some of the old engines. It soon became clear that there is a demand for British engines made in the later 1940's and 1950's and high prices are asked for those in good condition, and those still in their boxes fetch an even higher price.

I wanted engines I could use rather than hoard, so I had to find a way round the problem. In my search for useable British engines I noticed that worn out or incomplete engines could be had for £5 or even less, so I bought some of these and set about making them serviceable again. (Photo 1).

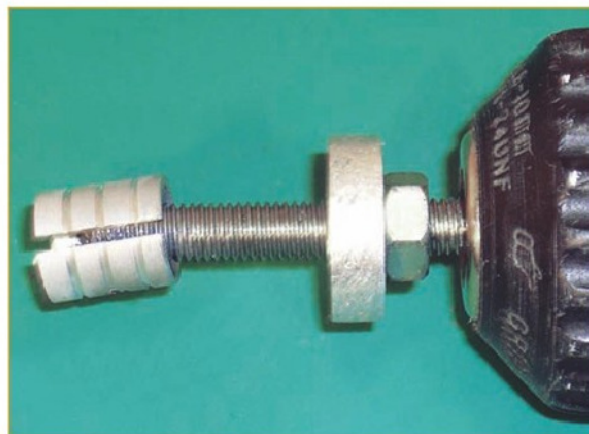
Simple turning

Over the years, I had collected a small number of tools including a Myford lathe, and a small stock of metal bar, so replacing needle valves and compression screws was a simple turning and fitting job. I also turned a set of cylinder fins for a diesel, which I bought in marine form.

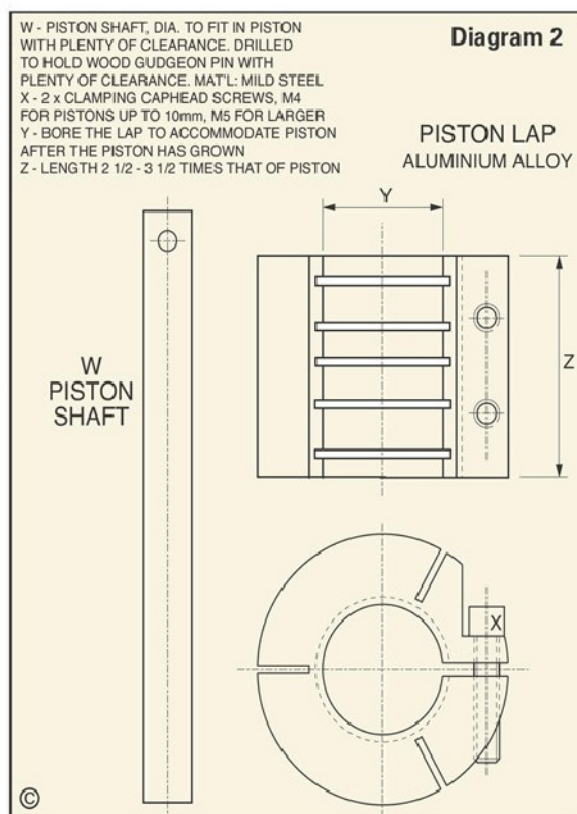
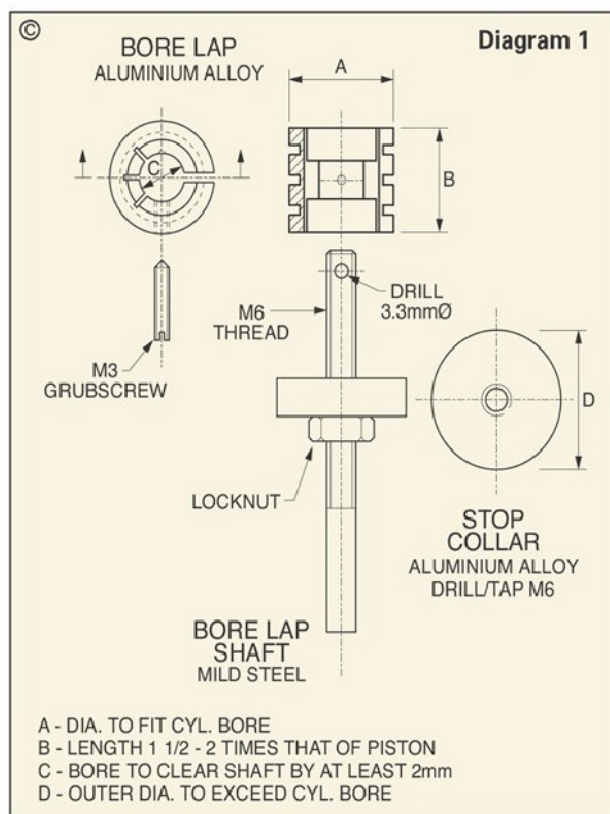
By far the most common fault was a lack of compression, particularly in small diesels, either through abuse or just worked until they were incapable of running and then discarded. I read some articles about model engine construction, which included instructions for fitting pistons to liners. Not all of them agreed so I tried some of the more likely systems and the following is the most successful I have arrived at. Originally I made completely new pistons, but also, I heard of a system for growing cast iron or



2. Heating the piston to cherry red before quenching; the contra piston waits its turn.



3. The bore lap mounted on its shaft and held in the drill chuck.



meehanite pistons so they could be used again in the original liners. The contra piston fitted to diesel engines can be treated in the same way.

The growing process used is as follows: construct a makeshift oven from fire bricks and with the piston and contra piston inside, a DIY type butane blow lamp is played on them until they are heated to cherry red and they are then allowed to soak at this temperature for about five minutes as in **photo 2**. After soaking they should then be quenched in a thin mineral oil. During this process, a growth of one or one and a half thousandths of an inch should have taken place, enough for our purpose providing the piston or liner has not been scored badly. Remember though, this only works once per piston. A scale will have formed on the components, which must be carefully removed.

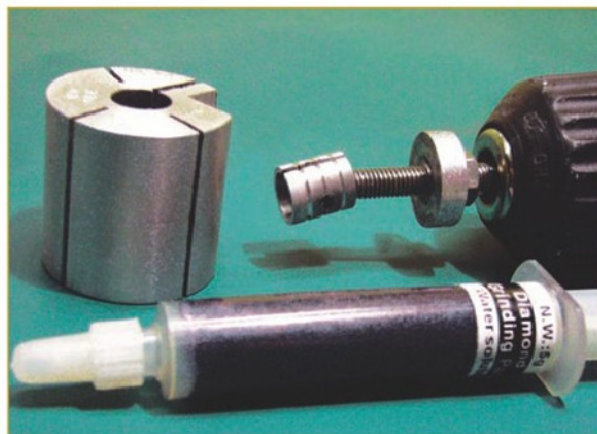
Ovality

Gudgeon pins are either a tight fit in pistons or allowed to float, often with soft end pads to protect the cylinder walls; the growing process does not affect these fits. Engines that have had several hours running usually show an ovality of the cylinder bore and this has to be corrected before the piston is fitted to it. This is a lapping process and a lap must be made as shown in **diagram 1**. A junior hacksaw can be used to cut the internal slots and a full size hacksaw to cut the expansion slot. The peripheral slot sizes and positions are not critical. (**Photo 3**).

I use a diamond lapping compound of 600 grit, mixed with a little mineral oil, **photo 4** unless much material has to be removed when 400 grit speeds the process to begin with then finishing with 600 grit after thoroughly cleaning the lap. This

compound is liberally smeared over the lap before it is entered into the bore, but first the liner itself is held between two pieces of hard wood shaped to hold the liner without distorting it when the whole thing is held in a vice as **photo 5**. The lap is loosely held on the shaft by the grub screw, which is also used to expand the lap. The shaft is held in the chuck of an electric drill, which turns at about 500 RPM. The lap is expanded until it contacts the cylinder walls firmly enough to make the drill work hard without actually stalling, and is entered from the bottom of the bore. As the drill turns the lap must move in and out through the bore, allowing about a quarter of the lap to protrude at the end of each stroke.

Make sure no side pressure is applied to the lap and it is free to self-centre at all times. Examine the bore after a few strokes and you will notice the lap has left



4. Piston lap, bore lap and a phial of diamond compound.



5. The bore lap is put to work. The cylinder is clamped between shaped wooden blocks.



6. A selection of bore laps for engines of different sizes.

faint marks; try to create an overall diamond pattern with these. Expand the lap as necessary and carry on the work until the pattern covers the whole of the bore and there are no scores along the bore. I must add here that occasionally you come across a soft liner that has been case hardened and if very much material has been removed you may have to case harden the liner again before finishing the lapping process. You now have a perfectly round and parallel bore. The bore laps need to be made in different sizes to suit each engine. **Photo 6.**

A small taper

When the manufacturers produce cylinders they usually hone them parallel, then with a lap the following shape is produced; the area swept by the piston has a minute taper from the top of the exhaust towards the cylinder top. On diesel engines the area above this is left parallel to house the contra piston and on some glow plug engines the cylinder head fits into the bore here. Other glow engines have a cylinder head, which fits straight on top. In the latter case the taper goes almost to the cylinder top. From the exhaust port down, the bore is expanded to give almost a thousandth of an inch increase on your lapped bore.

To reproduce the tapers I use the following method: - Set the collar on the lap shaft so the lap can not go further up the bore than the piston does in its normal stroke, then with the lap set to the tightest the electric drill will turn when set on a slower speed, give a single stroke into the bore until the collar halts the movement, then without stopping retract the lap as before and stroke again, this time change direction when the collar is about one millimetre from the cylinder base on a 1cc engine, less for smaller and more for larger engines. The next stroke is another two millimetres shorter and the next is another three millimetres shorter and so on until the top of the lap is seen through the exhaust port at the top of its stroke; at this point expand the lap again and carefully lap the area below the exhaust with three or four strokes on slow speed taking the last stroke to just above the exhaust before removing the lap. You may have to recharge the lap with compound



7. Several different size piston laps.

or just oil during this operation. This process will give you a perfectly serviceable bore ready for piston fitting. Now the liner can be washed in paraffin, using a toothbrush to clean the lapping compound from all the ports and corners. Finally oil it and put it to one side. Note, when using this bore lap on another engine, turn it end for end to reduce the risk of tapering.

Lapping the piston

To prepare the piston first make the piston lap as **diagram 2**. The blind slots are cut with a hacksaw and the closing slot can be cut using two blades in a hacksaw frame. The size and shape of the internal grooves is not critical; they help to hold the compound. (**Photo 7**). Next obtain a piece of wood at least half an inch thick to stand the lap on. There should be a hole large enough to clear the piston in the centre. Also made of wood is a temporary gudgeon pin to take the drive from the shaft to turn the piston. Should the piston jam while lapping, the wooden pin will break preventing damage to the piston. (**Photo 8**).

It is easier to use a drill stand to lap the piston providing it can turn at roughly 500RPM. Mount the piston on the shaft using the temporary gudgeon pin and hold the shaft in the drill chuck. Charge the bore of the lap with the lapping compound and place it on the wood block. (**Photo 9**). Now the piston can be lowered into the lap and the drill stand stop set so the piston protrudes by about a quarter of its length through the lap. The lap must be prevented from turning, small laps can be held by hand but larger laps must be clamped down. Remember to avoid any side pressure on the piston and it must also be free to self-centre at all times.

Tighten the lap until the piston is obviously being abraded, then start the drill. Again move the piston in and out aiming for the diamond shaped lapping marks on the piston and only allowing the piston to emerge by a quarter of its length from the lap at each stroke. Examine the piston after four or five strokes and if the lapping marks extend all the way round the piston wash the piston, and offer it up



8. A piston mounted on its shaft ready for lapping in a piston lap.

to the bore with a small amount of mineral oil. What we are looking for here is for the piston crown to just pass the exhaust ports without force; when this is obtained try assembling the engine and with a propeller fitted try to turn the engine over. Hopefully you will succeed, with the engine feeling stiff and going over top dead centre with a squeak. This is exactly the fit we need. If the piston will not reach top dead centre, return it to the lap and give it two more strokes, no more, and try again. Carry on until the engine will turn over, don't worry if it feels tight, so long as you can flick it over. Later when the engine is run the harshness disappears.

Perfectly square

Diesel engines will need to have their contra pistons fitted at this stage. After removing the scale from the heating process, offer the contra piston up to the top of the cylinder bore with the cylinder removed from the engine. The contra piston must be perfectly square with the cylinder and I find the best way to do this is by using a very small vice and holding the components between two aluminium pads. (**Photo 10**). The contra piston must be a firm gas tight fit but obviously has to be moved by the compression screw and be moved back up when the engine is



9. Lapping the piston in the drill stand.

flicked over. If the contra piston will not enter or is obviously too stiff you will have to reduce the diameter by polishing with fine wet and dry paper held on a flat bar and lubricated with oil. Holding the contra piston in the lathe can be awkward. Some manufacturers provide a thread inside the top. The engine illustrated had a $\frac{1}{4}$ BSF thread; I simply held it on a bolt in the lathe. I have also seen BSP threads used. Other contra pistons can be held on a soft tapered mandrel and steadied with a running centre.

Now all components, which might have been in contact with the lapping compound, have to be removed and thoroughly cleaned. The method I use is as follows: - using a clean flow of paraffin (from a plastic squeeze bottle), the components are scrubbed using a toothbrush. Obtain a Scotchbrite or similar flat pan scrubber, which has been used and is completely soft and carefully rub all surfaces to remove any remaining compound. Particular care must be taken with cast iron and meehanite, as they are porous. Cut the pan scrubber into strips with scissors to clean the ports, gudgeon pin holes and conrod small ends. Test for cleanliness by dampening a piece of kitchen towel with cellulose thinners and wiping everything. Keep cleaning until the towel shows no discoloration, this is most important. Assemble the engine and it is

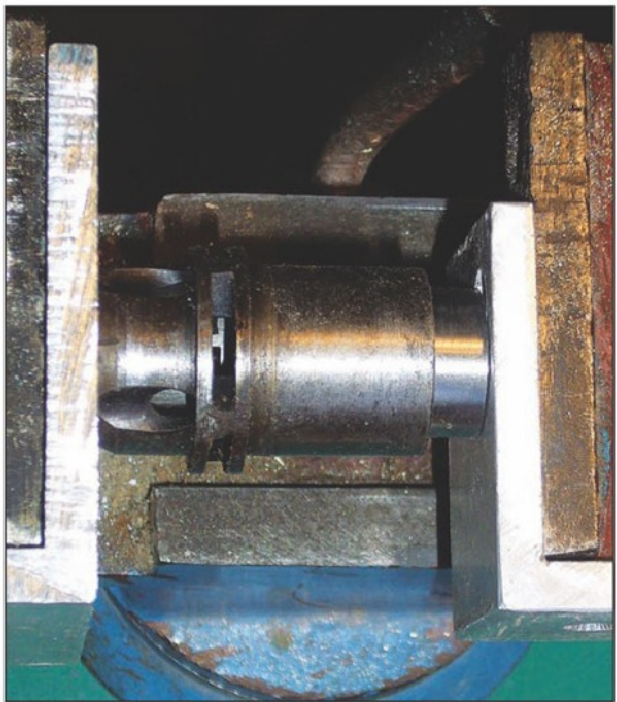
ready for a test run. Treat the engine as you would a new unit; use fuel with a high percentage of oil and try a large propeller for initial runs.

Hardened and tempered

Some engines have a different metallurgy to the above and will require different procedures: Mills engines have hardened pistons which will have to be replaced, in this case I use silver steel hardened and tempered, then lapped as above. Allen Mercury engines have meehanite liners as well as pistons and the 35 has an aluminium yoke in the piston to hold the gudgeon pin; unscrew this before heating the piston. Some ED Hunters also have a yoke. If you can obtain the engine tests for your engines you can ascertain the materials used in their construction.

Easier to hold

Making a piston is fairly straightforward. I start by turning the outside diameter with a fine finish. If the cylinder bore has been lapped it is possible to use the bottom of the cylinder as a gauge, if the piston just enters then this leaves a thousandth of an



10. Using a small vice to fit the contra piston into the liner of a small diesel engine.

inch or less to remove by lapping. Bore the piston and before parting it pays to mark, drill and ream the gudgeon pin holes, as the work is easier to hold at this stage. If the gudgeon pin is held by being a tight fit in one hole use a tapered hand reamer and try the pin until the fit is correct, then mark the piston so you know which hole is which.

At this stage the piston can be parted off, don't forget to allow enough material if the piston has a baffle. It is essential that the baffle, if your piston has one, is parallel to the gudgeon pin holes; I pass a bar through the holes and set the piston up using a dial gauge when milling the piston top for the baffle in the lathe.

It makes sense to keep the lapping compound away from every thing in the workshop. I keep the compound and all associated equipment sealed in a box in a cupboard. I wash my hands when lapping is finished or wear gloves. The blue decorators gloves from B&Q are paraffin proof.



Resource

Diamond lapping compound is available from
Arc Euro Trade
Telephone 0116 2695693
Website www.arceurotrade.co.uk

REMOVING BROKEN CENTRE DRILLS

Most of us have done it, broken a centre drill in an expensive casting. The question is how do we remove the broken centre drill without damaging the casting? One way is to carefully drill the broken bit out using a carbide drill. This works but the carbide drills are very expensive. There is however, a cheap source for these small

carbide drills. They are used extensively in the printed circuit board industry and are often available on the surplus market.

One of the best sources of these small drills are the Amateur Radio Rallies held around the country in the summer months. A box of 30 small carbide drills can often be picked up for a few pounds.

These are unlikely to be new but will probably have been broken in use and then reground. You can find details of a radio rally near you at <http://www.rsgb.org/events/index.php> which is the Radio Society Of Great Britain web site. Many thanks to Ted Fletcher for this useful reader's tip.

A PROFILE COPIER FOR THE UNIMAT 3

Maurice Rhodes shapes up.

A recent project required a number of caps similar in style to hubcaps and rather than having a plain surface, they needed a bit of simple ornamentation to be added. The fancy work was not to be any particular pattern, so there was no difficulty turning one of these in the lathe. Reproducing the remaining caps to match was the problem (photo 1). Having made a device some time earlier, to help with turning the convex and concave shapes for a small smokebox door, it seemed that the same device could also be used for the 'hubcaps' (photo 2). Although specific contours may be possible, the purpose of the device is mainly for repetition work.

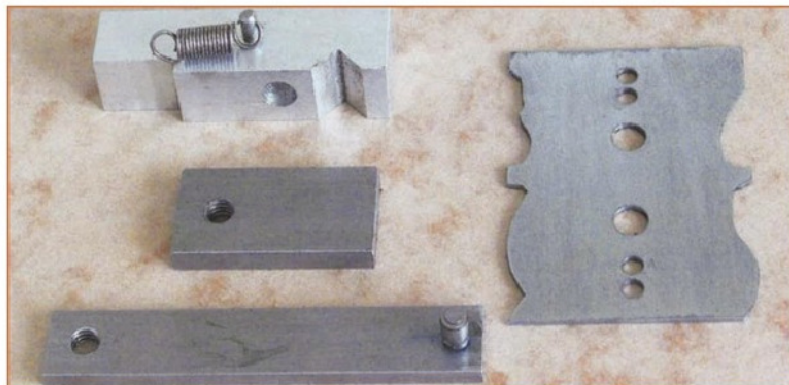
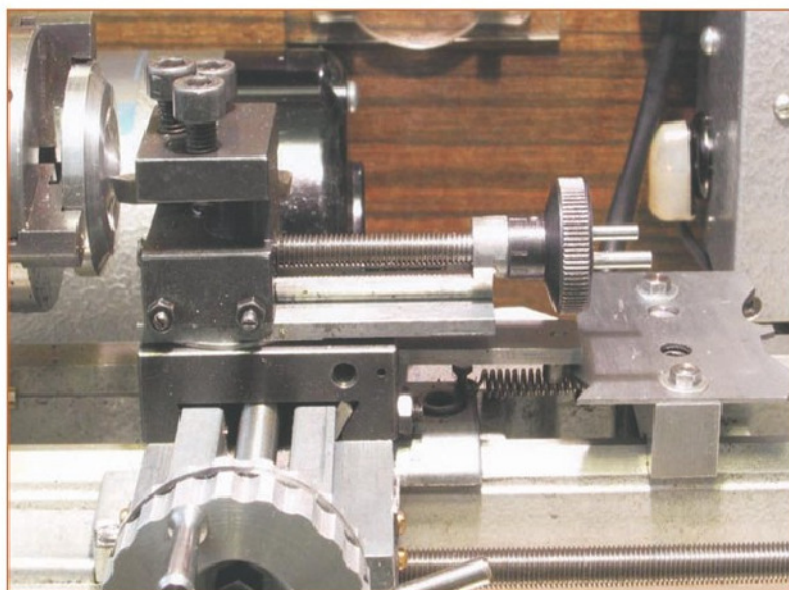
A block with an anchor point for one end of a spring is first clamped to the lathe bed behind the rear of the saddle. The other end of the spring is attached to a screw on the saddle (the hole for the screw can be drilled using a hand brace), so pulling the saddle towards the tailstock end of the lathe. Mounted on the top surface of the block is a template cut from sheet steel and shaped to a profile (photo 3). By turning the profile around or over, a selection of four profiles can be formed on the same baseplate. Two sets of fixing holes are provided to prevent the centre points of adjoining sections from overlapping.

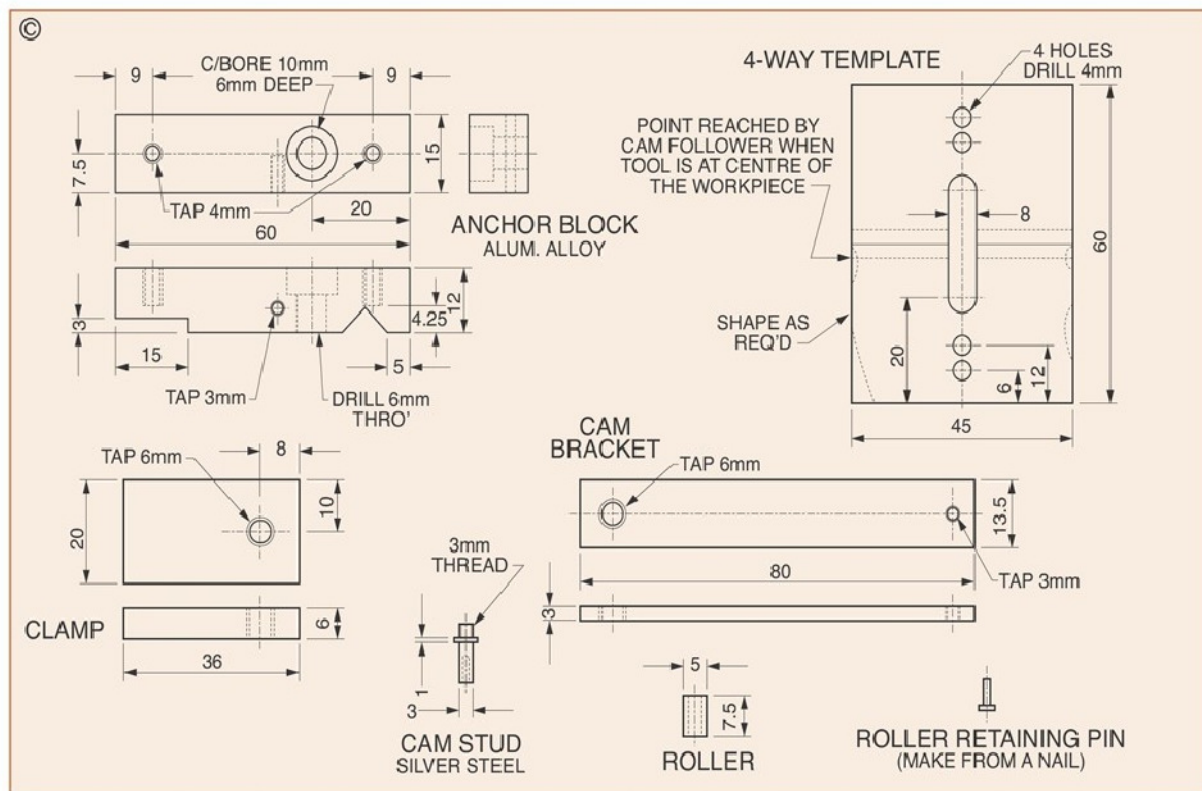
Simple to use

The 'Tee' nut used for securing the top-slide is replaced with a short length of bar, tapped at one end for the top-slide and with a small pin and roller fitted at the other end to act as a cam-follower. With the lead-screw bush loosened, the saddle is drawn towards the tailstock until the roller on the bar of the top-slide 'nut' pushes against the template, then by turning the cross-slide feed-screw, the cam will follow the template profile.

A tool ground to a similar shape as that used for thread cutting is set in the top-slide. The top-slide, which is used to feed the tool in, is set parallel with the lathe bed. It is important that should the tool be removed for sharpening, it must be re-positioned exactly, or a change of profile will appear on the workpiece. Only shallow relief is possible and steep angles against the pull of the spring should be avoided, though this is no problem if the angle is with the spring. A little help will be required at these points when returning the cross-slide for the next cut.

Specific template shapes may be possible with experiment, but sharp





corners on the template being followed by the roller will appear differently on the workpiece. The tool will also have some

effect as the different parts of its cutting edge come into play, during its travel across the work. For keeping the roller of

the cam follower in a place, a nail cut to length was used with the hole in the pin drilled to suit.



IN OUR NEXT ISSUE

Coming up in Issue No. 126 will be

Horology

Dick Stephen makes a spring loaded engraving cutter.



Bandsaw improvement

David Fenner describes a damper for the horizontal bandsaw.

Boring small holes

A miniature boring head by Harold Hall.



Issue on sale 22nd June 2007

(Contents may be subject to change)

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.

Aldi



The Aldi Supermarket chain may be best known for budget food lines, however they are often worth a visit to look for some of the non food items available, frequently electronics or DIY. A recent visit found the Ultrasonic cleaner back in stock at £15.99, and a 115mm angle grinder at £8.99. To go with the grinder, were packs of conventional discs at £2.99 and diamond discs for £3.99.

The conventional discs were offered as either a pack of 18 ultra thin (1mm) cutting discs or a 14 piece cutting and grinding pack. The diamond discs were offered as a pack of four chosen from three varieties, "segmented" for dry cutting concrete, bricks etc. "turbo" for wet/dry cutting on similar materials, and "full rim" for wet cutting tiles, ceramics or marble. The instructions indicate that the last is intended for use in a tile-cutting machine not an angle grinder. Three variations on the pack give a choice of contents from the types of discs, each being a one of each plus one. The purchase of a pack of these discs was not motivated by a latent desire to take up DIY, but to give them a try for sharpening carbide tipped tools.

Another item recently found in the same store, was a pack of four rechargeable Nimh cells, size AA for the princely sum of £1.99, - irresistible! Looking back over Aldi purchases, the other ones that come immediately to mind are: table saw - under £30, digital callipers under £9, computer graphics tablet A4 size - under £30, and a digital video camera at

under £80. Interestingly, the last item did develop a viewfinder fault and this presented an opportunity to test the store's guarantee policy. Having arrived with the faulty item and the receipt to prove date of purchase, I was immediately offered apologies first for the problem and second for the fact that it was no longer in stock. This was immediately followed by a no quibble cash refund. Full marks!



Machine Mart



Machine Mart's latest catalogue dropped through the door recently boasting a total listing of some 6500 items and something in excess of 650 new products with reduced prices on many items. They now list 52 stores located between Plymouth in the southwest, Deal in the southeast, and Dundee in the north. Two new stores in Burton upon Trent and Warrington are scheduled to open soon. For anyone who has not seen the catalogue, it runs to nearly 400 pages and covers a very wide range of building, automotive, engineering and leisure equipment. If you do not have one, the catalogue request line is 0845 450 1855 and the website www.machinemart.co.uk

On the Move

After some thirty years at their present address, Graham Stephens who runs Springside Models and Clay Cellars Castings, with his son Kristian, is about to move premises. The new location will still be at Newton Abbott, in Devon, and contact details will be confirmed soon. The Springside name is probably better known amongst the "Model Rail" rather than "Model Engineering" fraternity as they are highly respected suppliers of locomotive, buildings and detailing kits for 7mm, 4mm and 2mm scales. The Clay Cellars Castings side of things specialises in lost wax casting process, which allows the production of castings with exceptionally fine detail. While the majority of the business is trade based, they are willing to consider individual enquiries. They supply many and varied small hand wheels, also the manifold elbows for the Bentley BR2 model. The Springside web address is www.springsidemodels.com. Graham is also a member of Newton Abbott Model Engineering Society, whose site (www.nadmes.org.uk) carries a good deal of relevant information for those interested in using the lost wax technique.

Until the factory move is concluded, Graham may be contacted in the evenings at home on 01803 813 279.

WNT (UK) Ltd.

The latest promotion from this tooling supplier includes two parting off kit offers. One is likely to be too large for most home users, but the smaller offers a 26mm blade with ten inserts and ejector key for £69.00 plus VAT. Adding a clamping block would more or less double the price, but to make this part would be within the capabilities of man

In addition to a comprehensive variety of carbide tips, the mini catalogue also contains many types of milling cutters, - indexable single and multi tip, coated HSS, and solid carbide, also ball nosed forms. Although relatively expensive, some of the insert ranges aimed at small-scale work may be worth a look. The "TX" and "MiniCut" ranges are intended for cutting grooves, while many types of "Ultra-Mini" deal with different boring operations. Each of these ranges requires a dedicated tool tip holder and again, these do tend to be expensive, however home made versions should be feasible.

WNT United Kingdom Ltd are located at Sheffield Airport Business Park, Europa Link, Sheffield S9 1XU and operate a freephone sales line; 0800 073 2073



Socket sets from Chronos

Getting to grips with those small nuts and bolts can be a problem for many model makers and model engineers. To help with this, Chronos have responded to customer demand and introduced two high quality chrome vanadium socket sets, each to the popular $\frac{1}{4}$ in. square drive standard. The first is a purely BA set of nine sockets, covering the range 0BA to 8BA, and is supplied on a socket rail which may be screwed to a wall or shelf for easy access. The stock reference number is 3399, and the introductory offer price is £9.95 including VAT and UK mainland delivery.

The second set comprises 41 pieces and is supplied in a smart black steel case containing ranges of standard and deep sockets to BA, metric, and imperial standards. The standard length range includes not only those BA sockets from the 3399 set, but also 12 metric sockets from 4mm to 13mm. Within the deep socket section will be found nine metric sockets covering 4mm to 10mm, and ten imperial sockets, which deal with $\frac{1}{8}$ in. to $\frac{1}{2}$ in. A spinner driver handle is also contained in the box. The stock reference number for this set is 3398, and it is priced at £29.95 again including VAT and UK mainland delivery. For purchasers who may not have $\frac{1}{4}$ in. drive equipment, a suitable ratchet driver (stock No. 3723) is also available at £12.96.

Chronos are located at Unit 14, Dukeminster Trading Estate, Church St, Dunstable, LU5 4HU telephone 01582 471 900



Digi-Key Corporation

This is a firm which I had not previously heard of and which specialises in the supply of electronic components. They probably intend to rival a section of the range offered by the better known R.S. Components and Farnell. Their catalogue comes as a single volume of over 1700 pages. Their web address is www.uk.digikey.com



Variable Speed drives

The take up of inverter drives in industrial and commercial applications are often driven by energy saving aspects. For the home workshop, the main advantage is likely to be the variable speed facility rather than saved energy. The continued rise in popularity means that more suppliers and new products are regularly arriving on the market ensuring competitive pricing. Danfoss was historically perhaps better known in some quarters as a hydraulics business. They have recently announced a range of VLT Micro Drives covering power ratings from 0.18 to 7.5kW. Their website is www.danfoss.co.uk. Another firm advertising a low price drive is ABB who headline "from £95" although this excludes keypad and VAT.

For information on other manufacturers and suppliers, try Googling "variable speed drives". Typing in "inverters" tends to bring up the devices for generating mains AC from a low voltage DC input.

FIRESIDE READING

Electric Motors Second Edition

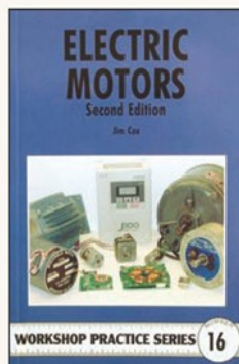
by Jim Cox

In the past, reference has been made on a number of occasions to two books by Jim Cox, "Electric Motors" and "Electric Motors in the Home Workshop". Both are published within the Workshop Practice Series, and each one is a mine of useful information, mainly on the use of electric motors but also on related topics.

The first of these has now been revised and updated to take account of technological developments which have occurred, especially with regard to motor types and control systems, (particularly variable speed drives), since it was first published in 1988. The popularity of the title may be gauged from the fact that it has been reprinted no less than ten times.

Following a common sense foreword on safety, the book then has ten chapters entitled:

- A few basics
- Induction motors
- Variable Frequency Drives & 3 Phase Operation
- Commutator Motors
- Stepper motors
- Speed control and electric braking
- Generators



Installation and protection
Identifying and using scrap motors
Test Equipment

For those whose knowledge of electrical matters is a little shaky or has become a bit of a distant memory, the first chapter alone is a justification for buying the book. It tries to "cover some of the essential elements of a two year course in basic electrics in a matter of a few pages" and in my view succeeds admirably, giving a concise explanation of the necessary concepts.

Workshop enthusiasts will probably find the chapters on induction motors, VFD's, and using scrap motors to be particularly relevant to their activities. The information given should ensure that pitfalls are avoided, and potentially much money saved. Under the heading of commutator motors

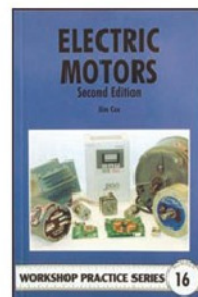
will be found useful data relating to a variety of sizes and voltage ratings, ranging from the miniature for model application, to the quite large, which might be used for machine tool power.

The final chapter discusses the use and adaptation of digital and analogue multimeters along with techniques for making relevant measurements.

This excellent book is No 16 in the Workshop Practice Series, extends to 152 pages and has over 100 illustrations. Many circuit diagrams are included. Published by Special Interest Model Books, the price is £6.95, and the ISBN no. is 978 185486 133 7.

Scribe a Line

Please send your letters to Scribe A Line (or Readers' Tips), The Editor, Model Engineers' Workshop, Magicalia Publishing Ltd., Berwick House, 8-10 Knoll Rise, Orpington, Kent, BR6 0EL or e-mail to david.clark@magicalia.co.uk and you will have the chance to win a book. Please remember to include your name and address. I have a copy of a book from the Workshop Practice range to give to the writer of the best letter (the editors decision is final) and also another book for the best readers' tip in each issue. Philip Robinson has been awarded 'Electric Motors (Second Edition)' by Jim Cox, for the best letter. There are no readers tips in this issue. Hopefully there will be plenty in the next issue. If you would like to purchase a copy of any book in the Workshop Practice series, please e-mail customer.services@magicalia.com requesting a book price list.



Star Letter

Philip Robinson via e-mail writes

This is the first copy of Model Engineers' Workshop that I have read, and I was impressed with the content (having read this issue, I phoned to order the previous two, which arrived the next day - good service). I have recently been seeking more information on metalworking, turning, etc., having been concerned with woodwork before. I have always repaired and modified woodworking machinery, and I thought it time that I pursued the metal side of it more professionally, having been a make-do and mender, and adopting any machinery to hand to help (e.g. my wife's variable speed woodturning lathe is great for hand held thread cutting - a big scroll chuck, and speeds down to 10 rpm - but don't get your thumb in front of the die-holder tommy bar!) Regarding Model Engineers' Workshop issue 122 page 38 - Renovating a Myford Super-7,

Mike Thurgood's mention of carbon arc brazing in the above article brought back memories of many years ago when I used this process to replace (as he suggests) bits of cars that had rusted away. Corrosion was much more prevalent then (or so it seemed). I can clearly remember replacing the sills / floor edges on an Austin A40 using the carbon arc torch.

The equipment was obtained from T F Keller & Sons, of Cattle Market Street, Norwich, who supplied a small transformer, the brazing torch, a "welder's helmet", and some carbon rods and flux coated (brass) brazing rods. A more refined version was available with a cooling fan on the transformer enabling it to be used continuously. The uncooled version had to be rested at intervals, as it got very hot!

I still have the torch and helmet, and still use it occasionally, though nowadays I connect it to my arc welder on a low amperage, the Keller transformer having "died" a long while ago. Keller's were located in an interesting building in Norwich, which I believe was once a steam engine showroom - they may still be there, but not selling brazing kits.

magazine is about. I also asked the owner for his special tip or tips on workshop layout, etc. (That proved to be quite a useful exercise as I used a lot of them to update my own workshop.)

I made a point of getting at least a couple of articles of small projects where the reader could shut him or herself away in the workshop for a day or two and come out with some finished tool or another, working on the principal that while reading about bigger projects is all very well most people want to have something to make as well as or perhaps rather than something to read. Of course at that time I started the magazine with only two projects that I managed to persuade the editor of the ME to part with, the rest I went into the workshop and made myself or persuaded a friend or two to make for me.

There were no contributors and it took a while for them to build up. Even when Harold Hall took over, although I left him a considerable number of projects, he had to make a lot of the projects for himself. I also tried to include as many small tips as possible, which were boxed and shaded. Finally each issue that I did carried a four-fold pull out centrepiece with a drawing of some project or another that appeared in the magazine. All in all I tried to keep things as simple as possible.

The only reason I eventually opted out of being editor is because the company wanted to increase the frequency of its publication. I was also doing a regular column for the ME and writing a number of specials such as World of Model Engineering and was involved with a couple of other magazines the company was publishing. Fortunately there are now a number of regular contributors so hopefully you will not have to dash into the workshop and make something for an article as was the case in the beginning and I am sure you will find editing MEW will give you a lot of pleasure. If I can at any time be of any help please do not hesitate to contact me, I am now a bit old in the tooth but am as keen as ever to see MEW successful.

I wish you the very best of luck in your new venture.

Stan Bray

David Clark, the new editor, emailed Stan Bray about the original concept behind Model Engineers' Workshop

Stan Bray replied from Lincolnshire

Sorry for the delay in replying but I have been a bit busy with one or two things and have not checked my e-mails for a few days. Then when I tried to reply to you I found that for some odd reason I could not send any e-mails at all and I have paid the bill honestly. Mind you it rather reminds me of a story I heard.

There were three men travelling in a car, one was an electrician, one a mechanical engineer and the third a computer engineer. The car broke down so they got out, lifted the bonnet to see what was wrong and each gave their verdict. The electrical engineer was quite sure it was electrical and said the circuit needed changing. The mechanical engineer

disagreed, he said it was a broken valve stem and the engine needed to be stripped. The computer engineer said "Let's just turn it off, shut the doors for a while, get back in and see if it starts."

I wish you every success with the magazine, I know I am a bit biased but I think it is easily the best model-engineering magazine on the market.

The original concept for the magazine was not far off the formula that it now follows. I wanted good general workshop articles and tried not to have any series. At that stage it was published quarterly and I thought that waiting three months for the next instalment of a project wasn't on. It is now published more regularly and so perhaps that idea is not quite so important. I tried to get a regular feature of a visit to the workshop of a well known model engineer, showing the general layout of the workshop, but giving particular attention to home made tooling as that is what the

Anthony Keogh writes by email

The Darex Drill Sharpening Attachment

I am no expert, but have been around quite a long time and I find Peter Brown's letter (March issue **M.E.W.**) rather puzzling. Is the four-facet method of sharpening twist drills really very widespread? I first came across mention of it in the instruction book on the Quorn, which I made quite a few years ago. I have had reasonable success in using the method and agree that it is rather time-consuming, but surely other methods are much more widespread.

Whether or no, my main reason for writing is to bring up the subject of the Darex sharpening system. Several years ago at an M.E. or trade exhibition I came across a stall selling the Darex. I thought, "Ah, here's the answer to my sharpening problems" and promptly bought one at somewhere around £100. Alas! I have been disappointed with it. Why I could not get good results I don't know, though I tried long and hard to "do as the book says". It is so long ago that now I cannot recall clearly the nature of the problems I met, and the device has reposed in its box at the back of a shelf in my workshop ever since. I wonder what experiences other users have had with this device.



Mr Davis of Reading writes

As a **MEW** subscriber and REMAP member, I would like to thank you for the publicity you give to REMAP. Although Engineers are always welcome, our panel (Berkshire) is also short of "admin types" i.e. Chairman, Treasurer and Publicity officer where engineering knowledge is not essential. I joined REMAP after a visit to the Model Engineer Exhibition at Olympia. I enjoy **MEW** and always find something of interest in it. (REMAP contact details can be found in **MEW** issue 122 on the Editors bench page).

David Paintin writes via e-mail

123 Cover picture

Dear Dave (Fenner)

You have very beautiful daughter - someone to be proud of - but I still think she should not be decorating the front of the magazine.

Dave Fenner replies

My daughter disagrees. She was included because she asked to be. As a professional beauty therapist and p/t model, there is no way she will adopt the oily hand appearance. The bikini was not featured as we felt it might raise blood pressure amongst some vulnerable readers. As it happens, Giles Parkes and I had an amusing phone discussion last night covering, inter alia, how many health and safety police would comment on the dangers of long hair etc.

Joerg Hugel writes via e-mail

On my desk is **Model Engineers' Workshop** issue no. 122. The lathe on the

cover page has really an attractive and pretty operator, but I hope before she starts any machining, she will change her outfit to narrow clothes and will protect her eyes and hair with goggles and a cap.

Brian Wood writes via email

123 Cover picture

I hope I am not the only one to spot the less than satisfactory electrical arrangements mounted on the Colchester lathe featured on the cover picture of Issue 123. Exposed terminals, cable draped casually down the front controls; naughty. The real crime of course was not doing the job correctly in the first place, and it presents a poor image for a usually excellent magazine. Bad timing for the new Editor too, sorry about that, but it couldn't go by without a comment.

Dave Fenner replies

When the Health & Safety police emerge from the cracks in the floorboards, you can say it's all at a harmless 24 volts.

David Ross writes via email

Clare Milling Collets

My **MEW** arrived today and I see on page 55 you have published my question about identifying and purchasing the Clare A milling chuck collets.

May I answer my own question having now found the answer? I eventually tracked them down to Home and Workshop Machinery of Sidcup who advertise in the **MEW**. They were able to supply me with collets of the size I required very reasonably and by return post.

Best wishes for your "retirement" from the magazine, it will be a hard act to follow!

Brian Corfield writes via email

I spotted David Ross's plea for help in *Scribe a Line* about information on Clare collets. I obtained a catalogue from Clare Fishers Ltd, 22 Spa Road, Bolton BL1 4AJ, Tel: 01204 521631 as I had a similar problem!

Lawrie Taylor writes via email

Mod's. to Malcolm Leafe's Clamp

The utilisation of Spur shelving is a clever bit of lateral thinking. Dare I suggest improvements?

By filing about $\frac{1}{16}$ in. off the lower lug on the shelf bracket to increase the gap between the lugs, the bracket will pop straight into the rail slots without tilting. This enables the lower edge of the jaws to lie flush on the rail.

I suggest jaws only $\frac{1}{8}$ in. deep so that clamped Contiboard can still lie flat on the bench. This requires the configuration that the bracket fits inside the U-section rail so that there is enough left for welding to the threaded bush. Purists could even make the sliding jaw T-shaped as a "key" in the slot to hold it upright.

Finally, a hex on the end of the feed screw allows adjustment by a small ratchet socket wrench. How the hex is welded/loctited/machined on the screw depends on your workshop facilities.

Neil Wyatt writes via email

Thanks for being a great editor of **MEW**, over the several years I have been a subscriber, and for your personal help and advice. I look forward to your continued involvement in the magazine, and wish David Clark every success.

Sadly, I must comment on one of the articles in your valedictory issue; that on evaluating capacitors is showing readers how to build a suicide machine.

When unconnected to a capacitor the full mains voltage will appear across the two test clips, and even when connected the voltage will approach the full mains voltage. One slip with a test clip or component lead, or just a capacitor with an internal short to the can would expose the user to a potentially fatal shock. This is the most dangerous electrical device I've seen published in anything dated after the 1960s.

The shame is that it could be made safe just by reducing the test voltage. Replace the mains voltage with a low voltage AC supply, 12 volts is more than adequate, and replace the bulbs with a resistor of say, 20 ohms. With either of these methods the measured value of the capacitor will vary depending on the mains frequency as well.

The simplest and most accurate way of measuring capacitance is easy with a modern digital multimeter able to measure small AC voltages (moving coil voltmeters are inaccurate at low AC voltages, and this technique also demands a meter with a high input resistance). Put five to twelve volts AC across two capacitors in series, one with a known

value. The voltages across the two capacitors will be in inverse proportion to their values. So if you use a 10uF capacitor and an unknown one, and the voltages are 4V and 8V respectively the unknown capacitor has a value of 5uF.

There are even more accurate methods, such as the Wheatstone Bridge that can be used for small values and exact measurement, but for the purpose of ascertaining the value of motor run capacitors that have uncritical values and wide tolerances, the above method is simple and above all safe.

Sorry to send you this missive at this time. I hope it doesn't detract too much from what I am sure will be a great deal of appreciation and good wishes, to which I would like to add my own.

Ted Fletcher comments by email

In reply to Neil Wyatt's comments all I can say is well, well, well, it would appear that we really have become a mambi-pampi nanny state. I and many others have been using this method of testing capacitors for, in my case 55 plus years, and have never ever heard of anyone receiving an electric shock or anyone being electrocuted when using this method.

As seen in the photos the croc clips are substantial. What or which hobby workshop has a Wheatstone Bridge I ask, maybe a TEC College but I and most others live in the real world. Actually I think Neil means an AC Bridge, Wheatstone bridge is for measuring resistance. I remember using an AC bridge at the Tec in the 1950's. Agreed some multi meters do have a Cap. range but for the odd time I need a multi meter with a Cap. range, I'll stick to the tried and trusted analogue type.

Life is an adventure and calculated risks are taken and I'm sure that readers are not all dangerous idiots. I have never heard of a capacitor fault to earth via the can, open circuit yes, short circuit yes (blown fuse), earth fault new to me but you live and learn. Neil mentions the capacitance value changing with frequency, true but I am only concerned with 50 or 60 Hz supply. I don't know of any Hobby model engineering workshop having a variable frequency electric supply, in former time Wadkins produced a frequency changer for use with their spindle moulders, but can't imagine any enthusiast having one of those.

Incidentally I have had my attention drawn to an article in the Brook Motor publication, "The Induction Motor" which shows an almost identical circuit diagram, it was suggested that I had poached the idea, we had a similar arrangement both in the army and civy rewind winding shops and we never had any safety problems. As we have become a mambi-pampi state I will close now, get my face mask, goggles, safe shoes and my site helmet on and go and make swarf, but I will be very careful with the Myford clutch or should I get my granddaughter to operate it remotely in the interest of safety.

I liked your brief article about BLACKING but be careful with the residual petrol, you might cause an explosion.

Received from Australia via email

Hinged machine mountings

I recently visited a "mature" model engineer, Eric Fewster here in Canberra. While looking around his well-equipped workshop, I noticed a bar guillotine and a hydraulic press against a wall. Initially I thought the location was a bit limiting and that reasonably sized jobs could not be accommodated, however on closer inspection I noted that the two items had been mounted on substantial pipe frames that allowed them to hinge out from the wall when in use. Very clever, I thought. I was assured that the concept was an Eric original and I pass it on with his permission to all who may find it useful. I have not supplied any drawings as anyone using the idea will have to make the dimensions to suit their equipment and will also use any bits of pipe that can be scrounged for the project.



Enjoy your retirement and the hobby. Sorry to sound cynical, it's my age. Ted.

Will Bells writes via e-mail

Regarding Mr. Ellis' letter in **Model Engineers' Workshop** issue 122 page 54 questioning the possibility of using a 12v car battery charger to power his cordless drill, I have to say that our esteemed Editor's comments (David Fenner) are pretty much on the button.

The characteristics of the high power permanent magnet motors used in these tools are such that they are designed to draw very high currents over short periods, when required. As the load is increased on the drill, the motor tries it's very best to help the determined user, resisting the drop off in speed by increasing the current consumption. At the point of stall, depending on the design of the drill, the current can be a surprising 30A, but 100A is possible. Of course, the tool will only take that sort of abuse for a short time - more than a few seconds and the internal wires will start to melt.

So, whilst no load running, or very light duty use may well be possible, using the drill in anger is, unfortunately, well beyond the capabilities of a standard battery charger, probably rated below 8A. As David stated, a car battery is capable of delivering the required power, but care must be taken to ensure that the cable from

the battery to the drill is adequately rated.

I personally use my cordless drill extensively (shamefully, I even use it for tapping holes), rarely resorting to the corded one, and usually manage well by having two battery packs and a fast charger. The cost of these tools has plummeted over recent years, but if the cost of the additional pack is too high, you may want to consider a corded drill. I was looking at one in my local supermarket for £7.99 recently, which is probably cheaper than the heavy duty cable you would need to connect a car battery - funny old world, isn't it?

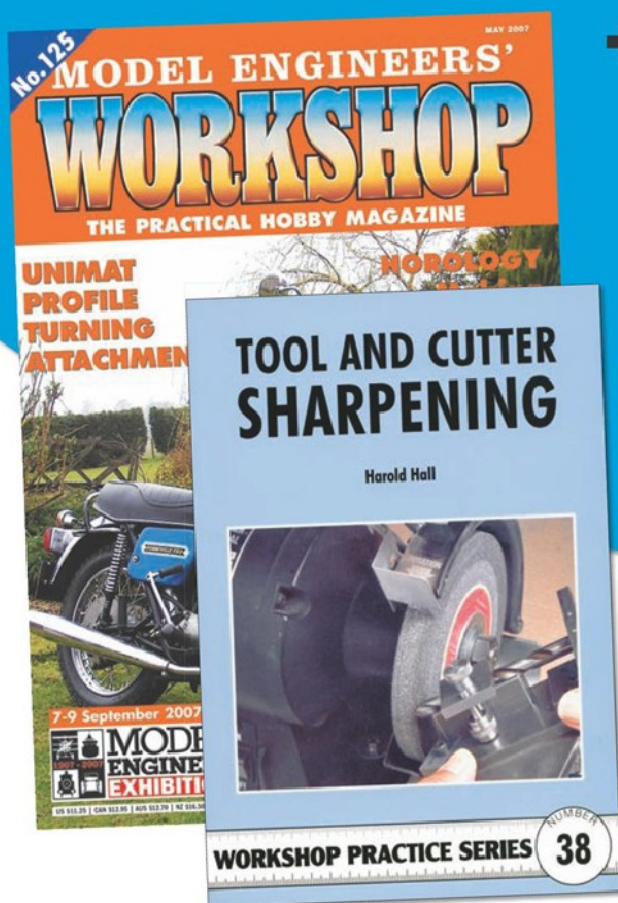
Arthur Davies writes from Australia

Protecting sharp edges in transit

I am sure that most of us have had to take lumps of metal home in the car and have been worried about them damaging the interior. In the past I have padded all corners and edges with rags, however, I have found that plastic shopping bags work better. Just take a plastic bag, shopping bags work fine but any will do, and stuff it with more crumpled up plastic bags and put the metal in. You will find that the bags have more resilience than rags do. When you are finished or when the bags have been damaged, they can be put in the bag recycling bin.

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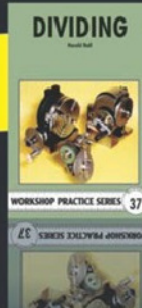
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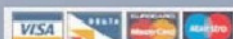


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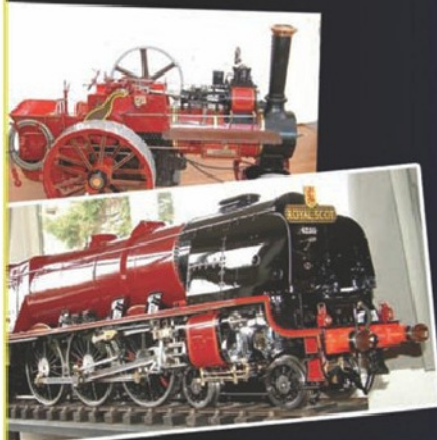
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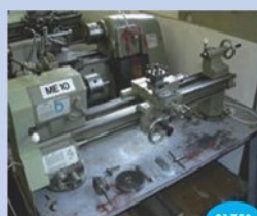
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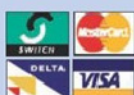
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