

No.66

JUNE-JULY 2000

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MODEL ENGINEERS'

WORKSHOP

THE PRACTICAL HOBBY MAGAZINE

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Suitable
for smaller
lathes

MEASURING TEMPERATURE

For better
process control

MACHINING A SMALL CRANKSHAFT

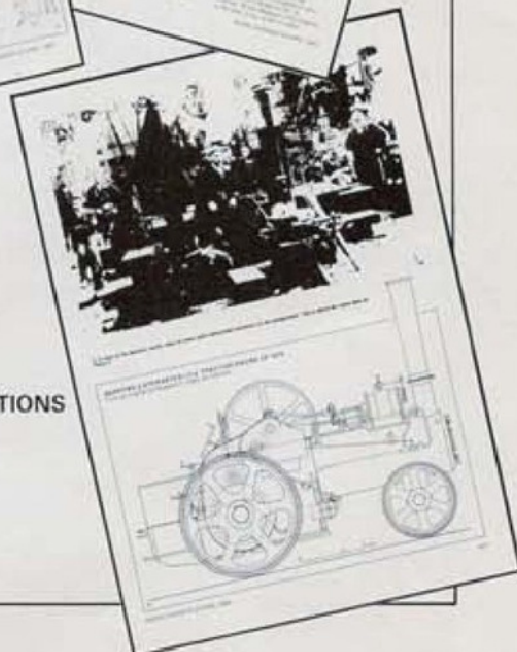
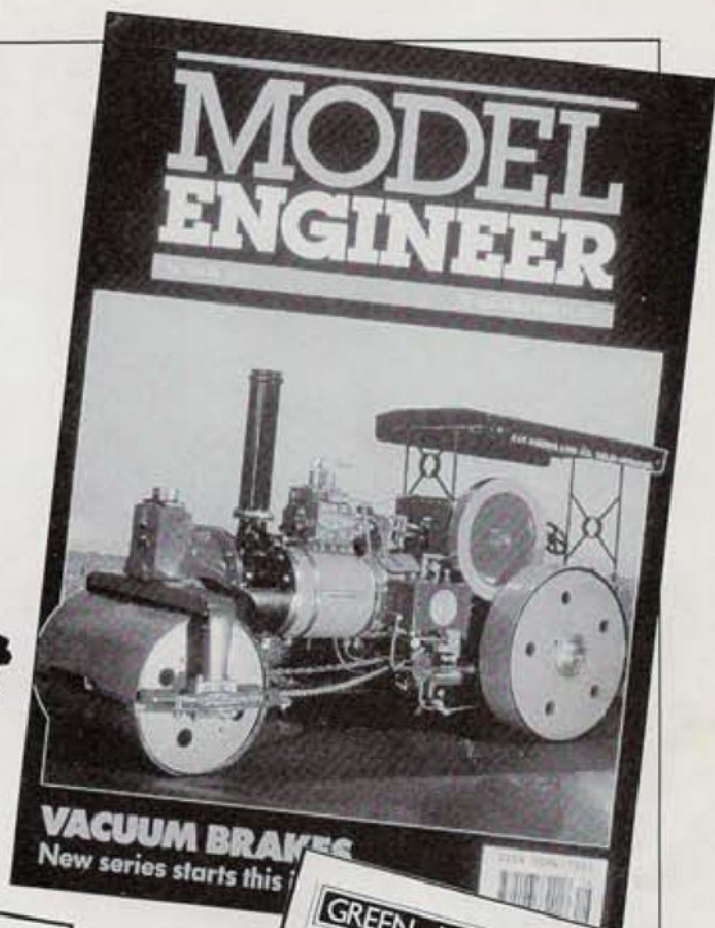
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and tooling

ELECTRO-MAGNETIC DEVICES

Principles and theory



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



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

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Nexus Special Interests
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EDITORIAL

Editor
Geoff Sheppard

Editorial administrator
Sarah White

PRODUCTION

Designer
Carol Philpott
Copy Control Manager
Lucy McGeough
Printed By
St. Ives plc (Andover)
Origination by
Derek Croxson Ltd.

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Sales Executive
Mark Pinkney

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Group Managing Director
Tony DeBell
Divisional Managing Editor
Dawn Frosdick-Hopley
Divisional Sales Manager
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Group Marketing Manager
Teresa Pilgrim
Newstrade Sales Manager
David Pagendam

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MODEL ENGINEERS' WORKSHOP JUNE-JULY 2000

CONTENTS

Issue No.
66

Editor: Geoff Sheppard

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

11

ON THE EDITOR'S BENCH

Geoff Sheppard's commentary

12

MEASURING TEMPERATURE

Practical methods which can assist in
the control of processes

17

A GENUINE LECOUNT MANDREL

A rare find

18

HAND TURNING Part 2 - Wood

Extending the application of the
process

24

A TESTING PROJECT

One home-built machine is used to
make components for another

27

TURNING A TORUS

Moving in unusual circles

28

A SPINDLE CLUTCH FOR THE SMALL LATHE

Adding a facility to a popular machine
tool

30

MAKING A SMALL CRANKSHAFT

Advice for newcomers to the hobby

32

BLOCKS & TRAMMELS

Simply made aids to setting and
marking-out

35

CNC FOR PRACTICAL ENGINEERS

Acquiring 'soft' data for subsequent
processing

40

AN ATTACHMENT FOR A BOSCH ROUTER

Extending the capability of a
woodworking power tool

44

SPINDLE AND SHAFT SPEED MEASUREMENT

Constructional details for a reflective rev.
counter

51

A WIRE BRUSH SUBSTITUTE

Polishing mops for the mini-drill

52

TRADE COUNTER

New items from our suppliers

54

ELECTRO-MAGNETIC DEVICES

An explanation of the basic principles

57

SCRIBE A LINE

Reader to reader

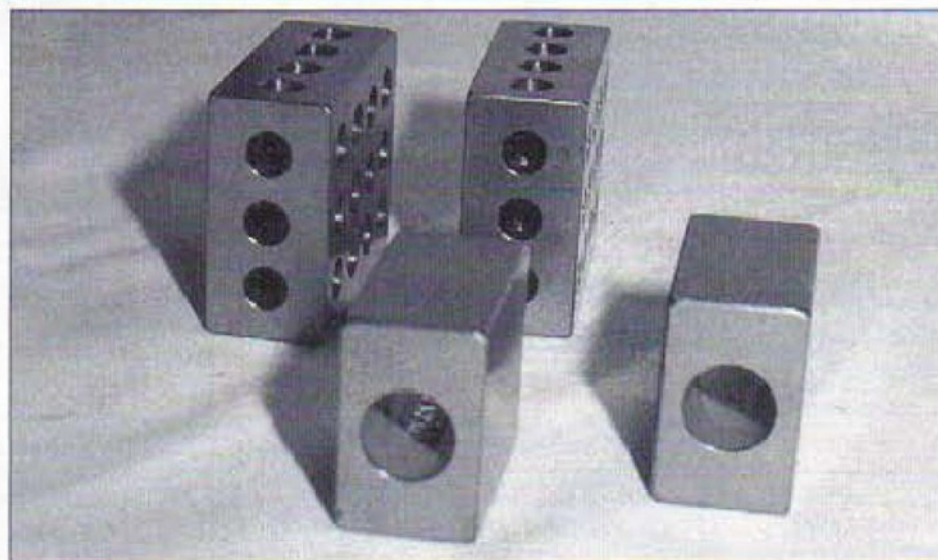
59

LINK UP

Readers' Sales and Wants

On the cover

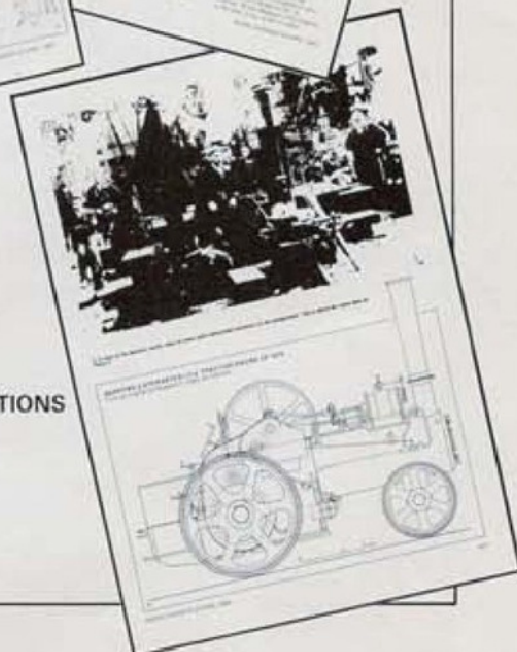
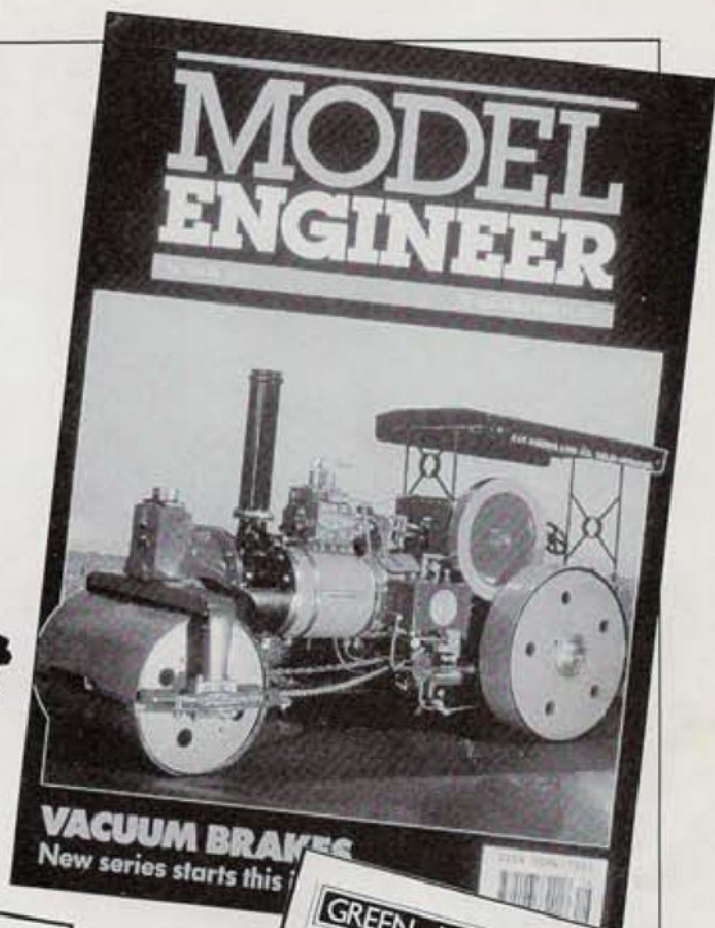
The 'Potts' Universal Milling Attachment has been available for many years, but is still a popular project. Advertised in 1946 at £13-15-0 (£13.75) finished or 30/- (£1.50) for the castings, the latter are still available from Woking Precision, but the cost is now a little higher! This excellent example won a Bronze Medal for John Slater at last year's Model Engineer Exhibition.



Precision blocks are not difficult to make and will find many uses in the home workshop. Len Walker gives full instructions on page 32

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ON THE EDITOR'S BENCH

Back last Autumn, I wrote of our interest in horse gins (sometimes known as whims), my wife having had the task of explaining the purpose of such a device to some young people visiting one of our local National Trust houses. Her task was made somewhat difficult by the fact that only the cobbled circle remains, all the machinery having disappeared a long time ago. We had been told of a working example at the Acton Scott Historic Working Farm which is situated near Church Stretton in Shropshire, so we managed to pay them a visit before the end of their season. As it happened, we were not able to see the machine working because the horses were otherwise engaged, it being a 'Threshing with Steam and Flail Weekend'. We were, however able to enjoy the sight, sound and smell of a superbly restored Fowler engine driving a threshing box. Many other activities were in progress, one being a demonstration of wood turning on a pole lathe and another was brick making, using a newly constructed kiln.

Our journey was in no way wasted because we were able to examine no less than three gins, one being permanently installed in the farm yard and connected to a range of farm machinery housed in an adjacent building. A second geared unit was set up as a portable machine, able to be located wherever required, while the third consisted of nothing more than a mill stone, free to rotate on a horizontal shaft which was pivoted at the centre of an annular trough in which the stone ran. This device was to be in use on the next weekend, crushing apples for a demonstration of cider making. Unfortunately, other commitments prevented a return visit to sample the product.

A few days later, we were surprised and delighted to receive a letter from a reader, offering a near complete horse whim if we could find space to accommodate it. Richard Brown, one of the team which looks after the collection of steam engines at Combe Mill which is located near Long Handborough in Oxfordshire, said that they had been given one by a local farmer some years ago, but had been unable to

find a suitable location in which to display it. Negotiations between the National Trust and The Combe Mill Society are now nearing a successful conclusion and, hopefully, by the time you read these words, the machine will be installed in its new home at Dyrham Park, the NT property situated just north of Bath. Replacements for one or two missing items will have to be located or made, but I hope that, in the fullness of time, it may be possible to see some period farm equipment actually demonstrated under one horse power.

All this means, of course, that there is yet another place of interest on our visiting list. Combe Mill houses, among other things, a double-acting rotative condensing beam engine which bears the date 1852. The maker is unknown, but both the boiler front and the boiler feed valve bear the name "Thomas Piggott, Birmingham". The boiler, of the Cornish type is said to be the original one, installed at the same time as the engine, and is thought to be the oldest one in steampable condition in the country. The pair can be seen 'in steam' between 10.00 am and 5.00 pm on the third Sundays in March, May, August and October of each year.

Also on the site is a breast-shot water wheel of 'Poncelet' design, General J. V. Poncelet having been a French engineer who improved the efficiency of the water wheel by introducing curved instead of straight buckets or paddles. This is of particular interest because the other water wheel with which we are involved, that at the Saltford Brass Mill on the River Avon, also incorporates a feature which some sources attribute to Poncelet, that of the inclined sluice gate controlling the flow of water to an undershot wheel. This design replaced the simple vertical gate which was subject to turbulence, which limited efficiency. The inclined gate, positioned at an angle of between 40 deg. and 60 deg. to the horizontal and controlled by a rack and pinion, forms a variable tapered nozzle which directs the water jet in a smooth flow towards the bottom of the wheel. One reference work I have states that Poncelet introduced this system in 1824, but other authoritative sources are convinced that the feature appeared at a much earlier date. It would be interesting to find confirmatory evidence.

At Saltford, work has been continuing throughout the winter to prepare to receive visitors, the open days occurring on the second Saturday of each month throughout the summer. A major task has been the replacement of the sluice gate of the one remaining water wheel, this job having been undertaken by Dorothea Restorations. This was of particular interest to me, as one of the directors of that company was formerly one of our

apprentices in industry and joined the group of engineers involved in the restoration of the Crofton beam engines. He became so enthused with the industrial archaeology scene that, on completion of his training, he left to set up as a professional restorer. His company now enjoys a world-wide reputation as experts in the field, regularly being called upon to undertake the most prestigious projects.

Unfortunately, at Saltford, very little of the original machinery survives, so it has been decided that we should commission a model of a stand of tilt hammers in order to better illustrate the battery process. Our first problem is to gather sufficient information on which to base the design of the model because all we have is a sketch based on the recollections of a former worker, now deceased, and a very early photograph of a mill in Germany, where the industry originated. I recall that, in the 1950s, the late W. J. Hughes and a colleague built a model of a stand of hammers formerly used in the steel industry and now preserved. There is, of course, also the installation at the Finch Foundry in Devon, but this is of a somewhat different form. If any reader has any relevant information, I would be pleased to hear.

Health & Safety Executive documents relating to passenger carrying miniature railways and miniature road vehicles

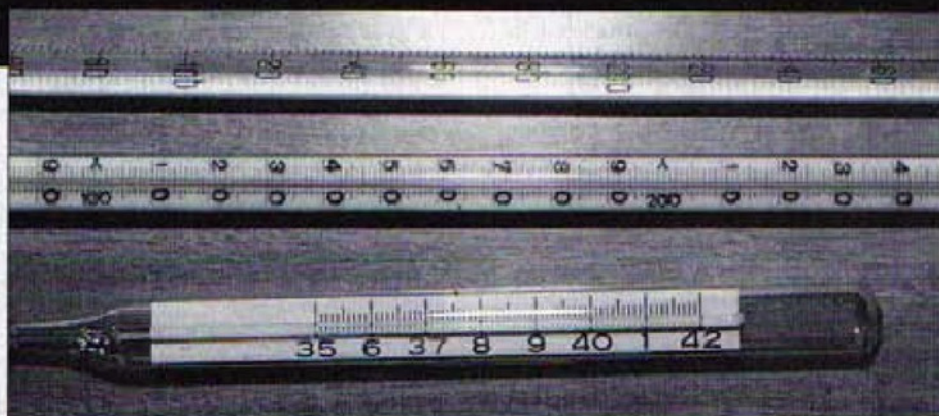
Dr Terry Williams at HSE's Glasgow office reports that the guidance note to be published as a free information sheet for miniature railways, miniature traction engines and miniature road vehicles has been delayed and will not now be published until early June. It will then be circulated through the trade press, Associations and Societies.

The miniature railways liaison group has also drafted a consultation document entitled *Passenger Carrying Miniature Railways; Guidance on Safe Operation* which will eventually replace Technical Note 3. It is specifically aimed at operators of miniature railways. Copies of the consultation document (not available until early June) can be obtained by sending your name and address to Dr T.G. Williams at the Health and Safety Executive, 375 West George Street, Glasgow G2 4LW. Anyone is free to take part in the consultation process. Your comments should be sent in by 31 August 2000.



MEASURING TEMPERATURE

Extending the range of processes employed in the home workshop make it likely that the ability to measure temperature to a reasonable degree of accuracy will be a requirement. Philip Amos describes some of the available methods



1. Top: plain thermometer scale, Middle: enclosed scale type, Bottom: clinical thermometer



2. Physical protection for mercury-in-glass thermometers

Introduction

There seem to be four main areas of home workshop activity where it becomes necessary to measure temperature. These are:-

- (i) Chemical solutions used in such processes as electroplating
- (ii) Heat treatment
- (iii) Foundry practice
- (iv) Ceramics

This article discusses what equipment can be used for these purposes under general headings of:

- A. Lower temperatures [item (i) above]
- B. Mid range temperatures [item (ii) above]

- C. High temperatures [items (iii) & (iv) above]

General

Standard temperature scales derive from fixed points such as the melting point of ice (0 deg. C) and the boiling point of water (100 deg. C). Gas thermometers which rely on Boyle's and Charles' laws have been used to extend the scales in both directions from -182.97 deg. C (boiling point of oxygen) to +3400 deg. C (melting point of tungsten). Accurate gas thermometers are large, cumbersome and difficult to use, and are unsuitable for routine work - they are to be found only in standards laboratories.

A. Lower Temperatures

Liquid in Glass Thermometers

Solutions normally are of various chemicals dissolved in water, which means the temperatures involved are between 0 deg. C and 100 deg. C. For this range, the liquid-in-glass thermometer is well suited as it is relatively inexpensive, convenient and accurate.

These thermometers have a glass reservoir connected to a long fine capillary tube sealed at the opposite end. The liquid contained in the reservoir is usually mercury and the space above the mercury in the capillary tube is evacuated. As mercury freezes at -39 deg. C, either dyed alcohol or pentane are used instead of mercury for very low temperatures.

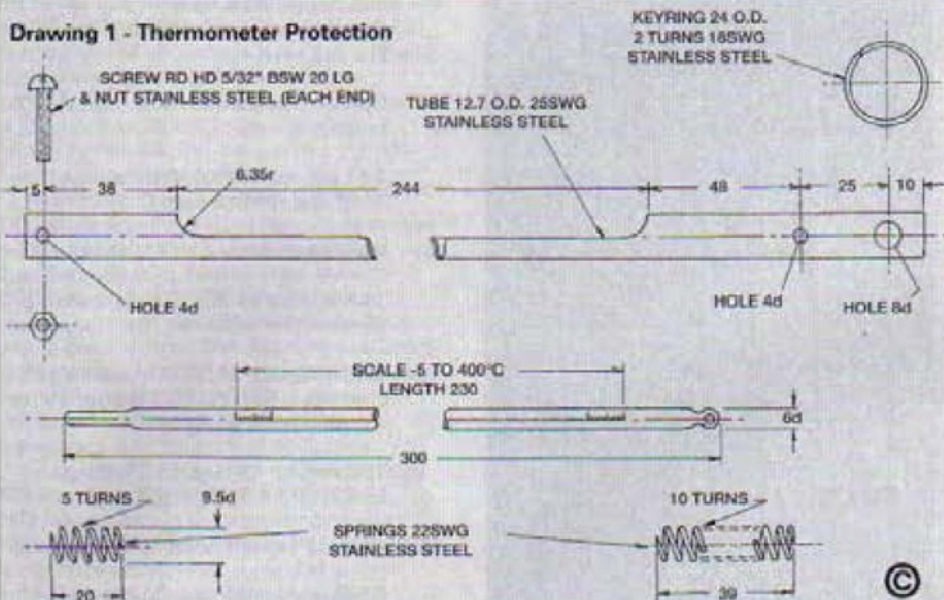
At the other end of the scale, mercury thermometers are available for use up to about 530 deg. C with special glass and the free space filled with nitrogen or carbon dioxide under pressure. There may be problems of stem distortion above about 480 deg. C. Chemical laboratory mercury-in-glass (vacuum) thermometers usually have a maximum reading of 360 or 400 deg. C and a minimum reading of -10 deg. C.

Alcohol-in-glass thermometers cover a range -70 deg. C to +65 deg. C, and pentane-in-glass types -184 deg. C to +21 deg. C. All have the outside of the glass capillary tube shaped so as to produce a magnified image of the liquid column - slight rotation of the thermometer will produce this effect, which greatly facilitates reading.

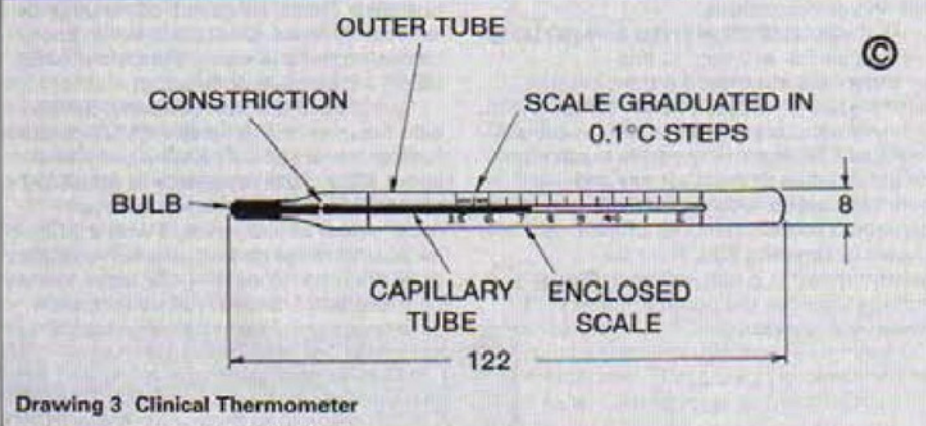
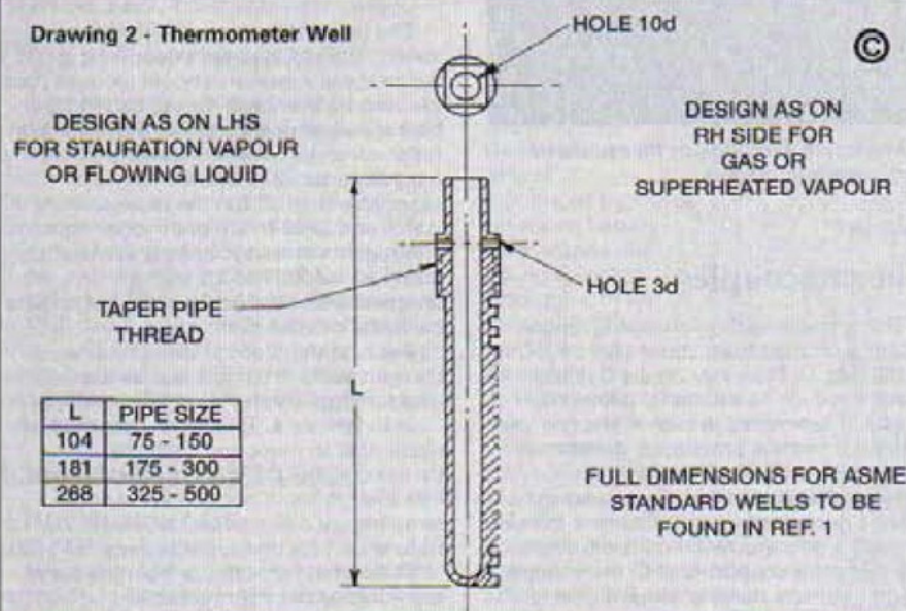
Thermometers are calibrated for total immersion; if only the bulb is submerged corrections may be necessary for extreme accuracy. This is also the case if the instrument is subjected to high external pressures (Reference 1). However, these considerations will not normally concern home workshop people.

Two styles are readily available and both are usually 300 to 400mm long. The cheaper of the two has its graduations engraved on the outside of the glass and these lines are filled with some dark colouring matter. However, many solutions destroy this colouring and the thermometer then becomes very difficult to read. This

Drawing 1 - Thermometer Protection



Drawing 2 - Thermometer Well



Drawing 3 Clinical Thermometer

problem has led to the production of enclosed scale thermometers, where there is a separate scale attached to the capillary tube and both are enclosed in an outer glass tube. Both types are shown in **Photo. 1**.

As these instruments are quite fragile, some physical protection is desirable. Mine are provided with spring mounting in cutaway stainless steel tubes, as depicted in **Drawing 1** and **Photo. 2**.

When it is desired to measure the temperature of a gas or vapour in a pipe, a thermometer well is used - as depicted in **Drawing 2**. The well is filled with a non-viscous liquid of high conductivity e.g. water, alcohol or kerosene for low temperature, oil or mercury for medium temperatures and molten tin or solder for temperatures above 315 deg. C.

To digress, the normal clinical thermometer (**Drawing 3** and **Photo. 1**) as

found in the home medical kit is usually a mercury-in-glass type with a very restricted range of 35 deg. C to 43 deg. C, but with a widely spaced scale for easy reading. (A healthy person's temperature only varies slightly from 36.9 deg. C). These thermometers are made with a constriction in the capillary near the bulb. As the mercury in the bulb expands with temperature increase it forces its way up the capillary, but as it cools down and the mercury contracts, the column breaks at the constriction, leaving the mercury above it in place, so that the temperature reading may be taken at leisure. This isolated mercury column must be shaken down again before re-use.

Thermometers recording maximum and minimum temperatures in the workshop may sometimes be of interest. A typical one is shown in **Photo. 3**. It comprises a U-shaped capillary with a sealed bulb on top of each leg. That on the left is completely filled with alcohol, and that on the right is about half filled, also with alcohol. The two alcohol columns are separated by a mercury column. There are also two very thin steel index pieces, one in each leg, the weight of which is insufficient to overcome the friction with the inside of the tube, so that they stay at the height to which the mercury column pushes them after the mercury retracts. They are re-set when desired by an external magnet, also seen in the photo. When the temperature rises, the left hand alcohol expands, pushing down the mercury column against the right alcohol column which also expands, but the expansion is taken up by the space at the top of the right hand column. Thus the index in the right column records the maximum temperature reached. When the temperature drops the process is reversed and so the index in the left column records the minimum temperature. It will be understood that the alcohol does the measuring; the mercury merely provides an indication marker.

Solid Expansion Thermometers

These are widely used in industry. Here the sensitive element is a bimetallic strip or coil, fixed at one end and with the other end moving a pointer to show temperature on a scale (see **Drawing 4**).

The bimetallic strip comprises two metals having different thermal coefficients of expansion [e.g. brass (L) and nickel (S) in the drawing], which are pressure welded together by rolling. In consequence of the different expansions, the strip bends when heated. Quality can vary from room thermometers costing a few cents, through the push-in rod-with-dial type for the Sunday roast to laboratory types of fair precision but greater cost. All need to be regularly checked as the zero point tends to change with use. The ranges are similar to the liquid-in-glass types but they are much more rugged instruments.

The same principle of operation is used in electrical thermal circuit breakers and motor starter overload protection where the bimetal is heated by the passage of current through it or through an adjacent heater coil.

Pressure Gauge Thermometers

These devices are also widely used in industry where remote reading is desired. The operating fluid may be liquid, vapour or gas, and the design is shown in **Drawing 5**. Cheap units for automotive use may have an accuracy of only 5 to 10% of full scale reading, but larger units for industrial and laboratory service can provide 1 to 3% FSR accuracy. As the bulb is sensitive to radiant heat, it is better arranged that the bulb cannot 'see' surfaces much hotter or colder than that being measured.

Digital Thermometers

As these are available in a wide variety of ranges they will be covered later below.

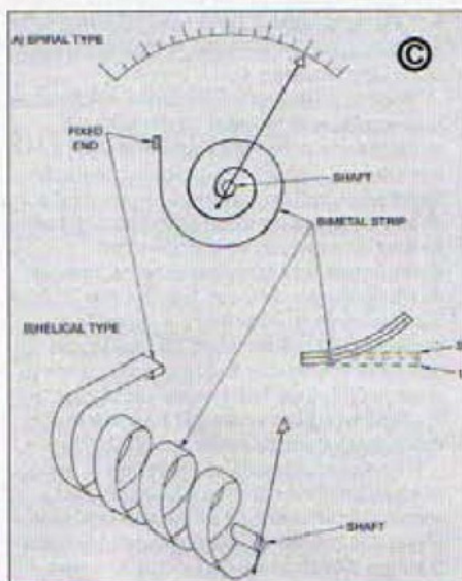
B. Mid Range Temperatures

Liquid in Glass Thermometers

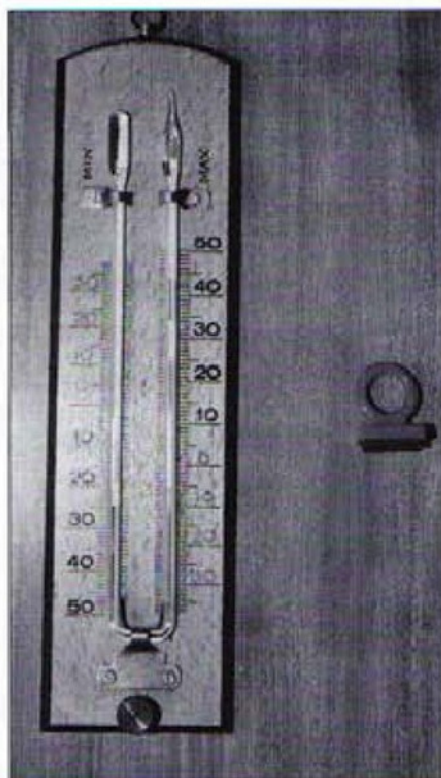
For tempering salts the normal range of temperatures required is from about 200 deg. C to 340 deg. C, which is well within the mercury-in-glass capability. The salt used is a mixture of sodium nitrite and potassium nitrate which melts at about 160 deg. C. I use a proprietary brand called Tempersal which I find melts at 175 deg. C.

Obviously you can't put the thermometer into the solid salt until it has melted and the thermometer needs to be warmed up gradually before this is done to avoid the glass cracking. When you later remove it there is a covering of solidified salt which must remain until the thermometer cools to room temperature, when (fortunately) the salt can be dissolved off in water. If you just put the hot thermometer into cold water it will probably crack.

Nevertheless, with these sensible precautions it is quite practical to use a mercury-in-glass type for this tempering



Drawing 4 Solid Expansion Thermometers



3. Maximum & minimum thermometer with resetting magnet

process.

Thermocouples

These cover (with overlapping ranges of temperatures) from about -200 deg. C to +1760 deg. C. They rely on the Seebeck effect, in which two wires of different metals, if connected at both ends, one end being hot and the other cold, generate a small voltage. The circuit shown in **Drawing 6(a)** shows the set-up where the voltage generated causes a current to flow through a galvanometer (millivoltmeter). The current is proportional to the voltage, which in turn is roughly proportional to the temperature difference between the hot and cold junctions.

As the cold junction in the drawing is in melting ice i.e. at 0 deg. C, this arrangement will measure the temperature directly. Accuracy with the millivoltmeter arrangement can be about 1 to 2% of FSR. A more accurate result can be obtained by using a battery and potentiometer to balance the voltage generated so that no current flows, as shown in **Drawing 6(b)**. Here the galvanometer is a null indicator. The voltage V across the potentiometer is iR where the current

$$i = \frac{E}{R+Z}$$

The voltage which balances the thermocouple voltage is

$$\frac{r}{R} \times V$$

so the potentiometer can be calibrated to read temperature. This approach improves the accuracy to less than 1% FSR. In effect, this measures the generated voltage directly and hence

the temperature difference.

Various metal combinations yield different voltages:

- (a) Copper/Constantan (60% copper, 40% nickel)
 - 1.11 mV for 10 deg. C difference
 - 16.03 mV for 316 deg. C
- (b) Iron/Constantan
 - 1.44 mV for 10 deg. C difference
 - 65.00mV for 1093 deg. C
- (c) Chromel/Alumel (90% nickel 10% chromium/94% nickel 2% aluminium + manganese & silicon)
 - 1.08 mV for 10 deg. C difference
 - 55.53 mV for 1371 deg. C
- (d) Platinum/Platinum with 10% Rhodium
 - 0.148 mV for 10 deg. C difference
 - 17.339 mV for 1649 deg. C

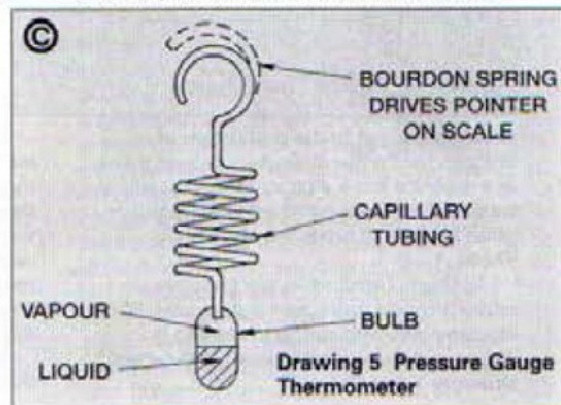
The upper temperature difference stated above is also the upper limit at which these materials should be used (but see also Reference 4). Combination (a) is best at low temperatures as the materials resist corrosion. For mid range temperatures (b) is suitable and less expensive than (c) but the latter is more stable and goes to a higher upper limit, although its output voltage is somewhat less than for (b). For the highest temperatures (d) must be used but is quite costly [about five times (c)].

Because the thermal capacity of a thermocouple is small it can be used to measure rapidly changing temperatures.

In Reference 4, Tubal Cain describes in detail how to make and calibrate thermocouples and their meters. He also lists their millivolt outputs for various temperature differences (see also Reference 1 for these, particularly Pt/Pt-Rh).

The use of leads made from the same materials as the thermocouples themselves greatly simplifies the whole business. These are called 'continuing' or 'extension' leads. Lead colours can be confusing; most are to US standard ANSI M96.1 - British are different.

I purchased a Chromel/Alumel device with 5m. continuing leads with US colours (yellow + and red -) in 1988 when it cost about \$A30. Total resistance in circuit is 24 ohms. This is used with an analogue multimeter I already owned with a 0-50 microamp range and an internal resistance of 3610 ohms. Measuring the latter was a bit tricky as, of course, you cannot allow



Drawing 5 Pressure Gauge Thermometer

more than 50 microamps through the meter without damaging it. A friendly company was able to do it for me with a high impedance digital multimeter - schools and colleges probably have the equipment available in their physics departments, so may be worth a try. My outfit is shown in **Photo. 4**.

I calibrated my set-up as suggested in Reference 4, using boiling water and melted tempering salt, with a mercury-in-glass thermometer with seven points from 25 deg. C to 400 deg. C. This set of points closely followed a straight line which was then extended from 400 deg. C to 1400 deg. C. From the currents and resistances in the circuit, the millivolts generated were calculated and found to be in close agreement with the published figures.

From 2 to 12 microamps corresponds to 180 deg. C to 1060 deg. C. I keep a calibration chart in the workshop to allow easy determination on the day of what temperature difference is needed above ambient (read from a mercury-in-glass thermometer) and so what current to aim for on the meter. It seems to work quite well.

Digital Thermometers

Instruments are available which show temperature directly on the digital read-out using thermocouple inputs. The instruments cost about \$A200 and the thermocouple, loose sheath, leads and power pack about another \$A110, so although convenient they are not cheap. These prices relate to Chromel/Alumel (up to 1200 deg. C max) and Nicrosil/Nisal (up to 1300 deg. C max). For Platinum/Platinum-Rhodium (up to 1400 deg. C max) the price goes up another \$A135 which makes it a very costly exercise. These instruments are very accurate.

Electrical Resistance Thermometers

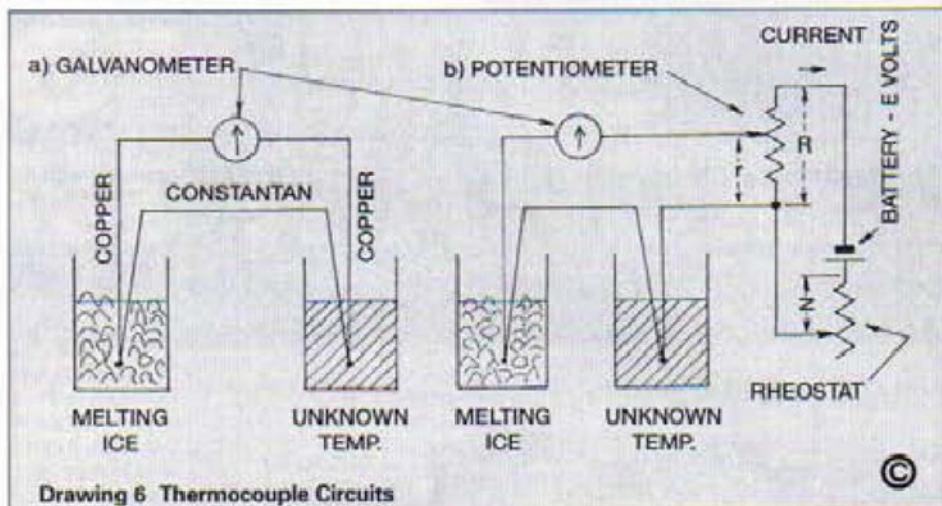
Using a bridge circuit and a null indicator as shown in **Drawing 7**, the change in resistance of a coil of fine wire of nickel or platinum can be measured to very close limits, and this change can be used to measure temperature. Such thermometers can measure temperature differences to one ten thousandth of a degree C. The scheme is useful for distant reading installations, where only a few degrees of temperature change is to be covered.

In this Wheatstone bridge circuit, the measuring coil 'A' ohms and its leads, 'L' ohms are in one arm, and matching dummy leads 'D' ohms (= 'L' ohms) and a variable resistor 'R2' ohms are in the adjacent arm. Resistances 'R3' ohms and 'R4' ohms are equal and form the other two arms. 'R1' ohms is another resistance with a variable connection. The null indicator will show that the bridge is balanced and then

$$\frac{A + L + R1 \cdot r}{R2 + D + r} = \frac{R4}{R3} = 1$$

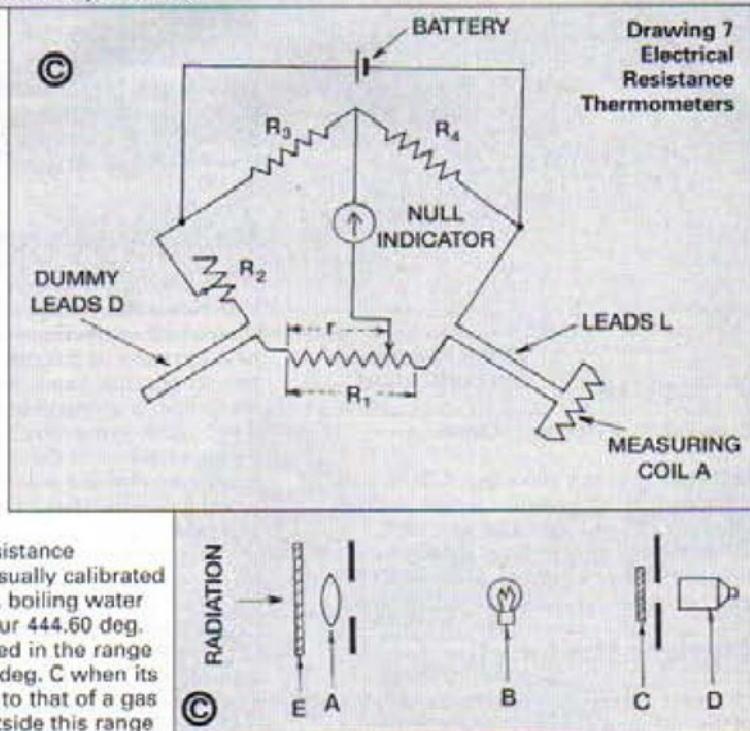
$$\text{so } A = R2 - R1 + 2r$$

If R2 is untouched after initial setting, then variations in resistance 'A' with temperature will require variations in resistance 'r' to maintain balance in the bridge, and hence the device can be



calibrated to show resistance variations in 'A' as temperature changes. Heating of coil 'A' is minimised by only connecting the battery while taking a reading, and thermoelectric effects eliminated by reversing battery connections and taking a further reading, with the average of the two being taken as correct.

The electric resistance thermometer is usually calibrated using melting ice, boiling water and boiling sulphur 444.60 deg. C). It is mainly used in the range -40 deg. C to 600 deg. C when its accuracy is equal to that of a gas thermometer. Outside this range additional calibration points are required.



Drawing 8 Optical Pyrometer

Colour Temperatures

Long before temperature scales were invented, blacksmiths used colours of hot steel as a guide to temperature in hardening and tempering operations. This is discussed in considerable detail in Reference 4 and illustrated with colour plates, which form a most useful guide.

Crayons

Some years ago 'Temperature Indicator Crayons' were available from a number of manufacturers. These are also described in Reference 4. They seem to be difficult to find on the market nowadays, and some manufacturers have certainly discontinued making them.

Magnets

The Curie point or temperature at which steels cease to be magnetic is about 50 deg. C below the temperature from which to quench, which gives some indication of the temperature of the workpiece - see again Reference 4.

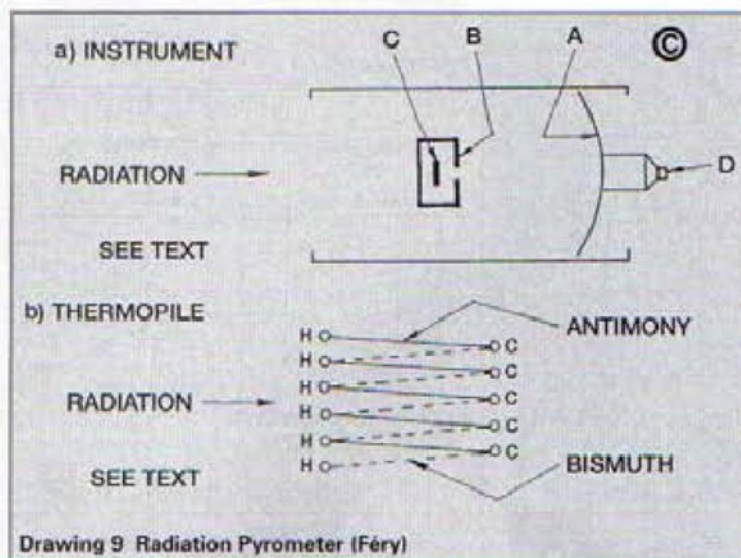


4. Chromel/Alumel thermocouple, continuing 5m leads and analogue multimeter (used on 0-50 microamp range)

C. High Temperatures

Devices to measure high temperatures are usually referred to as 'Pyrometers'. The temperature ranges covered by the (b), (c) and (d) thermocouples mentioned above and the digital thermometers in their upper ranges really fall into the category of pyrometers.

As cast iron melts at about 1100 deg. C



Under favourable conditions, optical pyrometers can have an accuracy within 1%. Favourable conditions means when the source is a black body radiator, such as a hole in the wall of a furnace. But, for example, with molten metals in the open, it can read low by as much as 150 deg. C. Likewise, screens of smoke or gasses

cause errors. For luminous flames some success results from using two different wavelengths - red and green. The instruments can be used down to about 650 deg. C.

Radiation Pyrometers

The design of this instrument is depicted in **Drawing 9(a)**. Radiation from a hot source falls on the concave mirror 'A' and is reflected towards diaphragm 'B' located near its principal focus. Behind this diaphragm is a strip of blackened metal 'C' which receives the radiation passing through the hole in the diaphragm. The measuring element is a thermocouple or thermopile which has its hot junction(s) attached to 'C'.

A thermopile comprises a number of thermocouples joined electrically in series with their hot junctions all at one end and the cold junctions all at the other end - see **Drawing 9(b)**. The hot junctions are exposed to the radiation while the cold junctions are shielded from it. Bismuth/Antimony is a typical thermocouple combination for thermopiles.

The mirror can be racked backwards and forwards to enable the image to be focused on the hole in the diaphragm, and the eyepiece 'D' allows this adjustment. The instrument is sighted on a large area such as an incandescent fuel bed or a hole in a furnace wall (black body radiators). The temperature attained by the hot junction(s) will be a function of the temperature of the source; it will be almost independent of the distance to the source provided that the entire field of the diaphragm hole is covered. The instruments are calibrated for black body radiation and can read 10 to 50% low when sighted on light coloured or metallic surfaces in the open.

Portable Infrared Pyrometers

With the surge in electronic and solid state technology since World War II, optical pyrometers and radiation pyrometers have been largely superseded by portable infrared pyrometers which provide digital read-out. They utilise the two colour principle referred to above to overcome problems of dust and other contaminants in the field of view, dirty viewing windows

and grey body sources. Typical temperature ranges available are 0 deg. C to 500 deg. C, -50 deg. C to 1000 deg. C, 700 deg. C to 2000 deg. C and 900 deg. C to 3000 deg. C, with accuracies of the order of 1% or less. Some come equipped with laser aiming to ensure the exact target is having its temperature read. Prices for the simplest ones are of the order of SA 500.

As many companies have replaced their old optical pyrometers with this new gear, one might expect the optical pyrometers to be available at reasonable prices on the second-hand market - it is certainly worthwhile being on the lookout for such items.

Pyrometric Cones

Originally called Seeger cones, but now produced by a number of manufacturers (e.g. Orton, Wengers and others) these are an inexpensive form of fusion pyrometer. They are small pyramids, about 50mm tall, made from mixtures of oxides and glass, to each give a definite melting point. A series of 36 cones with melting temperatures from 600 deg. C to 1400 deg. C is available, and the range extends up to about 2000 deg. C. The melting point depends somewhat on the heating rate and different melting point figures are given for different heating rates of 150 deg. C per hour and 60 deg. C per hour - e.g. cone 09 figures are 930 deg. C and 915 deg. C respectively. The cone shape collapses when it softens and bends, as shown in **Drawing 10**. They are mainly used in the ceramic industry, but can also be used to calibrate pyrometers. They cost about SA 0.30 each from ceramic supply companies who can give complete details of the range of characteristics available. Each cone can only be used once.

Conclusion

The home workshop can be economically provided with temperature measuring equipment to suit all its likely needs with:-

Mercury-in-glass protected scale thermometer - 10 deg. C to 400 deg. C range

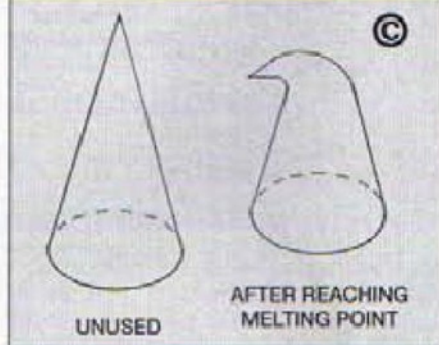
Chromel/Alumel thermocouple and 0-50 microamp meter

Set of Seeger cones

The use of radiated colours for furnace temperatures and oxide film colours for tempering steel avoids the need for any measuring apparatus for these processes - but better results can be obtained if instruments are used.

References

1. Mechanical Engineers Handbook - L.S.Marks - 1916
2. Handbook of Engineering Fundamentals - O.W.Eshbach - 1936
3. Heat - R.G.Mitton - 1939
4. Hardening, Tempering & Heat Treatment - Tubal Cain - WPS 1 - 1984



Drawing 10 Pyrometric Cones

and steel at about 1500 deg. C, it is pretty obvious that no metallic contact devices would survive to measure very high temperatures, and indirect means have to be used. Thus there have emerged optical and radiation pyrometers.

Optical Pyrometer

This is a device to measure the brightness of the radiation received from an object in a narrow band of the visible spectrum, by comparing it with the brightness of a standard light source. They have been in use since about the time of World War I.

The instrument is shown in **Drawing 8**. The radiation from the source passes through a lens 'A' to form an image in the plane of the filament of lamp 'B'. This is observed through the eyepiece 'D'. 'C' is a filter of red glass which removes all the radiation except that of a narrow band of wavelengths. The filament temperature can be varied by varying the current through it. When it is hotter than the source, the filament appears as a bright line against the background; when cooler it is a black line. The current is adjusted until the filament disappears, which means it is at the same temperature as the source. The current is then read off a milliammeter in series with the filament; this meter is calibrated in degrees C. By placing neutral tinted glasses 'E' in front of the lens 'A', the range can be extended to temperatures much higher than those to which the filament can be heated. For its lower temperature range the instrument can be calibrated by sighting it on sources of known temperature; for higher temperatures its calibration depends on Planck's law of radiation, but that is beyond the scope of this article.

A GENUINE LeCOUNT MANDREL

Hugh Smith of Norwich
acquired a device which he
was unable to identify until
Philip Amos revealed all

When I bought my 1948 vintage Myford ML7 lathe a couple of years ago, one of the main attractions was that it came with an enormous amount of tooling; milling cutters, taps and dies and a very large ammunition box containing nearly a hundredweight of reamers of every description. The same week I bought my first copy of MEW, No. 49, which contained an article by Philip Amos about the Quorn and sharpening reamers. It aroused my interest and so my first engineering project just had to be a Quorn. After a very enjoyable two years and after much head scratching, by some miracle, I have nearly completed a machine that sharpens things brilliantly.

I was most interested to read Philip Amos' latest article about Work Holding Mandrels in MEW No. 64, particularly the LeCount mandrel that he constructed from a photograph. It looked rather familiar, so after a quick rummage in a box full of old adjustable reamers, I found that I owned the genuine article. To the uneducated eye it looks like some kind of adjustable stepped reamer. So that's what it is!

It is obviously of pre-war vintage, and the jaws/blades show the signs of heavy use (misuse?). It will accommodate work from about 0.4in. to just under 1.0 inch. When new, I imagine that its nominal capacity was from 0.5 to 1.0 inch.

My mandrel differs slightly from the one that Philip Amos made in that the included angle of the taper is only 5 deg. to his 14 deg., so its grip is tenacious. Like his, there is no screw to expand it, the work-piece is slid on the blades up to the appropriate shoulder and the heel of the shank bumped against something solid. In the case of my device, not too hard, because it is next to impossible to release it if you do. Because of wear to the blades and the fact that the blades were in the wrong grooves (marked W, X & Y) it was also atrociously inaccurate and any thin sectioned material wobbled all over the place. I trued up the shoulders on the Quorn and this improved things somewhat, but I will have to set the Quorn wheel-head up on my lathe and grind the edges parallel at some time in the future if it is going to be of any real use in the workshop.

The only other detail in which my mandrel differs from the one described in



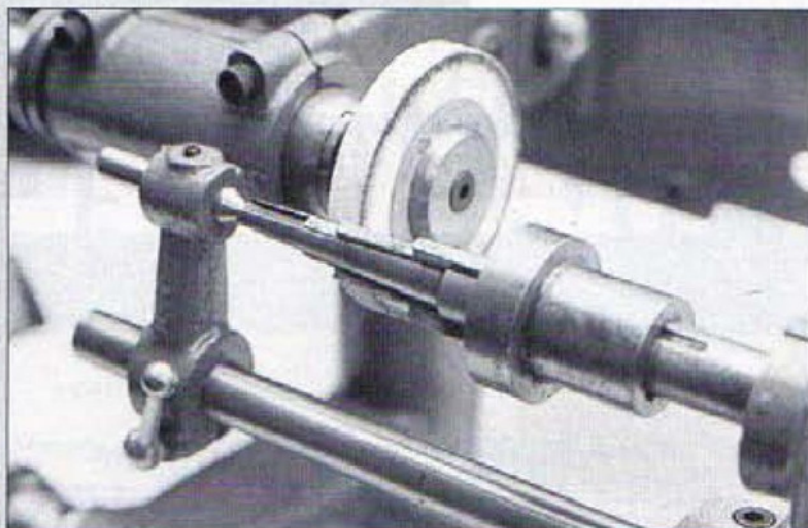
1. Hugh Smith's mandrel clearly shows the legend C. W. LeCount, Norwich stamped on the collar



2. The components, showing that the blades are housed in shallow tee slots



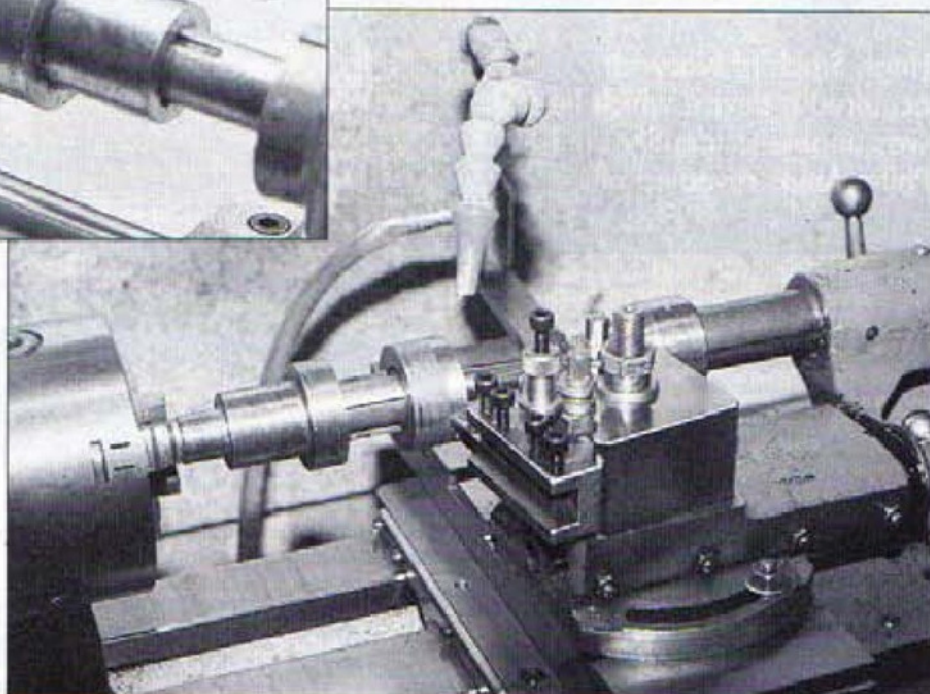
3. The mandrel set up for truing on Hugh's 'Ball Handled Wonder'



4. Grinding the steps on the blades

the article is that the blades are held in their grooves by minute T-slots only 0.020in. deep and can only be disassembled by pulling them out one by one at the small end of the taper.

I would like to thank Philip Amos for his many interesting articles over the time that I have been taking M.E.W. and especially for inspiring me to try my hand at making the 'Ball Handled Wonder'. Yes, I know he's taken them off his machine and I don't blame him as they are very fiddly, but they look wonderful!

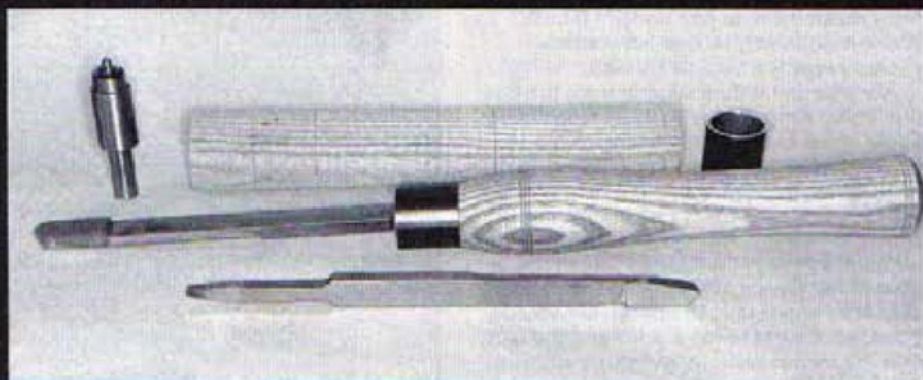


5. The Lecount in use

HAND TURNING

Part Two - Wood

Occasionally, an engineering workshop project can be enhanced by the incorporation of some turned wood components. Robert Newman describes some tools and procedures which may assist readers who are not experienced in working in this medium



1. The wood turning tools described in this article

Many years ago, an old clockmaking friend of mine surprised me when I found that the fine looking metal hand turning tools he had forged, hardened and tempered had been stuck in some tatty looking file handles. As I had borrowed, pinched, whatever, the general idea of my metal tool holder from him, I

made him up some decent handles in return, which he was kind to admit were far more comfortable in the hand and easier to control than the file handles.

In a couple of my articles I have suggested that a nice handle would not come amiss, but did not explain how to achieve this aim. I hope to rectify that

omission now. The handles of my metal hand turning tools in Photo. 5 of my article on metal hand turning were turned on my wood lathe. The handles you see in this article were turned on my metal working lathe using the tools and methods I submit for consideration.

It should also be pointed out that the



2. The components of the cone drive

metal hand turning tools can also be used to turn wood, it will take just a little longer. The cutting tool should have approx. 2 1/2 in. extending from the holder for this purpose. By the same token, the woodturning tools I describe can be used to turn metal, admittedly they are a bit long but will do the job.

The turning tools

There are various ways in which tools can be obtained. Firstly you can visit the local tool shop with five-pound notes, (minimum of five) clutched in hand and purchase a 1/2 in. half round and a square face scraper tool, that's without handles. Secondly, if the skills are possessed, carbon steel, 1/2 in. wide and 1/4 to 5/16 in. thick can be used to fashion, harden and temper the necessary tools. A third way is to scour flea markets, garage sales, boot sales etc. for old mortise chisels in the 1/2 in. to 3/4 in. wide range. These make fine tools; I have two of these as finishing tools on my wood lathe. The final way is to make the tools I suggest.

So-called scraping tools are the advised type to make. Why? Simply put, they are easy to make, easy to use, easy to demonstrate. It must be admitted that I prefer to use edge tools to turn wood; most wood turners do, but practice is required to become reasonably proficient in their use. Having said that, I certainly do not look down on so-called scraping when it is handled with some thinking behind it. There are times and with certain woods, when only scraping will produce an answer and this applies to turners the whole world over. A properly sharpened and honed scraper, held at centre height, will produce a very acceptable finish in hardwoods.

Obtain two pieces of free-cutting bright mild steel, 8 in. long, 1/2 in. wide, 1/4 in. thick. Machine 2 1/2 in. of one end so that you have a 1/4 x 1/4 in. section. This is clearly shown in the front tool in **Photo. 1** Two

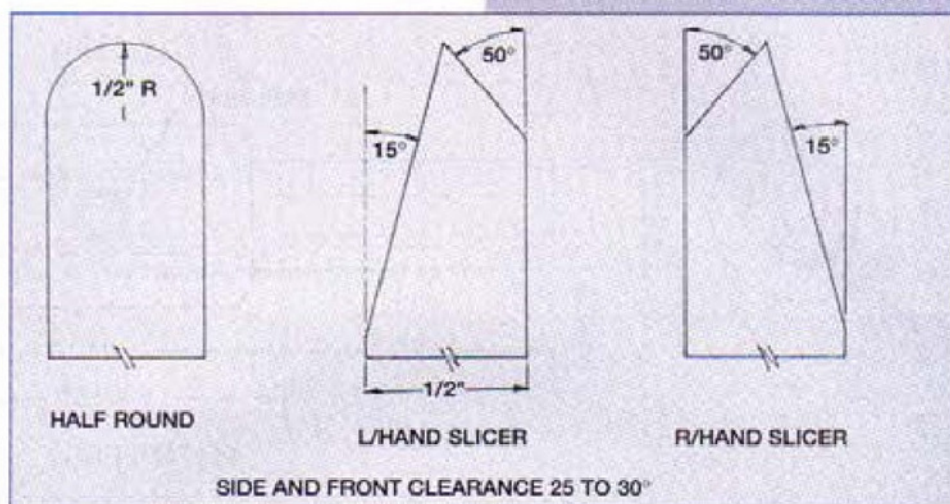


Fig. 1 Tool tip configurations

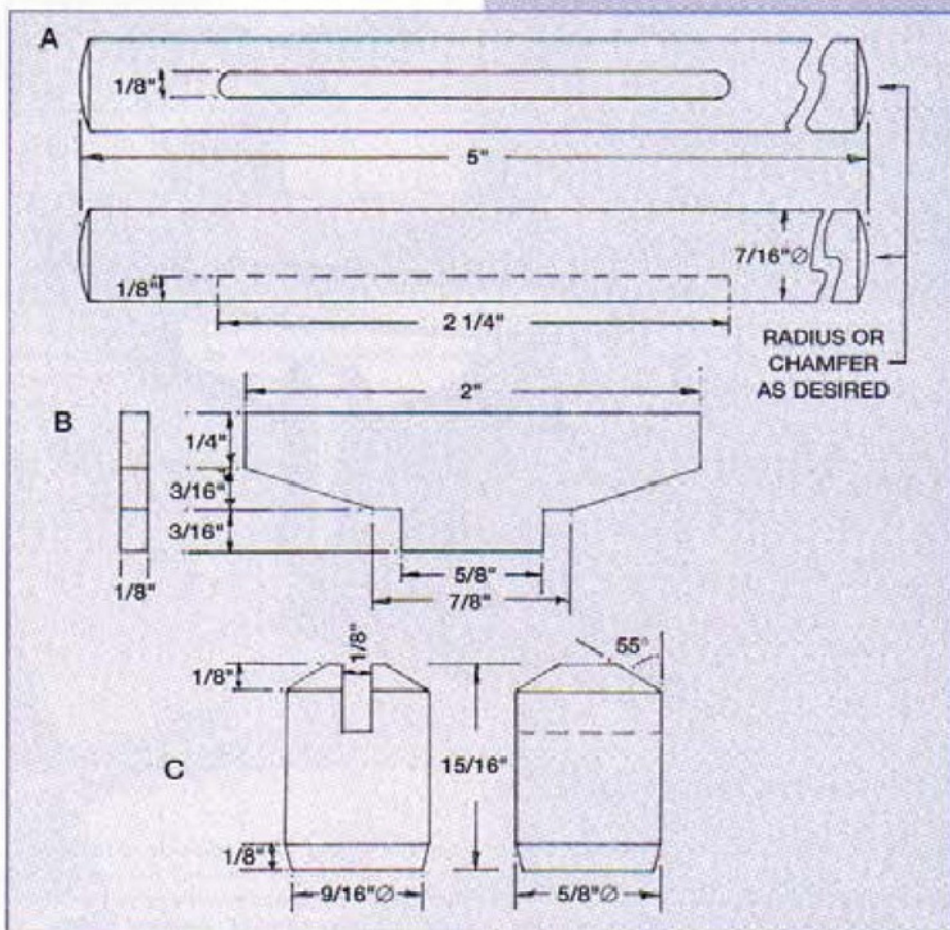


Fig. 2 Woodturning rest

pieces of High Speed Steel, 1/2 in. wide x 1 1/2 in. x at least 3/32 in. thick are required. "Where?" I can hear some of you ask, "Does one get that?". Answer: From the same type of place that both my friend and I got ours. I knew someone who worked in an engineering environment and I asked him if they ever broke or wore out the blades on the industrial hacksaws. (of course they do). I was rewarded with three large pieces of machine hacksaw blade, he with a bottle of plonk. My friend did likewise. An acquaintance, also a home machinist and an Accountant by profession claimed he knew no-one in engineering. It was pointed that the local industrial estate had no fewer than five

engineering firms plus one metal stockholder. We would have happily shared our booty with him, but he did better than either I or my friend, in that the HSS he obtained was thicker and wider. Tilgear, in a recent sale, were selling off very heavy duty blades for as little as four quid a throw. My friends and I took advantage.

The HSS can be cut with a cutting disc in a hand-held grinder. As the metal will almost certainly be burnt in the process of cutting, make the suggested width of the piece 3/4 inch. Once soldered in position it can be ground to the correct width. Clean all traces of paint etc. from the metal. Thoroughly clean the last 1 3/4 in. of the

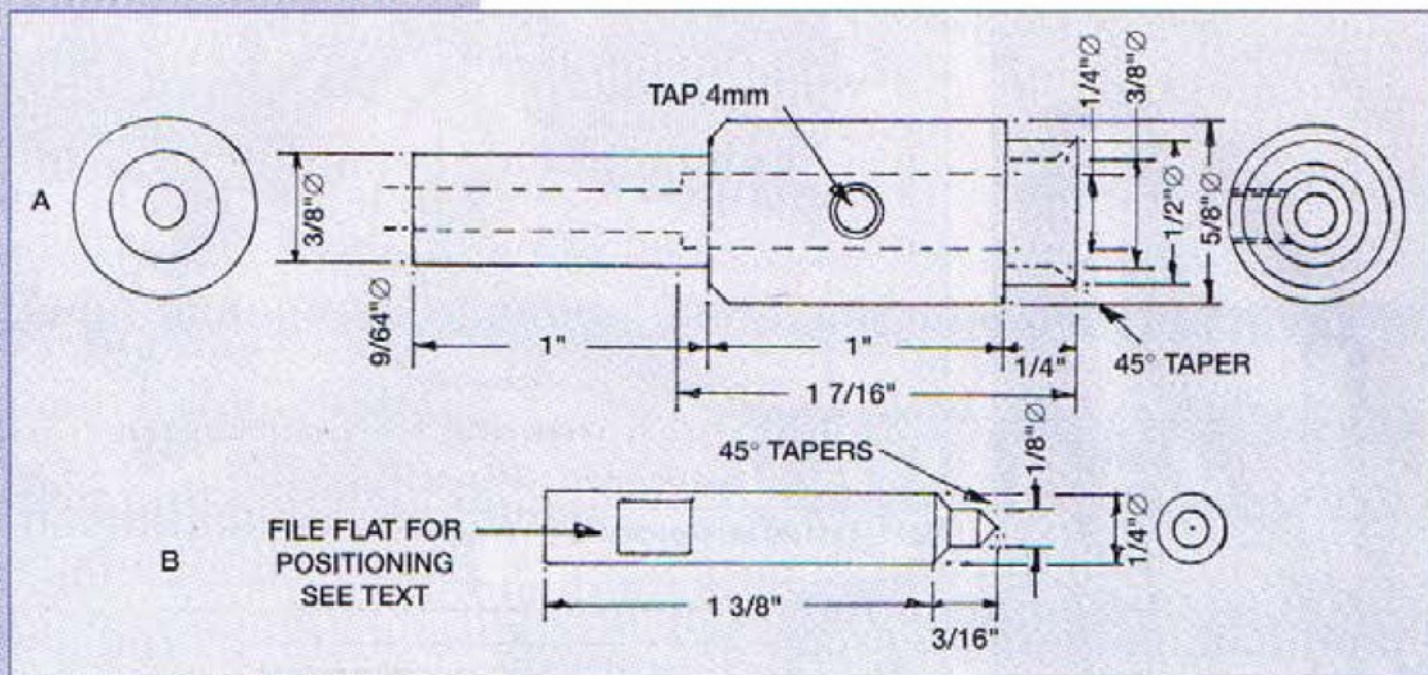
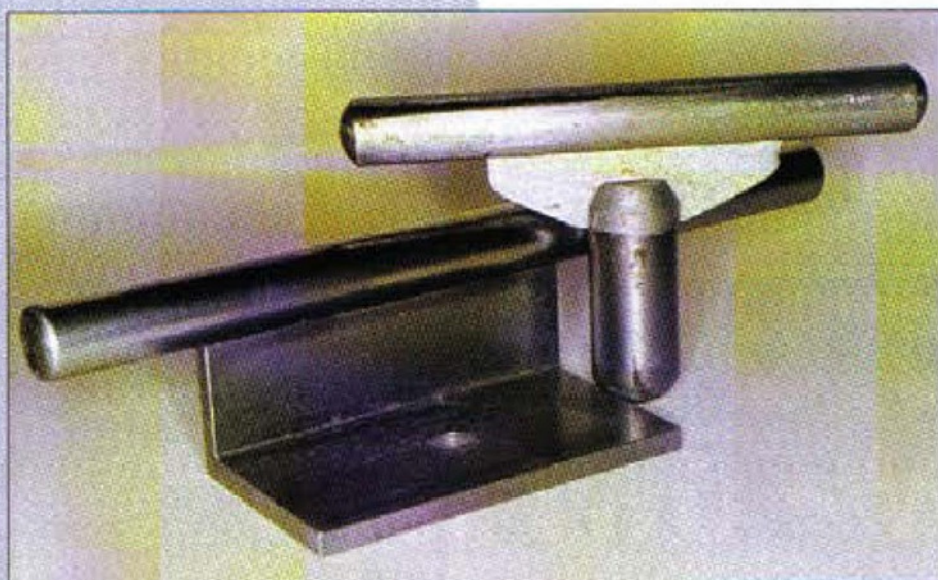


Fig. 3 Cone drive & centre



3. Two very simple wood turning rests

mild steel. The piece of HSS now needs to be silver-soldered to the end of the mild steel. Suggest silver solder in paste form for this job, together with plenty of flux. It is a sensible precaution to have some means of holding the HSS in close contact with the mild steel while heating. I used copper wire for this job. Even if it gets soldered to the work, it is easy to remove.

In the items shown, the HSS has been soldered in place on the top of the shaft; you can, of course, set it into the metal. Using thicker HSS material, I would do just that.

When all has cooled down, grind the tools to the two shapes shown in Fig. 1. Photo. 1 shows only one angle tool, which incidentally is called a Slicer; I would suggest you make a mirrored pair - you will not regret it. Edge clearance on these tools is 25 to 30 degrees. The top of the HSS should be polished and, together with the edges, honed to a very sharp edge for it is intended that these tools will

cut, not scrape. The underside of the tool should also be polished and the two bottom edges rounded off and polished. This is to allow smooth passage of the tool along the rest.

This article was finished in early September and then put aside for thinking time. This was just as well for, a couple of weeks ago, the latest catalogue from Kirjeng dropped on my doormat. On glancing through its contents, on page 8, a heading caught my eye - Rectangular High Speed Tool Bits. Third item down, $\frac{3}{16} \times \frac{1}{2} \times 1\frac{1}{2}$ in., cost 60p. I was straight on the phone, ordering some samples. They were exactly what was wanted. I am told that they have quite a few more. To make tools using these bits, I would use $\frac{5}{16}$ in. thick mild steel and sink the bit into the metal by about $\frac{1}{8}$ inch.

The tool rest

The hand rest, Fig. 2 and shown on the

right in Photo. 3 is designed to fit the adjustable rest detailed in my article on hand metal turning. The rest on the left is an efficient, simplistic version, fitting on the cross-slide or tool post of the compound slide; it is simple to make. No measurements are given as it will have to be made to fit the lathe for which it is intended. The height to the top of the rest is the centre height less the thickness of the turning tools. Method of securing the round bar to the angle iron is the same as shown in Fig. 2.

The rest shown in Fig. 2 is scaled to fit the Myford series. A slot is machined in the rod to take the support blade, Fig. 2 'B'. It worked out that the blade in the sample I made was a very tight fit and had to be pressed in place, which was fine. Part 'B' is silver-soldered to part 'C', only then is part 'A' attached. The blade is shorter than the slot in the rod to allow spot welding at each end if so desired.

Why a round bar rest? As some experience in wood turning is gained, it will be found that it is helpful if the tool can be manipulated so that the cutting edge is up or down in relation to the centre height, and a round shape is the best for this. This form of rest, albeit more substantial, with a machined and hardened $\frac{3}{4}$ in. diameter rest is my main choice for use on my wood lathe. This configuration also allows a finger to be hooked under the rest to allow better tool control.

The cone drive

This is the simplest and the easiest wood drive to make. It has the advantage for the tyro wood turner in that, should he have a 'dig-in', the wood will come to a halt without any damage being caused.

Photo. 2 and Fig. 3 show the construction, leaving only a couple of points that need expanding. The taper on the cone is best done with a suitably sized countersink; if not available, set over the top slide in the usual way. 30 deg. is the angle. A razor edge is not necessary, a 5 thou. thick edge

finish will do fine. The $\frac{3}{4}$ in. inner diameter of the cone and its flat base is best done with drill and 'D' bit or mill.

The $\frac{1}{4}$ in. hole to take the centre also needs a flat base, again a 'D' bit or mill is ideal for this task. When making the centre, a little extra length will not come amiss and will allow trimming. When the centre is fully seated home the base of the small cone at the tip should be level with the rim of the main cone. Using a grub screw, mark the centre at this position. Withdraw the centre so that $\frac{1}{4}$ in. of the shank shows above the cone, again mark with the grub screw. A flat should now be filed using the extremities of the marks as the total length of the flat. It would be politic to be generous towards the tip, just to ensure that the centre seats properly. The through hole is to allow a $\frac{1}{8}$ in. drift to be used for shifting sticking centres.

The handles

First prepare some ferrules. These need to be 1in. long and between $\frac{3}{4}$ in. to 1in. diameter, 16 to 18 gauge. Material - mild steel, brass, ally or copper. Wood for the handles, in order of preference, can be any of the following:- ash, hickory, boxwood, oak, beech or any of our native fruit tree woods. The wood needs to be in the round if possible, with the grain running along the length. Quality garden tools normally have $1\frac{1}{8}$ to $1\frac{1}{4}$ in. handles in ash or hickory and a replacement handle is ideal to make handles from. Don't expect to find such handles in supermarket DIY areas. Try good garden centres which stock plenty of tools, and independent hardware stores are also a possibility. The alternative is to turn the round and for that, billets of wood $1\frac{3}{8}$ in. square by $8\frac{1}{4}$ in. long are wanted. Find the centre of the end of each billet end and, with a No. 3 centre drill, drill the ends, but only far enough for the taper to begin to cut.

The cone drive should be set so that the centre is on its seat, with just the tip showing, and locked by the grub screw. Mount the cone drive in the 3-jaw chuck and, in the tailstock, insert a live centre. A dead centre can be used, but remember to grease the tip. Mount the billet between these components, locating on the end centres. Lock the tailstock and use the handwheel to press the cone home into the wood, so that it just bites.

Obtain a half-round lathe tool, hone the top face and the edge of the tool and mount it in a tool post at centre height. Start the lathe, setting a speed of approx. 500 rpm, then advance the tool into the wood until it just begins to bite. Note the cross-slide reading before withdrawing the tool and running the carriage to the right hand end of the billet. Add 0.020in. to the noted reading, setting this on the cross-slide prior to running the carriage to the left to take the first reducing cut. Add another 0.020in., then move left to right for the second cut. Continue this process and if all is going well and there is no splintering, increase the depth of cut by 0.010in. When it is seen that the billet is taking on a rounded shape, stop the lathe and set a pair of spring callipers to the required maximum diameter of the billet plus $\frac{1}{8}$ inch. If you look at **Photo. 5** you will see what is intended. Advance the

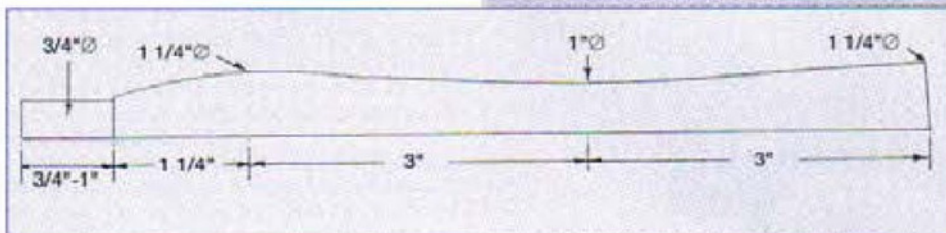
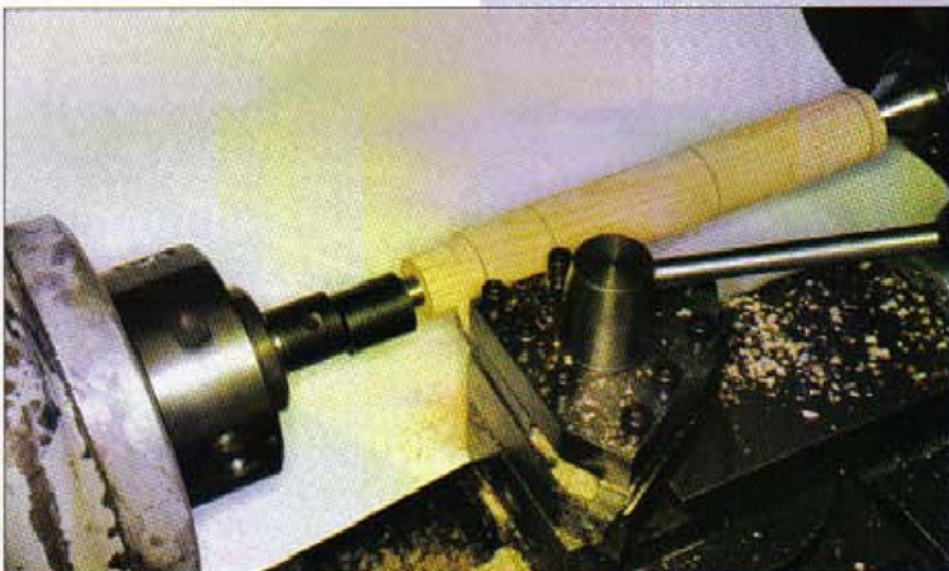


Fig. 4 The handle shape in half form



4. Cutting the seat for the ferrule. The tool is being traversed from right to left. The ferrule which is to be fitted is positioned over the centre of the cone drive, ready to be tried on the turned seating



5. Sizing the sighting groove which will determine the maximum finished diameter

lathe tool with the lathe running and cut into the wood, allowing the callipers to ride the groove, stopping the cut when the callipers pass over the wood. Take a felt pen and mark the bottom of the groove for the whole of the circumference. All that has to be done now to bring the wood to size is to keep sweeping back and forth along the billet, increasing the cut by a set amount, till the mark disappears. The round billet in **Photo. 1** was produced using this method, the sweep being pretty fast; you can clearly see the tool cut marks. Remember to give a cinch on the tailstock handle a couple of times in case

the billet tends to work loose on the cone.

The trick is to take it easy at the start when the corners are being removed. As the billet begins to assume a rounded shape, it is less likely that it will split off a sliver of wood, so a higher wood removal rate can be used. If you try to be too ambitious and remove too much, the wood will spin on the cone drive.

With the billet to size, remove from the centres, remove the cone drive and insert the billet in the chuck with the end marked by the cone outwards. Drill a $\frac{1}{4}$ in. hole 2in. deep in the end of the billet, remove from the chuck then dismount the chuck.



6. Shaping using the half round tool. The white background allows the generated profile to be seen clearly



7. Using the Slicer

Do not use the normal lathe chuck for wood turning unless you must as there is a risk of getting a clout from it when working with hand turning tools.

Set the cone drive with maximum extension of the centre and lock it in position. Mount the drive tool in a milling cutter holder, drill chuck or what have you, mounted in the headstock taper. Slip a ferrule over the drive (that is why the maximum diameter is so long, see **Photo No. 4**), then mount the billet of wood between centres again, the extended centre of the drive fitting in the $\frac{1}{4}$ in. drilled hole, driving the wood into the cone with the tailstock. With a pencil, mark

the principle positions of ferrule, maximum diameter etc. extending the marks all round the billet. They need to be visible when the lathe is running.

Hone the top and trailing face of a left hand knife tool. No mistake - left hand - all will be made clear. Mount it in the tool post at centre height. Set your spring callipers to the internal diameter of the ferrule plus $\frac{1}{8}$ in. then advance the tool to the wood, lining up the right hand edge with the end mark for the ferrule. Start the lathe, speed about 500 rpm, feed 20 thou. into the wood and traverse **left** until clear of the wood. Get the idea? The trailing, honed edge of the tool shears off the

wood - **Photo. 4** makes it clearer. Continue like this until the callipers slide over the wood, then carefully pare away the wood until a drive fit for the ferrule is obtained. Did I mention that the ferrule needs to be slightly longer than the seat cut for it? Press fit the ferrule and remount the billet then, using the lathe tool, trim the ferrule level with the end of the wood.

Set the spring callipers at the minimum diameter of the handle then, at the appropriate position, advance the round nose tool into the wood until the correct diameter is obtained. **Photo. 5** shows this operation. The tool post can now be dispensed with, substituting the wood turning rest adjusted to centre height less the thickness of the turning tool. When I first started woodturning, some twenty years ago, I had to learn from what few books were available. These books stated that scrapers were ground to leave a burr on the ground edge, the tool being held pointing slightly down, the burr doing the cutting. This works fine for soft wood for a time, but in hardwood the burr disappears right sharpish, the cutting stops or becomes difficult. The tool is hiked to the grindstone again, and so it goes on. It is not surprising that scraping has a poor name when the suggested method is that one tears at the wood with a blunt edged tool. My method, when I use so-called scraping, is to use a tool whose edges have been honed to a razor edge and which is presented at centre height. This is the method I suggest you adopt, especially on hardwoods. It will not produce the finish that a competently handled knife edge tool would, but it will be very acceptable and markedly better than a scraped effort with a burred tool, which is

essentially a blunt tool. Think on it.

It should be pointed out that if carbon tools are used, a finer finish still can be obtained, simply because one can obtain a sharper edge in this material than can be worked in HSS. The only trouble is that it does not last as long as the edge on a High Speed tool. Photo. 1 shows a completed handled tool which was worked and finished on my metal turning lathe, using the methods and tools being described. In case of comment, the correct clearance angle had yet to be ground on the tools. I did some experimenting with clearance angles to see how shallow I could get. The Answer, Zero, but I prefer the 25/30 deg. angle.

Turning the handles

Set the wood rest at centre height less the thickness of the tool at the tip. You have polished the top and honed the edges of your tools, have you not? Position the tool rest roughly central to the wood billet and about 1/4 in. from it and run the lathe at about 500 rpm. Starting about an inch to the left of the dimensioned centre and with the tip of the half round tool touching the wood, traverse the tool to the right, gently pushing on the handle to make the tool cut. You do not have a built-in aid like the metal turning rest to find centre - you have to find it. If the tool fails to cut, your handle is too low, you are trying to cut above centre. Raise the handle a bit and try again, the round rest allows this. Should you raise it too much the wood will let you know by trying to grab the tool. Practice a bit; it becomes a reflex action after a while. Once you have got the hang of getting the tool to cut, angle the tool rest to follow the line you wish the tool to follow. Now, with the index finger providing a guide by sliding along the underside of the round rest, you can work left to right, cutting downhill at all times. Photo. 6 gives the idea. You will find that you will get a much better idea of the shape you are achieving by placing a light coloured sheet of paper behind the wood and looking, not at the tool cutting, but at the top edge of the wood.

The suggested speed of 500 rpm is deliberately low just in case you get a catch when starting out. As confidence increases, I suggest you try the speed range 750 to 1000 rpm.

Using the slicer tool

Photo. 7 illustrates the use of this tool. Notice I have stopped short of the high mark, this being so that I will be able to finalise the shape better, later. Set the Slicer tool halfway between the ferrule and the high mark with the small flat just touching the wood, lathe speed about 750 rpm. Gently move the tool handle to the left pivoting about the fulcrum of the thumb and forefinger on the rest, and as the tool begins to bite, move it to the left, gradually increasing the amount of cut until you run free of the wood. The idea is to use the small flat to maintain control of the cut - in woodturning parlance it is known as riding the bevel. The photo shows that one cut has been taken, with another in progress. The last cut should start 1/4 in. to left of high mark and finish

at the ferrule join to the wood, in a graceful curve. Watch the top of the wood and do not attempt to take big cuts. Thin shavings, little and often is the rule. If your tool is nice and sharp, you will understand why I call it The Slicer.

Now use the same technique to blend in the down slope to the centre, only this time you do not push the tool, but pull it. It works like this. Line up the rest with the cut and, starting at the high point, lay the small flat of the Slicer against the wood. Raise what will be the leading edge about 0.002 in. from the wood and, keeping the tool at that angle, work your way down the slope to the minimum thickness point, shaping as you go. Sounds difficult does it not? Study the action of the tool; properly executed, the slightly raised leading edge slices off the unevenness as the tool moves along the wood. This may have to be done twice, remembering to shape as you go. Practice makes perfect. Remember - watch the top of the wood.

Should you have made a mirror pair of these tools, then you will find that the long faces of the tool are ideal for working external curves, with the short faces working the internal curves. All you have to do now is to shape the right hand side of the handle, but this time you work from right to left. The finishing cut is again made with the Slicer tool.

The shaping cuts to the end of the handle are made with the long side of the Slicer, starting at the extreme right of the wood. Remove the wood in thin slices, stopping short of the live (or dead) centre. Simply push the tool into the wood at centre height to make it cut.

A 120 grit abrasive can be used to finish the job, followed by diminishing grits to a 360 grit. If you have taken care you should not need excessive sanding. First use the abrasive against the grain at a low speed, 250 rpm, then work along the grain, repeating this with each grit. It is a mistake to use high speeds for sanding, it only work hardens the surface of the wood. If you want to decorate, do it now. Rings, as in Photo. 7 are made with the Slicer point.

Mount a 5/16 in. drill in the drill chuck held in the headstock taper. As a 1/4 in. hole exists in the handle, it is a simple matter to push the handle on to the rotating drill without it going astray. If in doubt with this procedure, then use the tailstock with centre mounted to guide and push the handle on to the drill.

Finishing

The finish is up to you. May I recommend the use of spirit or water based grain filler, three coats, each applied with a brush and allowed to dry between coats, preferably overnight? When each coat is thoroughly dry, sand the filler using 180 grit. After the final coat, sand again down to 360 grit then use 1000 grit steel wool, or 3M synthetic steel wool (preferred) with the lathe at a low speed, working across the grain at first, then along it to get a smooth finish. With a soft cloth, polish the handle. No other treatment is required, this finish will last for years. If it gets dirty, give it a wipe with methylated spirits to restore it to pristine condition.

As a matter of interest, the handle shape I have advocated is known as a



8. Another use for the tool rest - supporting the torque arm of the tailstock die holder when threading

Fishtale by the wood turning fraternity. Wood can also be turned by using the half round tool in the shear position. When you sharpen a pencil with a sharp knife you are shear cutting. The knife is held at an angle to the wood and one works downhill. With a turning tool, the tool is tilted so that the edge lies on the rest. The tool must be sharp. The angle at which the tool is to be held you find by experiment, around 30 deg. from the vertical is the starting point for most hardwoods. Work downhill at all times. Nicely rounded and polished tool edges are a must for this method of cutting. The finish, properly executed, is generally superior to normal scraping. Two points to remember, always work with the grain, always work downhill.

The tool rest has another use, demonstrated in Photo. 8. Fitted to the cross-slide it saves having to remove the tool post assembly to facilitate the use of threading tools.



Suppliers

Kirjeng M. E. Services, 17 Gables Lea, Sutton Bonington, Leics. LE12 5NW. Tel. 01509 672025. High Speed Steel toolbits

Tilgear, Bridge House, 69 Station Road, Cuffley, Herts EN6 4TG. Tel. 01707 873434. Heavy duty hacksaw blades

GLR Distributors Ltd., Unit C1 Geddings Road, Hoddesdon Herts EN1 10NT. Tel. 01992 470098. All metal, fluxes, solders etc.

A TESTING PROJECT



1. The home built small precision milling machine which required a project on which to test its capabilities

After completing my freelance precision milling machine (recently featured on the front cover of Issue 63 of *Model Engineer's Workshop*) I needed a project on which to put it to the test so that I could get a feel of the machine in action. Maybe some problems needed to be ironed out while it was in use. The 'FOBCO' Star drilling machine came to mind. It seemed a fairly simple straightforward machine to model, but, as it turned out, not so simple in $\frac{1}{12}$ scale.

After making a few sketches, I decided that the best approach would be to produce each component part on the end of a small square cast iron block, thus obviating the problem of holding each small item. When all necessary machining operations had been completed, the component would be

removed from the block and finished by hand. This was my plan.

Preparation

The first thing to do was to prepare eight blocks of high grade cast iron on my Raglan milling machine. These blocks were of various sections according to the components to be produced, but all made to $1\frac{1}{2}$ in. long.

The test

Now on to the new machine. A new three flute $\frac{1}{4}$ in. diameter cutter was secured in the spindle, and block number one locked in the machine vice. I switched on the motor and took a touch on the top

Barry Jordan needed a test project on which to confirm the capabilities of his small home-built milling machine. The resulting model won a Silver Medal at the recent Model Engineer Exhibition

surface of the block. After winding out from the revolving cutter, I lowered the spindle 0.050in. and proceeded to cut a channel across the block. No problem. The next trial cut was 0.100in., again straight across the block without difficulty. The third cut was at 0.150 inches and this time the little motor coughed and spluttered. It did not like this at all - in fact it stalled several times. I now know its limitations while cutting cast iron. I intend to find a more powerful motor in the future, but for now the current unit is fine.

When the milling machine was exhibited at an exhibition in the Autumn of 1999, the judges' report cast doubts as to the rigidity of the machine's work head. I can now assure them that their fears were unfounded. As can be seen from these photographs, the work head and spindle are quite adequate with no chatter or flexing in use.

The project

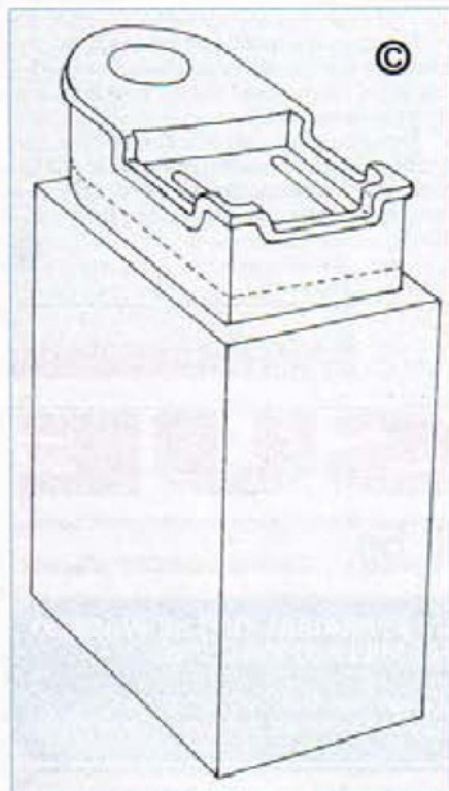
Each of the component parts of the 'FOBCO' drill was now milled on the remaining blocks: the base, table, main head, motor platform and the two halves of the top cover case. Profiles were filed and finished by hand and any holes drilled. Finally, each piece was cut from its



2. The $\frac{1}{12}$ th scale model of a FOBCO 'Star' bench drill which was used as the test vehicle



3. The milling machine set up for its first test

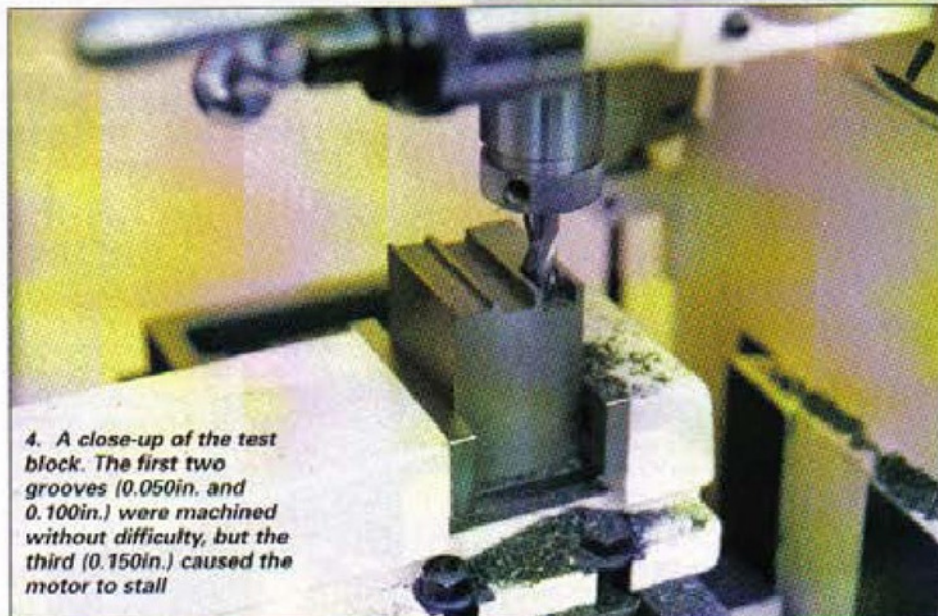


Sketch 1 The drill base formed on the end of a cast iron block

host block and finished ready for painting.

Facts about the model 'FOBCO' drill

All the main parts are made from cast iron. The main column is of mild steel and is hollow. The wooden base conceals a small electric motor and its 1½ volt battery. Through bevel gears, the motor drives a vertical spindle, which runs inside the main column, the final drive inside the top cover being by two small pulleys and a belt. Pressing a button on the wooden



4. A close-up of the test block. The first two grooves (0.050in. and 0.100in.) were machined without difficulty, but the third (0.150in.) caused the motor to stall



5. The base of the 'Fobco' Star being formed on one of the cast iron blocks

base brings the machine to life, the motor rotating the drill chuck at a stately 90 rpm.

The model is displayed in a replica of a clear pill bottle complete with label. The 'bottle' provides protection from sticky fingers at exhibitions and is made from acrylic rod (Perspex). This bottle is the final one of three produced as the first two were not to my liking.

A few sketches and fifty seven hours later - here it is - THE PERFECT TESTING PROJECT.

Since this article was written, the Miller has won a Gold Medal and the Bowyer-Lowe Challenge Cup at the International Model Show and the Drill in a Bottle has won a Silver Medal.

Just as a tailpiece, some mole gripping stuff!

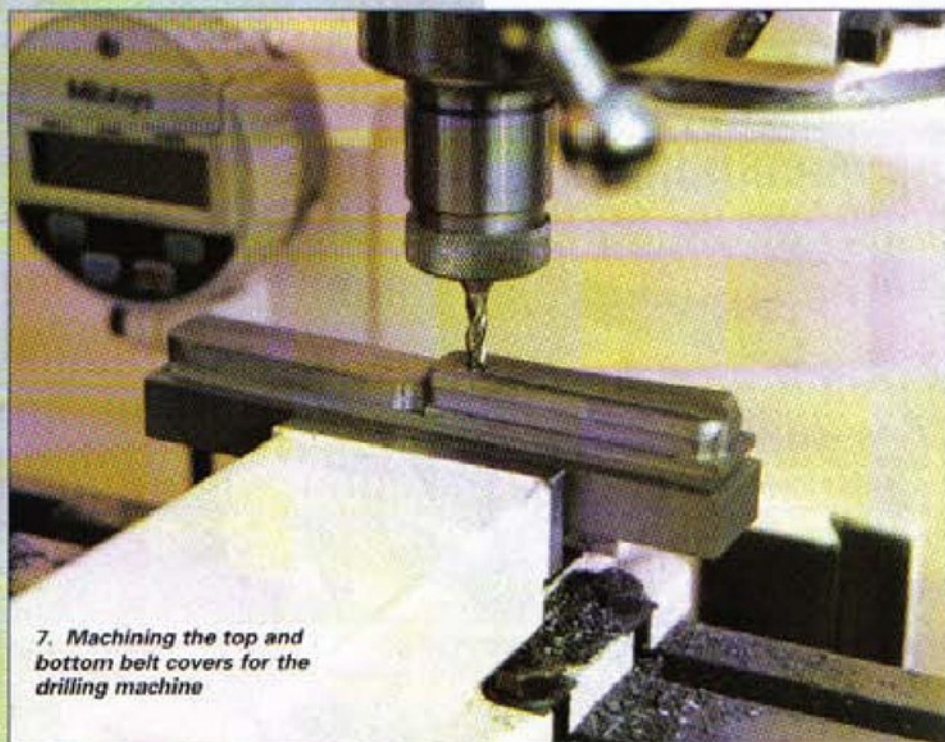
As with all model engineers, I never pass by a chance to add to my collection

of tools in the workshop. On a fine Sunday morning a few months back, I was travelling along the B6013 in Derbyshire and spotted pair of Mole grips lying across the white line in the centre of the road. By the time I had stopped the car I was about fifty yards further on.

As I was getting out, another car, going in the opposite direction, pulled up about the same distance beyond the grips. Both the other driver and I started to walk down



6. The advantages of keeping the component as part of the host block for as long as possible can be clearly seen



7. Machining the top and bottom belt covers for the drilling machine

the centre of the road. The pace quickened until we were both in a full gallop. We arrived at the Mole grips at the same time. Skidding to a halt, too out of breath to speak, we simultaneously looked down at the bounty, and then each other. He looked real mean. Shaven head, large ear ring and the infamous camouflaged jacket. You know the type. He thrust his hand down

into his pocket. My first thoughts were "Oh no! He's got a gun. Surely he wouldn't shoot me for a pair of Mole grips worth £8?"

He slowly pulled his hand back out. By this time my legs had turned to jelly, to weak to turn and run. I will never forget the look on his face as he opened his hand to reveal a ten pence piece.



8. An abortive attempt at producing a suitable bottle from Perspex



9. The completed machine in its pill bottle

There, in the middle of the road, we flicked the coin. As he strutted away with his prize, he punched the air with his fist and shouted "YES".

I now drive around in a pair of Nike trainers, just in case. Anyway, what did I want a pair of Mole grips for? No self-respecting model engineers use them, do they?



IN OUR NEXT ISSUE

Coming up in Issue No. 67 will be

TURNING FOR BEGINNERS

Harold Hall brings us the first instalment of an instructional course in the art of turning. Each article will detail the manufacture of a useful item, progressively introducing the various facets of lathe work so that, by the end of the course, newcomers to the hobby will have gained experience on the full range of capabilities of the screw cutting centre lathe.



Issue on sale 14th July 2000

IMPROVING THE VERTICAL MILL

By adapting a simple device, invented by a well-known model engineer over 40 years ago, David Machin has improved the location of the head of his milling machine.

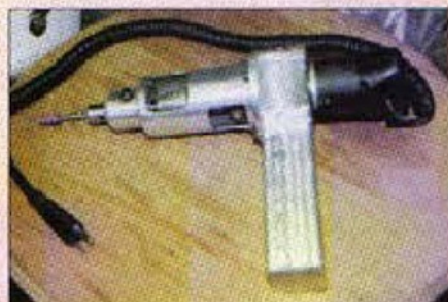


AN APPRAISAL OF THE WABECO CNC MILLING MACHINE

Clockmaker Dick Stephen gives his impressions of this versatile machine tool

A TOOLPOST GRINDER

Designed to fit a Harrison L5 lathe, Eric Eadon's adaptation of a mini drill could be modified to fit a wide range of machines



(Contents may be changed)

Turning a Torus



Owners of home workshops are often regarded as universal experts by friends and neighbours. Derek Brown recalls the time when the subject was soft furnishing!

How many times have I heard the comment "old so and so has got a workshop; he can make one I am sure"? And so another project starts in which the originator has no clue as to the time spent, nor the technique to be used to get the end result.

And so it was when a prominent local character wanted some more 4in. dia. wooden curtain rings of $\frac{5}{8}$ in. round section - in other words toroidal in form. Such artefacts could not seemingly be matched in the local emporia of soft furnishings, so the grey matter was put into gear and came up with the solution which worked like a charm.

First cut down your tree: go into the

forests of Honduras and fell a fine mahogany tree and cut from it the suitable blanks, turning the outsides to the correct diameter and drilling the centres $\frac{1}{2}$ in. for a draw bolt; the grain direction of the wood must be across a diameter. Face off the front of the wooden disc to finished thickness for the torus and place the blanks on one side to season while you make the tool for cutting the radius.

Radius tool

For a toroidal section of $\frac{5}{8}$ in. you will need a short length of gauge plate say $\frac{3}{4}$ x $\frac{1}{4}$ in. The philosophy is to provide a clearance on all edges of 8 deg. The first operation is to face the end at an angle of 8 deg. and to follow this by machining the two sides to a similar clearance, so that you have formed something like a giant exaggerated parting tool.

Now set the blank horizontally in a machine vice, the corner of whose jaw is set as the datum point of the machine. Next move the Y slide exactly 0.375in. in order that any cut may be precisely on the centre line of the tool steel. With a $\frac{5}{8}$ in. end mill in the spindle collet or tool-holder advance the X slide to remove metal 0.313in. deep, forming a perfect semi-

circular shape. In this form the tool would not cut, since we have not provided any clearance, so clamp the embryo tool to the lathe faceplate using two clamps for safety and counter-balance the assembly on the faceplate with say a couple of changewheels in order to achieve a good balance and avoid vibration. In order to mount the tool with its semicircular scallop running true, provide a $\frac{5}{8}$ in. dia. former sticking out of the tailstock chuck for a reasonable degree of location. Before finally tightening the clamping bolts the semi-circular surface

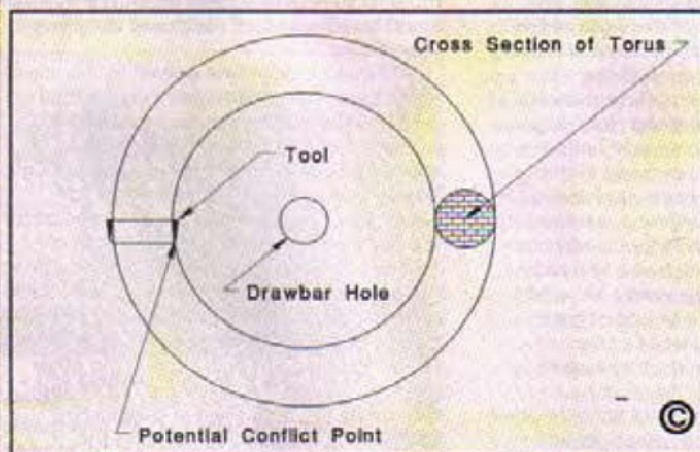
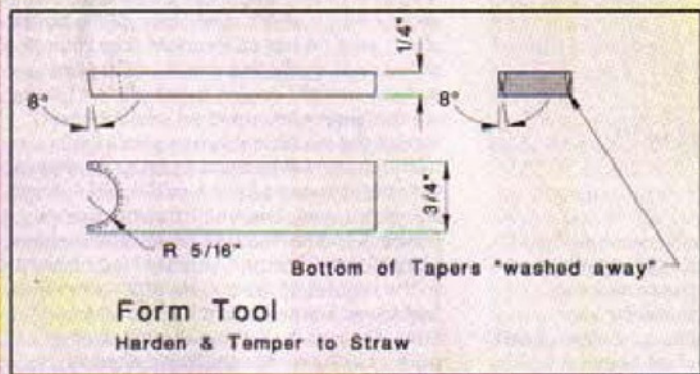
can be clocked, any eccentricity being corrected with the aid of a soft hammer. So we now have the tool running true on the faceplate. Set over the top-slide to 8 deg. and with a sharp boring-tool taper the half bore until you just clean up the whole of the original parallel section to the new tapered profile.

If you now carefully examine the tool you will see that all relevant surfaces are relieved to the same extent. To make it ready for use, harden by raising its temperature for a few seconds to bright (cherry) red and plunge vertically into water. Now rub on a carborundum stone until bright all over the top surface. Temper to mid straw colour by heating slowly, avoiding flame impingement anywhere near the business end of the tool. As the temperature rises you should see the colour of the unmachined mass of the blank gradually change to straw. If you withdraw the heat source the colour front should creep towards the cutting edge. When it reaches it the job is ready for quenching again. Examine the cutting edge; a final hone on a diamond plate or abrasive block ensures that the cutting edge is keen.

Cutting the Torus

Mount the form tool exactly at centre height in the lathe toolpost and make sure that at its innermost point the lower edge of the tool will clear the work. If relief should be necessary, provide this by hand grinding. As an aside, you can check by geometry whether there is a risk of the tool fouling the job as indicated in the second sketch, thus: if the tool height is $\frac{1}{4}$ in. and the clearance angle is 8 deg., the radius at which conflict starts to occur is given by $0.25/(\sin(8 \times 2)) = 0.907$ in. This means that in the example under consideration the inside radius of the torus (2in. - $\frac{5}{8}$ in. = $1\frac{3}{8}$ in.) is well clear of the inside edge of the tool and no further clearance is necessary.

The blanks of wood can now be fixed to the faceplate by means of a single draw-bolt through the lathe mandrel. If the bolt is steadied by a bush inside the mandrel so that it runs true, then the wood will also run true when it is reversed on the faceplate. Move the cross-slide out so that the tool is at the correct radius for cutting the circular section and LOCK the cross-slide rigid. With the lathe turning at about 600 rpm feed the carriage in slowly for a distance of 0.313 in. This should give a perfect semi-circular section to the job. Now turn over on the faceplate and repeat to the same depth, at which point the torus should part perfectly and remain supported in position, enabling the ring to be removed and admired! How is that for job satisfaction?



A SPINDLE CLUTCH FOR THE SMALL LATHE

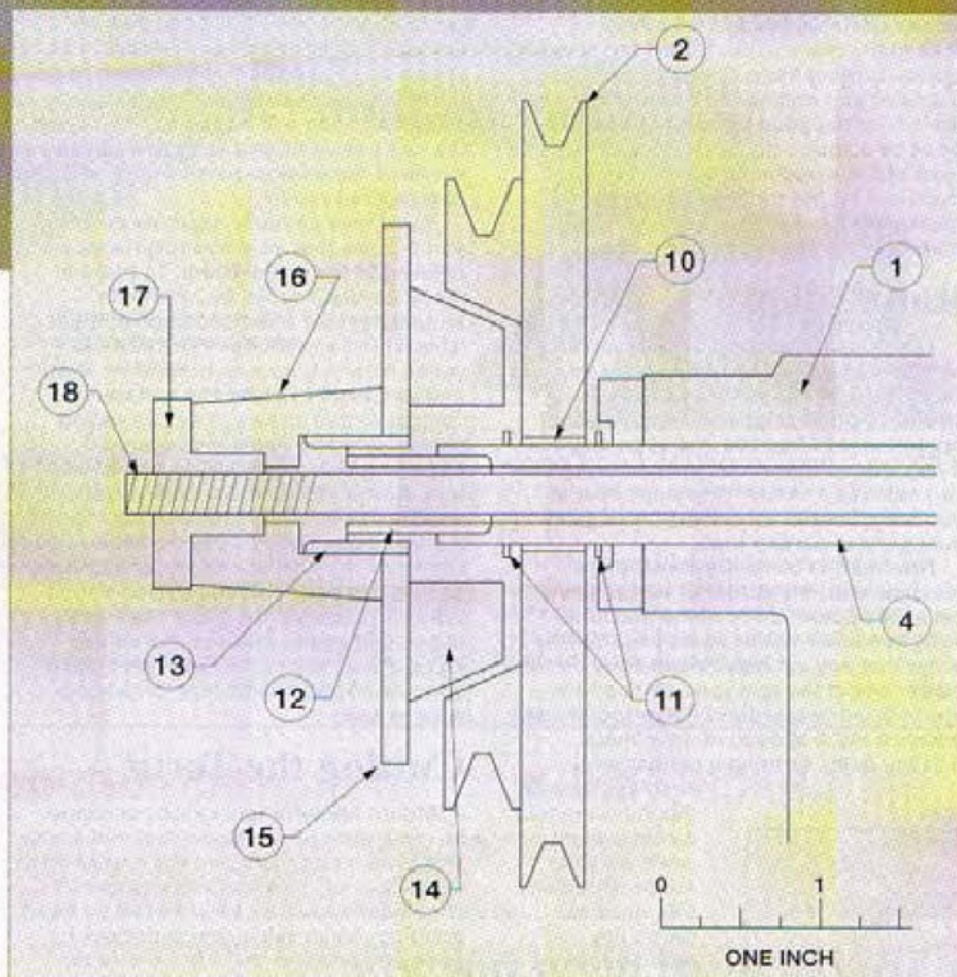


Fig. 1 Motor end of countershaft showing new clutch assembly

There must be many readers of M.E.W. who have enjoyed the extra convenience of a lathe equipped with a headstock spindle clutch. The present writer, who spent many retirement years in front of his Myford Super 7B lathe, moved into a smaller house and was 'down-sized' to the Myford ML10 model. Certainly, this excellent small lathe has many desirable features, some of which are lacking in certain models of the Myford Series 7 machines. Nevertheless, much too often, the writer found his hand reaching up for the clutch lever to arrest the chuck's rotation for a moment. As a result he decided to equip his ML10 lathe with a headstock clutch. The present article describes the construction of the clutch which, in some ways, the writer feels is superior to that on the Super 7.

The drive of the ML10, and the Myford Speed 10 lathe, is a pulley system, mounted on a separate cast-iron countershaft arm (Figures 1 and 2, Item 1). The countershaft pulley of the ML10 lathe has a flat outer surface, whereas the Speed 10 pulley is

smaller and recessed on its outer surface to provide a depression for a grease nipple. This depression can be deepened and modified so as to provide the female surface of a metal-to-metal cone-type clutch, similar to that on the Myford Super 7 machine. The deepening of the pulley recess and the tapering of the walls of the depression leave more than adequate metal for the satisfactory operation of the countershaft, yet provide sufficient conical surface on the pulley for good clutching.

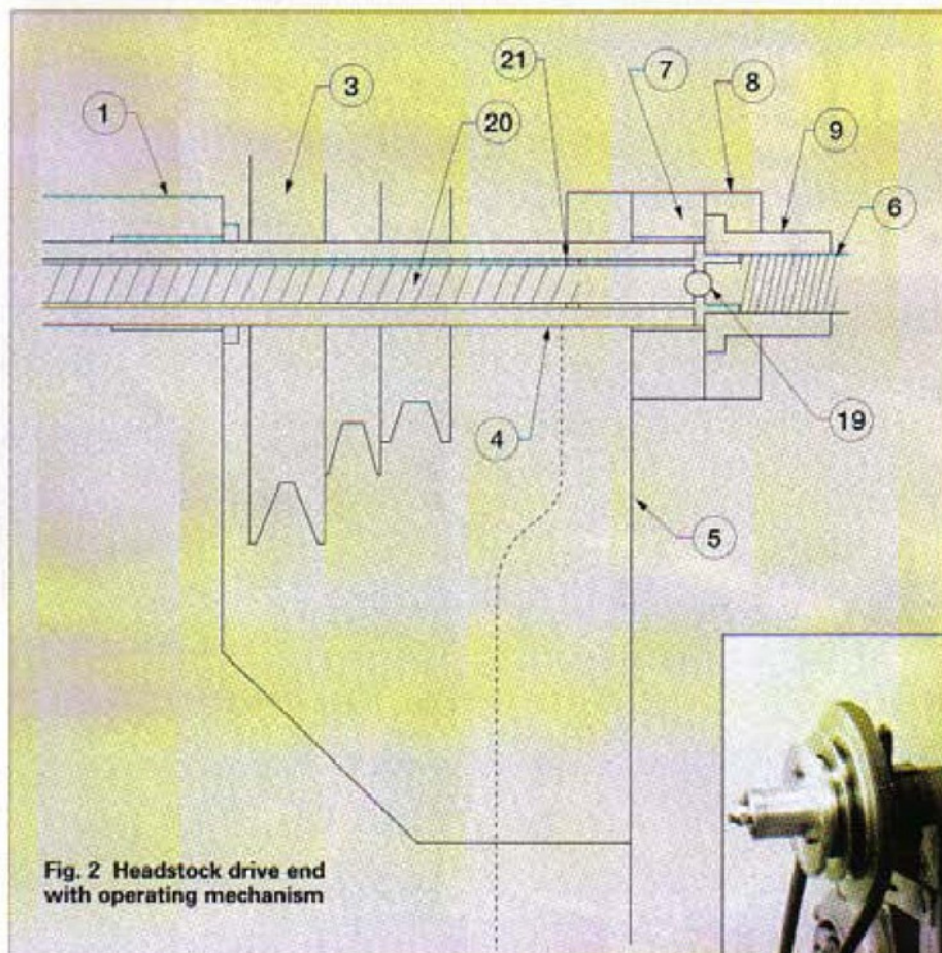
The countershaft of the ML10 lathe is a solid $\frac{5}{16}$ in. diameter rod, carrying at the 'motor end' the pulley mentioned above (2) and, at the other overhung end, a three-step diecast pulley which drives the headstock spindle (3). Rather than attempt to axially drill this countershaft, the writer 'shopped around' and was given a length of barrel steel with a 0.32in. bore which, after reaming, provided a satisfactory hole to accommodate the $\frac{5}{16}$ in. dia. clutch disengagement rod. No doubt an alternative shaft could be made from any suitable heavy walled tubing of acceptable size, the

When Professor Reg. Cane of Tasmania exchanged his Myford Super 7B lathe for an ML10, he missed the headstock drive clutch, so constructed this effective replacement

bore of which could be bushed down, in appropriate positions, to support the disengagement rod. The replacement shaft (4) was turned down and sized smooth to $\frac{5}{16}$ in. dia. so as to be a satisfactory fit in the two 'Oilite' bearings already fitted to the countershaft arm. However, the length of the replacement countershaft has to be about 10 $\frac{1}{2}$ in. for reasons which will become clear later in this article.

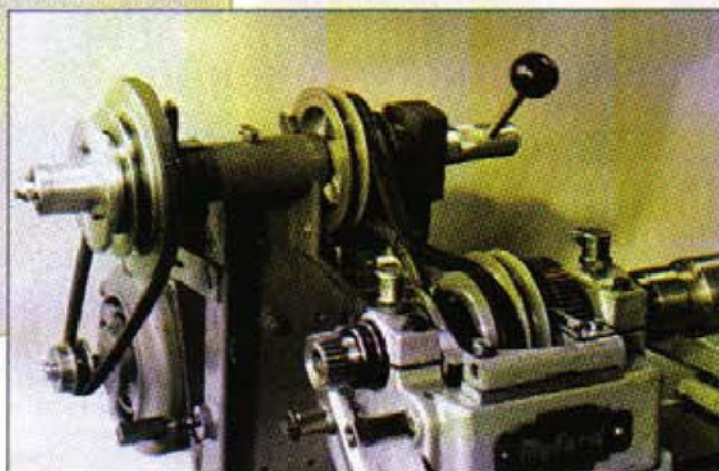
It was necessary to construct a suitable base for the declutching mechanism on the far side of the countershaft arm, and also to provide a third bearing which needed to be collinear with the existing two 'Oilite' bearings, but mounted on the far side of the three-step pulley which drives the headstock pulley. Because of the cross-sectional configuration of the countershaft arm, after much thought, it was realised that the returned edge of the casting would readily accept a length of 1in. x 1in. x $\frac{1}{2}$ in. angle-iron (5) which could be directly bolted along, and on top of, the right hand flange of the casting. By this means, a firm flat surface, at right angles to the plane of the countershaft arm, could be provided to mount the additional bearing and the declutching mechanism. In order to allow a suitable clearance for the additional fixtures, the motor was removed from its original position and remounted on a separate base, hinged at the bottom, and the hinge bolted to the bottom of the countershaft arm. This 'swinging' motor mount had another advantage as, by putting a multi-sheave pulley on the motor shaft and altering motor distances, a variety of spindle speeds could be obtained; of much use in milling operations.

Although thought was given to the use of cams for clutch disengagement, the final simple solution was to use a screwed rod, termed 'operating rod' (6), which could be slightly turned in, or out, to provide enough lateral movement to operate the clutch, about $\frac{1}{16}$ in. being ample. The final choice for the operating rod was a 3 $\frac{1}{2}$ in. length of $\frac{1}{2}$ in. dia. 8 tpi square-thread rod. Two 1in. x 1 $\frac{1}{2}$ in. rectangular pieces of steel, $\frac{1}{2}$ in. thick, were sandwiched and bolted together to the face of the top of the angle-iron. One piece (7) carried the third bearing and the other piece (8) carried the operating rod of 'top-hat' shape (9), both fixed in position by Loctite. The method of mounting the bearing and the nut is shown in the cross-



The male portion of the clutch consisted of three parts. The clutch plate itself (14), which was a truncated-cone disc of aluminium alloy, $\frac{9}{16}$ in. thick, bolted to the backing plate (15). The backing plate, of $\frac{3}{16}$ in. hard brass, $3\frac{1}{2}$ in. dia., was provided with a domed central boss (16) which housed the inserted hex. socket mentioned earlier. The general assembly can be deduced from Figure 1 (holding bolts not shown) and from the photograph of the whole clutch shown in an 'exploded' view in Photo. 1. The small fitting on the far left of the photograph is a steel insert (17) into which the disengagement rod (18) was screwed and upon which the disengagement thrust was exerted.

In order to install a spring to maintain good compression between the clutch plates, the bore of the countershaft at the distal end was enlarged to $\frac{3}{16}$ in. for a depth of about 6in. The declutching rod was a length of $\frac{5}{16}$ in. silver steel rod threaded at one end and screwed into the clutch boss.



2. The lathe headstock and drive assembly with the new clutch components in their normal operating positions. The additional swinging motor mounting plate allows a wider range of drive pulleys to be used

section drawing of Figure 2, and can be seen in Photo. 1. The right hand end of the operating rod was shrouded in a shaped piece of 1in. dia. aluminium, provided with a central hole to accept the end of the operating rod and fixed in position by a grub screw. In addition, a length of $\frac{5}{16}$ in. dia. steel rod, with a hand ball, was fitted at right angles to the shroud to act as an operating lever. The arrangement can be seen in the photographs.

The bolt holes for the sandwiched mounting plates carrying the bearing and the operating mechanism were made slightly oversize and the holding bolts barely tightened. After the new countershaft had been fitted and the assembly adjusted for minimum rotational friction, the bolts were firmly tightened, thus assuring collinearity of all bearings and the nut. After final adjustment, the plates were pinned in position with metal dowels. In Photo. 1 the operating rod has been deliberately screwed out to expose the thread and the

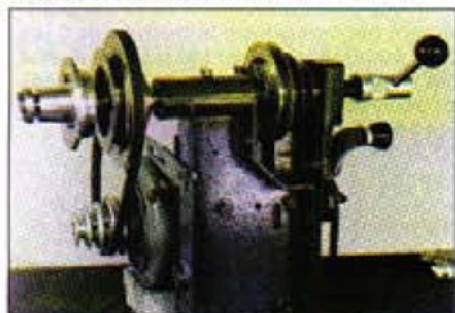
nut. It is in its normal position in Photo. 2. The lower lever shown in the photograph is the belt tightening lever, somewhat modified from the original Myford shape to allow for extra clearance.

The recessed Speed 10 pulley, in the declutched condition, needs to be freely rotating on the countershaft whereas, in the engaged state, the pulley needs to be connected to the shaft. To allow smooth rotation during disengagement, the centre bore of the pulley was enlarged and a bronze shell-bearing (10) fitted in the larger hole. After sizing, the pulley was a free fit on the countershaft and kept in lateral position by a pair of recessed circlips and washers (11). The next problem was to provide a mechanism to permit movement of the male clutch-plate for disengagement. Often such movement is allowed by a spline but this was not possible with the available facilities. The alternative chosen was the use of a short length of hexagonal steel ($\frac{1}{2}$ in. across the flats) sliding in a corresponding hex. socket (from a socket wrench set), the latter being made part of the clutch plate backing. By this device a powerful drive could be imparted to the shaft, whilst permitting sufficient lateral clutch movement for disengagement. The hex. stub (12) was fitted into a hole in the end of the countershaft and brazed into position. The female hex. socket (13) was forced into the boss of the clutch backing-plate by a press.

The other end was countersunk to accept a small steel ball (19) which impinged on the end of the operating rod. Lateral movement of the operating rod was thus transmitted, with little friction, to the far clutch plate. The compression spring (20), fitting over the declutching rod, was held, at one end, by the inner shoulder of the countershaft bore and by a fitted collar (21) on the declutching rod at the other end. Some adjustment of the strength of compression could be made by altering the extent of the 'screwed in' position of the rod into the clutch boss. Thus the clutch could be made to slip under excess load, if found desirable.

The clutch is operated by swinging, up or down, the operating lever seen in the photographs. The position of the operating lever could be adjusted by slackening the grub screw in the shroud and refixing. For reasons of clarity, the belt guards have been removed and the spindle drive belt has been tied. The replacement adjustable motor base can be seen behind the countershaft arm.

The clutch has been in operation for a number of years and, apart from removing traces of oil from the clutch faces, it has given very satisfactory service; an asset to any ML10 lathe.



1. The countershaft arm and motor, showing the new clutch arrangement. The clutch and its operating mechanism are seen in an 'exploded' position, so as to illustrate the construction

Making a small crankshaft

Newcomers to model engineering frequently choose a small steam engine as their first project. Harold Hall gives some suggestions on machining one of the more difficult items

Getting on for a couple of years back, in Issue 51, I described the use of some simple jigs and fixtures as an aid to lathe work. The vehicle on which the machining operations were carried out was a simple steam engine, the Stuart 10V. One major component I didn't mention in that article was the crankshaft as I had decided to take a different approach to the manufacture of that item than that suggested by Stuarts. The drawings supplied with the casting set suggest that it should be fabricated from five pieces of steel, and that these should be fixed by silver soldering or an adhesive. The five parts are, the two journals, the crankpin and two webs. Neither soldering nor adhesive appealed to me as I lacked confidence that I would get the components aligned accurately. An earlier 10H kit was supplied with a one piece forging and as I found the machining of this an interesting process, I decided to make this new shaft in a similar manner, but this time from a single piece of mild steel.

The machining of crankshafts seems to be something attempted quite frequently in home workshops, and as the simple single cylinder steam engine is a project frequently chosen by newcomers to the hobby, I thought that there may be a significant number of readers who would be interested to see how I tackled the job.



1. Drilling each end with two centres for use as in Photos 2 and 5

One piece construction

The ends of the central webs are radiused and these, with the two journals, were to be machined between centres. For this, both ends would have to be centred twice. A special fixture was also to be used to turn the crankpin.

A piece of steel was sawn, both to length and width, and from this the positions for the two centres calculated, as was the amount of packing required to bring the shaft to the height for centring, as shown in **Photo. 1**. For such operations, I have measured the lathe centre height above the top slide surface and noted this for reference when required. After mounting in the top slide, the edge of the material was moved to just touch the

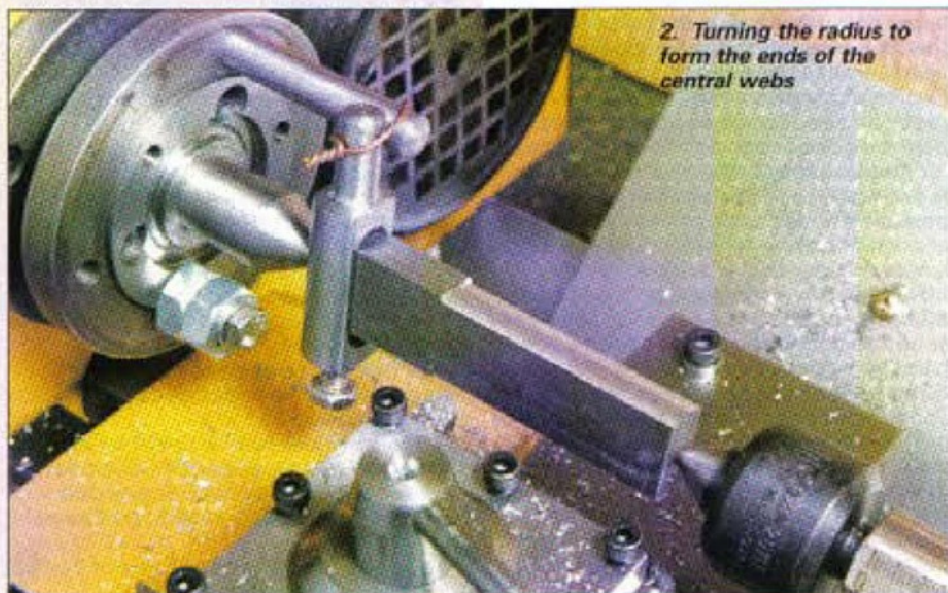
larger diameter of the centre drill, and then wound clear using the top slide. The cross-slide was then advanced by half the centre drill diameter to align it with the edge of the material. The dimensions calculated above were used to traverse the cross-slide, and the two centres drilled. The other end was centred similarly.

Turning between centres

This project provided the opportunity for making two small driving dogs, one to take the rectangular material from which the crankshaft was made. This is seen in use in **Photo. 2** whilst the radius on the ends of the webs were being machined. It is tempting to make do with some available item, maybe a small toolmaker's clamp in this instance. There is, though, a sense of security in having a proper tool for the job.

It was unnecessary to reverse the shaft to turn the radius from both ends, as it is only required in the central portion. As the cut is intermittent, the dog is firmly wired to the driving pin. Even with a continuous cut I feel that this worthwhile.

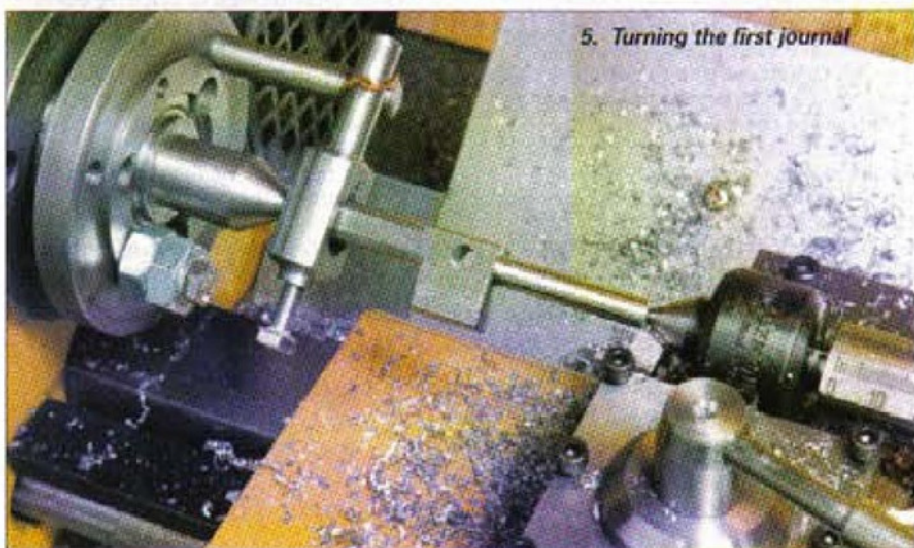
At first glance **Photo. 3** appears to be identical to **Photo. 2**. Closer examination shows that the shaft is now mounted on the other two centres and a small portion has been turned close to the tailstock centre. This is a little larger than the eventual journal diameter and acts as a guide for cutting away surplus material. Both ends were similarly turned. The two journals could have been machined fully at this setting, but the intermittent cut would have made it a lengthy process, so the bulk



2. Turning the radius to form the ends of the central webs



3. Turning a short portion of the end journals to use as a guide when sawing away the excess material to bring it to the form shown in Photo. 4



5. Turning the first journal

of the surplus metal was sawn away, as shown in Photo. 4. A hole was also drilled, as a starter for removing metal between the two webs. The shaft was returned to the lathe and the first journal machined to diameter and length, as seen in Photo. 5. Note that the single hole between the two webs was left in this form for this stage of the machining. The reason being that, had it have been sawn out as will eventually be required, it would have made the shaft considerably less rigid. A second lathe dog was made for the smaller diameter now being held. The shaft was then reversed and the second journal machined, again to diameter and length.

Crankpin turning fixture

It was now time to turn the crankpin and for this, the fixture seen in Photo. 6 was made, and used as in Photo. 7. The hole in the fixture has to be off-centre by an amount equal to the centre distance between the journals and the crankpin. This can be done by mounting the fixture in the 4-jaw, and using a dial test indicator set the total indicator reading to twice the centre distance. The hole can then be drilled and bored to size. Two grub screws, from the side, hold the crankshaft in the fixture while

the crankpin is being turned. A soft brass slug should be positioned at the bottom of each hole so that the grub screws do not damage the finished journal surface.

This fixture works very well, but I cannot claim that the idea is mine. However, like so many things, once the set-up has been used, a possible improvement can be recognised. If doing this again, I would make the slot across the fixture almost as deep as the eventual finished dimension of the web. A grub screw could then be provided to grip the side of the web, in addition to the two gripping the journal. This would result in a significant increase in rigidity.

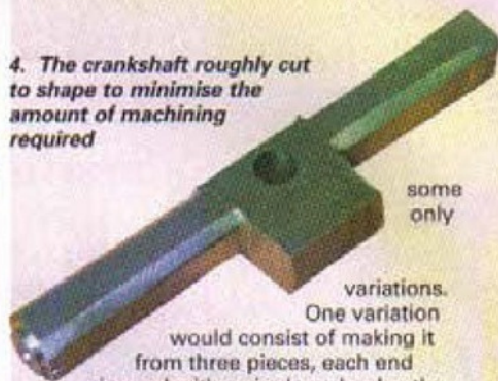
Turning the crankpin was carried out using a narrow parting type tool and the sides of the webs faced with left- and right-hand knife tools. I did have some problem with chatter, but using a narrower parting tool would have helped, as would the additional screw mentioned above.

Photo 8 shows the finished crankshaft with the two dogs and the crankpin turning fixture. This was an interesting and satisfying project, and a method that I can thoroughly recommend.

Other methods

Of course, the method described above is but one of many, some totally different,

4. The crankshaft roughly cut to shape to minimise the amount of machining required



some only

variations.

One variation would consist of making it from three pieces, each end journal with a single web, plus the crankpin. The single end journal and web radius would be turned between centres, generally as in Photos. 2 and 5. The web would be much thicker to allow for the centre drill impressions. Each end journal would then be mounted in the fixture in Photo. 7 and the web machined to width and also drilled for the crankpin. This hole would be smaller than the crankpin to allow the crankpin to be made with steps in the diameter, thus ensuring that the webs were easily assembled at the correct spacing. A crankpin would then be turned and fitted using adhesive and the two journals placed in vee blocks to ensure correct alignment. Finally, the crankshaft would be mounted between centres, generally as in Photo. 5, to skim over the outer faces of the webs and the crankpin.



6. The fixture to be used for machining the crankpin



7. Machining the crankpin using the fixture shown in Photo. 6



8. The completed crankshaft with two driving dogs and crankpin turning fixture, all three items being made specially for the project

BLOCKS & TRAMMELS



1. The four blocks provide a useful combination of heights on to which to set a workpiece

Precision Matched Blocks

These blocks (Photo. 1) are very useful for layout work on a surface plate, (raising work up to a comfortable height), or as precision packing on the lathe cross-slide. They can also be used as parallels on the milling machine or drill table, offering the choice of heights of approx. 1in., 1 1/2in., 2in. or 2 1/2in.

Ideally, they should be case hardened and ground but, with care, they can be left soft, provided that they are carefully used (and stored!) My own blocks are soft. Construction is straightforward, but a few words may guide someone out there. The essential dimensions are shown in Figure 1.

Detail 1

Use 2in. x 1in. bright mild steel stock which should be cleaned up and the ends brought square by milling or filing - as a pair. Accurately mark off all hole positions on both sides, then centre dot and centre drill deeply, again on both sides.

Flush off all faces with a fine Swiss file then with the block standing on a 2in. x 1in. end face, clamp to an angle plate which will fit on the drilling machine table. After lining up one hole, clamp the angle plate to the table. Using a sharp 1/4in. dia. drill, drill halfway through and follow up

Len Walker suggests that adding these simply made items to the workshop inventory would aid marking out and other operations

with an 1 1/32in. dia. drill - without moving the work.

Repeat for the other two holes, and lightly chamfer all three. Again flush off using a fine Swiss file.

Reverse end for end and repeat the drilling sequence as before, breaking through into the existing holes. The reason that these three are drilled first, through solid metal and from both ends, is that they are the longest and we want to minimise the chance of 'run-out'.

The four side holes are drilled next, using the same method (i.e. from both sides). Go easy - the drill has to cope with an interrupted cut.

Finally, drill the twelve holes in the 2 1/2in. x 2in. face, with the work firmly

clamped to the drill table, this time with great care. You can drill right through from one side, but watch out for turbulence halfway! Clamping is essential.

Next, using a sharp cutter, lightly countersink all holes neatly, as shown. Prove on an odd piece of BMS - nothing looks worse than a group of badly countersunk holes. Neatly chamfer all edges and corners, then a light rub on 600 grit wet or dry paper (on a surface plate) will remove any burrs from the six faces.

An alternative method of drilling Detail 1 is to clamp the block, packed up to centre height, to the lathe cross slide and, using the three jaw chuck, drill from each side as before. This offers more room for drill changing, which may be restricted on

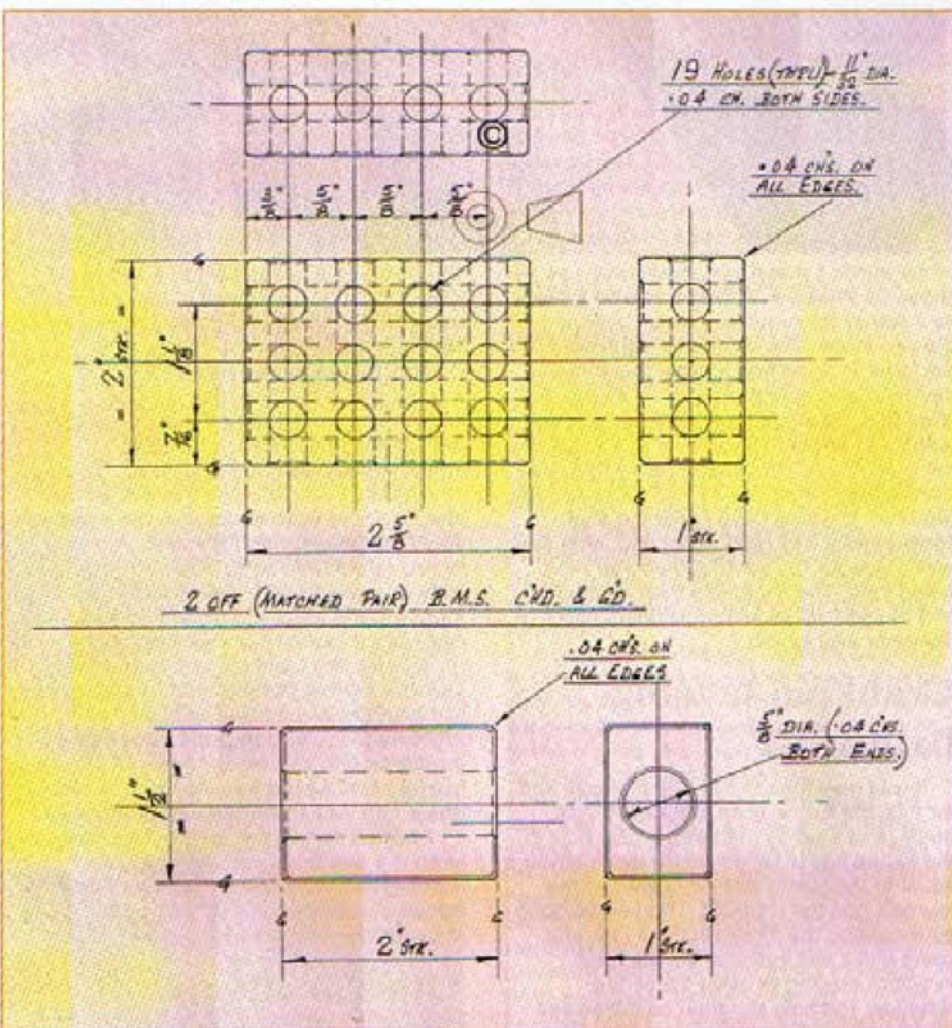
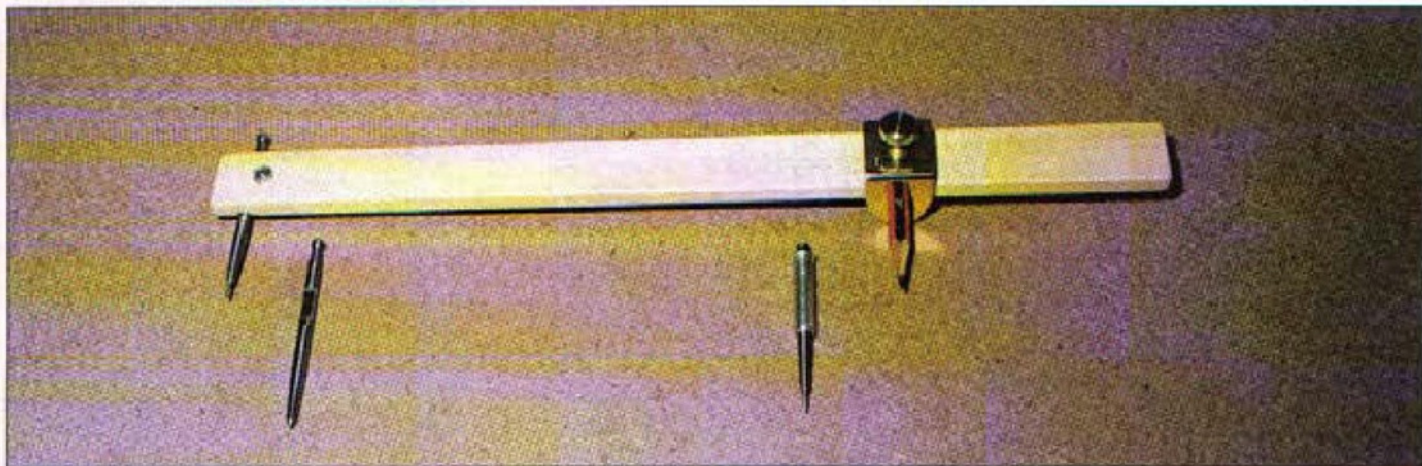


Fig. 1 Precision matched blocks - 2 off each, mild steel



2. The beam compass or trammel may be used with a pencil for drawing purposes or with the alternative scriber points for marking out

a small drilling machine. Each face of the block is set parallel to the chuck face by trapping a stiff 12in. steel rule between the chuck and the work before clamping.

Line up each hole using a centre drill held in the chuck. Lock the cross-slide and drill halfway as before, around all four edges.

The remaining 12 holes can now be drilled, the block being clamped to the drilling machine table, as before. Again, with care, these can be drilled right through, but do clamp securely. Interrupted drilling always calls for a steady hand on the tiller. Countersink, chamfer and deburr as before.

Whichever method you have used, the blocks can now be casehardened, if you have the means. As I have mentioned in previous articles, if you are lucky enough to have a friendly local Technical College, hardening and grinding may not be a problem.

Grinding

The majority of the grinding should be carried out with the blocks set up as a pair. First grind the top and bottom (2 $\frac{1}{2}$ in. x 2in. faces) parallel, then grind the two edges (2 $\frac{1}{2}$ in. x 1in.), with the blocks clamped to an accurate angle plate. Next, grind both 2in. x 1in. end faces square and parallel.

Clamp one block to the angle plate and set the 2 $\frac{1}{2}$ in. x 1in. face square to the magnetic chuck face, using a try-square, then grind. Reverse and grind parallel. Finish the other block to match. If your angle plate is fitted with an end fence, this is where it comes into its own - for squaring up work - no sweat!

Detail 2

The procedure to be followed is, of course, similar to that used for Detail 1, but this time using 2in. x 1in. stock

Clean up and mill both blocks to the 1 $\frac{1}{2}$ in. dimension, as a matched pair. Mark out the position of the $\frac{5}{16}$ in. dia. hole on one end of each block and centre dot. With each block held in turn in a four jaw chuck, set the centre dot to run true, centre drill, drill $\frac{1}{4}$ in. dia, right through then open out to $\frac{19}{32}$ in. diameter. Finally bore to $\frac{5}{16}$ in. dia. and chamfer the bore. Reverse in the chuck, set the bore running true and chamfer the other end.

Neatly chamfer all edges and corners, then the blocks can be casehardened and ground, using the routine described for Detail 1 (grind the top and bottom faces parallel, as a pair etc.). A very light 'matching' lick on the surface grinder, over the completed pairs of blocks, will guarantee accuracy.

I hope that you enjoy making and using these useful items of basic kit. I store mine (as usual) oiled, in a strong plastic bag - all in a cigar box (I usually scrounge one at Christmas!).

A Beam Compass or Trammel

This is a simple device, shown in Figure 2, which can be used for work on the drawing board or, by changing the 'points', can be used to scribe radii on metal (Photo. 2).

During a move from a house to a flat, I had to 'unload' so much stuff, including a Myford lathe (now happily bought back), and some drawing equipment, which included a nice beam compass.

Some time later, we bought a new spin dryer (a smaller round one) and in order to make a worktop, I had to mark out a series of circles on plywood and on the stumpy supporting legs. Always a glutton for punishment - just to "get it right" - I made this gadget. Who said that the snag about starting jobs was that you always needed to make something else first? Anyway, it does the job.

Being easily set and very rigid, so much so that I added the alternative metal scribing points, the length of the rammer wood beam allows a 12in. radius to be struck. It could even be made longer to suit larger work.

Construction hardly merits much comment, but the sequence of operations may guide newcomers to our hobby.

Make Detail 7 first, bent up around a piece of 1in. thick bright mild steel with nicely radiused edges. This can then be used as a gauge for the beam (Detail 1), aiming for a nice sliding fit along its whole length.

Transfer the two holes for the $\frac{1}{16}$ in. dia. pins from Detail 7 to Detail 9 to make sure that they match up, then fit the threaded bush, Detail 8 to Detail 7. The $\frac{9}{32}$ spigot needs to be turned so that it is a drive fit.

Next, assemble the pins (Detail 10) to

Detail 9, using a $\frac{1}{16}$ in. dia. hole in a scrap of $\frac{1}{4}$ in thick steel as a guide, to ensure that the pins are truly square. Make sure that the thread on the clamping screw (Detail 11) is a close fit in the bush (Detail 8).

Make Details 2 and 3, soldering them together and drilling for the $\frac{1}{16}$ in. dia. pin, but don't fit the pin yet.

Now make Details 12 and 13. I used a 'shouldered point' from an old pair of compasses for Detail 13, Araldited in position. Don't be tempted to use the deadly 'spike' found in school compasses, as they go on boring their way through the drawing paper and into the board for ever!

The beam (Detail 1), now to width, can be drilled to take Detail 12. A piece of spare rammer, clamped to the end of the beam in a drilling vise, will allow the off-centre hole to be drilled accurately. Drill a clearance hole for the 4BA countersunk screw as shown then, with Detail 12 clamped in position, drill the $\frac{1}{16}$ in. dia. hole in the beam, using Detail 2 as a jig, and fit the pin (Detail 6). The nut (Detail 5) is partly pressed into the beam, as shown in the G.A., in order to prevent rotation.

The beam, after adding chamfers and a final rub over with fine glasspaper, should be given two thin coats of polyurethane varnish (satin coat) This will give a durable finish.

A humble 'dog-end' of pencil is all that is required for detail 14. I used one with an hexagonal section - a flat fits nicely against the beam. In use, Detail 7 slightly indents into the hex. corners, providing a secure anchorage - all for free!

For metalworking

Make Detail 15 from silver steel, hardening the tip and tempering to straw colour. For the other end, form and drill Detail 16 to take a $\frac{1}{16}$ in. dia. silver steel scriber, hardened and tempered to pale straw. Araldite the scriber in position, along with the aluminium sleeve, as shown on the detail. Machine or file the flat, keeping it parallel along its length.

A useful tip, (sorry about that!) is to fit corks over the shouldered 'drawing-point' and the metal scriber, to protect them (and yourself) from injury.

Well, there 'tis - Happy marking out. Good luck, and work safely.



CNC FOR PRACTICAL ENGINEERS

- Acquiring data for CNC

In a previous series of articles (Issues 41 to 47), Richard Bartlett introduced his 'Compucut' CNC system and showed how it could be used in the home workshop. Subsequently, Peter Rawlinson built his CNC machine, described in Issues 53 to 56, around this system.

Richard now describes some recent developments and describes the process of digitising from a template or similar solid model.

To recap

In the introductory articles, the control files were composed in one of three ways:-

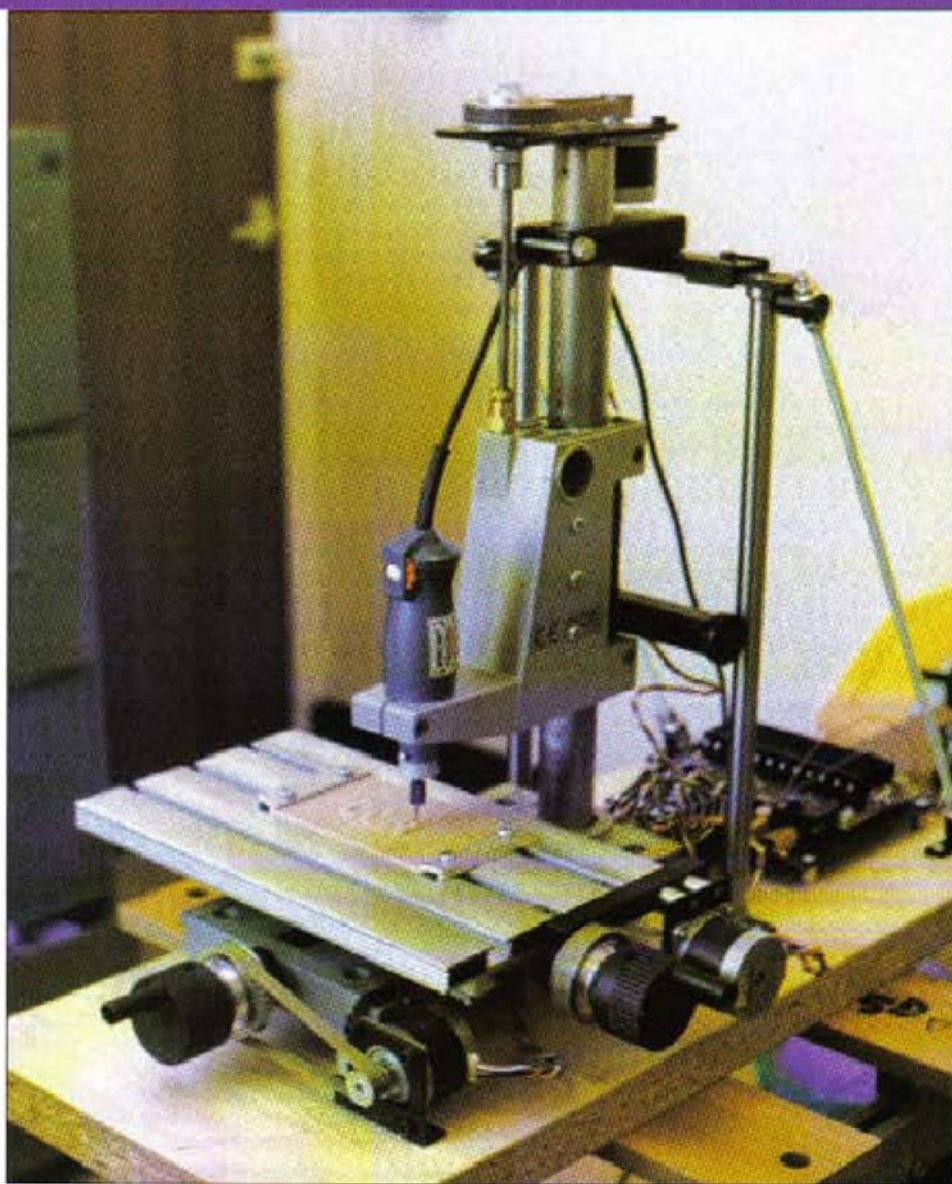
- by entering the number of steps directly in the text editor, as one would when typing an operation sheet.
- by drawing the component and then the required cutter paths in a CAD package and saving these to a .PLT file
- by drawing out the component to a large scale on graph paper and counting the squares to arrive at the required sequence of steps, which could then be edited into a control file.

What all three of the above methods have in common is that they can produce 'hard data', by which I mean that each cutter path can be checked back from the component specification or drawing and be re-calculated to plus or minus one step.

The dimensional accuracy and therefore, the success of many metal cutting projects obviously depends on maintaining this quality of control data. If you are going to produce a batch of con-rods for a Vee-12 engine, then drawing in CAD is the way to derive the data. Similarly, if you are cutting clock gear wheels, the program can derive the data directly from the parametric equation of the tooth form. Even then it is sometimes required to improve on what the entry level CAD packages offer in circular resolution, for example when milling arcs. Post processing programs for drawing data such as Compucut's CIRCDATA can provide higher resolution for the production of smoothly milled arcs and circles.

Going 'soft'

Not all CNC users need to accept the constraints of 'hard data'. Many enquiries/queries over the past couple of years have been made by modellers, sometimes working in materials other than metals, whose machining parameters are based on empirical data, the results of which may be assessed on a quite subjective basis. For them, if it looks right, and it can be reproduced exactly, then it is



1. WolfCraft adaptation to a 3-axis router

right!. This article is aimed at describing ways in which the 'soft' data for these, often 3-D applications, can be conveniently acquired.

'Soft' data will be taken to mean: "Data that is derived by a computer program in

conjunction with external hardware aids when used to digitise a two or three dimensional template, model, photograph, tracing, or sketch".

The aids to be described include self-build stylus copiers, digitising tablet,



2. A Compucutter machine set up to mill a turbine rotor

scanner, and digital camera.

There are several formats for CNC data files, but as the examples shown here are produced under the Compucut system, only those formats will be described in any detail. However, the techniques described should be transferable to any other 2 or 3-axis CNC system, but it is essential to hold the final machine configuration in mind when deciding on how best to digitise the required profile.

Although this first article is not about machine design, it is worth noting at the outset, that once we go from manual operation to CNC, the factors which affect the compromise between rigidity, cost, accuracy and ease of production are weighted very differently. The photographs of two differing machine configurations will emphasise this point.

Photo. 1 depicts engraving using a small overhead router kit based on a widely available compound table, built in

the usual XYZ 'rectilinear' configuration (this simply means that all axes are mutually perpendicular). **Photo. 2** shows the DIY Compucutter built in the less common configuration of 'curvi-linear' - I have borrowed the word from chart recorder terminology. It means that one axis moves in an arc. If this were a manually operated mill, we would need to convert each true vertical movement against a calibration table to arrive at the actual vertical leadscrew turns plus a correction in the horizontal axis. As the computer can be made to do this for us, the obvious advantages of greatly improved rigidity and ease of construction are there as almost free benefits. There is the 'once-only' overhead of producing either a calibration file or a compensating digitising board.

The following examples will be produced to run on one or the other of



3. Compensating digitising board set to 5x scale of the Compucutter

these machines. Note, the demo jobs are examples of 'How it might be produced', rather than 'What shape to make it'.

A worked example

A typical example of projects which involve digitising from a template is the manufacture of a turbine rotor for a model gas turbine engine. The rotor will be milled from circular blanks of alloys of nickel, chromium, molybdenum and manganese which are very prone to work hardening if the cutter is allowed to rub. The configuration of the Compucutter was chosen to make it very rigid and with ample power for milling turbines up to 4in. diameter.

Getting the data for the control file

You start with an idea for a prototype turbine blade profile. In this example, the blade section is uniform with a root radius. Because it is easier and cheaper, the radial indexing will be done manually by using a gear wheel with a tooth count which is an integer multiple of the number of blades on the hub. This is located together, with its indexing pin, on a 'bed plate' in the cross vice.

The terminology for the Compucutter motions is Vertical, Horizontal and Axial to the spindle. This means that the 'chord' (leading edge to trailing edge) of the blade profile lies approximately on the vertical axis, the thickness of the blade is generated in the horizontal axis and the blade length (tip to root) lies in the axial axis.

Sketch your blade profile at a size that is easily cut with tinsnips. This limits the smallest size, as the larger the template the easier it is to cut. Increase this size to give an integer value for scale, I find that five times is convenient. Cut the super-scaled template for your prototype blade from 1mm aluminium alloy sheet and smooth the edges. Drill a hole centrally for a mounting screw of a size whose head is contained within the template profile.

Mount the template on the digitising board (**Photo. 3**) at the angle of attack you think appropriate. Mark the position of the tail of the template on the board to give a datum for this angle. Mount a stylus of diameter equal to your proposed cutter diameter multiplied by the digitising scale (5x in my case). Check that one of the limit wires from the interface is connected to the stylus as the 'SENSE' and that the template is connected to 0v.

Check that the template is not upside down. It is easy to make this slip, but the turbine rotor will have been designed to spin one way only (left hand threads etc.). Move the stylus to the datum position, with the top edge of the stylus level with the trailing edge of the template and to the left of the template. Run the digitising program to progress around the template in a CLOCKWISE direction; this is important as this will produce the desired 'climb' milling. The rule is to digitise clockwise for an external profile, anti-clockwise for an internal profile.

Follow the program prompts and you will finally be asked to name the file which will be saved to disk.

The Digitising Board

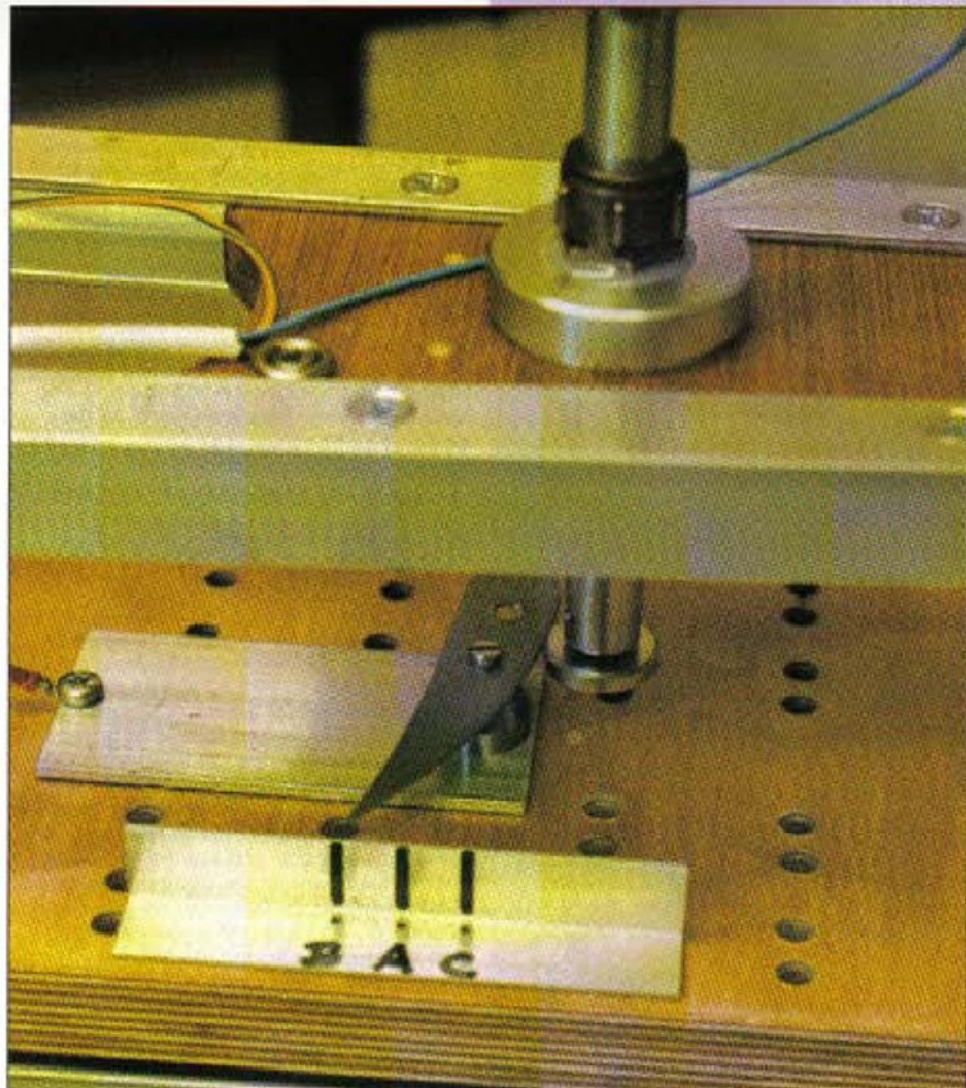
As the photo shows, the digitising board mimics the Compucutter in vertical and horizontal motions at some convenient value of scale, effectively logging its data with the same non-linear characteristic as the machine which will use the data, this being the auto-compensation feature. The digitiser can be lightweight, low powered and is conveniently mounted on a wall, where it will take little space. The stepper motors can be size 23 which are small and cheap. The table is carried on a linear slide using two tracks, each track carrying two recirculating ball carriages. These nicely engineered units are made for superior filing cabinet drawers, and move smoothly with no clearance and very little friction when loaded. The radial bushing and column on the prototype digitiser were leftover from a cheap bench drill bought for its motor head. With hindsight, I consider this digitising board to be rather 'over engineered' and have realised since that a pair of bicycle front wheel hubs would make an elegant and cheap linear rolling carriage, with the part frame and bottom bracket bearings plus chain ring giving a satisfactory radial motion.

In theory, (and the only theory is that of similar triangles), the leadscrew pitches of the digitising board should have been super scaled up from the pitch used on the machine, but in practice the program prompts for your value of scale and makes the necessary allowance. This way you only need one set of threading kit.

Proving the program

We now have the control data in units of motor steps for the vertical/horizontal profile. This can be imported to the text editor for the number of passes around the profile and the cutter axial feed per pass to be added. A screen prompt (SCR) tells the operator to manually index to the next blade space in order to repeat the roughing cut, a procedure which is repeated for all blade spaces.

My preferred way to program a finishing cut is to program/digitise for example, with a $\frac{1}{16}$ in. diameter cutter, to rough out with a 3mm diameter endmill, leaving $\frac{1}{16}$ in. short on depth, withdraw, then SCReen prompt for a change of cutter



4. Related sets of data at various 'angles of attack' are easily acquired from the basic set-up

to $\frac{1}{16}$ in. ball nose before repeating to full depth. This gives a finishing cut equal to the difference in radii between roughing and finishing cutters, using the same data.

These blade spaces are all exactly similar, so one can expect a blank of homogenous material turned concentric from its reamed bore to be very close to balanced when the blades are machined using the bore as a datum.

Rapid prototyping

Sets of related data can be digitised, for example with the template set at differing angles of attack (see Photo. 4) or by varying the number of blades on the hub. Since it takes approximately ten minutes to change the set-up and re-digitise a template, this method might be considered a viable 'rapid prototyping' system, as the second and subsequent turbines can be produced in **one** day. (I emphasize 'second' because the first run through a new system will always take longer than this.)

It should be noted that although the turbine blades produced above are three dimensional objects, the process is not 3-D milling. I think of it as 'multi-layered 2-D' because we use two axis interpolation plus an axial increment on each pass. Real 3-D will be considered later.

In the above example, the digitising

table was required to mimic the 'curvilinear' characteristic of the Compucutter to achieve the necessary compensation.

Stylus digitising can also be performed on the cutting machine which will be used to produce the component. This eliminates the job of making a special digitiser and also, if the template scale is 1:1, fundamental accuracy is achieved without leadscrew calibration, due to the fact that the same section of screw will be used to both digitise and cut a feature.

Photo. 5 shows some experimental blade shapes in different materials. The two at the rear are polyester resin, the middle row are aluminium alloy and the actual 'running test' material in the foreground is stainless 316. It is worth machining at least three adjacent blades to check on the cutter clearance between the previous blade, the currently cut blade and the next to be cut. This is still fairly inexpensive development as one can accommodate about five different profiles on any test blank.

An alternative technique

The above technique is easily implemented with a simple two axis CNC router to produce aero wing ribs. The



5. Test rotors showing a variety of blades shapes machined in polyester resin (rear), aluminium alloy (centre) and stainless steel



6. A system based on the reconfigured Wolfcraft components cutting clock wheels

following method is probably as simple as it can get: the template or 'broken specimen' is lightly clamped to the table. A cutter-sized stylus, held in the collet, is connected to one probe of a low voltage, low current 'buzzer' or continuity tester, and the conducting template is taken to the other. The cutter is set to datum X0,Y0 and the manual digitising program is run. The user presses the cursor keys to move the stylus to the points of interest along the profile. As the buzzer indicates contact between stylus and template, the user presses a key to log that pair of co-ordinates in X and Y. At the end of the profile, the resulting data is saved to disk file. This data is imported to the text editor to be written into a control file as in the previous example.

The template is then substituted for a workpiece and the stylus replaced with a cutter. The cutter is set to X0,Y0 and Compucut and Dremel do the rest.

To summarise, data acquisition using a mechanical digitising stylus offers advantages, with a few disadvantages, as follows:-

Pros:- It offers simplicity, accuracy and could well be the method of choice for those who are less than comfortable with CAD. If a replacement for a broken component was machined from data acquired by directly digitising the broken specimen, as suggested above, then this method, in my view, is a more elegant solution than drawing in CAD. By mimicking any machine configuration it can free the machine tool design from the ubiquitous XYZ rectilinear arrangement, to whatever best suits the cutting situation, or the mechanism you might already have under the bench.

Cons:- These include the small cost and time required to build the digitising table, plus the fact that the data is 'soft'. However, the usual connotations that accompany terms like hard and soft should be avoided in this case. Any implication

that soft data is somehow inferior data and that hard data is consequently better is not intended. The photos show fairly typical applications of each type. The turbine wheels are accurately produced in a difficult material on a rigid machine built to do just this sort of work, but the data is soft - it is based on a subjective idea.

The clock wheels shown being machined in Photo. 6 are being made on the two axis adapted table which can be built in a few hours, and although the plywood wheels are rated less accurate than the turbines, the parametric equation of the cycloidal tooth based on the full ogive is followed by the computer every step of the way. This is as 'hard' as data gets.

The Digitising Tablet and Electronic Stylus

These digital electronic / electro-magnetic devices are typically 12 x 12in. or 12 x 18in. (sold as A4 & A3) by approx. 1 1/2in. thick. The tablet creates an accurate electro-magnetic field across its surface, which is sensed by a puck or stylus (Photo. 7). The sensed data is returned to the PC where it is used to determine the position of the puck or stylus on the working surface of the tablet. The tablets are driven from the serial port of a PC, and were developed to replace the combined mouse/keyboard as the pointing device for CAD programs. In this example the stylus (Photo. 8), which is rather like a fibre tip pen whose tip is spring loaded away from an electrical contact within the barrel, is used as the sensing element. In addition to the 'rib' there are two buttons on the barrel which can be used in a similar manner to the mouse buttons. The stylus senses up to an inch above the tablet's surface and will sense through paper, wood or plastics.

The tablet and stylus can be used to produce an almost immediate control file for Compucut to rout out a 2-D shape such as an aero-wing rib, fuselage bulkhead, helicopter chassis panel or whatever. The control file data is generated by tracing around the broken model or cardboard cut-out of the desired shape whilst running the Compucut trace control program called STYLUS.exe. The stylus can be fitted with a small plastic sleeve, the diameter of which is equal to the diameter of the cutter to be used at routing time multiplied by whatever scale value you have chosen for your template. This provides the required cutter path compensation.

It is clear that the technique is not very different from the mechanical digitising stylus described previously, but the 2-D data received from the tablet is fixed in rectilinear format.

Set-up

This brief explanation refers specifically to the 'Trust' brand of digitising tablets and the 'Wintime' (WT) software supplied with them, chosen as an example because they are affordable at around £70. Other makes of digitising tablets which follow the 'Sumagraphics' standard may be found to work.

The procedure may be described, as follows:-

Make a directory called \TABLET and copy the DOS drivers supplied with the tablet into it. Also copy in the Compucut programs STYLUS.exe and TABCAL.exe.

First, a hardware test. Connect the digitiser to the PC using the stylus as the input device, rather than the puck. Power up the PC and at the DOS prompt, log in to the \TABLET\UTILITY directory and run the WTSETUP program by typing WTSETUP. At the screen, type 1 to select COM1 then ESC to exit.

Log in to the TABLET\RUNNER directory and type WTRUN. You should see the program fetch the WTINIT file and stream the default parameters down the screen, finally stating "Driver installed successfully". The PC and TABLET are now initialised to 9,600 Baud in relative mode.

Now log in to the TABLET\DRAW directory and then type SKETCH. This will test the tablet hardware and you can follow the screen prompts to check the stylus switches.

Assuming the tablet/stylus is fully functional, log in to the \TABLET\UTILITY directory.

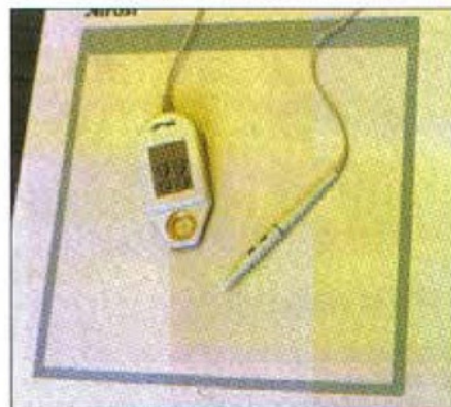
The digitising tablet and stylus can be used to trace around a profile (Photo. 9). The data is logged via a Compucut programme called STYLUS.exe, which uses the tablet in 'mouse systems' emulation mode at 1200 Baud. To enable this, at the DOS prompt type the DOS command: MODE COM1:1200,N,8,1. Run the STYLUS program by typing STYLUS from the \TABLET directory then enter.

Follow the screen prompt for a data filename (JOB.DAT), and scale factor then enter and you are on your way. Be prepared to start logging data at this stage or you will be 'timed out' by the DOS serial controller. If this happens, just rerun the STYLUS program and get going.

To set a convenient scale such as 1 thou. equals one motor step, run the calibration program TABCAL.exe and trace out the inside perimeter of a circular template of diameter equal to a nominal value plus the stylus tip width, say, 2 1/16 inches. This will return a cutter centre path of 2in. diameter.

Starting with a scale value of 1, keep taking traces and observing the results by listing the .DAT files until the required steps are shown in the REM statements in the .DAT file. These 'absolute' moves are included for calibration purposes. Alter the scale value until the digitising is suited to your choice of scale.

Note that 'as supplied', the stylus probing tip may be a 'wobble' fit in the



7. The 'Trust' digitising tablet with puck and stylus

barrel; mine certainly was and this can cause an involuntary movement of the barrel quite independent of the tip at lift off time. Remember that it is barrel movements that are sensed, not tip movements, the tip just does the switching and provides a visual reference to the probed point. The tip/barrel fit can be bushed either internally or externally to reduce the corruption of the last few samples of collected data due to relative lateral movements of tip and barrel. The bushing can also carry a mounting for a 'cutter compensation' ring of plastic, turned to equal the proposed cutter diameter.

The digitising tablet can also be used within the drawing environment of a CAD package. This example assumes the use of DraftChoice for DOS which supports a Microsoft mouse. Connect the digitiser to the PC and boot up. At the DOS prompt type `MODE COM1:1200,N,7,1`

Log on to your TABLET directory and run `WTSETUP`. At the opening screen type 1 to establish COM1 as the serial port for the digitiser, then type capital N for Microsoft mouse emulation mode, escape to quit the set-up program. (DraftChoice appears to work satisfactorily in either Microsoft mouse mode or Mouse Systems mode, but you must set the mode for one or the other in both DOS and DraftChoice.)

Run DraftChoice and select `CONFIGURE` from the FILE menu, select `SERIAL` and set the serial port to 1200 baud, No parity, 1 stop bit and 7 data bits. Accept these options and leave the configuration. Select `COMPLEX` from the DRAW menu. Pull down the `SETUP` menu and select `LINE`. Accept these options. Choose to `PLACE` a complex line and follow the screen prompts. These tell you whether the pen is UP or DOWN and this condition is toggled by pressing the stylus down onto the digitising tablet. With `PEN DOWN` and stylus lifted trace around your shape and terminate the line with a dip of the stylus. Escape, escape to terminate the complex line and choose `PLOT` from the FILE menu. Change the device to the HP7475 plotter, and send the output to a .PLT file. Choose to `PLOT` and the HPGL data will be written to your .PLT file using a scale factor set in DraftChoice configuration file.

Again, you will need to practice your stylus technique as it is very easy to terminate the line by dipping the stylus as you trace. Advantages are to be gained by reworking the stylus tip to reduce the lateral play and allow cutter compensation just as in the `STYLUS` program. Keep producing your test tracing of a circle of nominal diameter plus stylus tip diameter until the scale is set to return the HPGL file units equal to your drawing units. I prefer one thou. of an inch equating to one motor step, as this suits my preference for Imperial leadscrews of 50 thou. pitch.

The accuracy of tracing by stylus on a digitiser will always be subject to your keeping the stylus vertical. My tendency to lean the stylus whilst proceeding around the profile is very marked. Ideally, a twin parallel link system such as those used on a draughting head or tapping guide would carry the stylus to keep it square at all times. You will find the accuracy increases greatly with a little practice.

When editing the .PLT files to construct your control files, do look for the `PU` and `PD` commands to show where one

complex line ended and the next begins. Remember, Compucut does not respond to these and you will need to put in `CUNnn` and `CDnnn` moves to control the movement in the Z axis.

A simple application which shows the possibilities of the stylus method would be to digitise the components of a new aero-kit, and then rout them to a new scale.

Editing

A CAD program can be used to edit our digitised scans, in the same way that the test editor `EDIT` is used to edit our control files. An example of this is where we wish to make a mould for reproducing the scanned model, rather than cutting around the outside of the periphery. We cannot use the easy fix of a cutter sized collar on the stylus because the required cutter path is within the area of the template.

An external scan using a nominal collar on the stylus is taken as a polyline in CAD and saved in DraftChoice drawing format as 'YOURJOB'. The next drawing layer is opened and the snap disabled. Circles equal to the cutter diameter are placed around the inside of the profile, such that they share tangents with the profile at the points of interest. These would include start, finish and mid points of each curve etc. Save this and open the next layer which we will call 'YOURJOB.3' indicating layer 3. Select a Bezier line and draw around the centres of the construction circles in the direction and sequence required for cutting. Save this out as a .PLT file for editing into your control file. Complex moulds can be milled using multi-layered 2-D profiles produced using the 'TWEENS' facility in CAD, which could use YOURJOB.3 as a base profile and the plot of YOURJOB.4 as the apex profile.

When the test routine `SKETCH` is running the absolute values of X and Y are displayed on the monitor. `SKETCH` is intended as a hardware test facility, but it can also be used in 'quick and easy' applications such as to digitise the centres of an odd hole pattern or any feature that can be located by some form of tapered dowel or stylus. There is no provision for storing the data in this mode, so the user would make a note of the XY co-ordinates of each feature, use `STYLUS` if storing of co-ordinates is required.

Also in the 'quick and easy' vein, the tablet and the 'SKETCH' test routine can make up a 2-axis digital readout to be used with, for example, a modeller's A3 router. With the routing machine mounted firmly above, but well clear of the digitising tablet, a deep 'C' bracket is fixed to the end of the router table so that it locates the stylus underneath the router, just clear of the surface of the digitising tablet, and at an XY location that is close to digitiser X0,Y0 when the router is at its X,Y datum. The tablet is covered with a polythene sheet to stop dust entering the cable sockets and the `SKETCH` routine is run. The table is homed and the tablet moved in XY until the readout is X0,Y0, the table is then lightly clamped on its edges and you are ready to reproduce the drilling co-ordinates of the previously digitised hole pattern.

It is worth noting that this could be done manually, and whilst this is not actually CNC, it is data acquisition, and is in my view an interesting example of how



8. A pair of styli, one shown disassembled

the technologies of other disciplines can be borrowed (almost stolen at this price!) and put to use in any way that suits us.

The above suggestion that the digitising tablet is mounted beneath the machine for protection is quite arbitrary, a lathe application would require the digitiser to be at the rear right of the machine and mounted high to give similar protection.

To conclude, data acquisition by electronic stylus also has advantages and disadvantages, which may be summarised as:-

Pros:-

- Comes complete and ready to use,
- The specimen does not need to be conductive,
- Produces Compucut format data very quickly.

Cons:-

- Requires a little practice to keep stylus vertical when 'free hand' tracing, or the making of a light parallelogram holder,
- Some styli may need a little re-working to make the best of the capabilities of the tablet.
- In a future article, we will see how cheap video cameras (less than £50) and even cheaper scanners can provide us with control data.

Details of the Compucut system, the Compucutter machine and adaptations based on the Wolfcraft products can be obtained from Richard Bartlett at 17 Lime Tree Avenue, Tile Hill, Coventry CV4 9EY Tel. 01203 473851 Email: compucutters@compuserve.com



9. Whilst tracing around a profile, the co-ordinates of the data points are being stored in a file in the computer.

AN ATTACHMENT FOR A BOSCH ROUTER

Norman Hurst tells how he used his metalworking facilities to extend the capabilities of a friend's woodworking machine.

The requirement

My woodworker friend, Ernest, wanted to cut an arc in a wooden plaque that he was making. When he found that his Bosch POF 52 router could not be adjusted down to the radius that he required, he wondered if an attachment could be made to enable the router to cut arcs of smaller radii. The Bosch standard fitting gives a minimum radius of 75mm. This is shown in Fig. 1 and is the distance between the centring pin 'C' and the router cutter centre line. There is no problem with the maximum available arc, as this can be adjusted out to 215mm by reversing the parallel guide (fence). The inner limit of the pin 'C' adjustment however, is when it touches the edge of the base plate 'P' (Fig. 1). If the pin could pass under the base plate, the distance to the cutter centre line would be reduced. Ernest thought that a sliding plate with its own centre pin could be fitted underneath the router and he

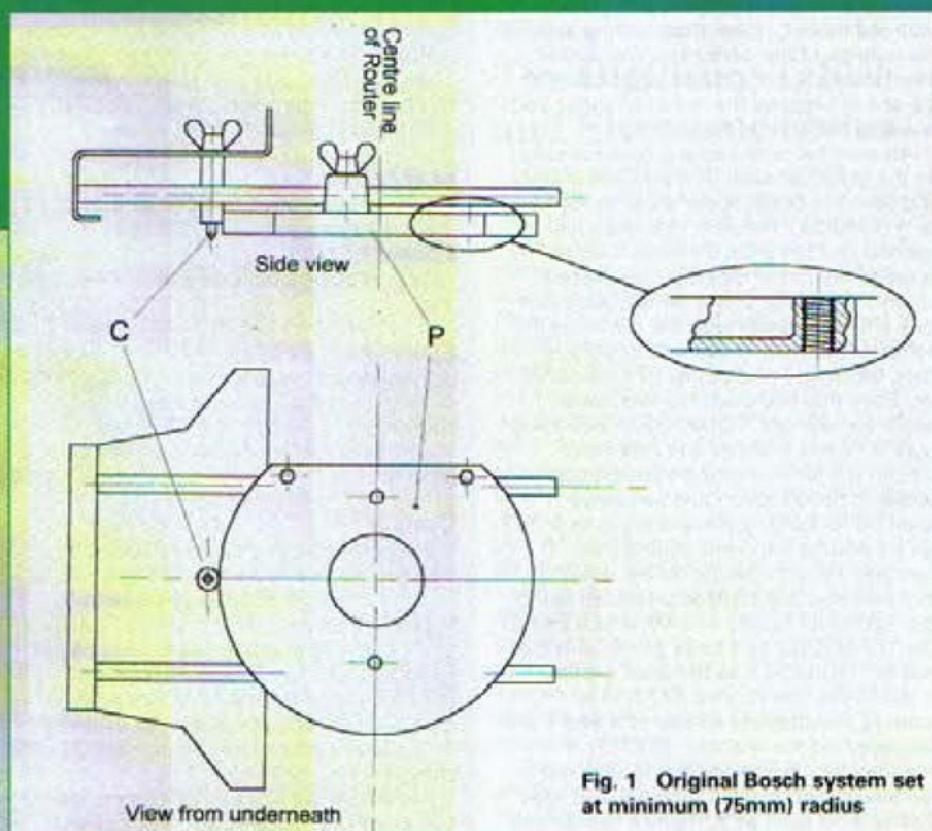


Fig. 1 Original Bosch system set at minimum (75mm) radius

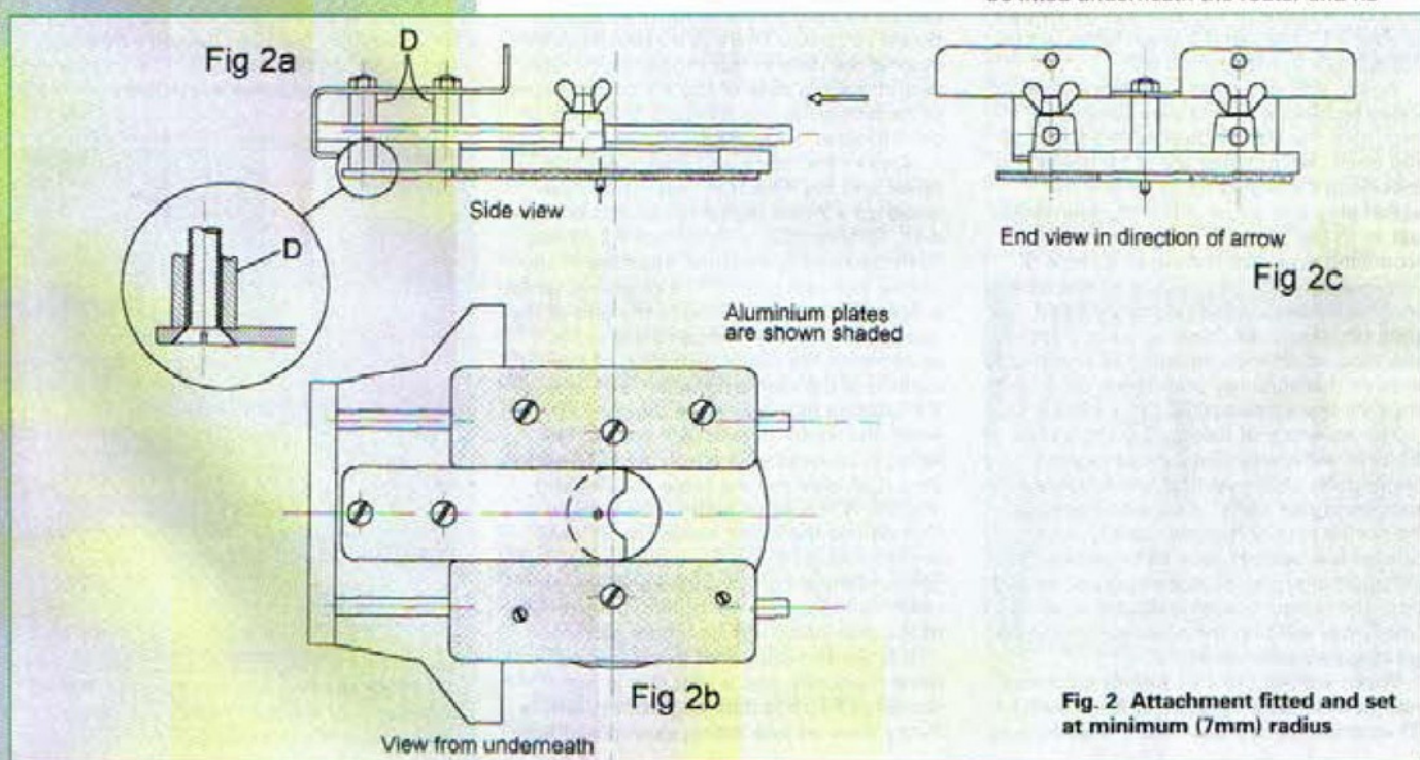


Fig. 2 Attachment fitted and set at minimum (7mm) radius

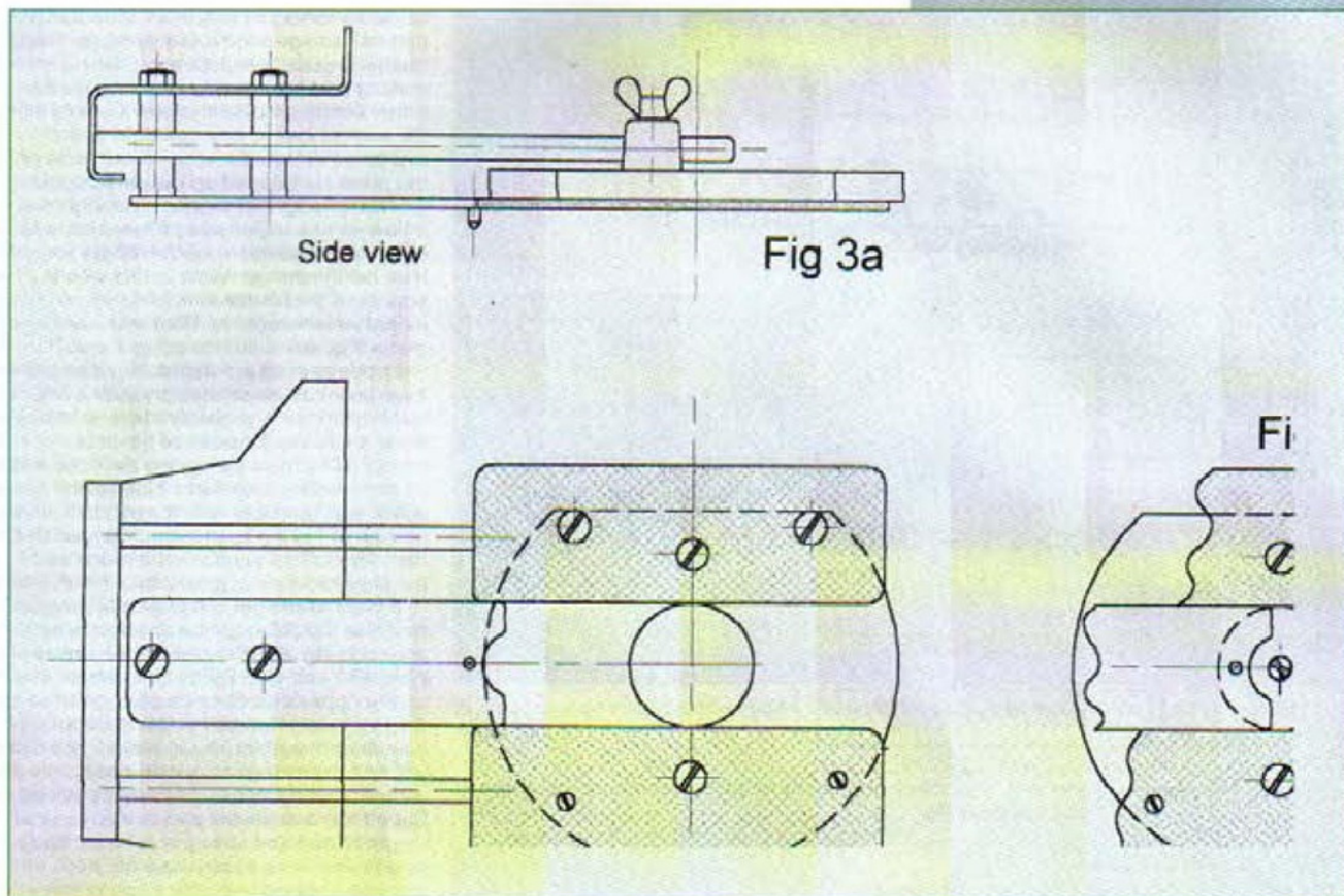


Fig. 3 Attachment set at maximum (75mm) radius

asked me if I could produce such an attachment for him.

This router is a portable hand machine and would be used for straight cuts using the fence, as well as for arcs and circles; therefore an arc cutting attachment would need to be removable. In the illustrations, I have only shown the lower, relevant, part of the machine which will have the attachment fitted to it. In Fig. 1, the fence is in the upside-down position, which is the necessary orientation for cutting arcs and circles.

The router base plate 'P' is made in an aluminium alloy cast material and is quite thin (2.4mm). It is stiffened with a flanged edge and bosses for screws - see the detailed inset in Fig. 1. Because of its light construction, Ernest was reluctant to have any more holes drilled through the bottom and hoped that the existing four M6 tapped holes would be sufficient. He also mentioned that any plates or other fittings positioned under the base plate would reduce the effective depth of the cutter, and this plate thickness should be kept to a minimum.

The solution

I decided that the attachment would consist of three plates positioned underneath, and that these would have at least the same area as the existing base plate. If possible, I would also make it to accommodate from about 10mm radius up to 75mm radius, thus giving a potential range from about 10 up to 215mm! The three plates would consist of a centre plate with the new pin attached and two side

plates. These side plates would be placed one on each side of the centre plate to act as guides. All three plates would be in contact with the work-piece, instead of the base plate.

In order to keep the underside completely flat, M6 countersunk screws would be used in the existing tapped holes. The depth of head of an M6 countersunk screw is 3mm, so that would be the minimum thickness of plate required - see detail inset in Fig. 2a. The existing centring point is 4mm diameter and it was decided to retain this size. Because it usually fits into a small hole in the surface of the wood, Ernest felt that it need not be hardened, which would make the job easier for me.

To keep the weight down - and because I had some - I decided to use 1/8in. (3.175mm) aluminium plate for the side plates - see Figs. 2a, b and c. The centring pin would be fixed permanently in its position in the centre plate, and because I felt that it would be difficult to achieve this in aluminium, I decided that 1/8in. mild steel would be the best material, and again, I had some available.

Because of the diameter of the existing base plate at 140mm (70mm radius), obtaining both a small cutter radius, along with the required 75mm radius was not straightforward. I achieved this by having a 'long' centre plate at its edges, with a 'short' plate - measured along its centre line - where the centre pin is located. This permits the plate to still be in contact with, and supported by, the circular base plate, whilst the centre pin has gone out to the necessary 75mm radius, as shown in Fig.

3b and Photo. 1. It is no use having a small potential radius if it cannot be used. That is another reason why I cut away the end of the centre plate into a curved shape, adjacent to the centring pin. With this arrangement, a 7mm radius could be cut, using a 'needle' size cutter, this result being well within my specification. Being a little more realistic however, in Fig. 3c I have shown an 8mm diameter cutter, cutting a 15mm radius. On my friend's router, one of the plates had one M6 screw only, and this I supplemented by fitting two M3 countersunk screws (Fig. 4c). With a base plate thickness of 2.4mm, I felt that this was the largest thread that could be safely tapped whilst still not weakening the base. Drilling and tapping these two small holes was the only alteration to the router itself, which Ernest accepted and I trust that the reader will also.

I have noticed that there are Bosch 'look alike' routers in some DIY stores and warehouses, probably of Far East manufacture. If you have one of these, a similar attachment could possibly be made.

Manufacture

First make the mild steel centre plate of 42mm width. This will have a thickness of at least 3mm (Fig. 4b). This width is the same as the hole diameter in the router base plate. Making it 42mm still allows for the greatest possible size cutter to be used and gives the maximum visibility to the cutting area. Make sure that the sides are straight and parallel to each other; this is very important. Next mark the position of

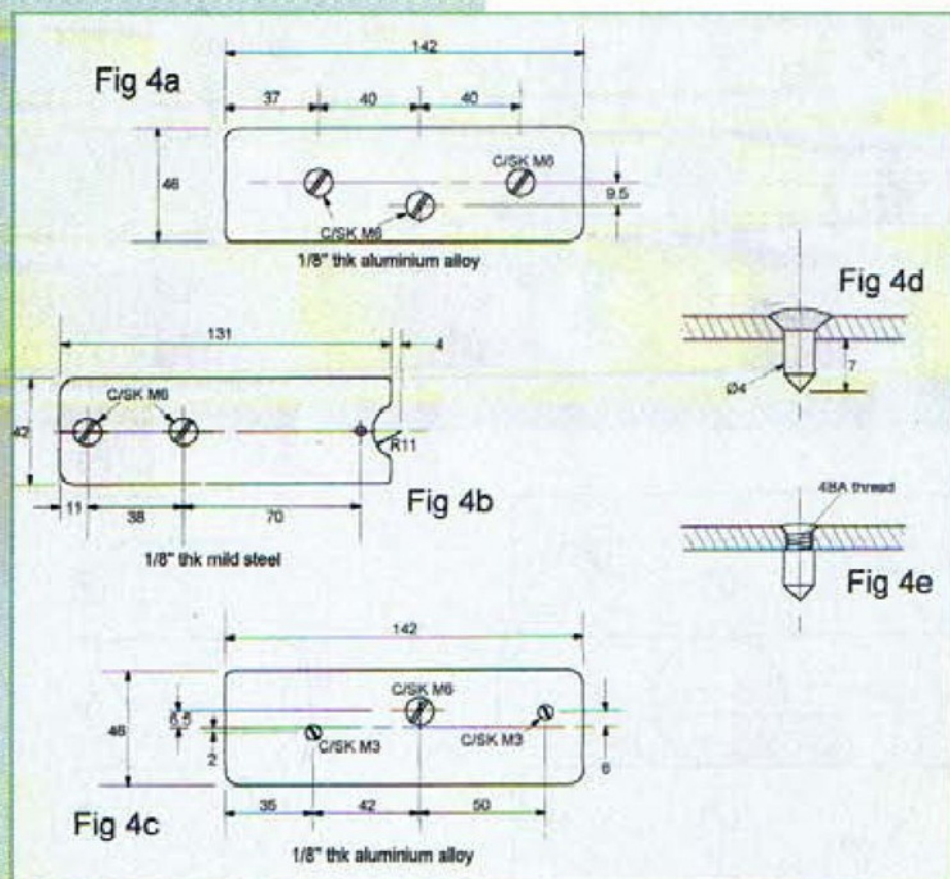


Fig. 4 Additional components

the end 6mm hole, but don't centre pop it. Clamp the plate in place on the base, as shown in Fig. 2b, making sure that the centre lines are in alignment. Bring the guide into position so that its end hole is approximately over your mark, and tighten the wing nuts. Place the assembly onto parallel strips on your drilling machine table and, using a 6mm drill, spot through the guide to the plate. If you are satisfied that the 'spot' is on, or very close to, your mark, drill right through the plate. Then drill through the second hole. Remove the

clamp and countersink both holes. The centres should be 38mm, but it is better to spot and drill through in the manner described. All holes in the plates and in the distance pieces will be drilled 6mm in order to keep the clearance to an absolute minimum; this is a precision job and any sloppiness will be detrimental.

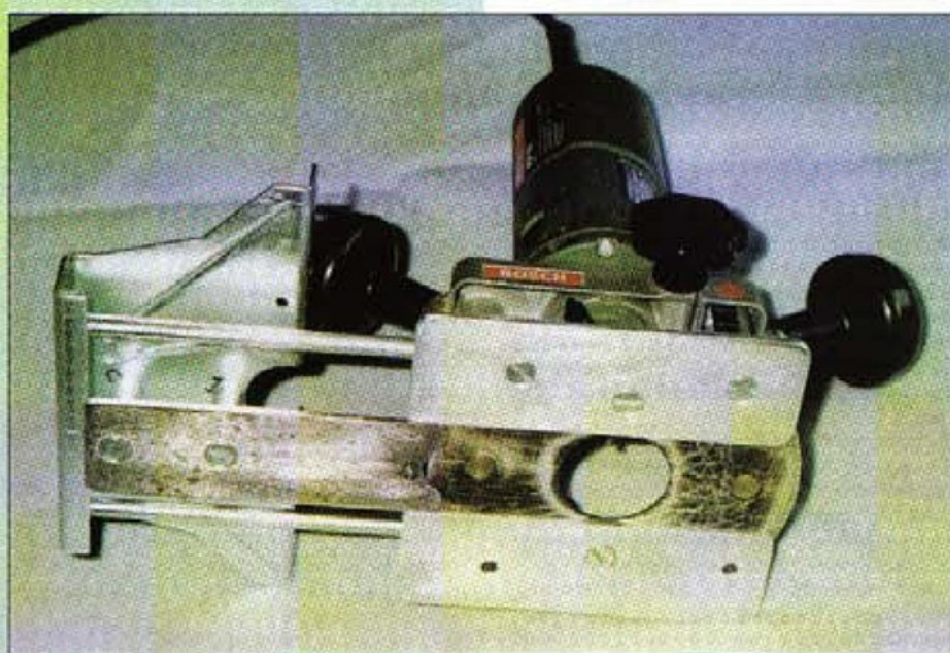
Make the centring pin from 4mm or 5/32in. mild steel rod. It will extend out from the centre plate by 7mm, including its point. I took the easy way out and welded it in its position, but it could be

screwed, riveted or brazed in; they all have their advantages and disadvantages. The method I used, is as follows:- After making sure that the pin would be on the router centre line, I drilled a 5/32in. hole in the centre plate to ensure a tight fit and countersunk it on the upper (flush) side of the plate. I shortened up the pin to about 8 or 9mm long, and tapped it through the hole from the upper side till the point was in its correct position; the top of the pin then being approximately in line with the bottom of the countersink. This left an indent which would be filled with weld metal (Fig. 4d). I did this using a small electrode with an arc welder, but it would have been just as satisfactory with a MIG welder and also - probably - by brazing or silver soldering. Because of the heat produced by the welding, the pin itself and its surrounding area had a blue finish which was removed with emery cloth, and no sign of having been heated remained. I then filed off the surplus weld metal on the upper surface to give a flush finish.

If you haven't got welding or brazing facilities, the pin could be screwed in as shown in Fig. 4e. Drill and tap the centre plate 4BA and very lightly countersink it on the upper side. Screw a piece of 4mm diameter steel rod with a 4BA (3.6mm diameter) thread for about 15mm - this will be long enough to grip the end without damaging too much of the thread. Cut off the unthreaded part to the required length (7mm) and form the point by filing or grinding. If necessary, saw off the extreme screwed end where you gripped it and may have damaged the thread. Screw in the pin from the underside as far as you can, and tighten, using pliers or a mole grip etc.; then saw off the protruding thread, just proud of the surface by a millimetre or so. Using a small ball-peen hammer, lightly peen over the end of the pin until the small countersink is filled. The top surface will then be filed flush, in the same manner as the above welded pin.

After making the welded pin as described previously, I made a (test) screwed one in a piece of scrap 1/8in. plate, using the above method. Not only was it successful, it was also quite straightforward and didn't leave the blue finish.

The next job is to turn up two aluminium distance pieces ('D' in Fig. 2a), each 12mm outside diameter by a little over 35mm long, say 36mm. The 35mm length is about the same as the plain section of the Bosch centring pin and the extra length allows for some material to be machined off to bring the distance pieces to their exact length. Again clamp the centre plate in its innermost position, as shown in Fig. 2b, making sure that the holes are approximately in line with their respective holes in the parallel guide. Tighten the guide wing nuts and then, using inside callipers, carefully measure the distance between the plate and the guide, adjacent to the end hole. Also measure adjacent to the inner hole. These dimensions should both be 35mm, and the guide surface should be parallel, but remember that this guide is made of sheet metal and may not be completely 'true'. Machine one distance piece to the first length and position it as shown in the left hand 'D' position in Fig. 2a. Place a 6mm countersunk screw through the



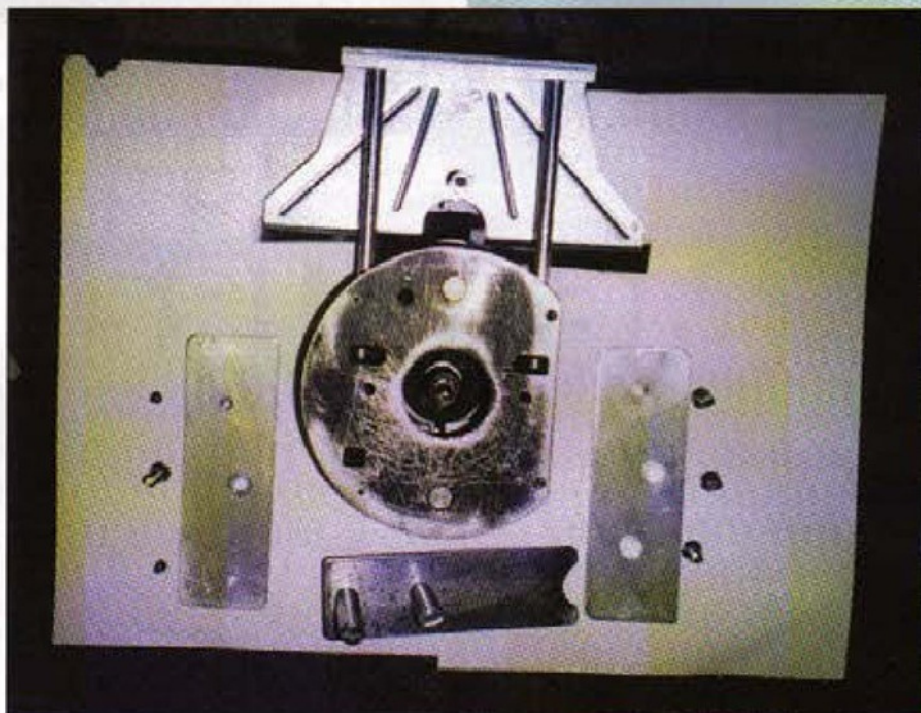
1. The Bosch router with the new plates fitted, showing that the new pivot pin can be brought much closer to the cutter axis

plate/distance piece/guide assembly and tighten up. Now remove the clamp. The centre plate should be lying flat, touching the base plate. If it is hanging down slightly, don't worry; remember that there is probably some 'spring' in the guide. Clamp the centre plate again, and again measure the second distance. You will probably find that this is different from your previous dimension. Turn the second distance piece to this length. Assemble with another 6mm screw, remove the clamp and test the system. When the plate/guide assembly is slid in and out, it should stay flat against the base plate and keep on its centre line. If it does not lay flat, the distance pieces should be adjusted by lengthening or shortening. The lengthening can be achieved by placing a shim under one end. If this cures the problem, make up another distance piece to the correct length, and assemble.

Making and fitting the aluminium side plates is straightforward. Dimensions are shown in Figs. 4a and c, but the screw centre dimensions are for guidance only. It is especially important that the inner edges be made straight and true, as these act as the guide to the centre plate.

With the centre plate secured and located at its innermost position, one of the aluminium plates should be clamped to the base plate with its inner edge resting against the centre plate, as the position shown in Fig. 2b, and with the cutter centre line aligned to a point 77 mm from one end (see Fig. 4). Spot through the centre M6 tapped hole in the base with a $\frac{3}{16}$ in. or No 13 drill. Remember that the base plate is made of a cast aluminium material, so be especially careful. Unclamp the side plate and drill right through it with the same drill. Offer the side plate up to the base to make certain that the drill hasn't wandered and that the holes are in line with each other. This can be ascertained by pushing the drill through or by sighting through the holes. If the holes are not in line, draw over the hole in the aluminium plate with a small round file. When you are satisfied with this operation, drill through with a 6mm drill and secure the side plate with a screw. It should lay with its edge touching the centre plate, the aim being to have a fairly tight sliding fit. A similar procedure would be carried out with the other 6mm holes, keeping in mind that the side plates will be secured to the base accurately and with the minimum of slop. The holes in the aluminium plates should now be countersunk and the M6 screws fitted. 15mm long screws will just stay clear of the guide rods, whilst still going all the way through the threaded holes.

Before fitting the M3 screws, test the system by sliding the assembly in and out. If it is tight in some places and slack in others, check with a feeler gauge or engineer's blue, and ease the tight spots on the side plates with a file. Alternatively, it may be necessary to move the plate with the single screw, around slightly. When this latter plate is correctly and securely positioned, drill two holes right through the side plate and the base plate with a tapping drill ($\frac{3}{32}$ in.). Remove the plate, open up these holes to 3mm and countersink. Tap the two small M3 holes in the base plate. As was previously



2. The components disassembled, showing that minimal modification to the machine is required



3. The router in use

mentioned, this is a cast aluminium alloy and it is a bit 'sticky' to tap. Replace and tighten up the plates and the job is almost complete.

Round off the edges and corners of the three plates to cut down the possibility of scratching the surface of the wood. Lightly file the plate surfaces to remove any burrs and to ensure that the screw heads are not protruding.

Photo. 2 shows the router attachment dismantled, and Photo. 3 shows a test cut being made. The spiral in Photo. 3 is formed by using two centre holes; these can be seen in the middle of the figure.

Materials list

2 off,	142 x 46 x $\frac{1}{8}$ in. aluminium
1 off,	131 x 42 x $\frac{1}{8}$ in. mild steel
2 off,	12 dia. x 36 aluminium
1 off,	4 dia. x 30 mild steel
2 off,	M6 x 50 steel c/sk screws and nuts
4 off,	M6 x 15 steel c/sk screws
2 off,	M3 x 10 steel c/sk screws

Dimensions in millimetres except where indicated.



SPINDLE & SHAFT SPEED MEASUREMENT

Prompted by Tony Jeffree's work on machine tool spindle speed measurement, Harry McCarty has devised a neat battery powered rev. counter

(photographs by John Dugdale)

After reading the excellent article on this topic in the August '99 issue of M.E.W. (No. 60) by Tony Jeffree, I decided to look into the electronic measurement aspects. The result is a rev counter having two ranges, 0 - 1000 and 0 - 10,000 rpm (Photo. 1), which is battery powered. It is designed to view a single mark on the rotating shaft.

The device consists of three parts:-

1. A Transducer
2. The Digital to Analogue Converter (DAC) Circuit
3. An Indicator

Transducer

This is a JA26D as suggested by Tony. I tried two other types but, taking into account performance, price and availability, the choice of the JA26D was confirmed.

1. The completed rev. counter assembly

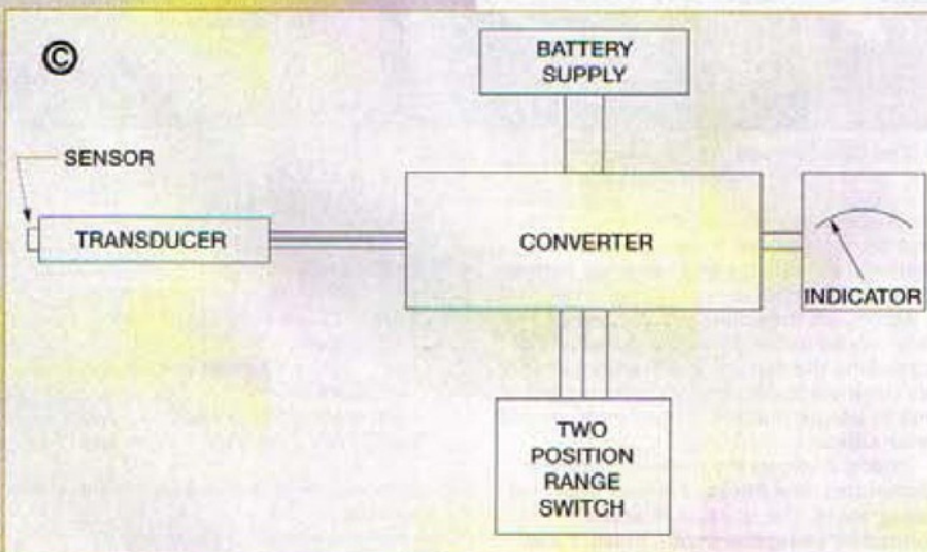
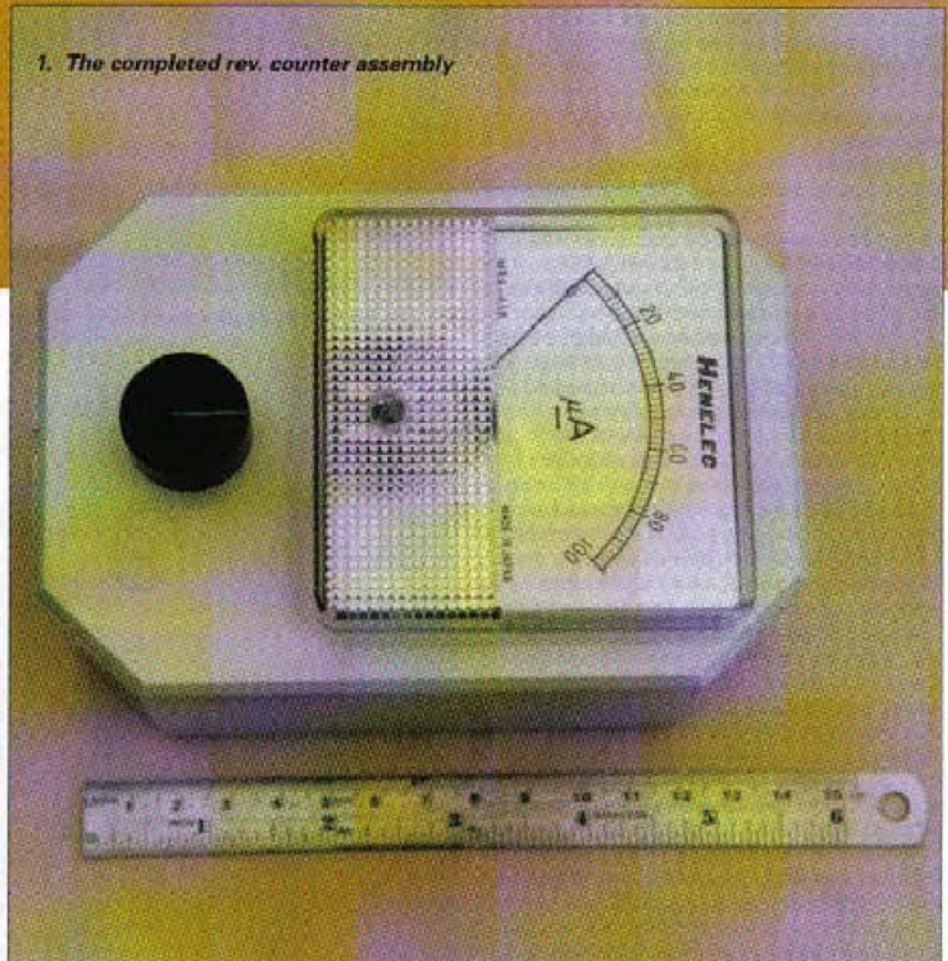


Fig. 1 System Layout

Converter

Once again, the suggestion by Tony of the LM2917 was ideal. It was designed for this purpose, is inexpensive, available and works very well.

Indicator

Various indicators can be used - Moving Coil Voltmeters of 50, 100 micro-amps or 1mA; Digital Voltmeters or additional electronics driving a series of LED lamps. My final choice was a 1mA full scale deflection (fsd) meter having 10 major divisions. These are generally less expensive than more sensitive types and are more robust.

Circuit description

Fig 1 is a block diagram of the system. The following points should be noted:-

Transducer

The circuit produced by Tony worked well, so I would suggest that it is used. For those who may not have access to his original article, Tony has produced an abridged version which is included here as Appendix A.

Converter

The LM2917 consists of an 8 or 14 pin integrated circuit, able to carry out all the electronic functions necessary to receive an input frequency from a few Hertz (cycles per second) to several thousand Hz. This signal is converted into a proportional DC voltage, able to drive a meter, solenoid, relay etc. at a current of up to 0.05 amps. Fig. 2 shows the internal layout of the LM2917.

The first stage is an amplifier/comparator which conditions the signal, resulting in a pulse of almost constant shape and area. It is then fed to a charge pump where the number of identical pulses charge a capacitor. The charge is then a measure of the number of pulses in a given time. A constant resistive bleed ensures that the capacitor does not become fully charged.

This is then fed to an operational amplifier/emitter follower combination, able to provide output drive. An internal voltage stabiliser of 7.56V is incorporated to reduce the effect of voltage changes.

Indicators

The design produces an maximum DC output voltage of 5.5 volts which is sufficient to drive any envisaged meter or indicator and permits adjustment.

Construction

Transducer

Please refer to Appendix A or M.E.W. Issue 60, August '99, page 47.

Photo. 2 shows the JA26D sensor mounted on a piece of Veroboard. I intend to mount this in a redundant pen body so that the cap can be used for protection.

Referring to Tony's circuit, I omitted the warning indicator, LED 1, and incorporated R2 and R3 in the leads connecting the transducer to the converter pcb, but these would fit on the Veroboard if desired.

Converter

Table I is a parts list of required items. I have included a ready-made pcb (**Photo. 3**) which has component positions clearly marked. The items in the list marked * are polarity sensitive and must be orientated correctly. Do not insert the IC until soldering is complete.

Table II is the resistor colour code, to assist component identification.

Assembly

Insert the IC socket. The identification at one end should line up with the white mark on the pcb. The diodes (three types) are marked with their type number, and the black band should line up with the white mark on the pcb. The remaining

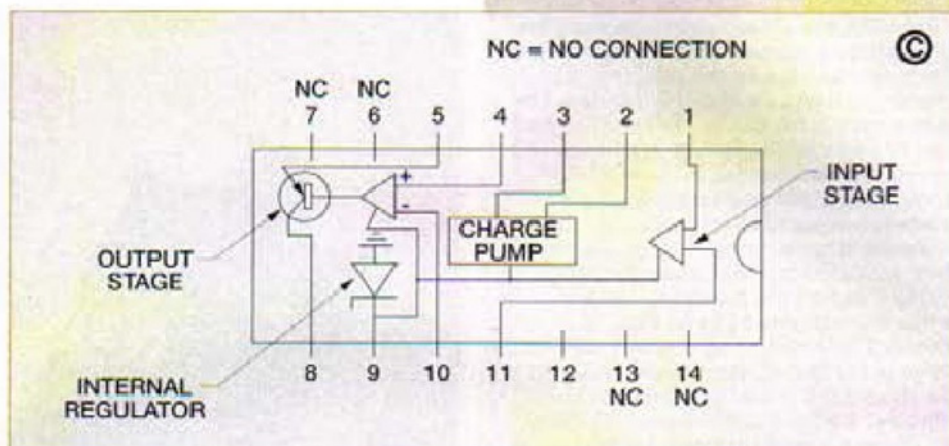
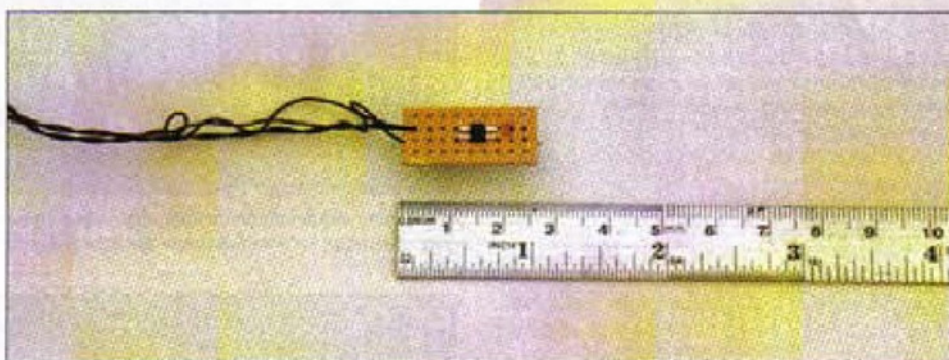
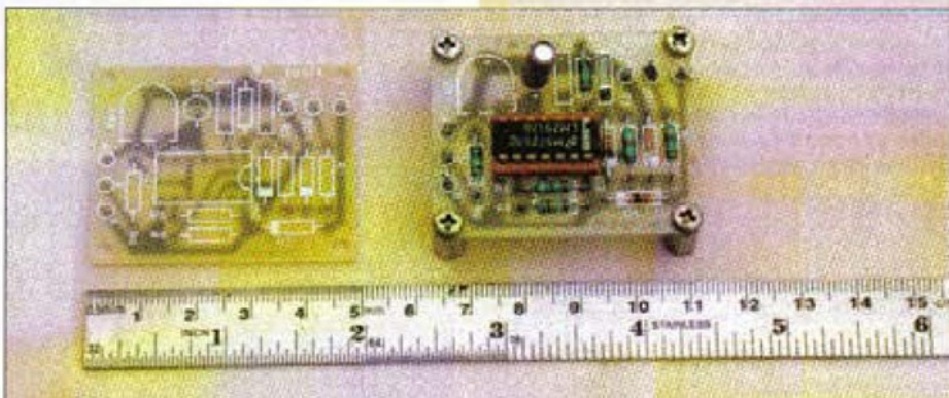


Fig. 2 Internal layout of LM2917N



2. The JA26D sensor mounted on a small piece of Veroboard. This needs to be housed in such a way as to be able to be directed at the rotating component. This one is to be fitted into a redundant pen body.



3. An example of the specified printed circuit board, shown with one which has been fitted with the components to form the printed circuit assembly (pca)

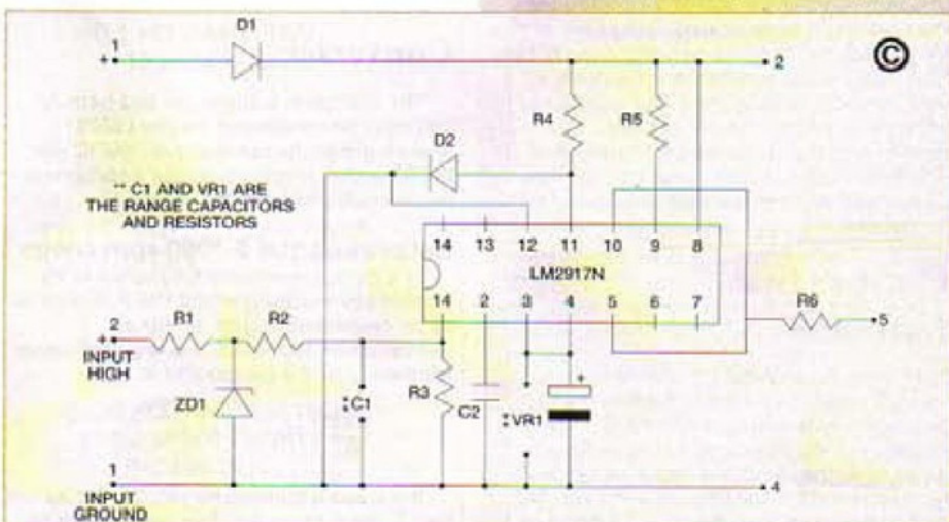


Fig. 3 Digital to analogue converter circuit

* item, C3, has a band with a -ve sign, the other wire being +ve, which must go into the hole marked + on the pcb. The remaining items can then be inserted. The component leads can be bent with a small pair of pliers to line up with the holes, taking care not to crack the component body. To retain the components, their leads can be gently bent back.

At this stage it is prudent to double check prior to soldering. If OK, solder the pcb.

Fig 3 depicts the theoretical circuit, while the pcb layout can be seen in Photo. 3. The range components are not fitted to the pcb, being mounted on the Veroboard at the rear of the meter (Photos. 4 & 5).

The range switch, battery leads, transducer wires and indicator leads can now be connected, Fig. 4 being the overall wiring diagram.

As previously stated, the maximum DC output voltage is a nominal 5.5 volts, so moving coil meters will have to be ranged. We therefore need to calculate the resistance required to produce a full scale indication with an input voltage of 5.5 volts.

Using Ohms law

Resistance (R) = Voltage (V)/Current (Amps).

In the case of a 1 mA f.s.d meter, we have

$$R = \frac{5.5}{0.001} = 5,500 \text{ Ohms}$$

This is the total circuit resistance and includes the resistance of the meter. This is a small proportion of the total circuit resistance and is catered for in the adjustment.

Another way of expressing meter sensitivity is in Ohms per volt i.e. the value of resistance required to produce f.s.d with an input of 1 volt. In the case of our meter

$$R = \frac{1}{0.001} = 1000 \text{ Ohms}$$

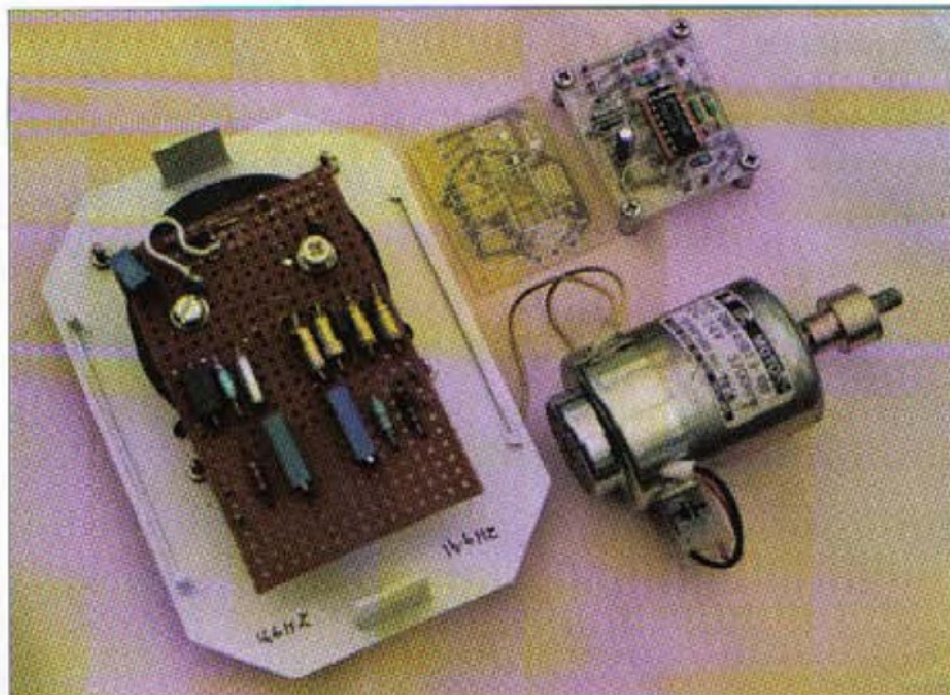
Therefore, a 1mA meter is 1000 ohms per volt.

If a Digital Volt Meter is used, VR1 should be fitted to the pcb, no further range resistors being required. Fig. 5 gives circuits for various indicators and suggested resistance values.

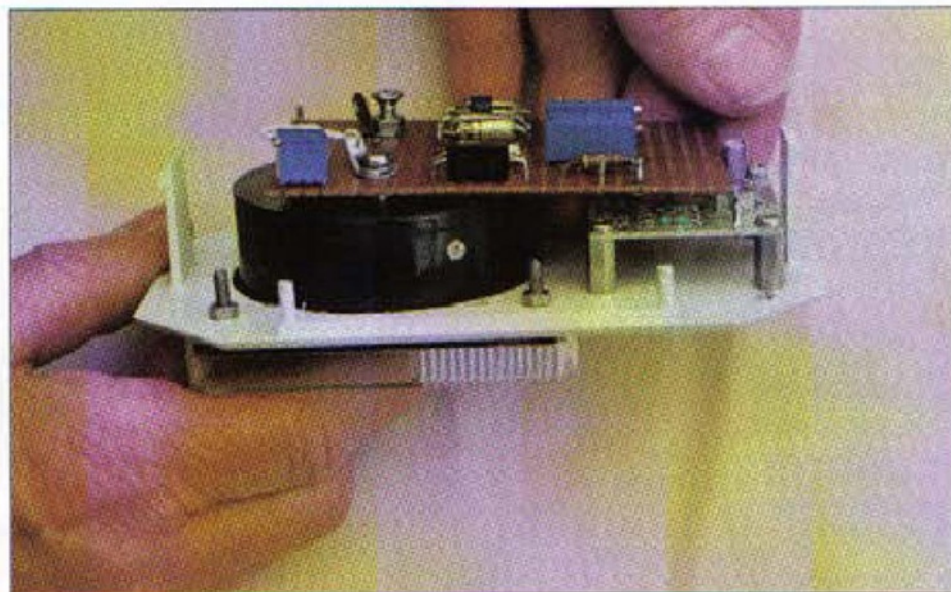
One last point - it would be preferable if the unit could be operated using only one 9V battery, but the internal reference of the IC is 7.56V which, allowing for battery deterioration, is marginal. The solution is either two 9V batteries in series or the unconventional (but cheaper) method of another couple of cells in series. The unit will, however, function correctly on a fresh 9V battery.

Calibration Indicator

Having decided on the indicator to be used, it needs to be set to 5V f.s.d. If you possess a reasonable meter - good, no problem. If not, a suggested circuit is given in Figure 6. If you intend to use a ferrous panel for the meter, fit the meter before calibration as they can be affected by ferrous objects.



4. A rear view of the meter, showing the range circuit components. To the right is the small motor which features an integral speed sensing device



5. This view shows that the pcb fits snugly below the range circuits

Converter

The indicator, transducer and battery can now be connected. Fit the LM2917, ensuring that the cut-away on the IC and the IC socket line up with the appropriate white mark on the pcb.

Calibrating the 0-1000 rpm range

The circuit measures frequency in Hz (cycles per second), whilst the indicator is to be calibrated in rpm, so for an indication of 1000 rpm, the required input frequency to the transducer is

$$\frac{1000}{60} \text{ Hz} = 16.66 \text{ Hz.}$$

If we use a composite strobe disc as Fig. 7, the pattern will be stationary in 50 Hz fluorescent light at 1000 rpm and, if the

transducer is looking in the area of the single mark, the transducer will be sensing 16.66 Hz. VR2 should therefore be adjusted to give full scale deflection.

Calibrating the 0-10,000 rpm range

This calibration uses a standard 3,000 rpm disc (Fig. 8) at 3000 rpm. In 50 Hz light, place the sensor over the disc when it will receive two pulses per rev, so the input frequency to the LM2917 will be

$$\frac{3,000}{60} \times 2 = 100 \text{ Hz}$$

which equates to the 6,000 point on the scale. Adjust RV to give this indication which, in the range under consideration is quite a good calibration point.

I chose this method because none of my devices could achieve 6,000 rpm. You could of course use another combination

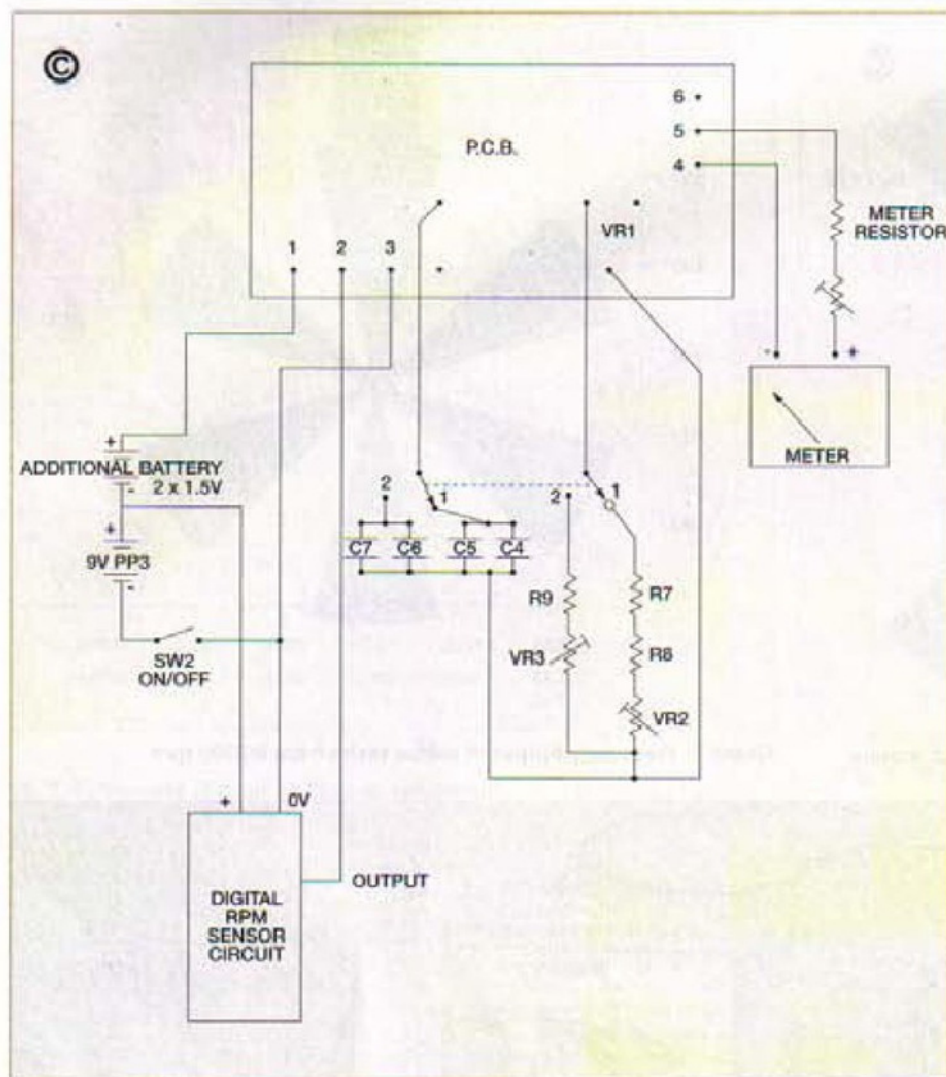


Fig. 4 Overall wiring diagram

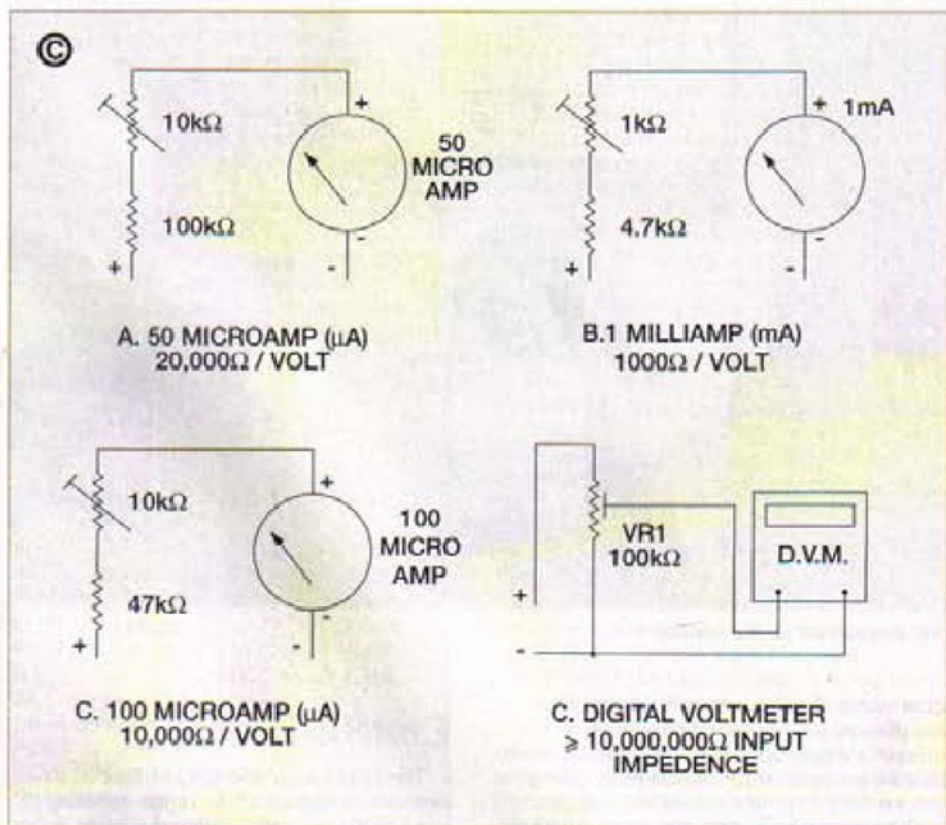


Fig. 5 Indicator circuits

of discs and marks to achieve the same result, and may wish to do so in order to check the linearity. I have used a signal generator for the same purpose.

Operation

I have used my unit over a period of weeks and found it to be reliable. I would agree with Tony's comments regarding the siting of the sensor.

General comments

The equation for the system is

$$V(\text{out}) = f(\text{in}) \times 7.56 \times C1 \times R1$$

where

$V(\text{out})$ = DC voltage into the indicator (calculated to be 5.5V, this being a little more than nominal for devices such as LED line of light indicators, allowing adjustment).

$f(\text{in})$ = Frequency input in Hz (cycles per second)

7.56 = The value of the IC internal reference voltage.

$C1$ = Value of the range capacitor in Farads (1 microfarad = 10^{-6}F) (1 nanofarad = 10^{-9}F)

$R1$ = Value of the range resistor in ohms.

The two values of capacitance were chosen to be available to the best tolerance and to ensure that R was in the region of 500,000 ohms to ensure the best output linearity. The quite large adjustment of R1 caters for component variation.

Sample Calculation

For 5.5V out, 16.66 Hz (1000 rpm range). Capacitance chosen - $7.8 \times 10^{-8}\text{F}$

$$5.5 = 16.66 \times 7.56 \times 7.8 \times 10^{-8} R$$

therefore

$$R1 = 5.5 / (16.66 \times 7.56 \times 7.8 \times 10^{-8})$$

$$= 5.5 / 0.982 \times 10^{-6}$$

$$= 5.6 \times 10^5 = 560,000 \text{ ohms or } 560 \text{ Kohms.}$$

Safety

Apart from the very obvious dangers of rotating machinery, if you intend to operate this device from the mains, the mains layout and wiring should be carried out by a competent person, and any metal enclosure MUST be correctly earthed.

Postscript

I recently purchased a small dc motor from a radio rally. These rallies are held at various locations throughout the year and are a wonderful source of inexpensive electronic and electro-mechanical items.

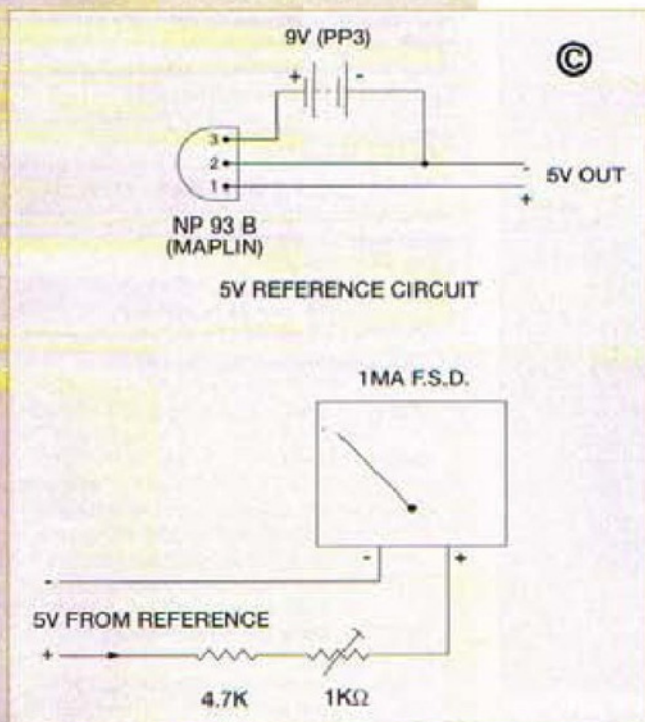
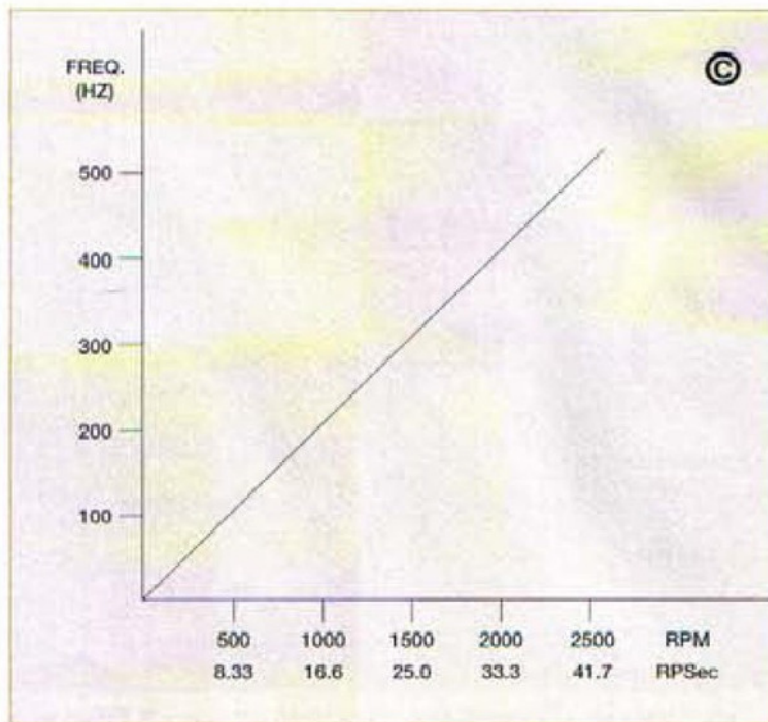
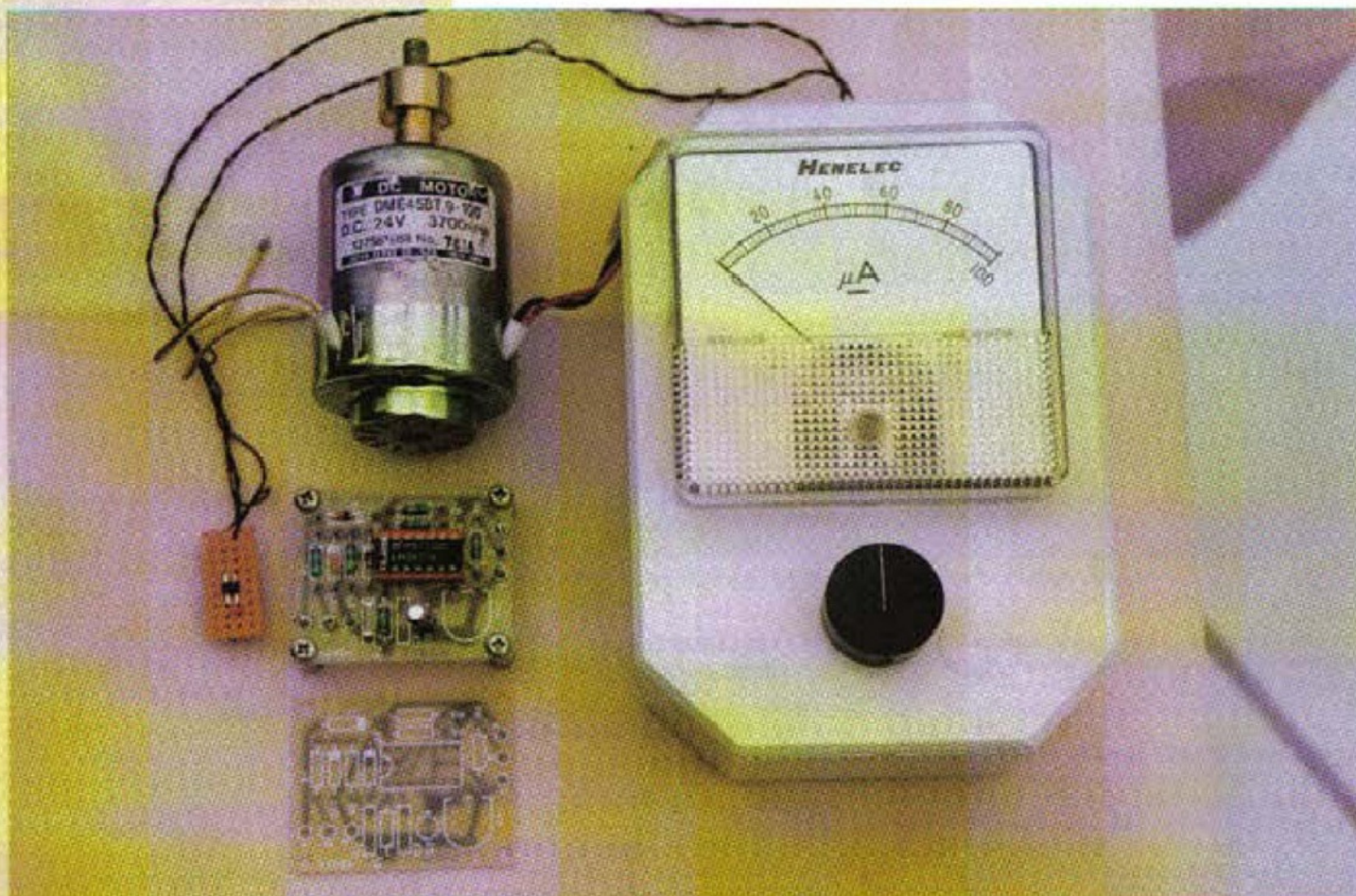


Fig. 6 Sample calibration circuit form 1MA F.S.D. meters



Graph 1 Frequency output of motor tachometer from 0-2500 rpm



6. The meter assembly, now in its protective box, connected to the sensor.

This motor had an in-built tachometer at one end, consisting of a circular magnet rotating inside a multi-pole stator. This motor may be seen in Photos. 4 and 6. There are no brushes or moving contacts, the only wear being in the bearings. The frequency output is a good

sine wave of adequate amplitude. The graph output frequency versus shaft speed is depicted in Figure 9. I have used this as a sensor into the LM2917, using the equation to recalculate the range resistance and capacitance. It worked very well.

Conclusion

The total cost of this project, less indicator, batteries, meter range resistors and enclosure, but including the items called up by Tony in his sensor design = £14.50.

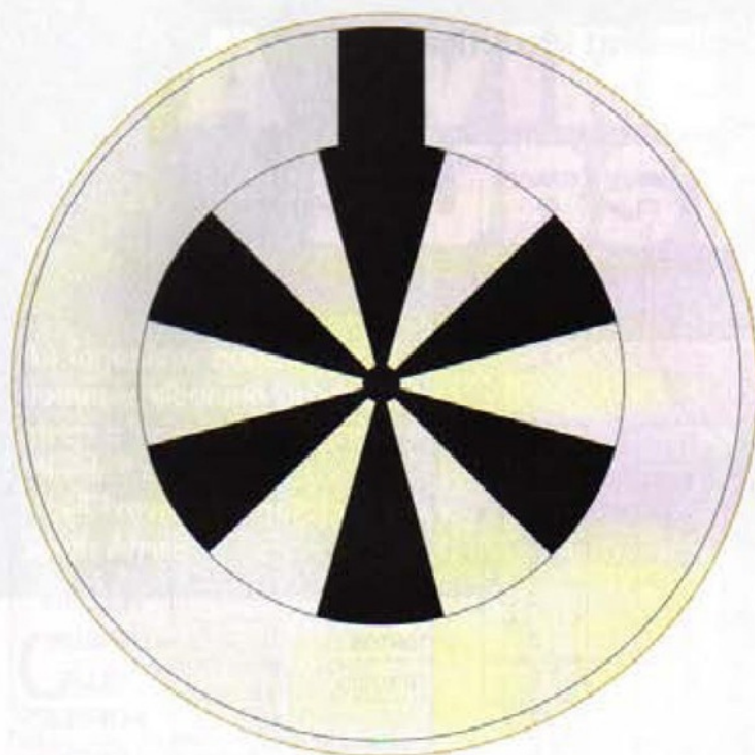


Fig. 7 Composite disc for 1000 r.p.m calibration

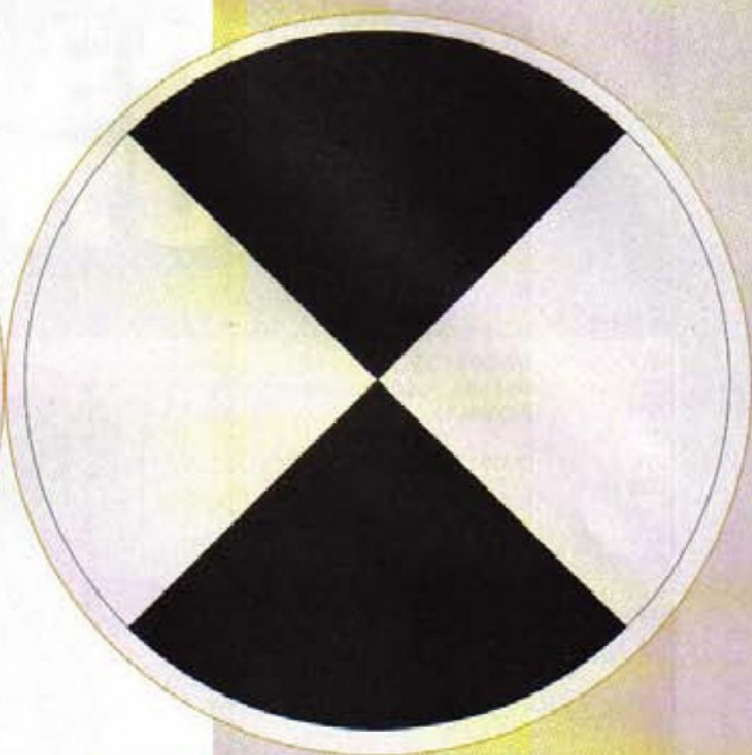


Fig. 8 3000 rpm disc for 6000 point calibration

Appendix A

Details of Tony Jeffree's simple Digital RPM Sensor

Figure 5 of the original article (reproduced here) shows a simple circuit that will allow an infra-red sensor device to generate a pulse train suitable for feeding into a multi-meter with frequency measuring capability. Components and part numbers are shown in the table.

The miniature DIN socket serves two purposes; firstly, to connect the external meter, and secondly, to switch on the power supply to the circuit. The red LED simply reminds you to unplug the meter (thus switching off the power) when you're done. The sensor device used was Maplin's Photo Reflector SY-CR102 (Part number JA26D), which is physically smaller than the one mentioned above – its package is about 2mm square.

Component Values for the Infra-Red Sensor

COMPONENT	VALUE	MAPLIN PART No.
PR1 (Photo Reflector SY-CR102)		JA26D
LED1 (Red LED)		PD02C
R1, R2	470 Ohms	G470
R3	10K Ohms	G10K
SK1 (Mini DIN socket)	3 pin	JX13P
PL1 (Mini DIN plug)	3 pin	JX01B
Strip Board	100mm x 25mm	JP46A
Battery connector	PP3-type	NE19V

Although the circuit diagram shows a supply voltage of 9 volts, this is not critical, and can be varied for other supply voltages by choice of different resistor values. The sensor is quoted as having a rise and fall time of 1 millisecond, so this would seem to place an upper limit of 500 Hertz on the pulse train that it can generate. With six marks on the rotating shaft, this represents a measuring range of up to 5,000 RPM; with a single mark, it should be possible to use this device to measure spindle speeds up to 30,000 RPM.

The photo reflector comes in a square black plastic package that has two rectangular indentations on the active side (the side you point at the rotating surface) and two pairs of wire leads. One corner of the package is chopped off to mark the ANODE lead. The lead directly in line with it, emerging from the opposite side, is the CATHODE. These two are the leads for the IR emitter diode. The other lead that emerges from the same side as the anode is the EMITTER of the IRI detector transistor. The fourth lead (in line with the emitter) is the COLLECTOR of the detector.

The main components can conveniently be mounted on a small rectangle of strip board. The following assembly instructions use letter and number co-ordinates to indicate the holes in the strip board where the various connections are made. Looking from the component side of the board, with the copper tracks running from top to bottom, the tracks are labelled A through E with A being the left-most track. Holes in each track are numbered 1 through 12, with 1 being the top-most hole. With the exception of the photo reflector (see instructions below), all of the components are mounted on this side of the board; the leads are passed through the holes and soldered to the copper strip underneath. The construction proceeds as follows:

Cut a rectangle of strip board to give 5 usable copper tracks with 12 holes in each track. This can easily be done using a junior hacksaw.

Carefully bend back the four leads of the photo reflector (PR1), and note which lead is which by reference to the diagram in Figure 5 and the description above. The Anode lead is soldered to A1, the Emitter and Cathode to B1 and B2, and the Collector to C1. The choice of orientation of this component, and whether you choose to mount it on the component side or the copper side of the board, will depend greatly on your chosen mounting arrangements. It may even prove appropriate to mount this component on a flying lead so that it can be located remotely from the rest of the circuitry. If the component is mounted on the board, it should be mounted so that its active face will be close to the rotating shaft (i.e., approx. 1mm from the surface) when the board/mounting bracket is in its final position on the machine.

Fit the red LED (LED1) with the Cathode in B4 and the Anode in D4. The Anode is the shorter of the two leads. (If you are unsure of the orientation, it can be tested by temporarily connecting R1 to one of the leads and connecting the assembly across a PP3 battery. Reverse the battery if the LED does not light. The LED lead nearest the -ve terminal is the cathode.)

Solder R1 between A6 and E6.

Solder R2 between D8 and E8.

Solder R3 between C10 and E10.

Solder a length of connecting wire from B12 to Pin 3 of the DIN socket (SK1).

Solder a length of connecting wire from C12 to Pin 2 of SK1.

Table 1 Component list

Component	Value	Type No.	Supplier
R1, R2	4.7K	M4K7	M
R3	22K	M22K	M
R4	10K	M10K	M
R5	470	M470R	M
R6	1K	M1K	M
C1	With range switch		
C2	0.01F	VW29G	M
C3*	2.2F	FF02C	M
VR1	100K Preset		
UH06G			M
(see Note 1)			
D1*	1N4001	QL73Q	M
D2*	1N4148	QL80B	M
ZD1	BZY88C12		
QH165			M
IC1	LM2917	WQ38R	M
PCB		YQ67X	M
Pins		PL24B	M
IC Socket		BL18U	M
Switch (SPST)		FH97F	M

Note 1:- Fit this item if you intend to use a Digital Volt Meter. If not, an equivalent is mounted on the range switch

Range resistors

0 - 1,000 rpm range			
R7	390K	TX51F	M
R8	56K	TX41U	M
VR2	200K	348-326	Farnell

0 - 10,000 rpm range			
R9	390K	TX51F	M
VR3	200K	348-326	Farnell

Range capacitors

0 - 1000 rpm range			
C4	0.068F	VW39N	M
C5	0.01F	JA92A	M

0 - 10,000 rpm range			
C6	0.0068F	JA91Y	M
C7	0.0015F	JA87U	M
SW2 (DPDT)		FH99H	

Batteries

B/H1	1.5V	YR60Q	M
B/H2	9V	HF28F	M

M = Maplin Electronics

Note: Apart from obtaining 5% capacitors and 1% resistors, none of the components is critical

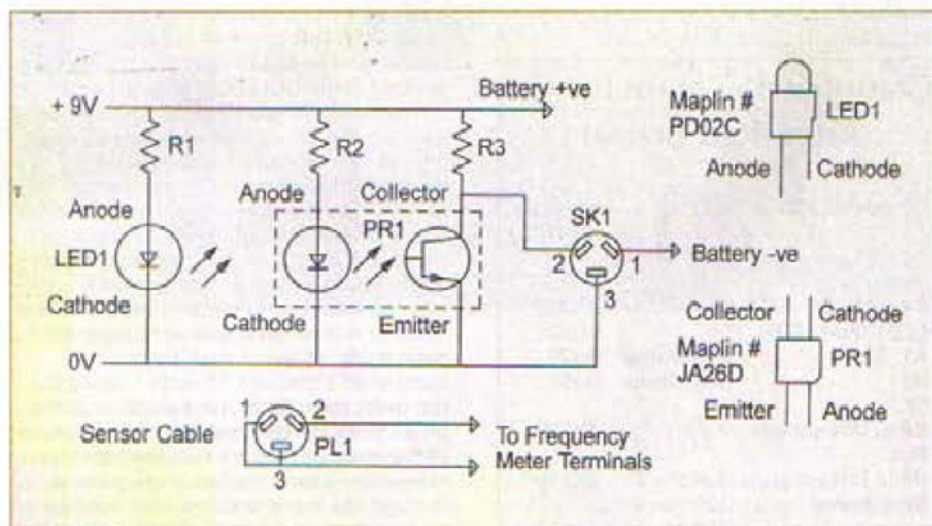
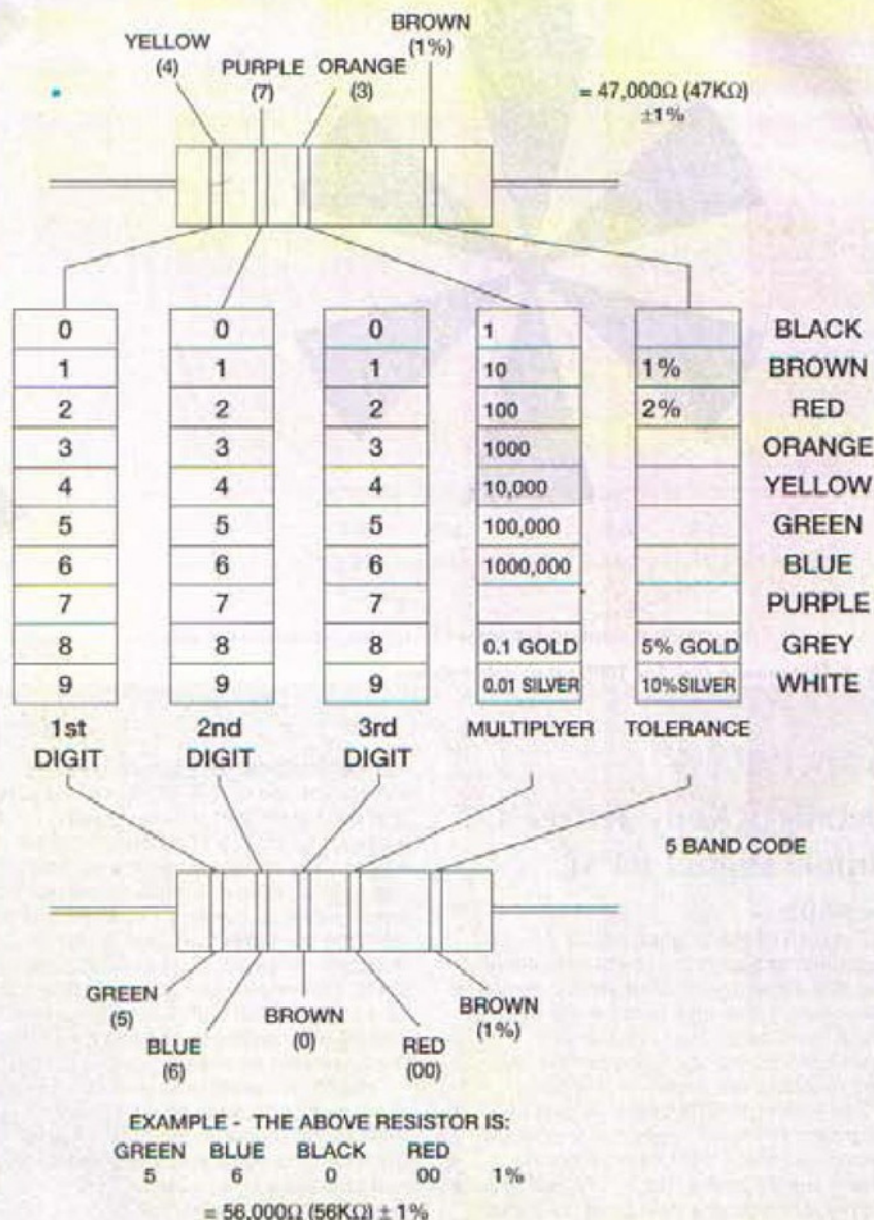
Connecting wire should be stranded, flexible. Maplin type 7/0.2 is suitable.

Solder the +ve lead of the battery connector to E12.

Solder the -ve lead of the battery connector to Pin 1 of SK1.

Finally, make up a cable to connect the assembly to the frequency-measuring meter. Connect pins 1 and 3 of a 3-pin mini DIN plug (PL1) together by soldering a wire link between them, and solder one of the meter leads to the wire link. Solder the other meter lead to pin 2. Fit plugs to the other ends of the lead to suit the meter. (Note that the polarity of the meter connections is not important.)

Table 2 Component identification



Appendix - Digital RPM Sensor Circuit

A WIRE BRUSH SUBSTITUTE

An ingenious adaptation of a domestic cleaning product has given a new lease of life to the Minidrill owned by Nevil Frewin of Fontainebleau, South Africa

Cleaning small items, whether they are for a model or perhaps some domestic chore can be a drudge. Often, I reach for my Minidrill and stop when I see the sad and motley looking collection of wire brushes in the bottom drawer. Wire brushes are not cheap and soon lose their effectiveness, the small ones intended for Minidrills being particularly ineffective and quite expensive. There has to be a better, more cost-effective solution somewhere.

The answer lay in the kitchen. A plastic scrubbing pad cut to make small discs and mounted on a small mandrel proved to be the answer (Photos 1 & 2). This led to other 'designs' as can be seen in Photo. 3.

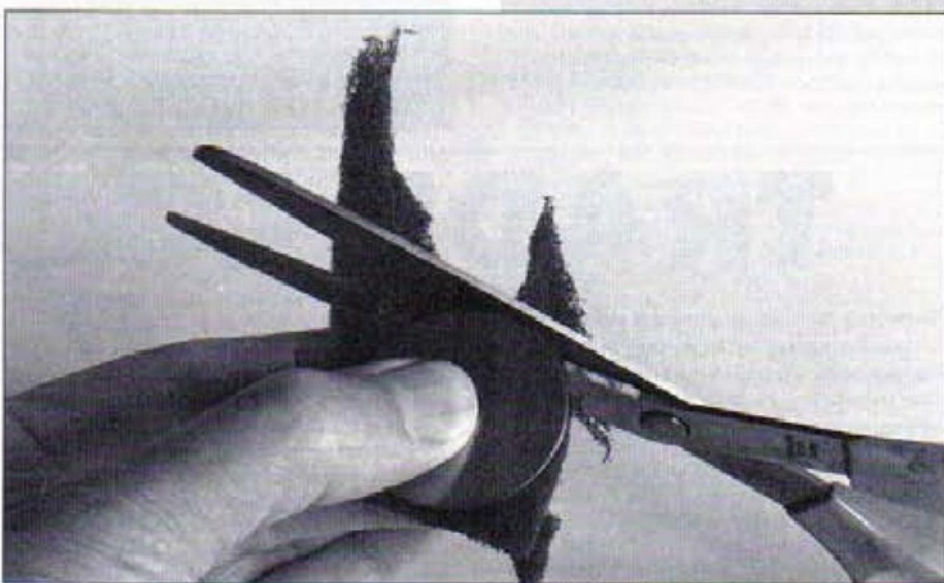
The plastic pads are made of a very tough material. When used as a 'wire brush' it wears away gradually, the advantage being that, as it does so, it exposes fresh hard plastic. The cleaning effectiveness does not deteriorate as it wears down. A further advantage is that this 'ablation' or wearing away means that the plastic does not clog easily and can be used on some jobs where other cleaning methods would be susceptible to clogging.

The fine particles which are constantly flying off are a very real danger and it is **absolutely essential to wear eye protection.**

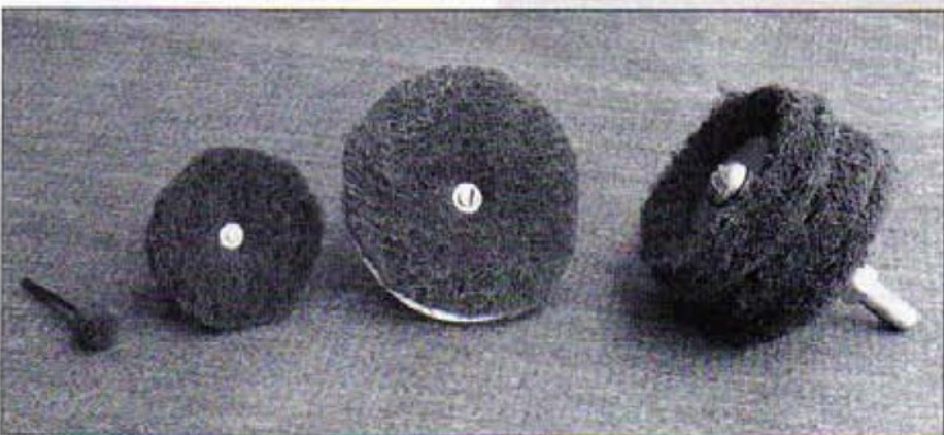
With the pad mounted on a small mandrel, even with only a small washer, sufficient torque can be transmitted without slipping for most small applications. For harder jobs, the top of a pill box with the rim cut off makes an excellent backing. Much more pressure can now be applied and corrosion can be removed from small articles, as shown in Photo. 4. For very delicate cleaning, a small wad Superglued to a small nail works well. I cut these wads using a piece of brass tubing mounted in a drill or drill press. A piece of broken portable radio aerial does the job perfectly. Photo. 5 shows the battery contacts on an old video remote control being cleaned. Please don't laugh - that is a wooden tooth pick, not a nail. For very delicate work they are better than a metal mandrel which might cause scratches if it pokes through the pad. Besides, the tooth pick makes a good 'shear pin' in the event that you get too enthusiastic. Many a kiddies' toy, remote



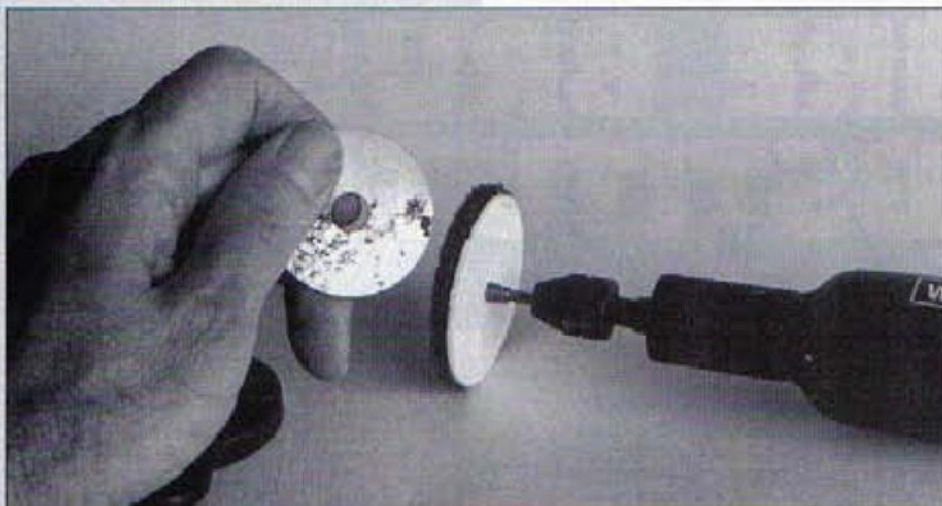
1. One of the abrasive discs mounted in a flexible drive



2. A large washer serves as a cutting guide



3. The form of the pad can varied to suit the job in hand



4. A plastic backing disc allows heavier jobs to be tackled

control and even an expensive camera have been resurrecting using a wad of plastic on the end of a tooth pick.

The plastic discs are very light. I have used a 40mm diameter one on an old Dremel which runs at about 25000 rpm without undue vibration. I do prefer to keep the speed down to 15000 or less - as with any tool, common sense and caution must prevail.

On the right-hand side of Photo. 1 is a stack of five discs mounted on a 1/4in. mandrel. This, used in an electric drill, is suitable for quite heavy work. I use washers about half the outside diameter.

Having tried several different brands of plastic scrubbing pads, I have not found any one significantly better than the others. The utilisation of my old Minidrill has increased considerably since I started using these discs and now some of those tedious cleaning jobs have become quick and easy.

I hope that this technique adds to enjoyment of your hobby as much as it has for me.

Supplier:- One example of a suitable material is 'Mirlon' by Mirka Abrasives, stocked by Tilgear (see Trade Counter, page 41)



5. The 'tooth pick mandrel' is more suited to finer work



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

S.J.E. Engineering can supply small fasteners

We have recently received a list of small fasteners available from S.J.E. Engineering of Normanton, West Yorkshire. The range available includes screws in most BA sizes in both brass and steel, with a selection of sizes also in stainless steel. Head types listed include hexagon, countersunk, round and cheese head, with some raised countersunk and dome head. Brass, steel and Nylock nuts can also be supplied, together with 2BA and 5BA grub screws and a small range of taper pins.

Miss S. J. English, 17 Altofts Lodge Drive, Altofts, Normanton, West Yorkshire WF6 2LB Tel. 01924 890596

Workholding with Climpex clamps

The Climpex Division of S. Murray & Co. of Old Woking, Surrey has released details of their latest mini clamping system which is designed to provide a means of precisely and securely positioning components during such

activities as painting and assembly.

The system includes a selection of stands, scaffold clamps, flexible arms, bulldog clamps and crocodile clips which can be used in combination to suit the required application. Each clamp is secured using a simple thumbscrew, so a variety of configurations can be built, dismantled and reassembled rapidly from the same components. The main components are constructed of steel with a protective coating for long life.

Climpex, Holborn House, Old Woking, Surrey GU22 9LB Tel. 01483 740099 Fax. 01483 755111

Compression springs and 'O'-rings

S & R Model Components of Beckenham, Kent are a small company specialising in the supply of springs and 'o'-rings, and are prepared to make these available in quantities as small as one, with no minimum order charge, subject to a minimum delivery charge of 70p on the UK mainland. Trading by mail order only, mainly via the Internet through their website, they are also happy to send lists of products via standard mail, in exchange for a First Class stamp or s.a.e.

Their product range contains both nitrile and silicone rubber 'o'-rings in virtually any standard size, plus springs in

both stainless steel and music wire.

Although only compression springs are listed at present, extension springs should be available soon, and they suggest that potential customers should watch their web site for new developments.

S & R Model Components, PO Box 168, Beckenham BR3 3WY. E-mail: sr.model.components@srmodcom.fsnet.co.uk Web site www.srmodcom.fsnet.co.uk

News from A & D Barrowclough Ltd.

A & D Barrowclough of Burnley, Lancashire have asked us to remind readers that they are still able to supply the 'Sharp' 4in. rotary table, either in kit form at £67.00 including VAT and postage or finished at £137.00.

Casting sets for two lathe attachments designed by Gordon Cornell and described in earlier issues of M.E.W. are also still available. These are the toolpost grinder (Issue 18) and the universal milling/dividing attachment (Issue 26). The castings can be supplied at 4 weeks delivery from receipt of order at £92.00 for the grinder and £110.00 for the milling attachment.

A & D Barrowclough Ltd., Elm Street Mill, Elm Street, Burnley, Lancs. BB10 1NY Tel. 01282 427048

Multi-purpose propellant for SuperSpray re-fillable aerosol paint spray can

Some while ago we reported that Phoenix Precision Paints of Cheltenham had introduced a re-fillable aerosol paint spray can. One limitation of this unit was that the standard gas used as a propellant (butane lighter gas) was not suitable for use with cellulose or acrylic enamels or with etch primers or water based liquids. They are now able to supply a multi-purpose propellant which is listed as being compatible with white spirit based enamels, cellulose enamels and Phoenix Precision Paints Single Pack Self Etch Primer.



Phoenix Precision Paints Company,
PO Box 359, Cheltenham, Glos. GL52
3YN Tel. & Fax. 01242 575326, E-mail:
sales@phoenix-paints.demon.co.uk,
Website:
www.phoenix-paints.demon.co.uk

Spring offers from Tilgear

We have recently had the opportunity to examine a number of items on offer from Tilgear of Cuffley, Herts.

Mirlon abrasive pads

These pads are of an abrasive impregnated web material which provide an effective means of cleaning and surface preparation with minimal stock removal, gouging or damage. They are ideal for creating a 'key' prior to the application of finishes, the flexible nature allowing complex contours to be worked with uniform contact.

Other uses include light deburring and denibbing, rust and tarnish removal. They would be ideal material from which to make the 'wire brush substitute'



described by Neville Frewin on page 50 or as an alternative to steel wool. They may be used wet or dry.

The pads measure 230mm x 150mm and can be obtained in three grades, General purpose (green), Fine (red) and Ultra Fine (grey).

A trial pack of three assorted grades is available at £1.75, while quantities of 10 cost £4.95 and 20 cost £8.95, all plus VAT and carriage.

'Cushioned' abrasives for plastics

Micro-mesh cushioned abrasive is intended for use on the harder plastics such as acrylics, particularly for the removal of damage such as scratching or crazing from transparent structures. It consists of a cloth backed material with a resilient layer of latex upon which a layer of abrasive crystals are bonded. When contact pressure is applied, the crystals recede and rotate slightly to present their sharp cutting edges evenly across the surface. They then all cut together with a fine planing action, resulting in a fine uniform scratch pattern. Successive application of finer grades of abrasive, each employed at 90 deg. to the preceding one, is used firstly to uniformly remove the damage, then to restore the transparency. Final finish is achieved using a liquid abrasive.

Although the materials can be used on the softer plastics such as polycarbonates, the makers warn that a slight haze may remain.



Tilgear supply the materials as a kit which includes six grades of abrasive, a foam block, liquid abrasive and soft flannel polishing cloth. Designated KR-70, this kit is available at 14.95 plus VAT and carriage.

Screw Magic for recalcitrant fasteners

Although not guaranteed to deal with every seized screw or damaged nut, Screw Magic fluid provides another weapon in the armoury of those who have to grapple with such things. Consisting of fine particles of real diamond in suspension, this material is applied to the tip of the screwdriver or spanner jaws and enhances the grip between the tool and component. When just about to give up, try Screw Magic. It may just make the difference.

The fluid comes in a trial size of 6gm at £1.95, Standard size (30gm) at £4.95 or Economy size (60gm) at £8.95.



Bend-A-Light high intensity light probe

When trying to view areas of poor accessibility, it is often difficult to provide adequate illumination and maintain the desired line of sight. The Bend-A-Light assists in this sort of situation because the small high intensity bulb is mounted on the end of a flexible 10in. alloy shaft and also provides all-round illumination.

The head assembly measures less than 0.2in. at its maximum diameter, so can be inserted through an aperture not a lot bigger than this dimension. The shaft can be bent through a wide angle, as long as a fairly smooth curve is maintained. Around 1/2in. appears to be a sensible limiting radius, the shaft being subsequently straightened without difficulty.

Powered by two AA batteries and operated by a switch at the base of the handle, the Bend-A-Light is supplied with an additional plastic tube which doubles as an extension handle or a protective cover for the shaft.

The Bend-A-Light costs £12.95 plus VAT and Carriage, spare bulbs being available at £4.95

Tilgear, 69 Station Road, Cuffley, Herts
EN6 4TG Tel. 01707 973434



ELECTROMAGNETIC DEVICES

Part 1 - An Introduction

Perhaps the biggest advance in the home workshop over the last century was the introduction of electricity, which allowed us to progress from the treadle lathe and hand-operated machinery. The essential component in this is the electro-magnetic machine, a source of mystery to many. In a new series, Tony Claridge describes some of these devices and the principles by which they operate. Part 1 looks at some fundamentals of electromagnetism

There is a common belief among model engineers that both electricity and magnetism are too mysterious to be understood by ordinary people, and furthermore they can be dangerous. This attitude has always puzzled me. Seventy years ago our predecessors built radio sets, which are considerably more complicated than most of the electromagnetic devices which we may need. Some of the more advanced radio enthusiasts designed their own sets! I am certain therefore that any model engineer with the ability to calculate a set of changewheels and the confidence to have a go will, with the help of this series of articles be able to understand how electromagnetic devices work, and will be able to design and make most of what they may need. At the very least, they will be able to choose what kind of device - solenoid, motor etc. - will best suit their requirements.

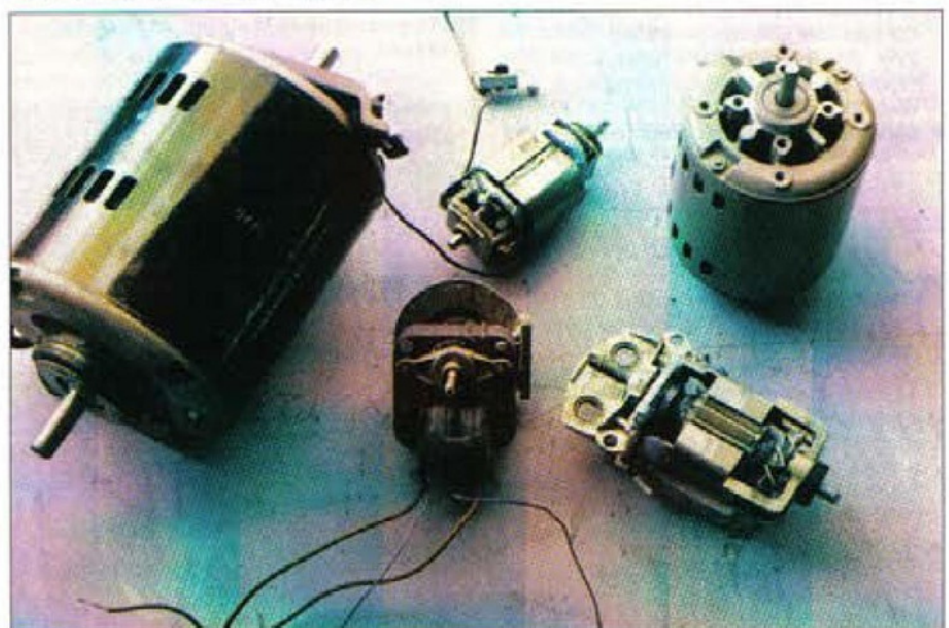
As in every other branch of engineering we can't get very far without a basic grounding in the principles and theory behind the subject. This first instalment is therefore devoted to sorting out the basics. When this is out of the way, things will become more interesting. Incidentally, you will probably find it useful to keep this part handy for when we get down to real applications later on. Perhaps a photocopy can be made so as to save this issue of the magazine from getting dog-eared.

Magnetism

You may recall from your schooldays being taught about things called magnetic 'poles'. My own early attempts to understand magnetism were bedevilled by a teacher using a hardened steel bar with a small ball on each end as an example of a magnet with 'poles'. Now magnetic poles have some uses in the academic study of the subject, but for practical purposes like ours, they are merely a misleading distraction. What we need to visualise is a magnetic field as being anywhere where there is magnetism, and which consists of a magnetic 'circuit'. It is usual to think of a magnetic field as being



1. A selection of small transformers, typical of those used in such items as battery chargers and electronic equipment



2. Five motors, ranging from a half horse-power capacitor start machine via a capacitor start and run machine rated at one tenth horse-power to a windscreen wiper motor and one from a food mixer. The one in centre front is typical of those used to drive small domestic fans

comprised of 'lines of force'. While in reality there is no such thing as a line of force, the idea is useful in understanding what is going on, and the concept has grown into the conventional way of describing a magnetic field, so forget poles, and think circuits.

We can picture the magnetic field as being made up of lines which resemble thin elastic bands, each of which forms a closed loop. The lines behave like rubber bands to the extent that they act as if they are in tension, so that they try to take the shortest path. However, they are different in that they do not like to be crowded together, and will take a somewhat longer path in order to avoid getting too close to one another. Figure 1 gives some idea of how the lines distribute themselves in one particular configuration.

If we ignore permanent magnets for the moment, every one of these lines owes its existence to the fact that it passes through a coil carrying an electric current. The coil is the source of the driving force which establishes and maintains the magnetic field, i.e. the lines of force. (Even a straight wire carrying a current produces a field. It takes the form of a circular ring with the wire at its centre and with its strength diminishing as its circumference gets bigger). The electric circuit (the coil) and the magnetic circuit (the lines of force) are thus joined together like two links of a chain. This linkage is an essential feature of all electromagnetic configurations.

Units of measurement

Now, in order to understand the subject of magnetism, we have to have a system of quantities and dimensions, so we now have to get to grips with this, much as we needed to understand length, volume, pressure, flow etc. when we first became involved in engineering. It will be easiest if I use Figure 1 to explain what's what.

What the figure shows is a cross-section through a cylindrical coil of wire, together with an estimated distribution of the magnetic field which results when an electric current flows in the coil. Also, the figure shows how the field can be divided into simple geometric shapes which will help us to make some rudimentary calculations. I dare say that the figure reminds you of those school demonstrations of iron filings being sprinkled on a sheet of paper underneath which is a permanent magnet. Now we can start to apply some dimensions and units to the situation depicted in Figure 1.

The first dimension is the driving force which is generated by the coil (while it is carrying current of course). This is simply current multiplied by the number of turns and has the dimension ampere turns, usually contracted to amp. turns. In the SI system of units which is now generally used in engineering, the property is usually abbreviated to amperes, since the amp turns can be thought of as the total amount of current wrapped round the cylindrical core. You will no doubt recall that the electrical source which drives the current through an electric circuit is called the electromotive force or EMF. In the same way, the magnetic source which causes the magnetic field is called the magnetomotive force, or MMF. So the MMF is the amp turns produced by the coil and its current.

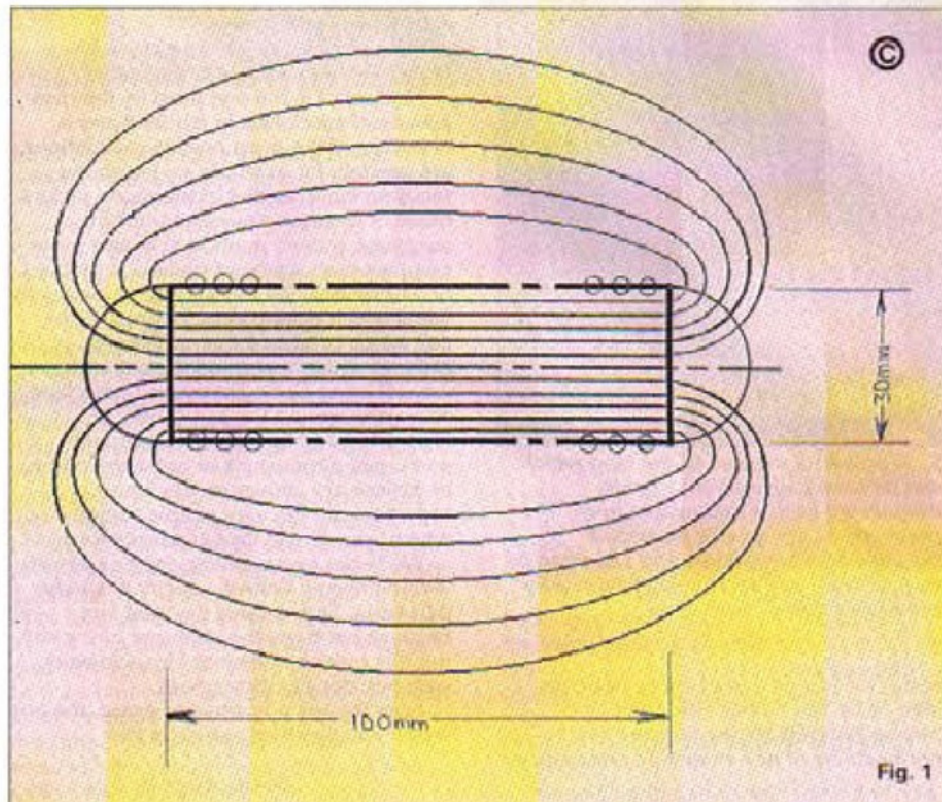


Fig. 1

The next thing to be defined is the total amount of magnetic field. Due to the terminology which was fashionable in the nineteenth century, and the idea that the magnetic field emanated from a magnetic pole, the name of this quantity is 'magnetic flux' and we can think of this as the total number of those (imaginary) lines of force which were used to visualise the field. The Greek letter ϕ (pronounced phi) is used to symbolise this quantity. The unit, like many others in the electrical field is named after one of the scientists who helped the understanding of the subject and is called the 'Weber' for which the symbol is Wb. Fortunately for us we won't have very much need to use this quantity in our calculations.

Far more valuable to us is the concentration of the lines of force, called the 'flux density'. Its importance to us will become apparent shortly. Again, the unit is named after a famous scientist and is called the 'Tesla', One tesla is the flux density of 1Wb per square metre. In passing, Nikolai Tesla is the inventor of the induction motor as well as many other things used in the world of electrical engineering. We use the letter 'B' as the symbol for flux density.

Now it is important to recognise that the MMF produced by the coil applies to every one of the lines of force which are shown in Figure 1. To be more exact, it applies to every part of the field which is visualised by the lines. We also need to consider how the MMF is distributed among different zones along the line. This is because we need more MMF per unit of length where the flux density is higher. We use the letter 'H' to indicate the amount of MMF used per unit length along the line. It has the dimension of amps (or amp.turns) per metre.

In order to calculate the field strength in tesla which arises from the coil's MMF we need to introduce a factor called 'permeability'. This is a measure of the ease with which the field is established in whatever material fills the space we are



3. A close-up view of the windscreen wiper motor

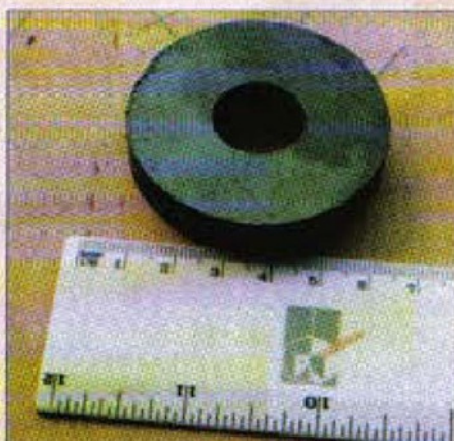


4. A solenoid which controls a valve on a washing machine

interested in. For non-magnetic materials, which means just about everything except iron and steel and certain uncommon metals such as nickel, permeability (for which we use the Greek letter μ) has the numerical value:

$$4 \times \pi \times 10^{-7}$$

Interestingly, the rather ungainly $4 \times \pi$ originates from those nineteenth century magnetic poles. It was once specified that a pole of unit strength would produce a field strength of one unit on the surface of a sphere of unit radius. The formula for the surface area of a sphere is $4 \times \pi \times r^2$. In case your mathematical skills are a bit



5. A powerful magnet of the kind which can be cannibalised from a scrap magnetron from a microwave oven. The magnetrons are usually discarded because of other failures and can often be cadged from any service workshop who otherwise throw them away

rusty, 10^7 means 1 with seven noughts after it, i.e. ten million. However, 10^{-7} means DIVIDED BY the number, so the permeability of non-magnetic materials is:-

$$\frac{4 \times \pi}{10000000}$$

Before we end this business about permeability, there is just one more magic number. When we have a magnetic material in part or all of the magnetic circuit, we have to modify the value of the permeability to account for the different properties of the magnetic material. We call this factor the 'relative permeability' and for most ferritic materials it has a numerical value of between 500 and 5000. We use the same letter, μ for both kinds of permeability but add the suffix 'r' for the permeability of free space, as it is often called, and the suffix 'r' for relative permeability.

So we end up, at last, with the important formula:

$$B = \mu_0 \times \mu_r \times H$$

This is by far the most useful formula which we shall be using.

For convenience the units and factors which have been described above are given in Table 1.

Quantitative analysis

Now we can go on to make some calculations about the field distribution which has been sketched in Figure 1. The first thing to point out is that making predictions of the field distribution is not an exact science. It relies on a certain amount of judgement, though with care it is practicable to get to less than 5% error. There are four ways of tackling the problem. In order of potential accuracy they are:-

- make a guess at the distribution and then divide the field into a small number of zones.
- divide the field into a number of simple geometric shapes and make calculations based on these.
- divide the field into a large number of rectangular blocks and again make

calculations about them.

d) use a computer program to apply a finite element analysis to the field.

Method d) is the one used by the most advanced specialists in the field and is necessary if the most precise calculations are needed, for example to design the focusing coils needed in television picture tubes. It is quite unnecessary for our purposes; indeed method c) is also more complex than we need, as also is method b). Fortunately we rarely need to deal with fields which extend very far beyond the coil which produces them. However, in order to show how to do the calculations, we will make some estimates of the field strengths around the coil shown in Figure 1. It will be helpful to us to use some real dimensions in order to do this, and these are shown on the figure, together with the very simple zoning which we will use for our calculations.

We begin by specifying the flux density within the coil. We will specify this to be 0.01 tesla. This defines the total flux because we know the diameter of the coil, but it is more convenient for us to work with flux density throughout.

Now the main formula to grasp, the one which we identified earlier, is that

$$B = \mu_0 \times \mu_r \times H$$

Re-arranging this we get:

$$H = \frac{B}{\mu_0 \times \mu_r}$$

Putting in the numbers for the field inside the coil we have:

$$H = \frac{0.01 \times 10^7}{4 \times \pi} = 795.5 \text{ amp.turns per metre}$$

and multiplying by the coil length of 0.1 metre, we arrive at 79.5 amp turns, which we can round off to 80. Remember that this kind of analysis is not precise enough to justify more than two or three significant figures in the answers!

We next do a similar calculation for the hemispherical zones at the ends of the coil:-

The distribution of the field shown in Figure 1 demonstrates that all the flux goes through the surface of each hemisphere. Now the area of the base of the hemisphere is $\pi \times r^2$, while the area of the spherical surface is $2 \pi \times r^2$. The mean flux density at the spherical surface is just half of that inside the coil, i.e. 0.005 tesla. A representative flux density throughout the hemisphere is thus about 0.007 tesla, and the length of the flux path is approximately equal to the hemisphere's radius.

The necessary value of H for this region is thus:-

$$H = \frac{0.007 \times 10^7}{4 \times \pi} = 5570 \text{ amp turns per metre}$$

and the MMF for each hemisphere is

$$5570 \times 0.0150 = 83.5 \text{ amp turns.}$$

The total MMF for the two hemispheres is thus $2 \times 83.5 = 167$ which we round off to 170.

The final zone is somewhat different. Its area nominally stretches out for ever, though its length also increases as it does so. Making some very rough estimates, we can judge



6. A holding magnet which is capable of bearing a weight of around 20 kilograms

the area to be around 0.01 square metres for a path length of about 0.16 metres, and using the same formula we arrive at an MMF of round about 60 amp.turns.

Summarising our calculations, we have:-

MMF for the field inside the coil	800 amp.turns
MMF for the field close to the coil	170 amp.turns
MMF for the outside field	60 amp.turns
Total MMF	1030 amp.turns.

So clearly we need not devote much attention to estimating the MMF needed for the field beyond the coil and the region close to its ends. There are some lessons to be drawn from all this. Firstly this kind of calculation is pretty crude, but still delivers a fairly good conclusion. You will have realised that if we had started by specifying the coil's amp.turns we would have to do what professionals call 'iterations' and the rest of us call 'trial and error'. However, this may not be all that hard to do once we have acquired a bit of experience. Old hands will sometimes use a formula where one makes the MMF equal to that which would be needed if the coil length were increased by an amount equal to its diameter, and then not bothering with any other calculations. In the case we have just looked at, this would give us a total of 1040, which is pretty close to the numbers we worked out above.

Before we end this rather tedious article, though, suppose that we were to place an iron bar inside the coil, and that its relative permeability were 1000. Then the MMF needed for this region would fall by a factor of 1000, which would drastically change the situation. In the next instalment we will deal with more typical magnetic circuits, which almost always have lots of iron in them, as well as some useful applications, but this exercise will have shown you, I hope, that the subject is not as mysterious as it appears to the outsider.



Table 1

QUANTITY	SYMBOL	UNIT	ABBREV
Total flux	Φ	Weber	Wb
Flux density	B	Tesla	T
Permeability	μ_0	Constant	
Relative Permeability	μ_r	Material Property	

SCRIBE A LINE

Calling Cuckoo Hall Lane former pupils

From Tony Aimer, Ferndale,
South Africa

My father, James Aimer was the woodwork and metalwork master at Cuckoo Hall Lane Secondary Modern School in Enfield in the early 1950's. He used to take groups of schoolboys to the Model Engineer Exhibition, where they would actually build models on a stand in front of and in contact with the general public. Pages 355 and 356 of Model Engineer, Issue No. 2783 Vol. 111, September 23rd 1954 refer.

My father's 80th birthday occurs later this year and I would like to trace some of these people, most of whom have probably retired by now, so that I can make mention of them on this auspicious occasion, especially as he expressed an interest recently in their subsequent careers.

If you were one of those boys, or know someone who was, please contact me at the address below, or give me a call on 002711-7923323 (home).

Tony Aimer, PO Box 609, Ferndale,
South Africa 2160.

Further thoughts on machining hobs

From Peter J. King, Christchurch,
New Zealand

I read with interest the letter from Mr. Turner in MEW 63. The incorrect setting out of the gears was my fault. For some reason beyond me, I typed '20' instead of '25', for which I apologise.

At the time when I was trying to work out this method of using a lathe with a gearbox to cut DP worms, I just started with conjugate fractions, Brocot's tables and a 'Texas Instruments' calculator - computers were horrendously expensive then. I never was very good at factorization; I have one of those awful minds that can happily accommodate geometry, 'trig', conjugate fractions etc., but gets lost trying to factorize. I have to laboriously work out dividing factors for gears with a calculator, otherwise - disaster!

About two years ago, I came across a passing reference to this same combination of gears in an obscure and old manual (pre-W.W.I) on the cutting of complex helices. It was being used in reverse to produce $\frac{1}{2}$ but I cannot remember why anyone would want 'one pi-eth'. I have never found this combination mentioned anywhere else in any other engineering handbook.

I suspect that a six-gear combination will produce a ratio that is accurate to many more decimal places; however this one is accurate to five places, which after all places errors in the millionths. I have grave doubts that any model engineer's lathe leadscrew is more accurate than a few tenths of a thou' over an inch after a good few years of use. I know mine isn't

quite that bad. I have an old DTI that measures in microns and the short check I made last year showed variables (converted to inches) of 0.00005in. - 0.0001in. plus and minus over about two inches (as near as I could guess), this after fifteen years of use.

When using a lathe/gearbox combination with this ratio to cut a hob or DP worm, it will be necessary to reverse the lathe to return to the start of the cut. This, when cutting the average hob/worm, will mean an axial cut length of perhaps two inches maximum. This means that the probable crest to crest and cyclical errors with a near perfect leadscrew would probably be in the order of 0.000002in. on pitch and 0.000015in. over the approximate 1.75in. of, say, a small DP hob (16 - 40DP). With reversal of the lathe in operation there can be no accumulation of error from the gearing beyond this. There will in any case be a variation of this order due to variation in temperature of the material/tool/machine. The lathe being of lesser accuracy, this ratio is satisfactory, as any gear inaccuracy is lost in the inherent inaccuracy. If however you require a worm of some ten to twenty feet in length, the degree of precision will have to be ascertained and other methods of production used to eliminate the very small but, at that length, measurable difference.

I note that very few model engineers realize that it is futile to 'chase tenths' - there are too many variables along the way. For 99.9% of all model engineering, all that is necessary is to be able to machine to 0.001inch. If your machinery will achieve 0.0005in. (a) it is small and new or (b) it is large and of tool-room quality, but even these will not hold that accuracy for ever. The only engineering requiring better accuracy for cylindrical components is usually in something like a diesel injection pump - and they are ground in any case! I have never had the nerve to ask any of the local gear manufacturing companies to estimate cost of a hob or worm to better than 0.000002in. on pitch - I think the reply would just possibly teach me a whole new line in 'engineering Esperanto'.

Engineering adhesives

From Richard Atkins, Wanganui,
New Zealand

The following may be of interest in relation to Harold Hall's article on the use of adhesives (M.E.W. Issue 64, Feb./Mar 2000).

Some 40 years ago, I acquired a well worn Macson lathe plus an unused 6in. 4-jaw chuck, threaded to suit a Myford lathe, which I had to bore and screw to fit the Macson. Retiring some 15 years later, I was able to get a new Myford Super 7, so kept the 4-jaw which was bored again and fitted with a steel bush which, in turn, was screwed to fit the Super 7.

The bush was secured using ROCOL Fitlock retaining compound (similar to Loctite) and has been perfectly satisfactory ever since.

Lathe tool packing

From Stan Coote, Sevenoaks,
Kent

Thank you for John Brittain's contribution 'Avoiding the Use of Packing' (M.E.W. Issue 65). I am tempted to copy his luxury system.

My current approach to packing is, having got the tool to centre height, to keep the packing with the tool by binding up with copper wire, packing and wire being freely available from scrap sources.

It is worth making up a 'fake' tool from a square bar end (mild steel or brass) that achieves centre height without any packing. This can then be used, on any flat surface, alongside your tool to determine the required packing - much easier than fiddling on the topslide. The thickness of the fake tool is, of course, arrived at by checking against a precise centre-height column set on the lathe shears.

From George Swallow, Dorking,
Surrey

Something has snapped! You know how you can put up with things for a long time, until someone points out that you don't have to? So it is with John Brittain's article on toolposts and packing.

I sold my old Portass over a year ago and bought a second-hand Super 7, complete with the kosher Myford four-tool turret, a great improvement, or so I thought. Before that I had the right packing Sellotaped round every tool, ready for the old nut, bolt and clamp system on the Portass. Some of these assemblies would not go into the Myford slots, and some of the tools I cannot now get down to centre height, even with no packing at all. Besides the need for packing, there are other discomforts; when you want to use a boring tool or turn between centres from the tailstock end, at least two of the other tools have to come out because the tool needs to be on the other side of the turret to reach the workpiece.

Reluctant as I am to interfere with anything Myford have done, JB has induced me to revolt. I shall do all the heavy work at evening classes, which will be a contribution to my NVQ.

I see that evening classes continue to be advertised in ME and MEW and I wonder whether any of them have the same arrangements that we have? At Redhill, there is a recreational engineering course advertised every year, but it is not funded and is never run, so we are all dragooned into the NVQ course that attracts Government funding. Besides our projects (and we can make what we like), we have to mix in with the first-year apprentices, be lectured in the theory, do written work, and take exams, all to keep the college afloat! The one good thing about it is that whereas we old lags used to keep our heads down and get on with our jobs, there is now a more sociable atmosphere of those united in shared suffering.

You may recall my article on bowmaking planes a few issues ago ("Are you a friendly model engineer?"), and my

e-mail address published after the article on the clock-wheel cutting machine. These have led to a number of chatty e-mail links with other readers of MEW, a discovery that not all of them have lathes and workshops, and a few of the one-afternoon jobs that I mentioned in the first article. Locksmithing seems to be a fruitful field in which the model engineer can act the saviour. I have since then made replacement keys for several old locks, and I repaired a safe lock one Saturday afternoon for someone going on holiday two days later, with his valuables about to become uninsured.

Tool and Cutter Grinder details

**From Ted Wale, Porters Lake,
Nova Scotia**

Looking back over the last year's issues of M.E.W., Paul Bowler's tool and cutter grinder shown on the cover of Issue 56 (February - April 1999) caught my attention. This machine appears to be a version of the tool and cutter grinder first featured in the American Magazine 'Projects in Metal' by Glenn Wilson being, in part, based on the spindle and housing due to Philip Duclos shown in 'The Home Shop Machinist'. Paul justly earned a Highly Commended Certificate, judging from the cover shot, at the M.E. Exhibition in Class A5: the reporter (M.E. No.4088 p255) on this class refers to its transatlantic origin.

My reason for writing is that I, and my fellow club members, have had some considerable experience with this design, which now sharpens milling cutters very well, but it was not always thus.

Firstly, to anyone who has the desire to make one, I would say "Go ahead. It is a good compromise between simplicity and performance. It is not a Quorn, but it does not try to be and it works". BUT be warned. 'Projects in Metal' made it very clear that the drawings were produced AFTER the machine had been made and first written up. It is clear that the author did NOT make it from the drawings. The result, as so often happens in these circumstances, is that the drawings contain errors which are very difficult to avoid without a 'make to drawing exercise'. To the best of my knowledge the needed corrections have not been published.

Secondly, while many of the mistakes are obvious as one proceeds with the piece part making and comparing one with another, some are not noticeable until assembly starts, and a few are only revealed when the machine is tried out. This results in disassembly and parts being modified or remade. I am not criticizing the publishers as they made it very clear that the drawings were 'after the event' and we all know that this can happen. The problem is that someone obtaining the drawings now does not have the advantage of reading the magazines then as subscribers and so does not realize the situation.

Thirdly, I have a set of drawings with the errors (I hope all of them) marked in with pencil as they were discovered. I could make these available to anyone who intends to make one of these useful

machines or maybe Paul Bowler has such a set, probably in better shape than mine. Our club made the grinder as a club project and, as different parts were made by different members, most of the problems did not arise until the parts came together on one bench for final assembly.

Fourthly, we were very tempted to do as the cover photo shows that Paul Bowler has done and dispense with the compressed air feed to the main spindle. Many home shops do not have compressed air available, but there are simple solutions to this in the volume that we need as modellers. The original spindle design by Duclos, as well as the machine by Glenn Wilson, required an air spindle, which our club found to be almost essential. Fully extended the spindle overhangs the housing by nearly half its length and the cutter being sharpened extends again beyond that by a significant amount. Even a very slight amount of freedom in the spindle/housing assembly translates into what can be an excessive amount of movement of the tool tip at the grinding wheel contact. We didn't realize when we started how sensitive satisfactory grinding is to the correct presentation of the tool to the wheel. An error of a few thou (4-6) can destroy the small rake angles needed in this application. This is NOT like grinding a lathe tool which is where we started. A small error can produce a tool that either won't cut properly and overheats (rubbing behind the cutting edge) or which dulls quickly in normal use (excessive rake giving a poorly supported cutting edge). It is very difficult (almost impossible without sophisticated grinding equipment) to make a spindle and housing that has virtually zero slack but at the same time has the freedom of movement that the sensitive touch of good grinding requires.

Fifthly, this problem disappears when air at 20/30 psi is fed into the centre of the housing, 50 psi being even better. For a good air spindle, a controlled amount of clearance is needed, well within the lathe capabilities of model engineers. The air, leaking out at the ends, centres the spindle and holds it there with a surprising amount of force. The design maths of an air spindle show this. The machine is much easier to make and a good performance is easier to achieve.

Lastly, and very importantly, this outrush of air at both ends prevents the ingress of the fine grinding dust that is all around when the machine is in use. This can be disastrous to the spindle in a very short time - enough said.

I hope that Paul will not be too upset at my comments which are only meant to help. Others may be encouraged to make one of these, having seen Paul's magnificent model of what is a relatively simple machine. After all that is what modellers and modellers' publications are all about isn't it?

9in. South Bend Lathes

**From A N Eastwood, Etchingam,
East Sussex**

My 9in. South Bend Model A lathe is apparently identical to that of your

correspondent, Mr. Bert Martin (MEW No. 57), also having 444-Z stamped on the gearbox index. It is an excellent machine except for the fact that, in its original configuration, the flat belt slipped under load. I have given this problem a lot of thought, and delayed this reply until I had completed my conversion to V-belt drive.

My first conclusion was that this model lathe cannot be converted to underneath drive as the bed is too wide. South Bend underneath drive lathes are somewhat different in construction at the headstock end to provide clearance for the flat belt, which must pass behind the gearbox. All is not lost and a conversion to V-belt drive can be made in one of three ways, any of which could be accomplished without recourse to a second lathe.

Method 1. Machine a single A section pulley groove in the largest step of the cone pulley, putting this groove as far away from the bull wheel as possible to avoid interference from the back gear pin. The groove will break into the two holes for the pin, but this will not matter, as the pin only enters about 1/16in. into the cone pulley. Drive the lathe via three belts as follows:- Motor mounted beneath the lathe headstock under the bench, with first drive belt down to a countershaft near floor level. Second drive belt from a commercial four step pulley on the countershaft, upwards to a similar pulley on a shaft fixed at centre height behind the lathe. Third belt from a 4in. pulley on the fixed shaft to the lathe. The distance between the headstock and the fixed shaft can be kept fairly short and this arrangement is about the nearest you can get to a true underneath drive. Do not even think of putting a vee groove in the second step of the cone pulley as there is a deep oil groove in the cone pulley bore. To machine the cone pulley you will have to remove it and make up a temporary drive. This can be done with a spacer machined from scaffolding tube to replace the cone pulley and fill the gap between the bull wheel and the thrust bearing.

Drive the lathe with a pulley fitted to an adapter made so as to fit into the mandrel bore at the back. You need a slow speed, so fit the largest pulley you can find and aim for about 100 rpm. Before stripping the lathe prepare a between centres mandrel 1.625in. diameter to take the cone pulley. Leave the mandrel oversize until you have the cone pulley out of the lathe, then turn it down to a snug fit. Press the cone pulley up against a shoulder on the mandrel, which should have a reduced diameter for a nut and washer to hold the cone pulley in position and provide drive.

Method 2. Convert the cone pulleys to Poly-Vee configuration. You will need to find a UK belt specification, as I am not sure if British belts are the same as the ones in my American Browning catalogue which shows that J section belts have 1/8in. rib spacing, and 10 rib belts are 1 1/2in. wide. This method should overcome the belt slip problem, but still needs plenty of space behind the lathe.

Method 3. This is what I did. I had two iron castings made for new pulleys to give a five speed drive with A section belts. I have a second lathe, but even so I fully machined both castings on the South Bend. The maximum pulley

diameter on the headstock is 4.625in. and the smallest 3.375in., each step being 1/4in. larger or smaller than the next one. A good speed range from a single speed countershaft is obtained by a countershaft pulley having diameters ranging from 2.0625in. to 6.4375in. in equal steps. Conventional multi step pulley systems are arranged for constant belt centres, but I have arranged a link and pin system to allow five different countershaft positions whilst retaining the original belt tensioning system. By drilling the holes in the link after installing the pulleys and belt, I obtained correct belt tension on all of the five pulley steps without further adjustment. This method is fairly complex and clearances are small. The cone pulley had to be turned away to leave a hollow shaft 2.2in. diameter integral with the backgear pinion. The new five step headstock pulley is fitted to this with Loctite, and holes drilled for the backgear pin. A Myford oil nipple (2BA) is recessed into the front face of the assembly with a drilling to connect with the aforementioned oil groove. Two holes 1/4in. diameter drilled through the bull wheel allow lubrication with a Myford oil gun, and avoid oil getting onto the pulleys. These holes were drilled first, 180 degrees apart, then the oil nipple was fitted to the pulley. The holes for the backgear pin were positioned so that the oil nipple is accessible with the bull wheel and cone pulley locked together. This conversion is very successful, but does require great care, and clearances are tight, such that I had to mill a recess in the rear backgear guard to clear the flange of the smallest pulley step. It would be easier to provide just four speeds. My original flat belt drive had direct speeds of approximately 230, 400 and 725 rpm. The new arrangement gives speeds of approximately 180, 315, 435, 635 and 850 rpm, with backgear speeds from 35 rpm.

More on older lathes

From A. J. Vantomme, Mortsel, Belgium

I recently became the owner of a small lathe, belonging to the effects of a very old clockmaker. There is no maker's name plate, only a small brass plate with the number 125 punched in it in a very primitive way.

Total length of bed is about 18 inches (450mm), cast in one piece with the foot. The bed section resembles that of my Pultra lathe, with central T-slot and T-bolts with eccentric levers to clamp headstock and compound slide.

The parts A and B (see photograph) are later additions, the one on the compound slide providing a taper adjustment. The spindle runs in adjustable bearings, and originally had a 1/4in. bore, into which a sleeve has been fitted to accept 10mm collets with drawbar.

The alloy pulley for a V-belt is probably not original. One would expect a 3-step flat belt pulley on a machine of that age, and there is room for it. Next to the pulley is a clutch, activated by a small lever with an eye on the rear of the headstock, as found on some industrial sewing machines, for foot operation.

The slide is moved lengthwise by the knob and lever C by rack and pinion, travel approx. 30mm. Cross feed is by knob D through a coarse thread, and is spring loaded!

The tool bar clamped to the slide is double ended, with a square in each end, and to the rear of centre line. Both movements are limited by micrometer stops graduated 0-50.

Suggestions are made that it could be a copy-lathe for turning brass clock ornaments (finials, columns) or spring barrels.

Perhaps some reader may help to find some more precise information, for which I would be very grateful.

From Tony Jeffree, Sale, Cheshire

Having read the Scribe-A-Line entries in Issue 65 regarding older lathes and obtaining information and spares for them, readers with access to the Internet may find Tony Griffiths' website to be a useful source of information. Tony is a dealer in second-hand lathes and accessories; his website (<http://www.lathes.co.uk>) carries his current stock listings, but also carries a huge and fascinating archive of information and photographs covering almost every make and model of lathe imaginable. With reference to Peter Hyde's enquiry regarding the 3.5in. Cromwell, it appears from looking at Tony's Cromwell web page that he is able to source copies of the maker's handbook. His used lathe listing currently includes a Cromwell lathe. (Usual disclaimer - I have no connection with Tony Griffiths other than as a satisfied customer!)

Regarding James Barrie's enquiry about the Myford drip feed lubrication system, I quote from my Myford ML7 manual:

"Normally the drip should be set as slow as possible, but if prolonged high speed is undertaken, the rate may be increased".

That is the only advice they give on the subject. The other couple of sentences that relate to the sight feed lubricators deal only with the method of adjustment of the needle valve by means of the thumbscrew and how to refill the oil reservoir. I can only assume that this information applies equally to the older Super 7 lathes with the same drip feed lubrication system. Myford still sell copies of their original manuals; the current accessories price list includes two versions of the Super 7 manual, one labelled "before power cross feed", so presumably this relates to the earlier version of the Super 7. Myford's contact info. can be found in their advert on page 10 of M.E.W. Issue 65.

LINK UP

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

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

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- Clock pinion cutter, 0.8 module, 8 leaves. Clock wheel cutter, 0.8 module, 55 to 134 teeth. Cutters needing re-grind acceptable.
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(October/November '92).

Roger Ball, Camelot, Green Lane, Frogmore, Camberley, Surrey GU17 0NU, Tel. 01252 871809

- M.E.W. Issues 2, 4 to 9, 11 to 16, 19, 21, 27 to 29, 33.

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