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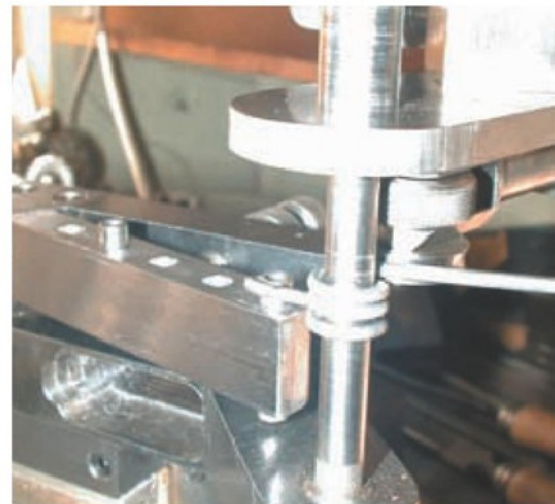
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SCRIBE A LINE

Reader to Reader



Inside

Peter Rawlinson's pipe bender also produces
continuous coils. (see page 37).



Front Cover

The superb "Quorn" by Mr G. D. Tyler
shown at Sandown Park represents the high
end approach to tool and cutter grinding. A
simpler system for lathe tools is offered by
Ted Wale on page 12.
(Photo Mike Chrisp)

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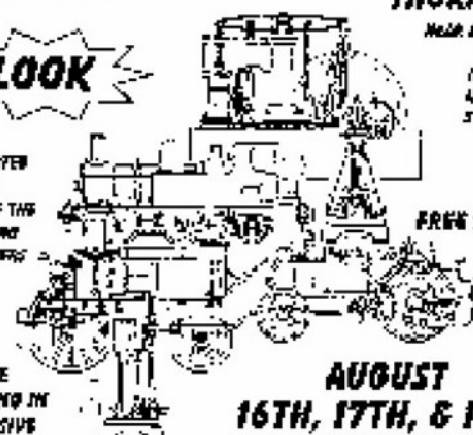
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L2 1/2 - 1/2 - 3/8 - 5/8 - 7/8 - 1	14.70

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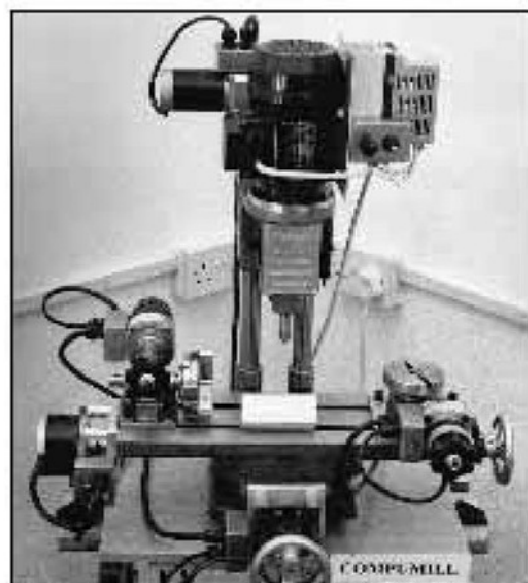
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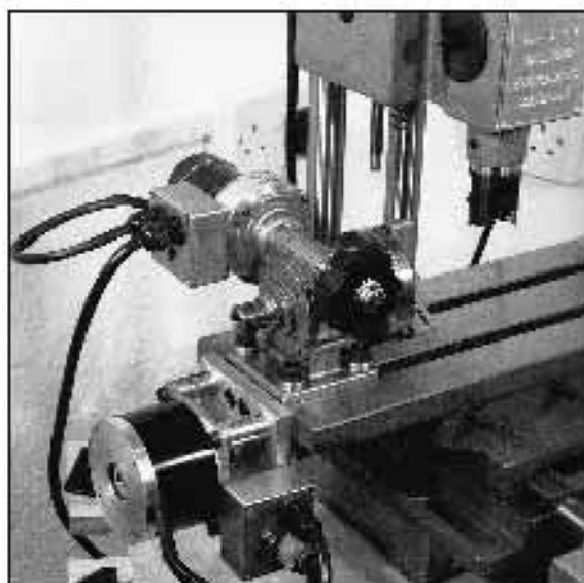
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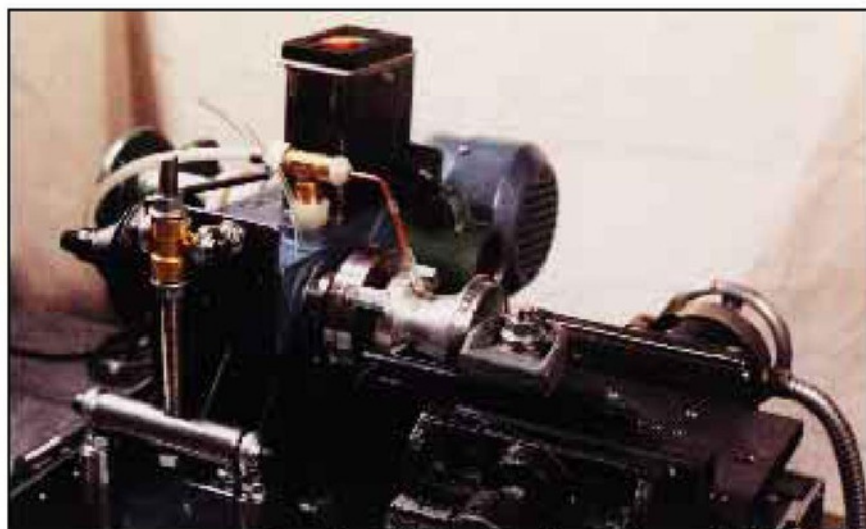
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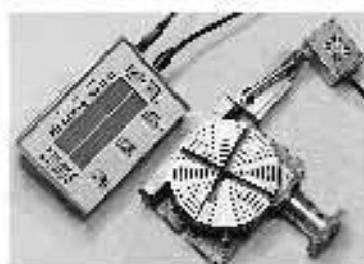
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Dave Kinnear

ON THE EDITOR'S BENCH

workshop safety, this came as an object lesson in risk assessment. The risks are not always due to the most obvious causes.

Technology marching ever forward

Looking through the content of the Mach 2002 exhibition underlines the advances in the professional machine tool field, and the generally downward movement in costs. I can remember in 1979, my employers purchasing a CNC machining centre with 12 tool autochanger, at a cost of around £55,000. The combined influences of far east manufacture, and cheap computing power mean that today, similar manufacturing capacity can be purchased for around £30,000, and today's machining centre will be faster and very much easier to programme. Other features available today include spindle speeds of up to 60,000 rpm, feed rates of up to 40m/min. accelerations of around 1g, tool change chip to chip times of under two seconds, and coolant fed through the spindle and tool at high pressure.

Advances in turning technology give us oil bath bar feed units capable of vibration free high speed operation, and the lathes themselves frequently feature auto tool change, with powered tooling (effectively built in milling spindles) and primary and secondary headstocks. Thus it is possible to start with round bar, and in addition to the conventional turning operations, also mill flats, hexagons etc. cross drill and tap. Then part off and transfer to the secondary spindle and continue to machine those back features which traditionally were dealt with by a second machine.

Laser cutting has been with us for many years, but powers and speeds continue to rise. Less well known than laser cutting, but now making inroads into the subcontract market, is the water jet cutting process. This is accomplished by feeding high pressure water through a fine nozzle typically made from sapphire. The resulting high velocity jet is then used to cut a wide variety of materials, including glass and stainless steel. In some cases, an abrasive material may be added to the water, allowing profiling of materials up to 300mm thick. As the process is cold, it avoids the possibility of heat affected edge surfaces which may result from oxy-acetylene or laser cutting.

The reductions in the real cost of machine tools coupled with their year on year increase in productivity, in turn feed through to drive down the cost of components from subcontract manufacturers. This was recently brought home to me when sourcing parts for an automation project. Four stainless discs around nine inches diameter, each with eight slots and other details, were purchased for a total of around £60.00. A dimensional tolerance

of plus or minus 0.2mm had been specified, however, on inspection, the deviation from nominal was too small to measure with digital calipers. Some home workshop enthusiasts will no doubt wish to enjoy the satisfaction of doing the whole job from start to finish. However if time is limited, then it may pay to examine whether, bearing in mind the cost of material etc, some items may be better farmed out. Many CNC shops used to impose a programming charge which deterred the small customer. With modern systems, this can frequently be avoided if the drawing is prepared on a CAD system, and is presented along with the file on disk.

Nostalgia near Nevis

Conversation at the weekly meetings of our local model engineering society frequently drifts away from models to other subjects of related interest. As we have several members whose interests also extend to motorcycles, this is a topic which often arises. It emerged that the Scottish Six Day Trials would be taking place, and that these would be preceded by a two day event based at Kinlochleven, (near Fort William) specifically for pre 1965 machines. Two of us arranged to play truant for a day, my accomplice being Ron Mercer who has done his own fair share of trials riding in the past. The weather stayed sunny, and the first days of May are way too early to tempt out the redoubtable Scottish midges, so we were able to enjoy the event against a backdrop of magnificent scenery.

The car park start area gave Ron a chance to catch up with old acquaintances, and both of us to have a close look at some 180 beautifully prepared motorcycles. Along with the better known makes such as AJS, Matchless, BSA, Triumph, Royal Enfield, Francis-Barnett, and James, we also found those produced in smaller numbers like Dot, and Greeves.

"Pipeline" stage follows a rocky stream bed uphill for several hundred yards alongside the hydroelectric water pipes. Getting to the top on foot was by no means easy, and served to underscore my admiration for the competitors. Spectating from above, one was able to appreciate contrasting techniques and levels of ability. Many riders would arrive at the top in a state of near collapse, exhausted by the sheer physical effort involved in wrestling with the machine, others, like seasoned campaigner Blackie Holden made it look like an effortless Sunday afternoon jaunt.

Naturally, by the end of the afternoon, the previously immaculate machinery had acquired a fair share of dust, mud, and occasional scrapes, dents and other damage such as a fractured oil pipe. What was then noticeable was the spirit of cooperation to find a fix to enable the competitor to continue. But of course that is what you come to expect in a sport where riders take part for the fun and the personal challenges and which is not driven by financial pressures from manufacturers, sponsors, etc. Other areas of motorsport such as Formula 1 might pick up a few pointers.

A Cautionary tale

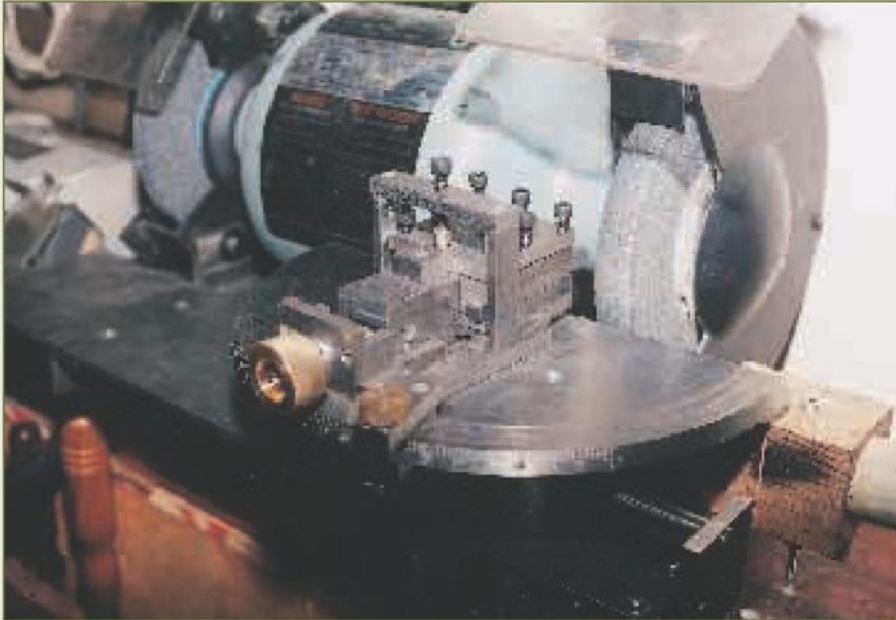
An accident from an unexpected quarter resulted in the loss of a pair of spectacles, but fortunately nothing more serious. On the general subject of workshop safety, we are accustomed to concentrate on the potential risks associated with rotating or reciprocating machinery, mainly mechanical and electrical, and to pay little heed to static items such as hand tools, workbenches, vices, etc. During a visit to a friend's shop, he showed me the parts of a Hemingway kit for a ball turning device he was making. Thus inspired to make something similar, I returned later to break off from rebuilding the Rickman Metisse, and to start the sequence of events that would result in the loss of said spectacles. The scrap box had been raided, the back of the envelope sketched on, and various parts made.

All went well, until the 16 gauge gib strip was nearing completion. In order to hold the small strip, I had gripped a 2in. universal vice in the main 5in. bench vice. This then allowed sufficient clearance to file the 60 degree edges. The accident was caused by the two factors of untidiness and carelessness in conspiratorial collaboration. My bench, as always was liberally covered with offcuts and other pieces with no immediate home. In particular a 10 inch length of 12mm by 3mm strip steel, had been left with about one inch overhanging the edge of the bench, and vertically below the little universal vice. In my haste to remove and check the gib, I inadvertently slackened the main vice.

What followed reminded me, albeit on a smaller scale, and in a split second, of Hoffmann's story of the man and the barrel of bricks. Predictably, the small vice descended and struck the overhanging end of the steel strip which was then launched skywards (courtesy of the laws of conservation of energy and momentum) with much higher velocity, to be stopped only by me leaning over, and thus smashing one lens.

As I have always taken what I considered to be a common sense but arguably somewhat cavalier attitude to

GRINDING FIXTURE



Introduction

I am not a trained machinist but I took up modelling, and so machining, after retirement. The result is that many skills are not as ingrained as they would be in someone apprenticed and properly trained as a machinist. One of these is lathe tool grinding. I have read several books on the subject and I know what has to be done in the normal case and where to find the info on the special cases. The problem is doing it. If I set out to grind up a new tool, or to touch up one existing, the end result is very variable. A few excellent, some good, many poor, some plain bad and many result in having to regrind the tools to achieve a better performance, often still with limited success; I don't have the experience to make a good job every time and I don't



1. Toolholder fitted with rectangular toolbit holder which presents the bit at the specified angle

have to do it often enough to acquire it as a natural skill. I feel that it would not be unreasonable to assume that there must be many modelers in the same boat whether they admit it or not. Hence this article. We just don't hold the tool the right way instinctively, we don't present it the right way instinctively and each time we dunk it in cooling water any careful "correctness" we have struggled to find is lost and we must start again to try and find it.

For a long time I have felt the need of a grinding fixture that would take the guesswork out of this essential support job. Of course there are several machines on the market that do this and more, from the Quorn to the Worden, the latter so ably demonstrated by Mike Chrisp and Geoff Sheppard while at the Primrose Valley/Filey Show. and written up in MEW issue 71/p38. Some people would say my attitude is defeatist as I should set to and learn the skill: maybe so but, at eighty years of age, I avoid as far as possible a grinding self tutorial if I can. (pun-ugh). I also avoid purchases of equipment that I

Ted Wale of Porters Lake, Nova Scotia suggests a straightforward device for achieving accurately ground lathe tools.

feel I should be able to make (or rehabilitate from misuse or age).

A little while ago a friend of mine, Jim Wright also of Halifax NS, was putting together a design of a tool holder and in it he has a brilliant idea, (a different application of an already used holding method). I use the word brilliant deliberately because the very simplicity of it makes it a brilliant solution to the problem. As I read the Worden write up at about this same time the two ideas (Wright and Worden) came together into a design concept that seemed to me to have potential. I envisaged a method of grinding lathe tools with all the correct angles for any variety of materials and doing so on my ubiquitous bench grinder which is an essential part of every workshop.

I set to work, drew up the bits and pieces, made them and tried out the system. After a few mods (as most newly developed articles need), suddenly correctly shaped lathe tools appeared every time!

Basic information

Enough of the history of this interesting exercise; a few words on the information, on the tool setup, which follows. I have kept the construction as simple as I can, for my own sake as well as for anyone else. It should make a good exercise for our newer and junior readers. For instance, I have made virtually all of it from 1/2in. MS when many parts could be made from sheet metal; but 1/2in. MS allows simple fixing together of parts with 4-40 screws (6BA or M3 might be suitable alternatives) into their thicknesses. (In N. America Bright (Cold Rolled) MS is not readily available in small quantities for modelers



2. Commercial and home made adjustable toolholders

so I used Hot Rolled M.S. It is a pity as the result doesn't look anywhere near as good) The considerable addition in weight occasioned by using $\frac{1}{4}$ in. thick material over sheet metal is no disadvantage, in fact I strongly suspect that it makes the grinding more effective as the larger mass leads to a smoothness of movement.

As will become obvious, a highly desirable part of this whole system is the interchangeable and height adjustable tool holder for the lathe as shown in **photo 1**. It is sold by several tool suppliers, each slightly different in size and construction, all embodying the same principle. The interchangeable part is sketched in **Fig 1**. No dimensions are given there as they vary slightly between different makes and significantly between normal and heavy duty models. For our purposes the only critical dimensions are those of the horizontal slot in which the tool is normally held- marked X. This should be $\frac{3}{4}$ in. x $\frac{1}{2}$ in. if $\frac{1}{4}$ in. square HSS tool bits are to be used and 1in. x $\frac{1}{2}$ in. for $\frac{3}{8}$ in. square tool bits. Larger tools than this are probably not used in modelling but the system can be designed for any size.

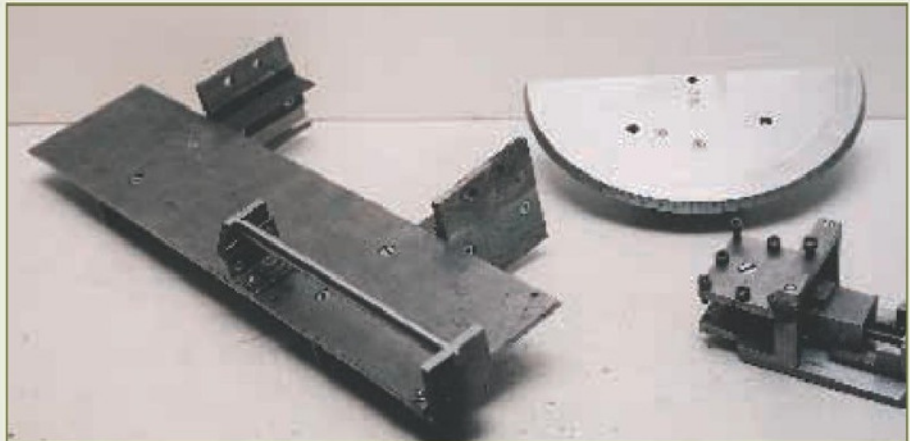
The photos and drawings given here are for the $\frac{1}{4}$ in. square tool bits and assume that the slot dimensions are slightly larger than those quoted to allow easy entry of material of that size: (just a few thou over is quite adequate). I have kept the number of drawings, and their detail content, to the minimum necessary to allow the parts to be made, dispensing with the classical three views and using photos to illustrate assemblies in many cases.

Tool post holders

As soon as I had worked out the system concept, the first thing I did was to make another half dozen of the interchangeable parts (fig 1) as I could see that they would be needed if I was to reap the full benefit of the new system. These can be made quite quickly from a bar of MS. For my holders I needed a piece 3in. x 1.25in. x 9+x in. The "+x" in the length is to allow for the saw blade cut off scarfs and for any hold down depending on the milling method used. I cut the dovetail slot right along the length of the bar, then cut the six slots across the bar (remembering the band saw's scarf



3. Six toolholder inserts for $\frac{1}{4}$ "x $\frac{1}{4}$ " toolbits, covering left and right hand and various rake angles



4. The various components of the Grinding Fixture

between each), then I cut them off separately. It didn't take long to mill the 45deg. chamfers at each end and the step, and then to drill-and-tap the height adjuster hole. These height adjusters are soon made from a $\frac{3}{4}$ in. dia. rod, each piece drilled right through and tapped. The only slight difficulty is that you need either a special long tap, or a suitable machine tap with a reduced diameter shank. These six holders went with the three originally supplied with the complete toolholder. (Photo 2). This little exercise saved me a significant amount of money as they are not cheap to buy. I shall make another six in the near future, having already bought the stock.

Basic system

The following discussion concerns grinding HSS lathe tool bits only: not carbide tips which are a horse of a different colour, not end mills which I would love to be able to grind up. Perhaps one day, for these, I will have a brilliant idea, or perhaps I will make an already existing design.

In the system I am describing the correct presentation of the tool bit for grinding is not controlled by a hand holding it and an eye guiding it but by a fixed tool holder held in a fixture where the angles are all preset and made ONCE on a milling machine.

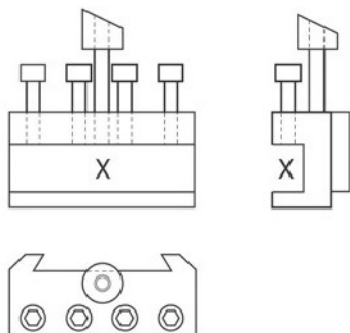


Fig. 1 Lathe tool holder

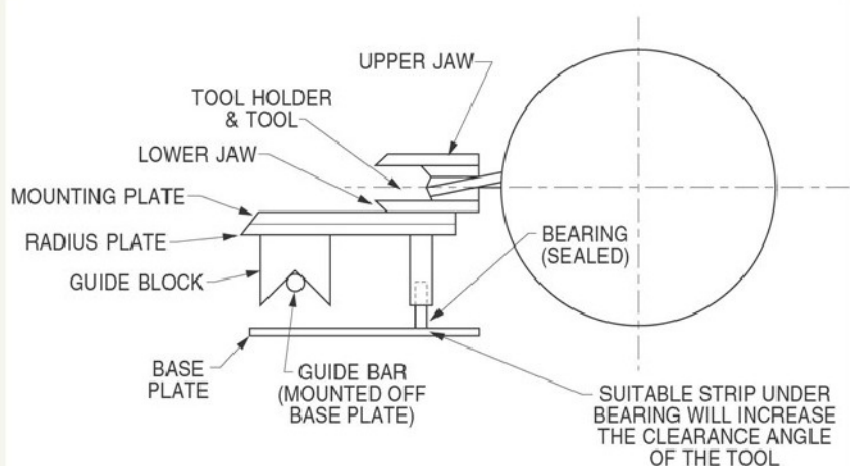
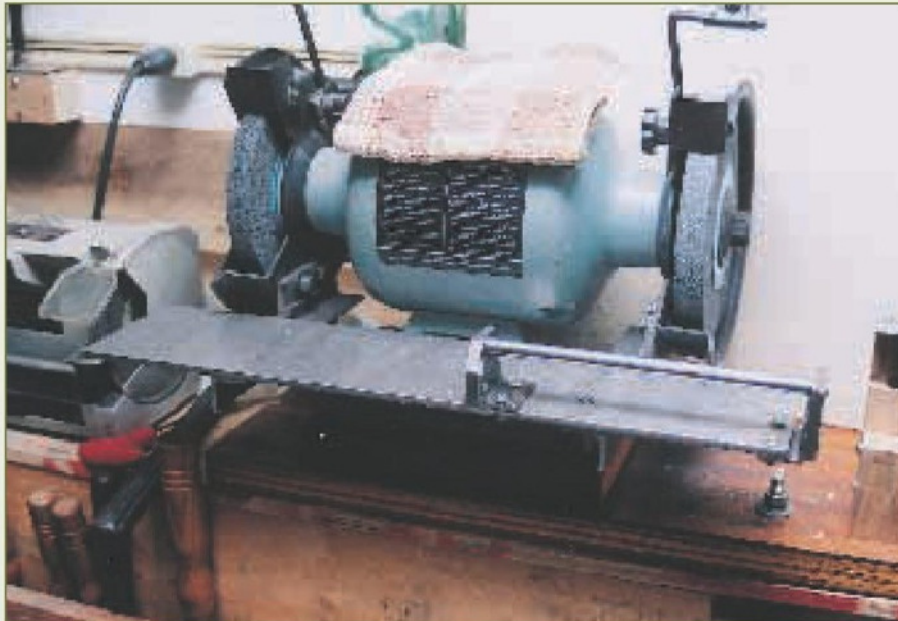
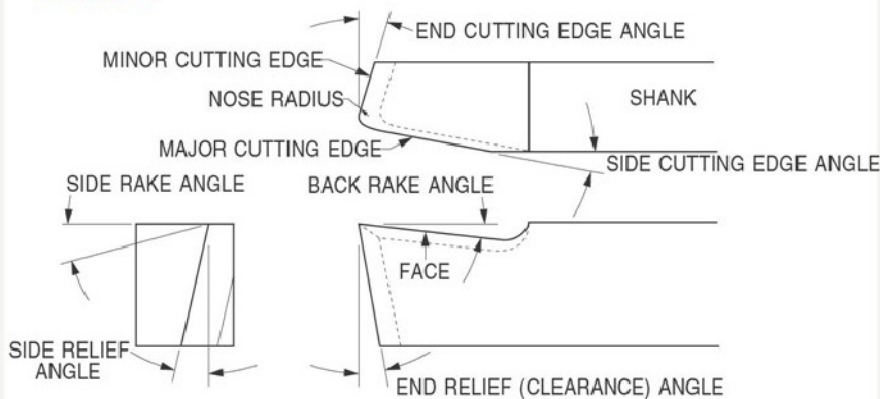


Fig. 1a Height layout



5. The baseplate fitted to the bench grinder

Table 1



DEFINITIONS USED FOR DESCRIBING THE GEOMETRY OF SINGLE-POINT CUTTING TOOLS

©

HIGH SPEED STEEL LATHE TOOL ANGLES FOR VARIOUS MATERIALS

Workpiece Material	BHN	Back rake	Side rake	End relief	Side relief	Edge
Steels	< 225	10	12	5	5	15
	to 325	8	10	5	5	15
	> 325	0	10	5	5	15
Stainless						
	Ferritic	5	8	5	5	15
	Austenitic	0	10	5	5	15
	Martensitic	0	10	5	5	15
Cast Iron	< 300	5	10	5	5	15
	> 300	5	15	5	5	15
Zinc Alloy	80-100	10	10	12	4	5
Al,Mg Alloy		20	15	12	10	5
Cu Alloy		5	10	8	8	5
Superalloy	0	10	5	5	15	0
Ti Alloy	0	5	5	5	15	0
Thermoplastic	0	0	20-30	15-20	10	0
Thermosetting	0	0	20-30	15-20	10	0

To understand this it is necessary to look at the various angles involved, five in number. There are many publications on this subject- throughout this article I will follow the definitions given by Schey (ref 1).see his pages 482/3. The two angles that are most important, are the Back rake (also known as Top rake), and the Side rake(which terms are, I believe, very widely used in the machining world). These angles vary quite widely depending on the material being worked. The next two (in importance) angles are the Side relief and the End relief (often referred to as Side clearance and End clearance). These vary very little and are there to ensure that the heels of the tool do not rub against the work material and so hinder good cutting action. The last is the Cutting Edge angle; this is more a matter of the way the tool bit is presented to the work and less a matter of grinding. These features are illustrated, and the various angles appropriate to particular materials summarised in **Table 1**.

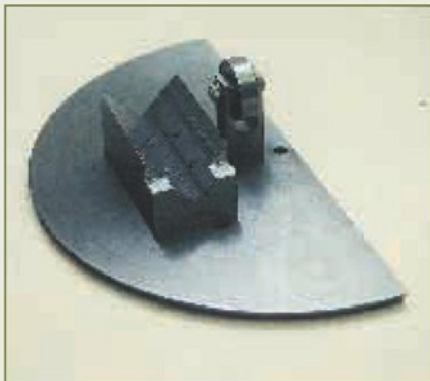
The active top face of the tool bit is a flat face set at a compound angle with reference to a horizontal plane from the lathe centre line. But if the bit is held in a tool holder (itself horizontal) that tips it up (back to front) at the Back Rake angle and at the same time tips it sideways at the Side Rake angle then the required compound angle will be presented to the work, without any grinding, by the face of the square tool bit as supplied. It will then only be necessary to grind the two relief angles PROVIDED that the bit is presented to the grind stone in exactly the same way as it is presented to the workpiece. That is what this system does as it turns a highly skilled manual procedure into a simple fixture operation (isn't that what the Industrial Revolution was all about?).

To produce this result a steel insert is sized to the dimensions of the slot X in Fig 1. A slot is then cut into this insert to take the tool bit (here $\frac{1}{4} \times \frac{1}{4}$) which runs from front to back at the Back Rake angle while being tipped over at the Side Rake angle. The angles of this slot are set accurately and cut on the milling machine. Six of these tool holder inserts are shown in **photo 3** cut for left and right hand tooling and for various rake angles.

To grind the relief angles a fixture is made to hold the tool holder insert and bit and to present it to the stone while keeping the holder horizontal (as when it is used in the lathe tool holder). The fixture traverses the bit across the face of the stone while advancing it incrementally after each traverse. The fixture is capable of being set at any angle that the grinding requires in the horizontal plane so making it capable of grinding special shaped tools. The clearance in the vertical plane is automatically



6. Radius plate - upper surface



7. Radius plate showing underside details

produced by offering the bit cutting edge slightly above the centre of the stone.

The grinding fixture

This consists of three parts as shown in **photo 4**. These are the base plate (left), the radius plate (centre) and the carriage (right).

Base Plate

The base plate mounts on the holes used for the tables on the grinder as shown in **photo 5**. I do not give any dimensions for this as it will vary from grinder to grinder but it should be kept well below the normal table height to allow enough room for the carriage to operate at wheel centre height (see **Fig 1A** and text). Readers will see that I made mine to be adjustable: this adjustment turned out not to be needed but it seems to be a useful precaution. (The duster on the grinder in photo 5 is to prevent reflection from a bright aluminium label).

The base plate carries the guide bar for the radius plate; this bar is 7.5in. long and placed, with the guide block, so that the radius plate, with the carriage, traverses equally either side of the grind stone.

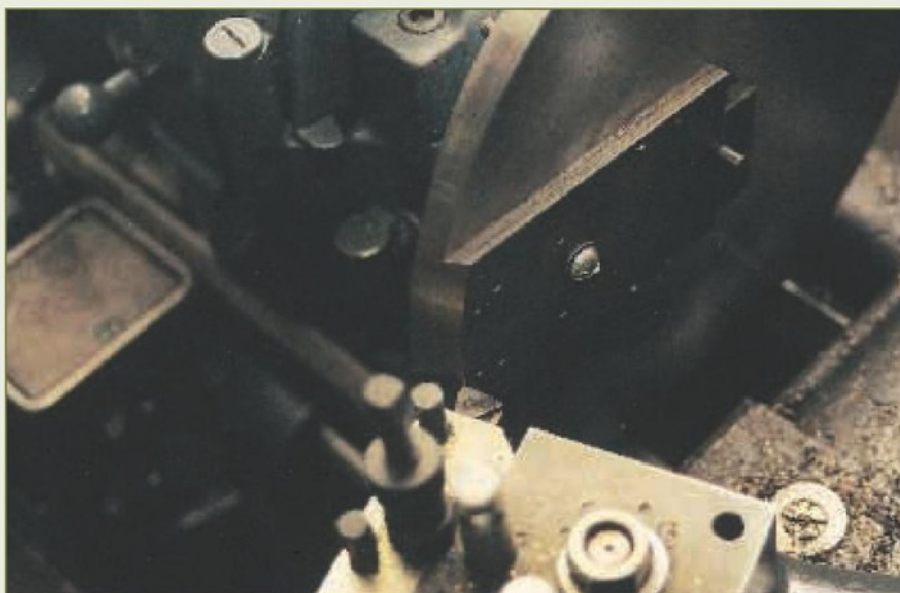
Radius Plate

The radius plate assembly consists of three parts as in **photos 6 & 7**, the plate itself, the guide block and the bearing leg assembly. No dimensions are given in **Fig 2** for the last two as they depend on the base plate and on the grinder. The guide bar, the guide block and the bearing leg are made to support the radius plate horizontally while allowing it to traverse. The machining of the V feature in the guide block is seen in **photo 8**. Originally, I made a guide block with a hole right through it to fit the guide bar. I fitted two seals to keep the grinding dust out; they didn't and the assembly seized up very quickly. I purchased two expensive seals with the same result although they lasted longer. Finally a club grey beard said "Make it a V and it will clear itself". The simplest are always the best particularly in this case as it gives the additional big advantage that the whole can be lifted off at any time when the grinder is needed for something else.

To make the radius plate I purchased a piece of steel (laser cut from a sheet) which was $\frac{3}{16}$ in. thick and just under 10in. in diameter- to suit my 10in. Southbend. The best centre was found and marked. It was mounted on the face plate and a $\frac{1}{4}$ in. hole drilled on the centre- this hole eventually



8. Machining the V feature in the guide block



9. Machining the radius plate and the carriage plate together to ensure the edges align.

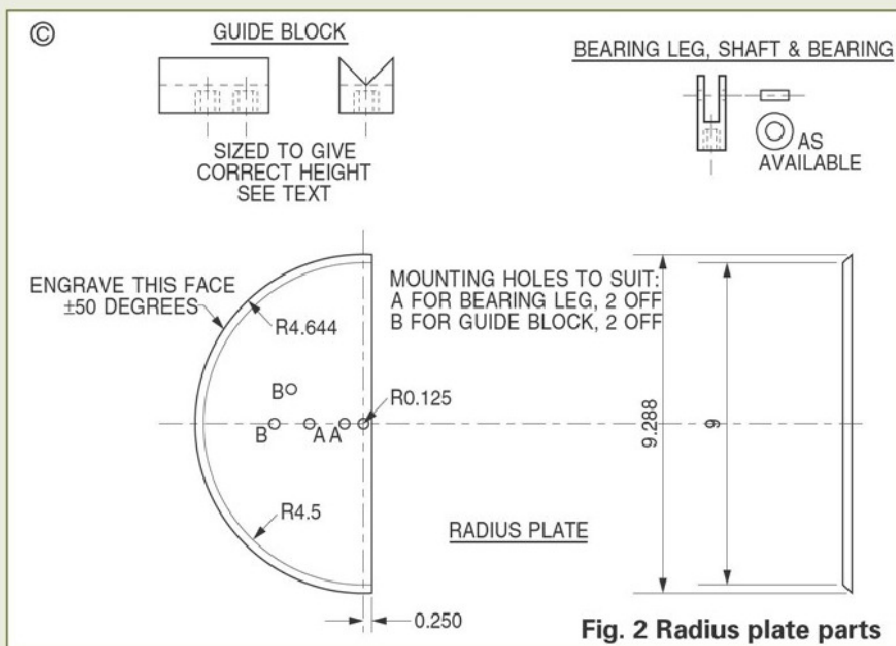
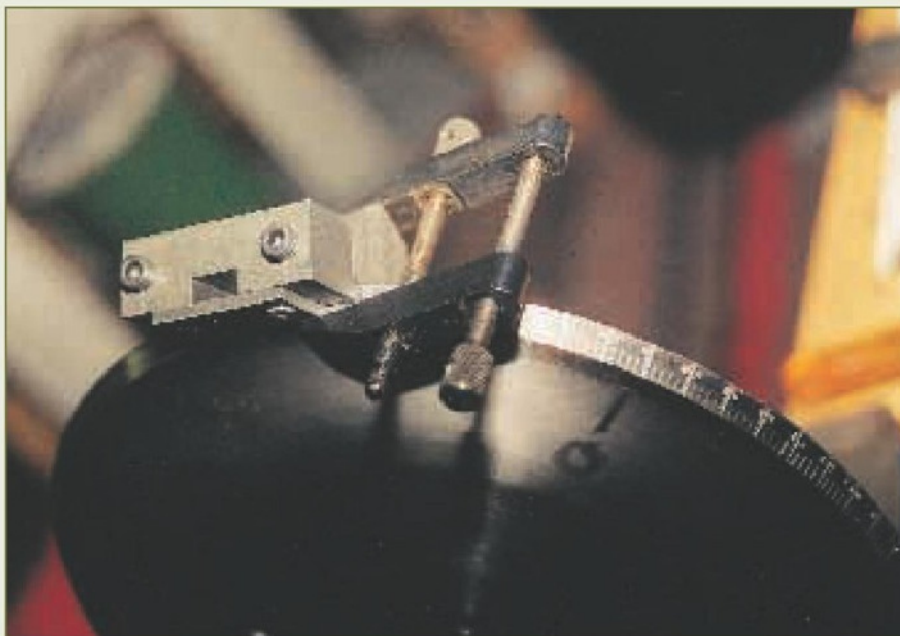


Fig. 2 Radius plate parts



10. Engraving the angle marks



12. The Punch Holding jig in operation.

becomes the pivot for the carriage. One side of the plate was faced up true. The plate was turned over and the other side made true the thickness being now reduced to $\frac{1}{4}$ in. I cheated here as a friend offered to surface grind it for the final finish and I jumped at the chance. The problem I was having, which led to the surface grinding, was never solved after several cuts trying different procedures. I could not get a good pattern free finish right across the plate. The difference in cutting speed from a radius of nearly 5in. down to a radius of $\frac{1}{4}$ in. was too great to allow any satisfactory combination of revs, feed and tool shape over the whole face that I could find. At one point or another, and usually from the centre to some distance away from it, a nasty turning pattern appeared. If the central band was made right then all hell broke loose at the outer band as the cutting speed increased OTT. It was impossible to stop once or twice across the face to change the parameters as this left a much worse mark

at the change point. I had a little under 125 thou to play with in the trials and I used it all. None of these effects would have prevented the plate doing its job but it just looked a totally unprofessional mess. If any readers have successfully solved this problem, then perhaps they might like to air their thoughts via Scribe a Line.

After surface grinding the plate was remounted on the face plate and the elemental carriage mounting plate was bolted to it. A piece of $\frac{1}{4}$ in. rod in the pivot holes lined up the two. The outer edges of both were turned together thus ensuring that they lined up as in **photo 9**.

The work was now transferred to the horizontal mill where the face plate boss was gripped in the dividing head chuck (a long time ago I had turned this boss true to the plate centre for just this type of job). A special plate and legs allowed the dividing head to present the edge at the correct angle for engraving the angle marks. (**photo 10**). Guided by the view in a dentist's mirror and with a great deal of



11. Punch holding jig, punches and spacers. Note the ground mark on each punch to help ensure it is used right side up.

care the marks from +50 to -50 were cut on the edge of the plate and the three fiduciary marks cut on the carriage mounting plate edge. In spite of the care, two of the $\frac{1}{4}$ in. end mills were lost in the process. This was definitely not the way to do it. I should have bought a new portable grinder (mine had died a while before and not been replaced) and mounted it on the milling table in a suitably made holder. The rest of the setup would have applied but at least the cutters would have been turning at close to their required speed.

The last job on the Radius Plate is punching the numbers on the angled flange. A piece of hex stock with its 60 deg angles helps to make a good holding jig for the punches as shown in **photo 11**. The spacers on the left align each punch the correct distance either side of the angle marks. It is shown in use in **photo 12**.

To be continued in the next issue.



References:-

- 1) Introduction to Manufacturing processes. John A Schey
- 2) Tool handed definition. Schey and "How to run a lathe" Southbend Lathe Works.
 - A) A right hand cutting tool starts its traverse at the right hand end of the cut and then traverses to the left.
 - B) A left hand cutting tool starts its traverse at the left hand end of the cut and then traverses to the right.
 - C) The right hand tool is the more frequently used in normal lathe operation where the workpiece sticks out from the chuck a relatively short amount; in reducing the diameter to size; the cut usually starts from the outboard end and moves towards the chuck.
 - D) Also a left hand tool is used to face the right hand END of the workpiece (the cut being outside to centre) as set up in (C) above for diameter reduction. If the cut is taken from centre to the outside then a right hand tool is needed.
- 3) Machining Data Handbook, Machinability Data Centre, Metcut Research Associates. Cincinnati Ohio 1980.

MUSING ABOUT... STAINLESS STEELS

Trevor Marlow casts light on some of the intricacies of the metallurgy of stainless steels in layman's language.

As a reader of Model Engineer's Workshop, you will often need to select a material for a novel purpose. At such times, if stainless steel is seen as a candidate, you will need information about the properties that are directly relevant to the intended application, such as strength, toughness, weldability or ... whatever. Also however, you will need to know about those behavioural "oddities" of stainless that often emerge during the fabrication processes, or during the subsequent service life.

Finding out about those *oddities* then presents a minor difficulty. While it is easy to obtain data sheets or texts to provide mechanical and other properties, getting information about the *oddities* is a different matter. They can have origins ranging from when the steel was being made, from when it was being stored, from when it was being formed, and from when it was being welded. After all that, there are those *oddities* that can occur while the material is in service. Having such diverse origins, information about the *oddities* is unlikely to be collected in one text or under one heading.

Here then, for what they are worth, I present these musings. In part, they seek to explain in non-technical language some of the terms that are used to describe the types and features of the stainless steels. In other part, they are recollections of occasions when stainless has proved to be far less than stainless. Finally, there are descriptions of when it has exhibited surprising behaviour during fabrication or subsequent service. Some of the content is from personal experience, some is from the technical literature for stainless, and some is gleaned from reports of materials problems experienced in Europe and the Americas.

To avoid the reader developing the heavy eyelids condition, I will in these musings seek to avoid technical terms, complicated explanations and detail (*I will however seek to explain the origin and meaning of vital materials identities (such as "Austenitic") that are, both in formal texts and in everyday descriptions, often used without explanation*). I will blithely skip from one topic to another. I will often add notes, in italics, to expand, just a little more when it seems appropriate. If you want more detail (within reason!), you are welcome to contact the author.

A fascinating material...

When my attention was first drawn to a stainless steel, many decades ago, I was

fascinated. How, I wondered, when it is still predominantly iron, can this material remain pristine through long exposure to the elements? (*It did not help my composure or understanding when I discovered that some bits of stainless were strongly attracted to a magnet, while others were not!*).

Since that distant time I have learned to parrot the explanations for stainlessness as offered in many texts, but I must confess that I still am not much wiser! I remain fascinated. Also, I still do much pondering about the "oddities" and their causes. If you decide to use stainless materials for real purposes, it is odds on that you will meet with at least some of these phenomena.

So: why doesn't it rust?

A start to these musings must be to go back to that first question: why is it stainless? Stainlessness, after all, is its definitive property.

The most commonly offered explanation is along the lines that when sufficient chromium is added to the iron, and the surface of that alloy is then exposed to an oxidising environment, that surface then takes on a very thin oxide coating which tends to be insoluble, impermeable, continuous and self-repairing. Such an explanation can be so easily understood, and accords with so many everyday observations, that it has been provided in some texts as if it is the totally proven and unarguable explanation. That explanation is in fact a *very convenient working hypothesis* that will serve for all everyday purposes. I often use it, and will indeed use it in this article. While we are in muse mode however, we should in passing at least observe that *other* explanations have been offered for stainlessness, even though those alternatives are now largely forgotten. The one thing that all parties can agree is that, when we reach a certain level of chromium addition, and expose that iron-chromium alloy to an oxidising environment, something very special happens to the surface!

(Notes: Stainless steel isn't really stainless until it has been exposed to oxygen or some other oxidising environment. The term used to describe whatever it is that happens during such exposure is "passivation". The nature of the oxidising medium and the duration of the exposure have been found to be important. As example, old surfaces tend to be more corrosion resistant than new

surfaces. Also, even in something like hydrochloric acid, to which stainless is not stainless, a pre-passivated surface will afford resistance for a short while, whereas an unpassivated surface will start to dissolve almost immediately. Perhaps such phenomena have been contributory to occasions where two identical pieces of stainless have, in the same solution, exhibited corrosion rates differing by more than one hundred times!)

What are the "alternative, largely forgotten hypotheses" for stainlessness?

One such hypothesis is that oxygen atoms bond to the surface ("*chemisorb*", from adsorb "*of a solid or a liquid, to accumulate on its surface a thin film of the molecules of a gas or liquid that is in contact with it.*") in the edge-of-lattice sites where metal atoms are "missing". Another hypothesis is that sufficient chromium (that which gives a ratio of about one chromium atom to every seven iron atoms) allows development of a continuous iron/chromium/oxygen pattern that has a special inert property. Still another hypothesis is along the lines that iron atoms are dissolved away at the surface until, on a statistical basis, we are left with an all-chromium surface that then "sorbs" oxygen. The several hypotheses beyond that inevitably start to get a little ... er ... complicated! They largely involve the location, availability and configuration of electrons in the iron and the chromium, and the vigour with which oxygen will bond to a surface made up of those atoms. Some of the arguments are rather persuasive, since besides offering explanation for stainless steels, they offer good explanation of passivity phenomena found in several other metal systems.

There have been wide-ranging contributions to the arguments. It has, for instance, been observed that iron and chromium atoms (because they have high values of Heat of Sublimation) must be very strongly bonded to their neighbours. That presents no problem to an explanation of passivity based on oxygen sorption, but formation of an oxide apparently requires that those strong bonds are broken. Perhaps that seems to suggest that a sorption process is the most probable? Maybe.

All in all, stainlessness is a complicated little topic. Several research workers seem to have demonstrated the presence of a ...

something ... let's call it a film. *(For instance, it was found possible (using electron diffraction) to study the arrangements of metal atoms under an unpassivated surface, but not under a passivated surface).* Other workers have demonstrated that if there is anything there, it must be exceeding thin! Some workers have managed to remove films from passivated surfaces, only to have other workers suggest that those films might have been generated by the treatments intended to isolate them! As an interesting little snippet, what are we to make of the fact that, way back in the late 40's, a very respected worker reported that stainless steels can be passivated in argon!

In my own mind's eye I see a metal surface, details unknown, that is completely and tenaciously covered by a layer of gas atoms, in a manner rather like barnacles may be seen to cover a boulder on the seashore. We must leave it at that. As said, I just don't know. *(Barnacles, by the way, can cause serious damage to stainless steels, by providing the conditions that lead to Crevice Corrosion!)*

Is "stainlessness" special to these "chromium in iron" alloys?

Some "ordinary" irons rust only very slowly, particularly when the metal is old, see e.g. the widely reported Iron Pillar of Delhi. Also, pure iron can lay doggo ("passive") in very strong nitric acid, despite dissolving vigorously in a more dilute nitric. There are many such phenomena. Peculiarities of surface are not special to stainless steels, many metals and alloys are protected in a broadly similar fashion. The key feature about stainless steels and those "many other metals" is that, if the peculiarities of surface did not afford protection, all such metals would soon (or eventually) become nothing more than corrosion products. Only the "noble" metals (e.g. gold) are destined to remain uncorroded, it being "energetically favourable" for them to do so.

When is it stainless? When is it not?

Having added sufficient chromium, the figure being 12% or so, we obtain an alloy that performs very well in most oxidising situations. It does not however perform particularly well either in situations that are not oxidising or that are too oxidising. It performs well only in between those conditions. So, if you drop a bit of stainless in cool, dilute nitric (a moderately oxidising acid) it will outlast your great-grandchildren, whereas if you drop a piece of stainless in a non-oxidising acid (say, hydrochloric), remember to bid it goodbye as you do so. *(Note: The stainless steels can offer good resistance to some non-oxidising media provided that the media contains sufficient oxygen).* The "too oxidising" situations occur rather rarely, to be found either in hellish brews, or under an impressed electrical potential, or in situations where an oxidising liquid has

been allowed to be stagnant. That latter situation is one of the reasons why it is vital to avoid crevices. We can return to that topic later.

Carbon, the cause of generations of problems ...

The earliest users of austenitic stainless steels soon realised an unwelcome feature of the new material. If it was welded, using similar material as filler, then on exposure to some environments, the weld corroded away! On investigation, it was discovered that the grain boundaries of the weld and adjacent materials were no longer stainless. They were heavily attacked, allowing rapid penetration between the grains and even, sometimes, for the grains to then fall away. The attack earned the description "weld decay".

Further investigation led to recognition that the reason that the grain boundary material was no longer stainless was because, locally, there wasn't sufficient available chromium. What had happened was that the chromium, in the region of the grain boundaries, had precipitated as strange carbides. *(The carbon, being a relatively tiny atom, tended to be concentrated at the grain boundaries).*

The steelmakers at the time were unable to remove sufficient carbon to prevent the occurrence of weld decay. The only remedy proved to be to give the welded material a heat treatment which removed the precipitation. No problem on small items, but not practicable on many larger structures.

In due course, researchers arrived at a reasonable solution. Further elements were added to the stainless mix, elements which had such a high affinity for carbon that they "fixed" most of the carbon. Fixing the carbon thus prevented the formation of chromium carbides, thus in turn preventing the local denudation of chromium.

Finding a cure for weld decay was not to prove the end of story. Further service experience showed that the modified ("stabilised") materials could sometimes exhibit a different type of corrosion, in the form of intense attack at the junction of the fused and unfused materials. The removal of metal was so localised that investigators likened it to a cut made by a knife. Because of that, the descriptive term for that type of attack came to be "knifeline". It came to be recognised that, other things being equal, steels that had been stabilised by additions of titanium were knifeline attacked much more heavily than steels that had been stabilised with niobium. The latter steels were then to serve at least adequately, until better steels came along.

Those better steels resulted from the steelmakers managing to reduce carbon contents to such a level that chromium carbides were not readily precipitated. So, weld decay was largely cured, and since there then was no point in making "stabilising" additions any more, so too was knifeline attack. The material near the welds continued to be attacked at *rather* more than "remote parent" rates, but the big problems due to carbon were over.

Why there is more than one kind of stainless.

If we can make a stainless steel by adding sufficient chromium, is that all there is to it? No, not really, because apart from a few castings, a simple chunk of unfabricated material is usually not much use to anybody. In the real world we usually have to make our metallic materials into knives, springs, sheets, tubes, rods etc. Often we then have to join sheets, tubes etc. to make complicated assemblies that will serve specific purposes. Obviously, depending on the context, such assemblies will need to be sufficiently strong, sufficiently leakproof etcetera, for the intended purpose. In some situations we might need stainlessness linked to superb formability, or ability to take a razor-sharp edge, or phenomenal toughness, or ... well ... you name it! These many requirements have caused evolution of some hundreds of stainless steels. That number can however be slotted into five or so primary categories.

Five primary categories? What are those categories?

The primary categories of the stainless steels are known as the ferritic, the austenitic, the martensitic, the duplex, and the "precipitation hardening". I will seek to explain each, in turn. *(Note: You might at this point ask a very reasonable question, which is, why do we need to go into such explanations? Well, for starters, in any category there are lots of alloys, as example there are 22 or so standard ferritics, never mind all the specials! The total of alloys in any category range over wide ranging chemical constitutions, so we cannot point to any one such alloy and say "That is (the) ferritic". They all are! Furthermore, as we will see, an alloy of a particular constitution can have one identity at one time (say, be austenitic, when hot) and another identity at another time (say, be martensitic, after quenching). In the light of such opportunities for puzzlement, is it perhaps easiest to know why something slots into a particular category? If you have no interest in such matters, and are only interested in the oddities, move down to "Stabilised, are you sure?" and carry on from there).*

To facilitate the explanations, we will refer to **Figure 1**, which shows a **much-simplified** diagram to facilitate explanation of some types of stainless steels. (Note: Much important detail has been deliberately omitted!). This diagram has increasing temperatures on the vertical axis, and increasing chromium contents (in iron) along the horizontal axis.

Note: I use the descriptions "Solid Type A" and "Solid Type C" in these explanations because I know that some people, new to the topic, are uneasy when faced with the Greek "alpha" and "gamma", as used in formal texts. The term "phase" in what follows means "structured or arranged in a particular fashion".

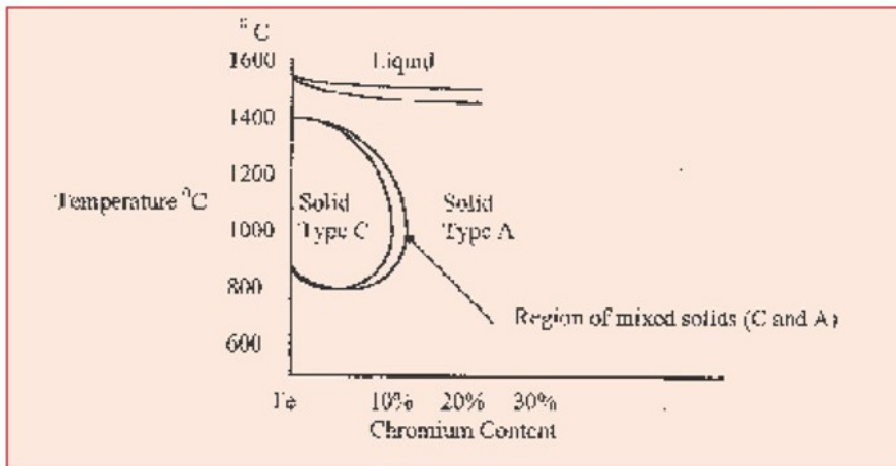


Fig. 1 The effect on structures of adding chromium to iron

Note: You might wonder: why no "Solid Type B"? The reason is that, in times past, men pondered the possibility of such a phase (they called it beta of course!) associated with the switch in magnetic properties at the "Curie Point". Such ideas aren't fashionable any more, so we are left with a gap in the sequence.

Note: The sequence of phase identities used to go alpha, beta, gamma, and delta, with delta being that phase nearest the melting point. For our purposes, on our diagram above, I have shown all ferrite as "Solid Type A". In more formal literature, particularly those describing weld microstructures, you may come across the description "delta ferrite". This is a ferrite that has survived all the way down from those near-melting temperatures.

We can use and develop this diagram (Fig 1) to explain what is meant by "Ferritic", "Austenitic" and so on, and how we arrive at those different structures. Let us get familiar with the diagram and what it represents.

Let us look along the horizontal axis until we arrive at the alloy with 20% chromium. Looking directly above that 20% marker, we see that the diagram is totally uncomplicated. All the way up to the melting point, we have "Solid Type A". Nothing else. The physical reality that is being described on our diagram is that a 20% chrome (and thus 80% iron) alloy is "happiest" with one type of crystal structure over all the temperatures on the diagram. No matter how long we cook it, it will never change to anything else.

Now let us look at zero % chromium on our diagram. Zero % chromium is of course pure iron. Let us examine what happens when the temperature of that pure iron is increased. Notice that up to about 900 deg C or so, the labels on our diagram tell us that it is "Solid Type A". Then, above the 900 deg C or so, the labels tell us that it is "Solid Type C", until at around 1400 deg C, we get a reversal. Our "Solid Type C" is shown to change back to "Solid Type A". It then remains in that latter state up to the melting point. The physical reality that is described by those parts of the diagram is that pure iron is "happiest" to be in one state up to about 900, it then is "happiest" in another state up to about 1400, and then it is "happiest" to revert to a "Solid Type A" state.

(Note: As I will explain, these "Solid Type X" states are the ways that the atoms

pack together, layer upon layer. When there is easy change from one Solid Type to another, the atoms "shuffle" with great elegance and economy of effort).

Having gone to the trouble to figure out our diagram, we are now in a position to benefit as we examine and explore the terms such as Ferritic, Austenitic etc.

What is "Ferritic Stainless"?

We will now cast our minds back to the simple corrosion resistant alloy I described earlier, that made by adding the 12% or so of chromium to iron. If we examine our diagram at 12% chromium, we see that it is "Solid Type A" at all temperatures. So, it must be Type A at room temperatures. Further study of our diagram shows that the Type A is also the way that the atoms are packed in a bit of cold iron. Having such similarity of structure, it is then not surprising that in many ways the mechanical and physical properties of ferritic stainless are quite like those of a mild steel. For instance, those alloys stick to it! Within the range of these "ferritic" alloys, many are specifically "tailored" to have optimum properties for one purpose. As example, using the alloys tailored exactly for that purpose, it can be a great material if you wish to make complicated pressings etc. Containing little if any nickel, it is relatively cheap. It is sufficiently stainless for most applications, but it has one big drawback. That big drawback is, that if you need to weld it, those weld regions can be very prone to failure by cracking. There often isn't an easy way around the problem, which explains why, for a lot of jobs, people use the austenitic grades.

What is "Martensitic Stainless"?

We can arrive at the easiest explanation of the Martensitic Stainless Steels using our Fig 1 diagram, but note however right from the outset: the cost of a simplified explanation is that we will need to do a minor correction at the end of the day.

Consider for starters the alloy at 10% chromium. Let us visualise how it cools down from high temperatures. Soon after solidification, we see that it is a Type A

material. As it cools further, it is "happiest" to be a Type C material. (No problem here. Since it must still be somewhere around 1200 deg C, the atoms can shuffle easily to their new "preference"). Further cooling will then bring us to the point where the atoms would be "happiest" to change again, back to the "Type A" material. There is however, at this stage, a difficulty. At the lower temperatures, shuffling isn't quite so easy. Transformations are sluggish. So, particularly if the material is subjected to a quenching treatment (a rapid cooling curtails the opportunities for change), the result is rather like a motorway pile-up. There is change all right, but to a chaotic structure, to something that we can liken to a randomly oriented pile of needles or broken floorboards. It is sufficient for our purposes to think of that chaotic tangle as the martensitic structure.

Such tangled structures do not deform easily. Nothing slips easily, nothing slides easily. The consequence is that, when we examine the material properties with our testing machines and instruments, we find that the metal is "hard" and "strong".

(Note: The properties (and microstructure) of a martensite can be very variable, depending on the particular constitution of the steel and on the thermal treatment it is given. The carbon content is particularly important in this context. A steel containing hardly any carbon will remain relatively soft and compliant. A steel with a lot of carbon will, before tempering, be incredibly hard and as brittle as glass).

You may ask: Where does the identity "Martensite" come from? The answer is that it happens that this tangled condition (which I have described as "a randomly oriented pile of needles or broken floorboards") occurs during heat treatment of ordinary alloy steels. As such, it was investigated long, long ago by Adolph Martens. To honour that effort, the structure came to be called Martensitic. It then followed as natural consequence that the term would be applied to such structures when they were found in certain stainless steels. The martensitic stainless steels can therefore be thought of as broadly comparable to our range of everyday alloy steels. Their great virtue, besides the stainlessness, is that by a simple heat treatment, they can be made very hard and very strong. Great stuff (the high carbon varieties) if you are making surgeon's scalpels!

Now we come to the time where we need to make the minor correction mentioned right at the beginning of this "Martensitic" section! Recall that for clarity of description we chose to examine the case of a 10% chromium alloy. That is fair enough, except that we then realise that the chromium content of that alloy falls short of the 12% figure needed to provide us with the fully stainless condition. Now then, notice that we cannot get round that problem by simply increasing the chromium content to 12%, since such an alloy does not properly go through the "Type C" to "Type A" change. The solution we can arrive at is that we do increase the chromium content, but we also add other elements (such as carbon and nickel) which will cause distension of the "Type C" curve. Tricky stuff. By making the loop

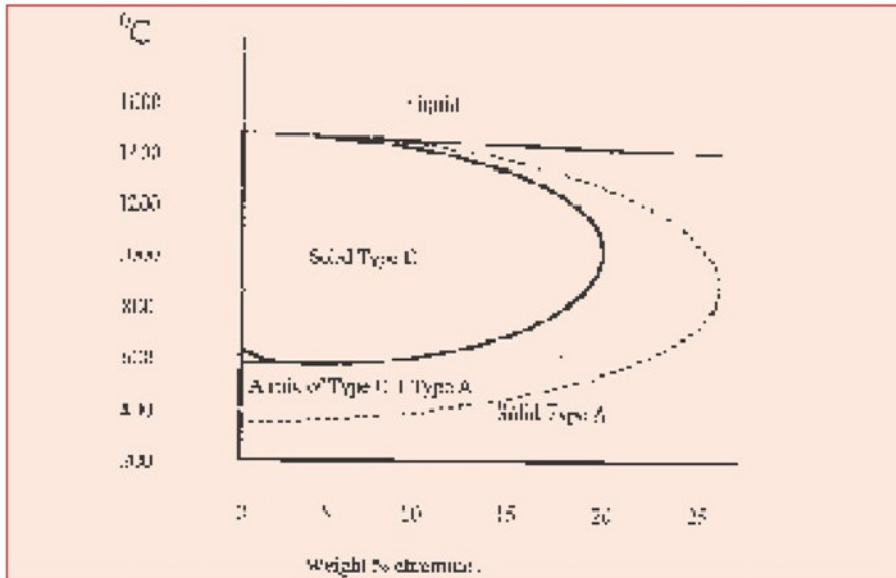


Fig. 2 The effect on structures of changing chromium content in an iron/chromium/nickel alloy when nickel is fixed at 8%.

bigger, we make it possible to have a martensitic structure developed in a material with 12 or more % of chromium, so we can have super hardness and strength in the fully stainless condition.

What is “Austenitic Stainless”?

And so we come to the austenitic stainless steels. These are so darned useful that they are everywhere. Being the most useful of alloys, but with more than their fair share of the “behavioural oddities” I warned you to expect, it is best if we now spend a minute looking at what they are and what dictates their properties.

We have already, above, noted that we have to add other elements (such as nickel or carbon) if we want to make a stainless martensitic structure. When we seek to make austenitic stainless, we again have to add such elements, only more so!

In our efforts to study this topic, we now come up against a minor difficulty. That difficulty is, *that there isn't a totally easy way to draw a graph of the preferred crystal structures of alloys that contain more than two components*. In Fig 1 above we looked at a horizontal axis with pure iron at one end and pure chromium at the other. How can we now look at the solids types existing in a *three* way mixture: of iron and chromium and nickel?

The way that we will choose is to fix one of the components at a particular value, in our case we will fix the nickel at 8%. We then can construct a simple two dimensional graph (Figure 2) with maximum iron (i.e., 92% iron plus 8% nickel) at one end of the horizontal axis, and maximum chromium (i.e., 92% chromium plus 8% nickel) at the other.

If we compare the two diagrams Fig 1 and Fig 2, we see the major difference (of adding 8% nickel) being that the “Type C belly” has about doubled in size. Also, whereas in Fig 1 the “mixture of Type C and Type A” region is small, in Fig 2 that “mixture” region is much bigger. Now, with our new diagram we can examine a real alloy and start to understand what

“austenitic” is all about. Let us look at an alloy at 18% chromium, remembering that *every alloy on our diagram already contains 8% nickel*.

Let us now visualise how an 18Cr/8Ni alloy *might* cool down, by tracing down the thick black line in Figure 3. We need not concern ourselves with what happens at high temperatures. It is sufficient to see that between about 1200 C and 800 C, the alloy should be “Solid Type C”. Below about 800 C, the Solid Type C should start to change to Solid Type A, until finally at about 450 C it should all be Solid Type A.

As said, that is how the 18Cr/8Ni alloy *might* cool down. What *actually* happens is very different! The presence of so many mis-fitting atoms makes the transformations (from one type of solid to another) very sluggish. So, at “ordinary” cooling rates, transformations effectively cease while everything is still Solid Type C! That is the definitive thing about our austenitic stainless steel. It is one in which, at room temperatures, and for an indefinite time, it can exist in a structural arrangement that really “belongs” to

higher temperatures. So, austenitic stainless steels are essentially all “Solid Type C”, and the properties of the material are dictated by that structure.

One such property follows from the fact that Solid Type C is relatively remote from the region of the diagram where alloys are ferromagnetic. So, the austenitic stainless steel is usually not strongly attracted to a magnet. The other characteristic properties (it work hardens, it work strengthens, it is tough, it can become ferromagnetic, and so on) follow in part from it being the Type C structure and in part from it always having the latent tendency to change to the Type A structure. We will return to these matters later.

What is “Duplex Stainless”?

In the context of the home workshop, these are relatively minor players and you may never meet up with them. The name comes from the fact that they are made up of two major constituents. Under a microscope, it is often seen that islands of austenite are set in a sea of ferrite. (Note: *In the manufacture of stainless steels, several things happen that lead to heterogeneity, which is the concentration (or denudation) of certain elements at certain locations. At the same time, diffusion is sluggish. The result is that the stainless steels, examined at microscopic levels are often found to be a mix of several “constituents”. Additionally, across any constituent, chemical composition may be very variable.*)

The duplex alloys were originally developed because they offered degrees of advantage in situations where standard grades had proved less than satisfactory, e.g., they have better toughness than the ferritics, and they are more resistant to Stress Corrosion Cracking than many of the austenitics. Duplex steels can now be made to contain nitrogen. Such alloys can be cold worked to very high strength, and may exhibit excellent corrosion resistance in the as-welded condition.

(Note: for Stress Corrosion Cracking: see elsewhere in this article.)

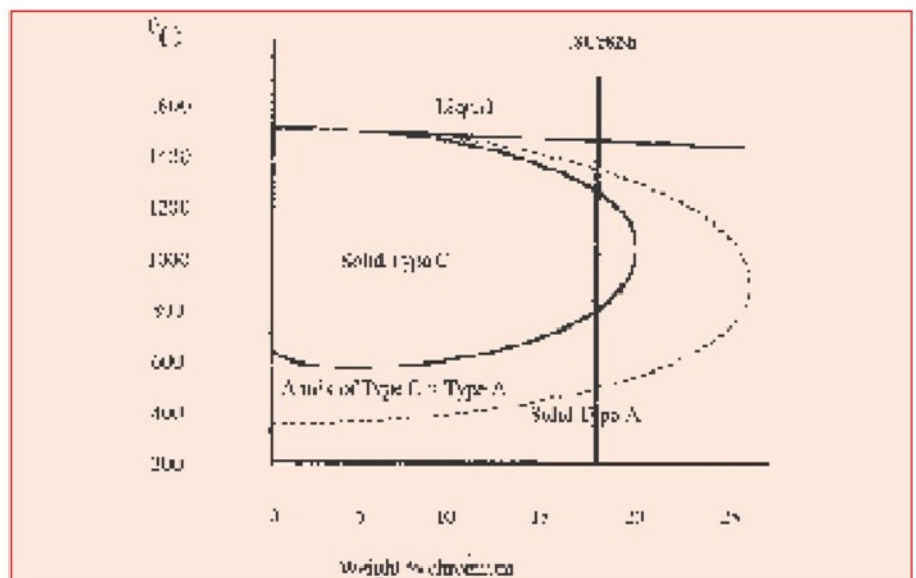


Fig. 3 The cooling of an 18Cr/8Ni alloy

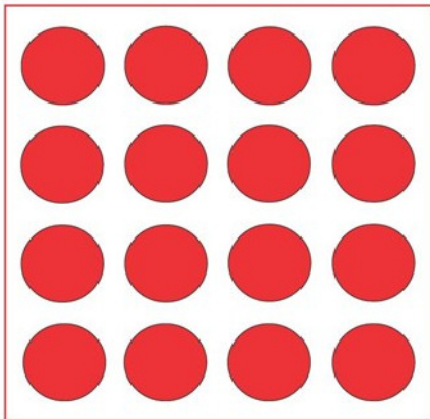


Fig. 4 A first layer of atoms on which we may build the ferrite structure.

What is “Precipitation Hardening Stainless”?

(Background Note: Precipitation Hardening is a phenomenon brought about by special alloying additions and thermal treatments. These result in widespread generation of particles, by precipitation from the mix of metal atoms. The particles, which are large by comparison to the sizes of atoms, inhibit the rippling processes (“dislocation movement”) whereby metals deform at relatively low stresses. The consequence is that higher stresses are needed to cause deformations such as indentation or extension. We see that need for the higher stresses as the metal being “harder” and “stronger”).

As has been described, some stainless steels can be made hard and strong by cold work, and others can be made hard and strong by quenching to produce the martensitic “pile of needles and broken floorboards”. Such treatments are not always convenient however. So, it would be very nice to have a stainless that becomes hard and strong if given a simple thermal treatment, at relatively low temperatures.

The requirement for such a stainless has led to several types, which have become collected together under the title “Precipitation Hardening”, even if that title might not always be strictly accurate. The elements used to bring about the precipitation (titanium, aluminium, copper, molybdenum...) are often used in combination. In some of these steels the precipitates serve to strengthen what starts off as, and continues to be, a Type C structure (an austenite). In others, the hardening is brought about by having a Type C alloy with such a constitution that it is more than usually prone to transform to martensite, that “pile of needles and broken floorboards” described earlier. These latter alloys are given a thermal history that ensures that they *start off* as a Type C structure, but they only remain a Type C structure until they are warmed and/or worked. Such warming and/or working causes the transformation to martensite, which of course makes the steels harder and stronger. The process is then rounded off by precipitations *within* the martensite, so there is still further hardening and strengthening.

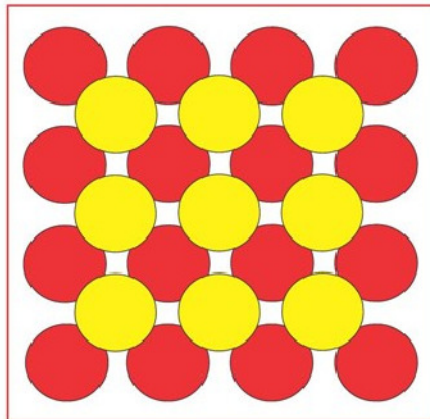


Fig. 5 The second layer of atoms in our ferrite structure.

So much for technology, now for a bit of good old-fashioned carping and prejudice! I must confess that I am not enamoured with these alloys. They are OK if you are in desperate need of special combinations of strength and toughness, but the simplicity of the original idea seems to have been lost. Instead, we have ended up with complicated and mysterious constitutions that seem to defy all logic. Compared to the other grades, they do not prove to be very corrosion resistant. Heat Treatments can be tedious and complicated. There can be misunderstandings and complications re the condition in which the materials are provided by the supplier. With their special benefit being special combinations of strength and toughness, it is particularly distressing that they often will be found “out of spec” re hardness and strength even when their complicated heat treatments have been followed to the letter. In total, I suggest that these alloys are not for the faint hearted.

These identities ferritic, austenitic and so on: what do they come from?

The identity *ferritic* comes down from the latin *ferrum* for Iron. The other two identities (martensitic, austenitic) come down from the early investigators, from Adolph *Martens* (mentioned previously) and from W.C. Roberts-Austen. The terms ferritic, martensitic and austenitic actually describe the *structure* of each material, the *structure* being the way in which the atoms are packed together. So, for instance, a ferritic steel is not chemically just of one composition, it is not just of one mix of metals. Essentially, it is made up of whatever mix of metals and treatments will lead to the atoms layering in the ferritic pattern.

This “ferritic” structure. Can I visualise it?

To get the basic idea, examine the pattern shown in **Figure 4**. Each of the red circles represents a spherical atom. Note

two things: that the atoms are arranged in squares, and that there is some space between the atoms. (Note: You could arrange snooker balls on a table top in such fashion).

Now, if we assume that atoms will move to pack as closely as possible, where is it likely that a second layer of atoms might choose to rest? (Where would a second layer of snooker balls, under gravity, choose to settle?). The solution is illustrated by the positions of the yellow circles in **Figure 5**.

Right. Now where will a third layer “choose” to rest? Since those spheres must settle most comfortably in the spaces between the yellows, they must be *directly above* the original red circles. The fourth layer must then lay *above* the yellow circles. And so on, for many thousands of layers. Notice how, on the sketch, the lay of atoms is the same, side to side or up and down, as I have described for the layering process. Notice the symmetry of the whole structure. Notice that any yellow atom is (in 3 dimensions) in a “box” of eight red atoms, and that any red atom is are similarly “boxed” by eight yellow atoms. You are, in effect, looking at how the iron atoms lay in a piece of cold iron, and similarly, how the mixture of iron and chromium atoms lay in piece of ferritic stainless. Often termed “body centred cubic”, that is the structure of ferrite, and also a range of other metals such as chromium, molybdenum, vanadium and niobium.

What about the “austenitic” structure? Can I visualise that?

To get this picture, examine the arrangement of the first layer of atoms shown in **Figure 6**.

Note that, in this instance, each atom is in firm contact with its nearest neighbours. Now, as before, we visualise where the atoms of the next layer will rest most easily. (Where would a second layer of snooker balls settle under gravity?). Our second layer of atoms will rest most easily in the hollows between any four of the “first layer” atoms. Using yellow circles for the second layer we get the arrangement of **Figure 7**.

The same pattern, but in a different position. A third layer of atoms would rest over the sites of the red circles, a fourth would then rest over the yellow circles... and so on. The term used to describe the austenitic structure is “face centred cubic”, which is, “based on cubes, but with one extra atom in every face of every cube”. That is how the atoms are laid in a piece of *hot* iron or in a piece of *austenitic* stainless steel. (and, incidentally, how they are laid in copper, nickel, aluminium, lead, gold, silver and platinum).

(Note: For “hot” in the sentence above, I mean between about 900 C and about 1400 C.)

(Note: In order to illustrate with greatest simplicity, Fig 7 is “plan view”. If viewed from other directions, such an assembly of atoms would be seen to be a compact, three dimensional assembly of perfect hexagonal arrays. No room here for a full description, unfortunately!)

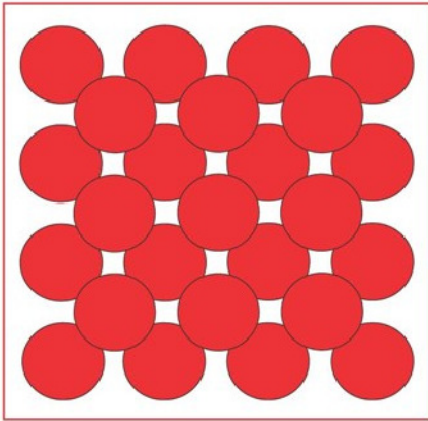


Fig. 6 The first layer of atoms on which we may build our austenite structure.

Structures such as those sketched above can change one to the other (say a Type C (austenitic) to a Type A (ferritic)) if they are "pressed" to do so by changes in temperatures or by details of the chemical constitution. You may wish to re-examine the question "How is it that we can get the same structure in a piece of *cold* stainless steel as we get in *hot* iron?" As described earlier, the explanation is that our austenitic structure is a frozen memory of what was "preferred" at a previous time. It is retained in the atomic arrangement that was "preferred" when it was at the higher temperature. There is incentive for change, but all those foreign atoms have made things very, very sluggish.

(Notice, by the way, the ease with which this structure can deform. Visualise the large number of ways that, in three dimensions, the "planes" of atoms might slide one over the other. Such visualisation suggests the properties that will result, and explains why some metals are so workable.)

What about the Martensitic structure. Can I visualise that?

We could arrive at the visualisation of martensite by working through our layers

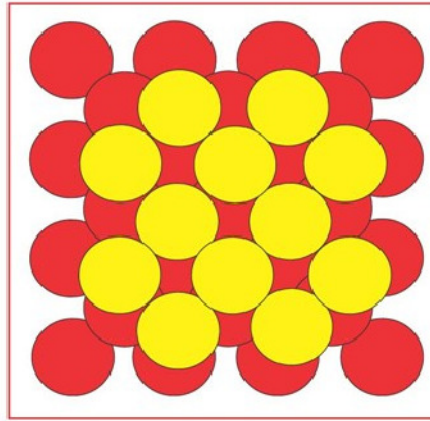


Fig. 7 The second layer of atoms in our austenitic structure.

of atoms, as we have done previously, but the drawings would be too complicated for our purposes. Instead, let us arrive at a sufficient visualisation by building on what we have done previously. Figs 4 and 5 formed the basis from which we built up to the ferrite structure. Then recollect that every odd-numbered layer (3rd, 5th etc., any that would be coloured red) is laid exactly above the previous odd-numbered layer. Thus the *sheets* which are in *square array*, build up to a *volume* that is in *cubic array*. (The even-numbered layers provide an atom (which I have coloured yellow) at the centre of each cube, so in total we have a structure that is "Body-Centred, Cubic").

Now, visualise what might happen if a previous structure ("Face-Centred, Cubic", our austenite) went through the transformation process of becoming the "Body-Centred, Cubic" structure but something got in the way. (That "something" is carbon, sitting between the bigger (metal) atoms). If cooling is slow, it has the chance to get out of the way. If cooling is quick, it hasn't. The consequence, the structure resulting from "something having got in the way", will be something that resembles the "Body-Centred, Cubic" structure, but it will be deformed. The nature of the deformation is that something gets stretched!

In a cube, the three axes are at right

angles to one another, and the three sides are all of the same ("unit") length. The deformation to the cube that we get in our martensite is that the three axes are still at right angles one to the other, but only two of the three sides are the same length. The length of the third side is now made different, it having been strained by the presence of carbon trapped between the bigger atoms. The term for the martensitic structure therefore is "body centred tetragonal". For our purposes we can think of it as a distorted ferrite. (Note the significance of the level of carbon content. A lot of carbon leads to a lot of distortion, which makes any deformation and flow very difficult, which means that we end up with a hard and strong material. Conversely, if we have very low carbon, there is hardly any distortion, which means that deformation and flow remains fairly easy, hence our material remains relatively soft and weak). The situation is made more complicated by various crystallographic phenomena which, for the purposes of this article, we can ignore. I suggest that while we should be aware of the origins of the body centred tetragonal structure, but that for our workshop purposes, think of the structure of martensitic stainless as resembling a random pile of needles and shattered floorboards! They both deform with equal difficulty!

Can I visualise the Precipitation Hardened structure?

As noted elsewhere, several different types of structure are hardened in this fashion, so you will have to do a visualisation job for each! Basically, you start off with visualisation of a structure that can deform, then you visualise introduction of many vast obstructions (i.e., the precipitation). It then does not deform anywhere near as easily (i.e., it is hardened).

In the next issue, we will address the question of identifying stainless, various pitfalls, and some aspects of failure.



Quick Tip

From Mr M Rhodes of Bridlington

On those machining operations when it is required to keep a count of each turn of the handwheel, the following may be preferable to the pile of washers method which is often used.

Even the cheapest calculators nowadays can be programmed with a constant, and so it is possible to turn the calculator into a simple up down counter as follows:

1. Switch on the calculator and index a 1
2. Press the + key. (Many calculators need this to be pressed twice)
3. Press the = key
4. Press the zero key (this to reset the display)

This completes the programming and now when using the machine, as each turn of the hand wheel is completed, pressing

the = key will increment the "Counter" by 1. On reaching the required number of turns, pressing the +/- key (if the calculator has one), will with successive presses of the = key count back to zero. Further presses produce a count up again. Alternatively press the zero key to begin another count for calculators without a +/- key

A preset amount can also be entered to count down to zero. For example, to count down from 10.

5. After step 4 above, enter 10 on the keypad.
6. Press the +/- key to display the - sign. Now, each time the = key is pressed the display will decrement by 1.

The process can be taken a stage or two further. If at step one, instead of entering 1, you may choose to enter the number of millimetres or thous which relate to one turn of the handwheel. The display will



The Calculator (complete with oilstains) is a versatile alternative for the traditional pile of washers

then indicate linear movement of the table for each complete turn. It is also possible to enter a required length of cut at step 4, then press the +/- key and count down, being careful to refer to the handwheel on the final turn.

TRADE COUNTER

Book Reprints

The approach of summer should hopefully herald weather less suited for fireside reading. However if sun bathing in a deck chair with a book to help plan the next workshop project is your chosen relaxation technique, then the recent reprints from Tee Publishing may well be of interest. Available once more after an absence of several months is *"A Man and His Lathe"*, by Lawrence H. Sparey, which is aimed specifically the Myford ML7 owner. The chapter headings give a general insight into the contents: Suggested Improvements to the ML7, Home Made Accessories, Myford Accessories, Aids to better Results, and Notes on Maintenance. Interestingly, a design of boring head shown in this book appeared somewhat familiar. About twenty years ago, I borrowed one made by a friend, and produced my own using his as a master. Now I know where he found the design.

"Lathe Accessories – how to make and use them" by Edgar T. Westbury was last reprinted in 1964, and has therefore been largely unavailable for the past thirty years.

Written with general reference to the smaller lathe, the book's nine chapters are entitled: Devices for Centring, Chucking Accessories, Toolholders and CutterBars, Dividing Appliances, Simple Milling Attachments, Steadying Appliances, Various Forms of Cutters, Aids to Screwcutting, and Miscellaneous Accessories.

Both books are well illustrated with numerous photographs and line drawings (many with details and dimensions). For the newcomer to the hobby, each provides a source of ideas, accessories to make, and distilled wisdom, for the old hand, probably a few added tricks of the trade, and a reminder of many things long forgotten.

One other title reintroduced, again written by E. T. Westbury is *"Flash Steam"*. For those who may wish to look beyond conventional model boiler designs, the content of this publication could provide an alternative approach. In addition to an overview of history and development, the book provides much detail on types of boiler and engine arrangements, together

with information on firing methods, boiler feeding, and valve gears.

These and other books are available from TEE publishing on 01926 614 101, or through reputable booksellers.

Tapping it Large

Guy Lautard in Canada, sent information on his website www.lautard.com which amongst other offerings and links to other interesting sites gives news of plans to manufacture a batch of special taps for accurately cutting the Myford spindle nose thread (1.125in. dia. by 12 tpi BSW right hand) in homemade faceplates, catchplates, chuck adaptors, etc. This thread is used by Myford ML10, Diamond 10, and all 7 series lathes, prior to the latest "Connoisseur" models. Price for the tap is stated to be \$96 plus carriage. The website gives full details. The taps are not made or approved by Myford, but are offered as a means to accurately produce the required female thread form in the various accessories that may be used on a Myford.

IN OUR NEXT ISSUE

Coming up in Issue No. 84 will be

Milling Machine Projects for Beginners

Having concluded the successful Lathe Projects series, Harold Hall presents guidance and projects related to the Milling Machine.



Taming a Wandering Head

Philip Amos adds a reinforcing clamp to improve the accuracy of his Taiwanese Mill/Drill.



Nickel Plating

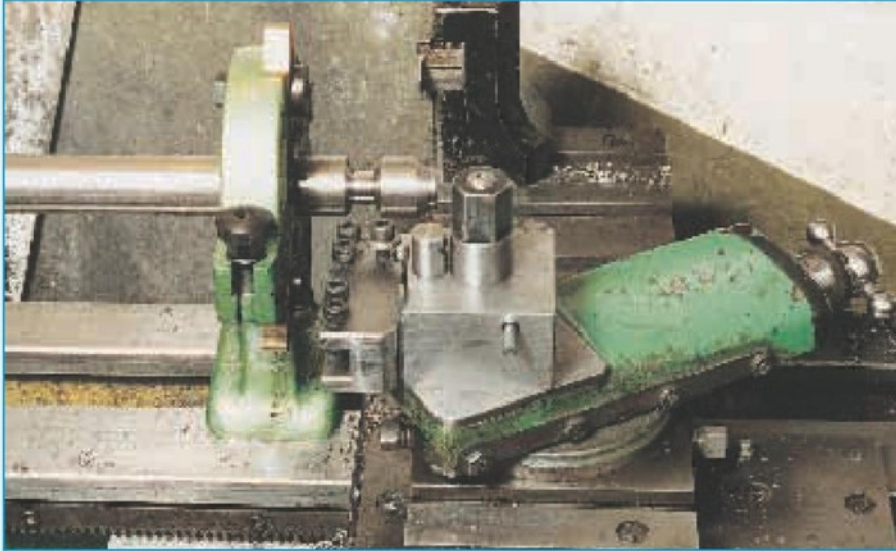
Peter Rawlinson gets to grips with DIY electroplating.



Issue on sale 2nd August 2002

(Contents may be subject to change)

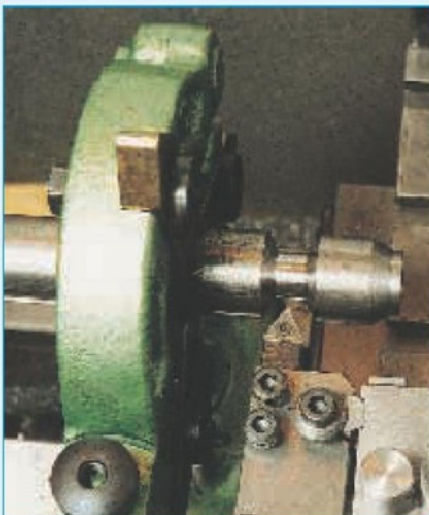
LATHE PROJECTS FOR BEGINNERS (17)



11. Making multiple short parts in this way avoids finishing up with many short stubs when parts are individually held in the chuck.

Collets (3)

Take a length of 22 mm. diameter say 300 mm. long and place in the three jaw. Use the four jaw if your three jaw is not sufficiently accurate. Fit steady adjacent to the chuck and set jaws. Move steady to 50 mm. from end of bar for machining the first collet, **Photo 11**. Face end. Centre drill and drill, just smaller than the bore of the collet being made. With a drill, 1.3 mm. smaller than the bore of the collet being made, drill to a total depth of 42 mm, this is about 0.2 mm. larger than the core diameter of the thread eventually to be cut. Machine 16 mm. diameter and the 30 degree taper. Machine groove, **Photo 12**, diameter depending on bore of collet being made. I used a triangular tipped tool for this so the



12. Turning the collet groove.

groove has sloping sides. Bore the collet making it a close fit on the cutters to be held. Machine the outer diameter to 22 mm. to be a close fit in the collet body. Part off at 38.2 mm. length. Move the steady back towards the chuck and make the next collet.

Using a four jaw chuck (unless your three jaw is very accurate) fit the first collet, protected, and adjust to run true. Face end to a length of 38 mm. Lightly chamfer end. Make thread, free fit on endmill thread, using a single point tool, **Photo 13**.

Cut a piece of 20 mm. square about 50 mm. long. Fit four jaw and fit piece of metal making it run reasonably true. Face end. Centre drill and drill, say 12 mm. diameter, and 6 mm. deep. Bore to 22 mm. diameter, 5 mm. deep, **Photo 14**. Drill and tap M5. Using available scraps of material set up guides for positioning collet and fit suitable slitting saw in the chuck, **Photo 15**. Make first slot. Remove collet with holder, rotate 90 degrees and make second slot. Repeat for slots 3 and 4, **Photo 16**.

The Milling Chuck. In this second part of the concluding project, Harold Hall draws the series to a close, having shepherded and encouraged the raw beginner to a stage of being an accomplished turner.

Using the same setup principle but with collet raised with additional packing, make cut-out in base of collet using a 6 mm. endmill, **Photo 17**.

Holdings (4 and 5)

Make these following the same procedures, where appropriate, as for the collets. Take note of the comments on the drawings regarding positioning of holding screws. These holders are not slotted. Dimensions for the positioning of the holding screws are not given as I am not sure that the position of the flats on the end mills are standardised from make to make. In this context it may be worth while standardising your source of supply of such cutters.

Collet locating peg (6)

Place a piece of 10 mm. diameter in the three jaw. Reduce diameter to 8 mm. over a length of 10 mm. Lightly chamfer end. Part off at 16 mm. overall length. Shape end of peg, by hand if necessary. Fit into collet body. On the drawing, I have suggested that the peg be retained by centre punching, Loctite would be a suitable alternative.

"C" Spanner

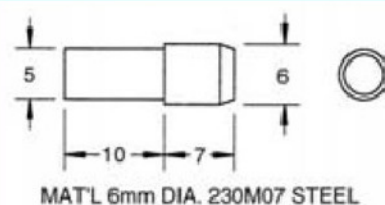
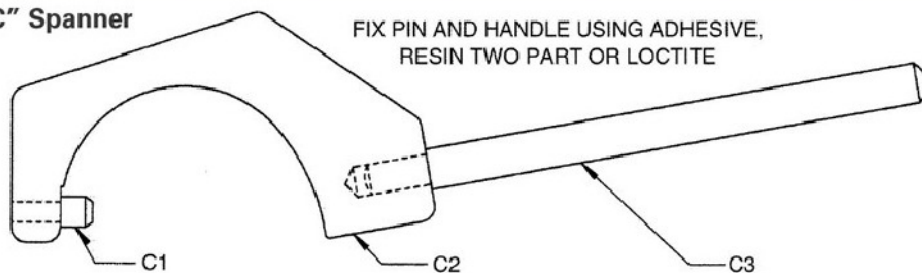
The components required for this are shown as C1, C2, and C3, and as making the item is relatively straightforward, I will only detail the major points. Cut a piece of steel for



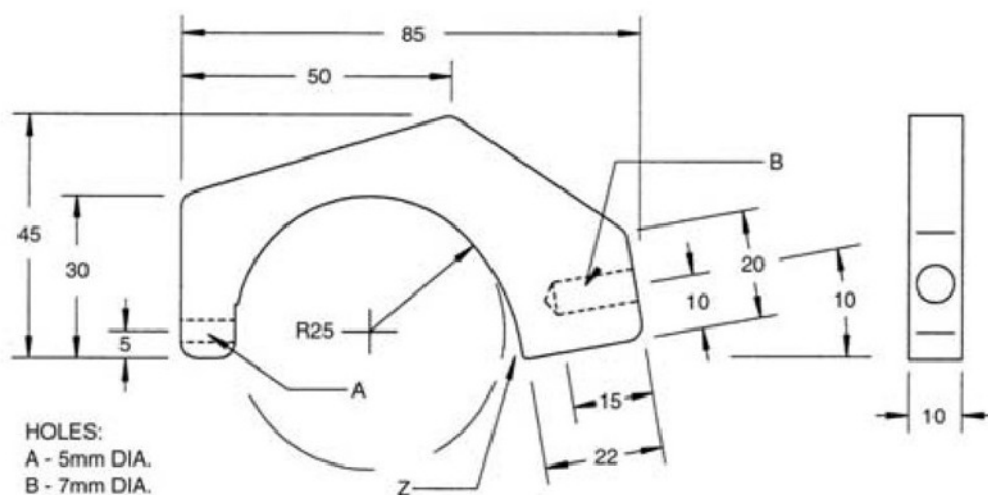
13. Making the thread in the base of the collet.

"C" Spanner

FIX PIN AND HANDLE USING ADHESIVE,
RESIN TWO PART OR LOCTITE



C1 Drive pin



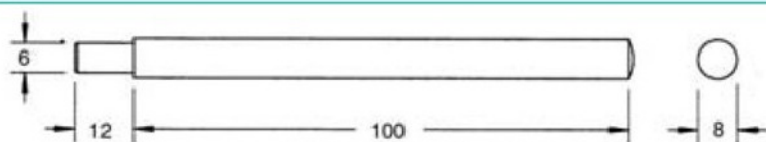
HOLES:
A - 5mm DIA.
B - 7mm DIA.

NOTE:

Z - SHAPE TO ENABLE SPANNER TO FIT COLLET CLOSING RING

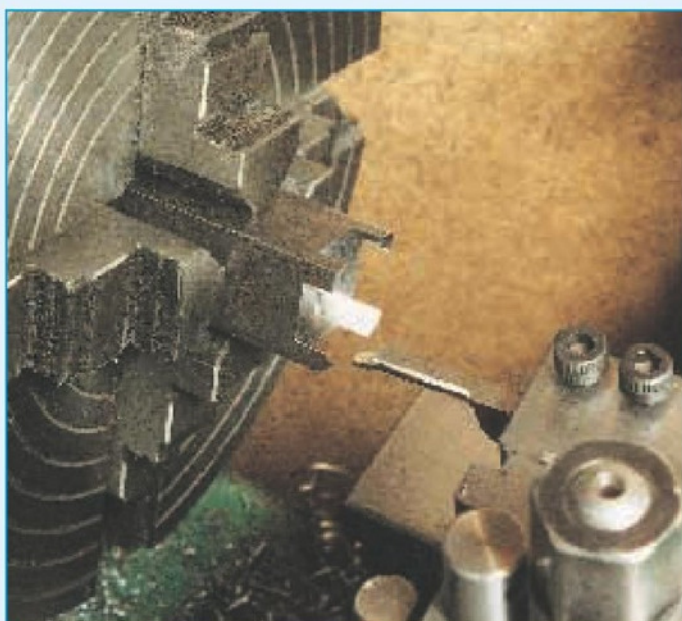
MAT'L 45mm x 10mm STEEL, GOOD COMMERCIAL QUALITY (080A15)

C2 "C" Spanner body

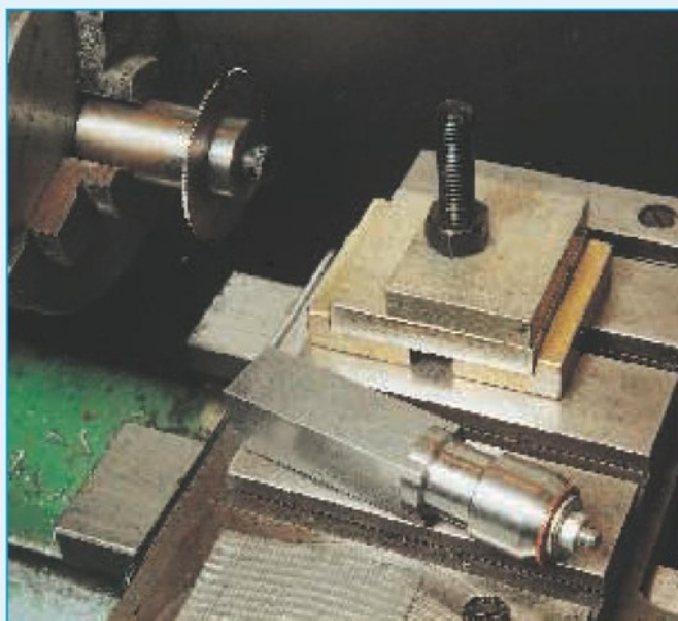


C3 Handle

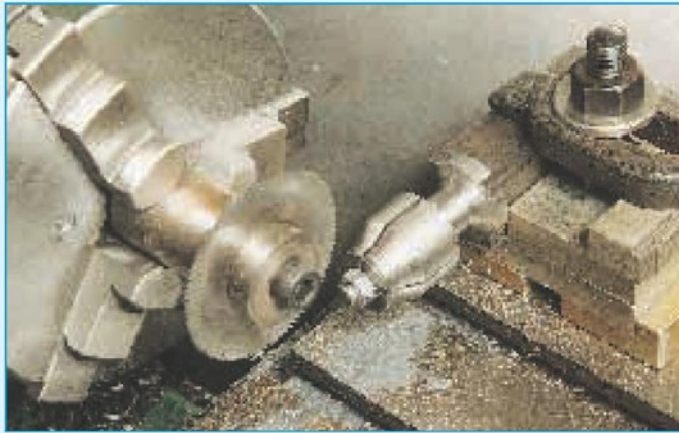
MAT'L 8mm DIA. 230M07 STEEL



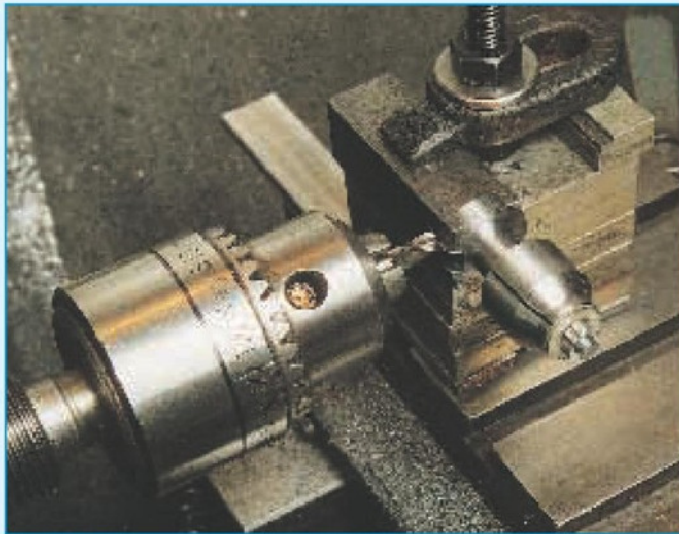
14. Making a fixture for holding the collets for slotting, see photos 15 and 16.



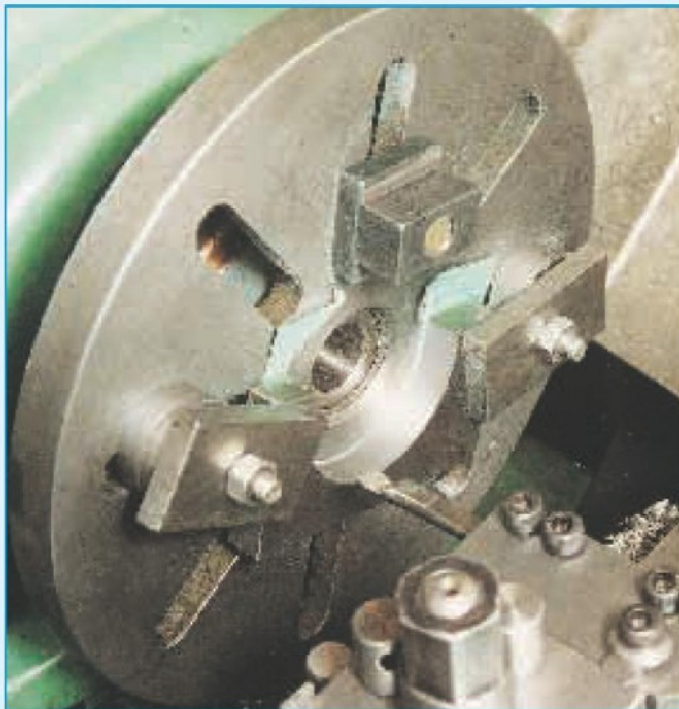
15. Setup for locating collet holding fixture, see photo 16.



16. Collet being slotted.



17. Using the same holding fixture for making the cut-out in the base of the collet.

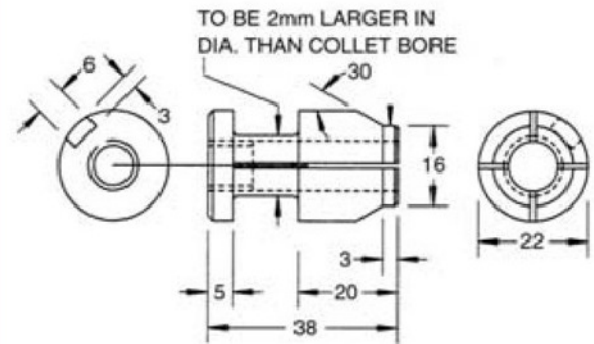


18. Boring the "C" spanner.

the Body (C2) mark out the centre position of the cut-out and centre punch. before making the cut-out, drill hole "A" ensuring it is in line with the centre point of the cut-out.

Fit faceplate and position body on this using the tailstock centre in the centre punched impression, clamp in place. Place a piece of thin card between body and faceplate to avoid the boring tool

damaging the faceplate as it breaks through. Balance faceplate assembly. Centre drill and drill 10 mm. diameter. Bore to 25 mm. radius, **Photo 18.** Shape. Drill hole "B". Make other parts. Assemble.



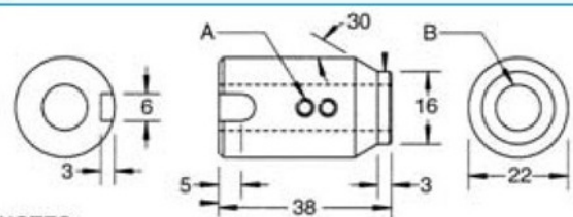
NOTES:
THERE WILL BE NO 3mm PROJECTION ON THE 16mm AND 5/8 COLLETS 20mm WILL BECOME 17mm, AND 38mm WILL BECOME 35mm

MAT'L 22mm DIA. 230M07 STEEL

SLOT COLLET WITH AVAILABLE SLITTING SAW, 1mm TO 1.5mm WIDTH PREFERRED

THE THREAD IN THE COLLET BORE IS 20TPI WHITWORTH FORM, FOR BOTH IMPERIAL AND METRIC SHANK DIA'S. MAKE THIS A VERY FREE FIT ON THE CUTTER SO THAT ONLY THE COLLET JAWS ESTABLISH THE POSITION OF THE CUTTER IN THE CHUCK, THEREBY ENSURING CONCENTRICITY OF THE CUTTER HELD WHEN IN USE

© Fig. 3 Collets

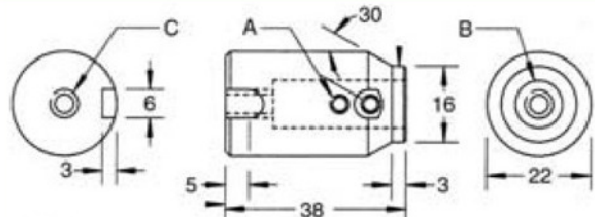


NOTES:
THERE WILL BE NO 3mm PROJECTION ON THE 16mm AND 5/8 HOLDERS, 38mm WILL BECOME 35mm

HOLES:
A - M4, 2 OFF, POS'N TO SUIT CUTTER, SEE SEPARATE DRAWING
B - DIA. TO SUIT CUTTER

MAT'L 22mm DIA. 230M07 STEEL

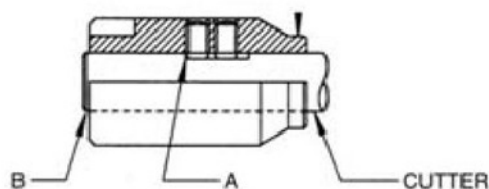
Fig. 4 Holders, large diameters



HOLES:
A - M4, 1 OFF ONLY, POS'N TO SUIT CUTTER, SEE SEPARATE DRAWING
B - DIA. AND DEPTH TO SUIT CUTTER
C - M6

MAT'L 22mm DIA. 230M07 STEEL

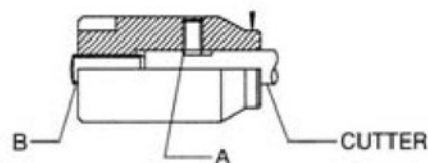
Fig. 5 Holders, small diameters



POSITION THE TWO GRUB SCREWS SUCH THAT THE ONE NEAREST THE BASE OF THE HOLDER IS AGAINST THE END OF THE FLAT (A) ON THE CUTTER, WHILST THE END OF THE CUTTER IS JUST OUTSIDE THE END OF THE HOLDER (B)

THIS ENSURES THAT THE CUTTER CAN NEITHER MOVE IN OR OUT OF THE HOLDER WHILST HELD BY THE COLLET CLOSING RING

Grub screw positions Large diameter cutters

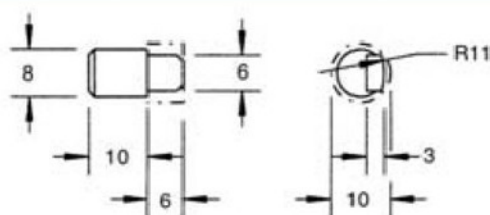


POSITION THE HOLDING GRUB SCREW SUCH THAT IT IS AGAINST THE END OF THE FLAT (A) ON THE CUTTER WHILST THE END OF THE RESTRAINING GRUB SCREW IS JUST OUTSIDE THE END OF THE HOLDER (B)

CHOOSE LENGTH OF RESTRAINING SCREW TO SUIT FOR 6mm DIA. SHANK CUTTERS THE HOLDING SCREW WILL HAVE TO BE POSITIONED ON THE TAPERED PORTION OF THE HOLDER, SEE DRAWING FOR PART 5

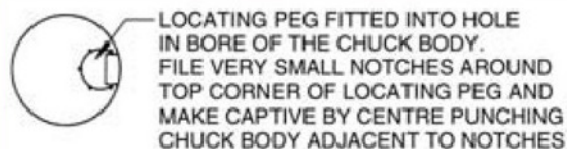
THIS ENSURES THAT THE CUTTER CAN NEITHER MOVE IN OR OUT OF THE HOLDER WHILST HELD BY THE COLLET CLOSING RING

Grub screw positions Small diameter cutters



MAT'L 10mm DIA. 230M07 STEEL

Fig. 6 Collet locating peg



Collet locating peg assembly

The completed kit

Photo 19 shows the completed kit, with the exception of the 16 mm. threaded shank collet which had not been completed at the time. Incidentally, at this shank diameter cutters can be had up to 20 mm. diameter. Readers who wish to use the full range of both imperial and metric cutters will require even more collets, in which case the saving over even the cheapest commercial chuck will be considerable.

Put to the test

I was confident that the chuck would work satisfactorily with threaded shank end

mills, as with these any turning of the cutter in the collet has the action of pulling the collet forward into the closing ring thereby holding the cutter even more firmly. Holding a large, plain shank cutter was though an unknown quantity. I therefore made my first task a heavy cut taken with a 16 mm. cutter. The 6 mm. by 4 mm. wide cut, seen being taken in **Photo 20** was taken at a fairly high feed rate without any sign of complaint. I am confident therefore that the chuck will perform without problems, not only with threaded shank cutters but also with large plain shank ones also.

May I finish by saying thank you to

readers for staying with the series, despite its length, and I hope that there are now many more who feel more confident regarding their abilities when using the centre lathe, the machine at the centre of most workshop projects.

In a forthcoming issue I shall turn my attention to a series of Milling machine projects, which it is to be hoped will provide guidance and encouragement to readers who may be less experienced on such equipment.



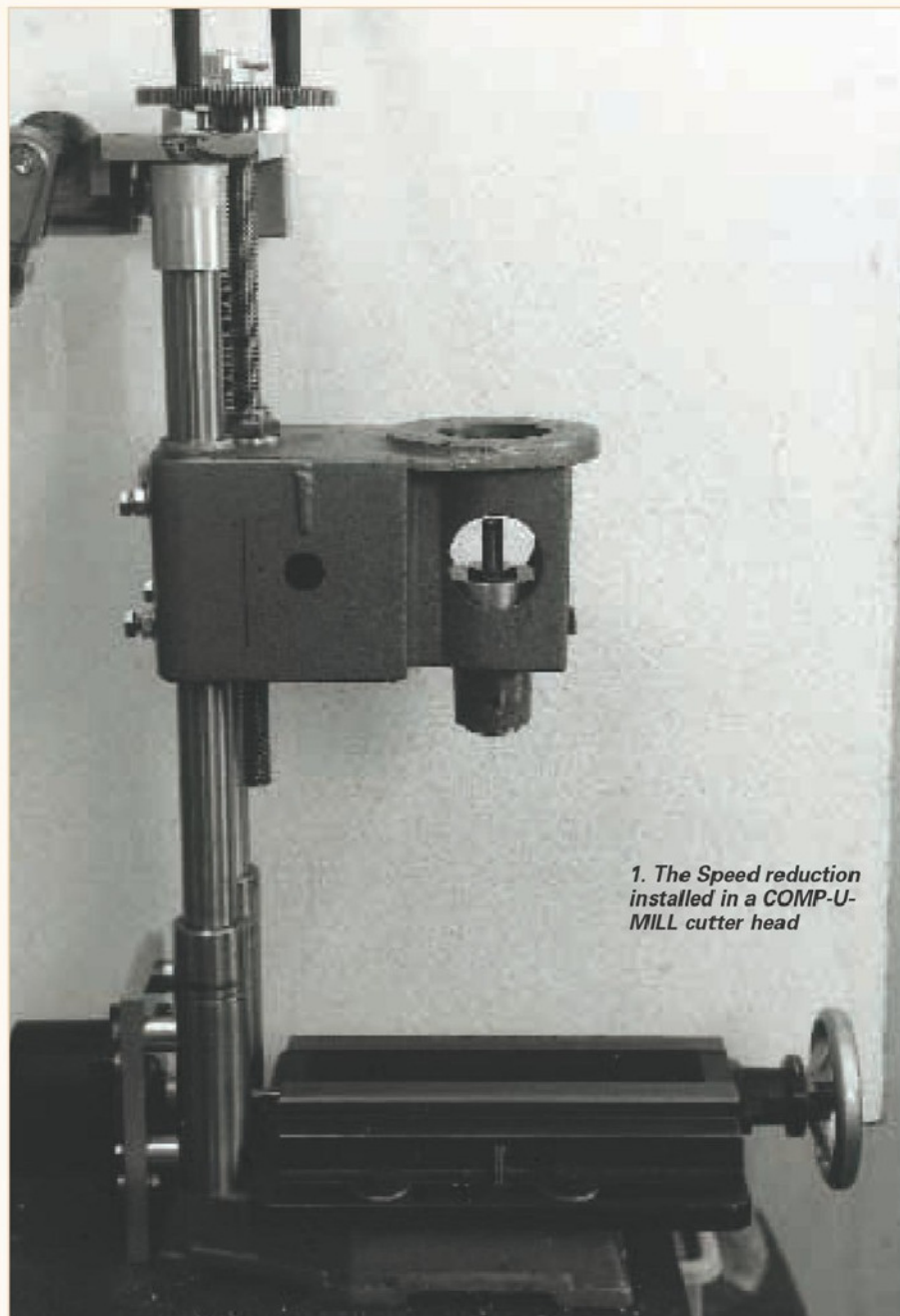
19. The finished kit.



20. Taking a heavy cut (6mm. x 4mm.) using a 16 mm. plain shank cutter fitted in a holder rather than a collet. The chuck performed perfectly.

Ref 1 Milling Cutter Chuck MEW issue 5 page 40.

DEVELOPING THE COMP-U-MILL THEME



1. The Speed reduction installed in a COMP-U-MILL cutter head

Spindle speed

For all balanced cutter operations from 2 inch face mill down to pointed engraver cutters the mill's fixed speed of 1425 rpm gives satisfactory results. If you wish to fit an un-balanced cutter, a boring head for example, the cutting speed MUST be reduced. Alternatively, if your machine is used mainly for engraving, milling prototypes for jewellery etc. then the work throughput can be significantly improved by increasing the cutter speed.

Increasing cutting speed

For engraving and profiling sheet material for clocks/model aero work etc, a 3-phase, 2-pole, 415/220v flange mount motor can be used with a variable frequency inverter drive to give quiet, brush-free operation. Brushless dc motors are available from model shops and offer a viable drive for engraving. If one doesn't mind brush gear on 'long-term' machinery then dc and universal

Having covered construction of the basic milling machine, in the two previous issues, Richard Bartlett examines the options for speed control, and presents a design of epicyclic reduction gearbox.

motors with electronic speed control can be used.

My choice here was an aluminium framed Western Electric motor, rating plate details are 250watts, 2750 rpm at 50Hz. This speed can be increased to 6600rpm by increasing the inverter frequency to 120Hz. For prolonged engraving at top speed use a needle roller or ball race to replace the oilite bronze bush at the spindle nose. This will necessitate an oil seal at the lower end of the bearing. This higher speed "motor swap" option still allows the use of the simple silver steel individual arbors which can be extended yet retain great rigidity. A cheaper but rather noisy alternative to the inverter higher speed drive for engraving or wood/plastics model making is to fit a variable speed router as a replacement for the induction motor. These are very cheap at thirty pounds for 550 watt variable speed model with 6 & 8mm collets (Ferm from Screwfix) which can be fitted via a 1/2inch thick alloy adaptor plate. Again, use a ball bearing or needle roller for the lower bearing. You will need to turn a silver steel spindle with the lower end reproducing the collet chuck detail of the router and the upper end turned to 8mm to engage the router collet chuck. Since the router bearings are only taking the light axial load, the only components likely to wear are the motor brushes, so buy some spares.

Speed reduction

The simplest solution from the point of view of least work, is to replace the motor with a 3phase, 4-pole, 415 / 220volt, 1/4 hp flange mount motor and fit a variable frequency inverter controller. This gives REDUCED power performance from 100 up to 3000 rpm. The inverter I use is by Telemecanique type Altivar 08 (RS 321-6876). An alternative motor (mine is RS 329-0802) can be fitted on a 1/2inch alloy adaptor plate locating both the motor flange and headstock bore to ensure concentricity.

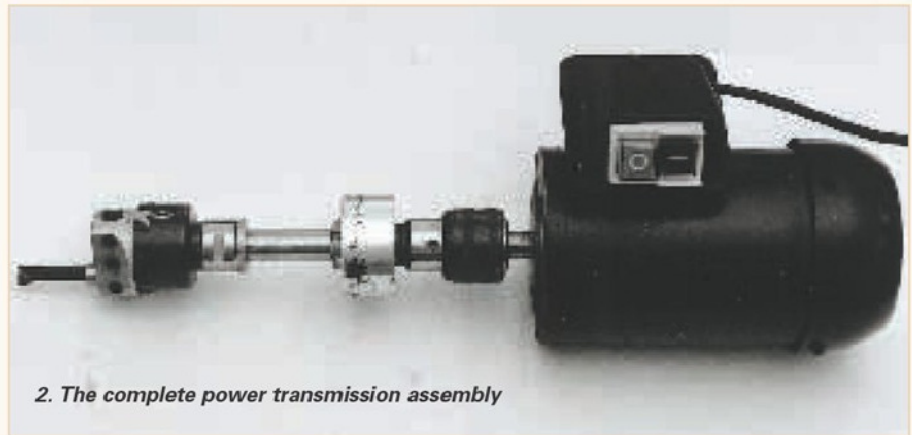
When buying this motor/controller combination I was hoping for good power throughout the speed range of approx 10 to 120Hz. which would have been the ideal "out of the box" solution.

However, on testing it was found that the torque dropped off appreciably at

lower speeds. This “undocumented feature” of the controller called for the use of additional mechanical gearing, which I chose to provide via a DIY epicyclic gearbox of 3:1 reduction. As it was fun to do, and can be used without the inverter unit to give a fixed 3:1 reduction, I offer the details here. The reduction box can be seen in a head unit in **Photo 1**, and the complete power train is shown on **Photo 2**.

Reduction gearbox – description and operation

The epicyclic lower speed drive uses 3 pinions to balance the radial loads. Lateral stiffness of the drive shaft is maintained by bushing the top of the main spindle and allowing the extended primary drive shaft to enter this needle roller bushing. The prototype gear reduction unit uses Module 1 size gear teeth. The chuck mounted primary drive pinion (sun gear) is EN24T steel and has 12 teeth, the three planet gears can be steel, brass or acetyl (Delrin) and have 12 teeth, the internally geared steel annulus has 36 teeth. There is no “hunting tooth” in this choice of teeth as they have been selected on the basis of the largest tooth form that will comfortably fit into the machine but as they are generously rated and will always be well lubricated, their less than ideal wear characteristic due to the repeated tooth engagements for every turn will not be a problem. If you try a different combination be aware that the maximum entry for top



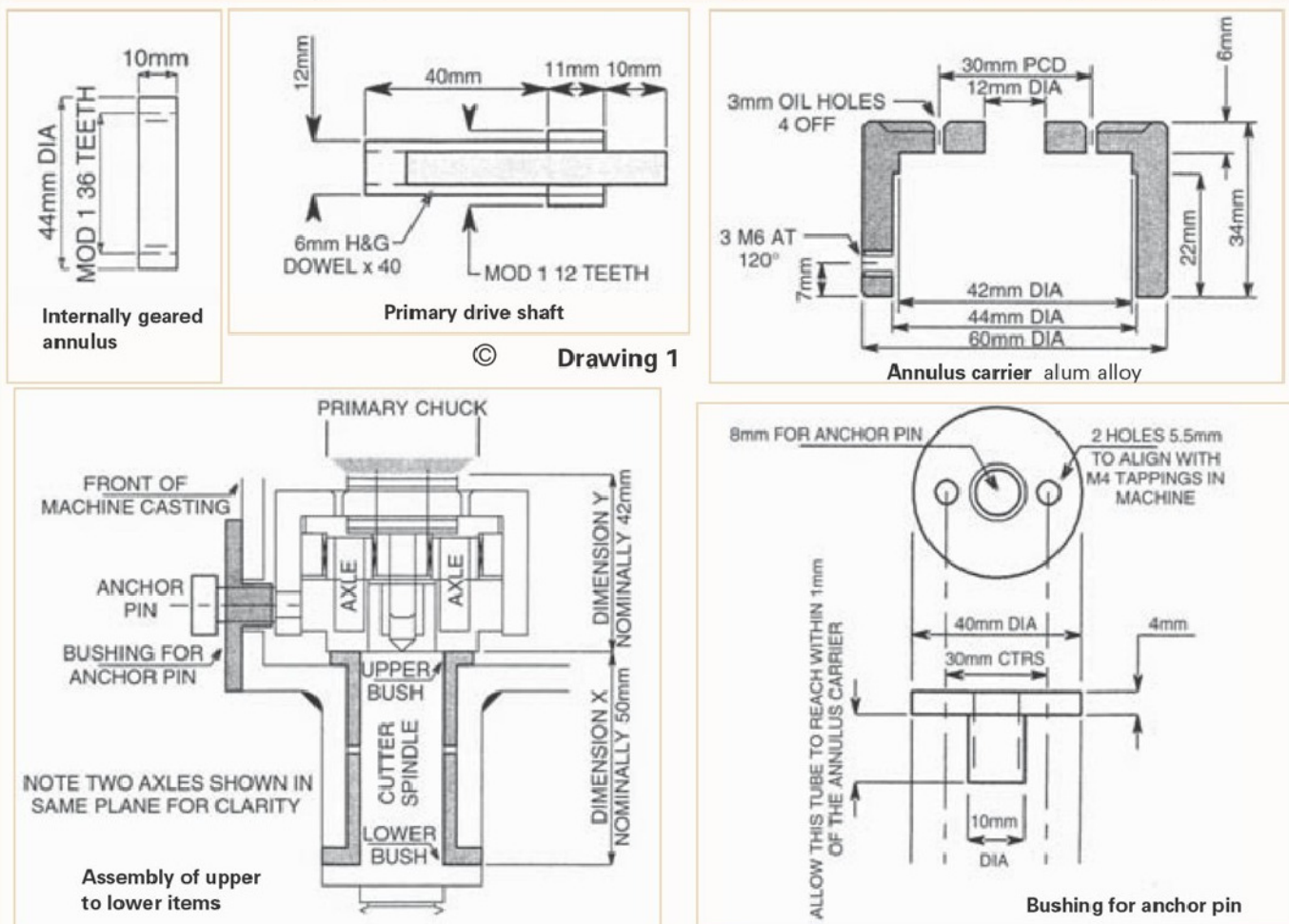
2. The complete power transmission assembly

loading the annulus carrier into the casting is 60mm diameter.

The lower gear ratio of 3:1 is selected by releasing the planet gear carrier from the annulus carrier by withdrawing the three grub screws from the annulus carrier, (Refer to **drawing 1**), and then lock the annulus by screwing in the anchor pin mounted on the front of the machine. The primary drive pinion now turns the planet gears which also mesh with the fixed annulus. This causes the planet gear carrier to rotate in the same direction as the motor but at 12/36 of the speed. The planet carrier is a solid extension of the machine spindle. The annulus carrier is located between two roller thrust washers on the primary drive shaft (drawing 1).

The high speed ratio of 1:1 is selected by unscrewing the anchor pin from the annulus carrier. Without turning the

annulus, turn the cutter spindle until one of the white painted flats on the planet carrier is viewed through the anchor pin hole. Fit an M6 grub screw onto a hex key and feed it into the anchor pin hole to engage with the tapped hole in the annulus carrier. Turn the grub screw until it just contacts the planet carrier. Turn the cutter spindle through 120 degrees and fit second grub screw, repeat for the third screw. Progressively tighten the screws to balance the pressure around the three locations thus avoiding pushing the annulus off centre. I have since resorted to painting a line on the annulus carrier and the spindle to make this initial lining up simple. Fit the 1/8 BSP blanking plug into the anchor pin location to avoid having the spindle lubricant flinging through the hole. Note, the 10mm dia. extended tube of the anchor pin bushing entering a 12mm



© Drawing 1



3. The drill guiding spigot set into the planet carrier to ensure that the planet axles are located on the 24mm PCD.

drilled hole in the front of the machine allows the anchor pin to be adjusted on final assembly to locate exactly into the annulus carrier. This tube also prevents

one of the three grub screws from falling off the hex key and down into the cutter head casting when changing gear. Turn the tube length to allow it to reach within 1mm of the annulus carrier.

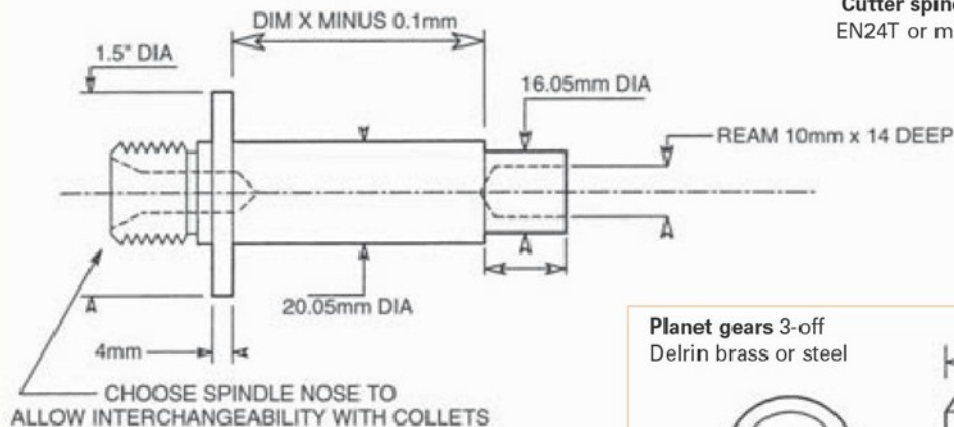
The spindle "end float" is limited between the main spindle headed bushings which are pressed in from either side of the lower part of the cutter head iron casting. This dimension is marked "dim X" on the assembly drawing, and for my machines was nominally 50mm.

Use the 'neutral' gear setting by removing the three grub screws from the annulus carrier to allow the spindle to spin when checking for end float. When in high gear, fill the lower bush housing with oil up to the bottom of the annulus. When in low gear also squirt oil into the internally toothed annulus through the drilled oil holes in the upper face of its carrier, this feeds the driving pinion needle roller, the three planet gear axle pins, the annulus thrust races and percolates down to the lower bush reservoir. Note, the 2mm recess on the upper face of the carrier, squirt oil into this recess and in a few minutes it has run down the four oil holes.

Using this gearbox costs us one of the original features, that of using simple, dedicated silver steel cutter arbors. Because the cutter spindle is now a fixed part of the epicyclic gear unit, one of the common standard spindle noses has to be adopted which will carry both 1/8 inch engraver cutters and 2 inch face mills.

Since the Compucutter machine uses a Taig (Record, Sherline, Peatol etc) 1/8 inch 16tpi spindle nose I will stick to this for interchangeability. The cheap Taig collets can carry the smaller cutters up to 1/8 inch diameter. Larger end mills, boring head, flycutter, face mill etc. are made or have their holders modified to screw on to the 1/8 16tpi nose. If you have an open choice then J&L sell spare collets for the 'JET' die-grinder in 1/8 inch and 1/4 inch size. These are good quality hardened and ground units, the 1/8 inch variety is supplied with a hardened collet closing nut to fit 5/8 x26TPI. Part Nos. FLA-85250 and FLA-85000.

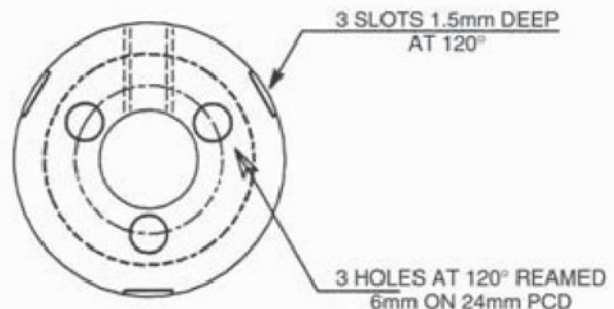
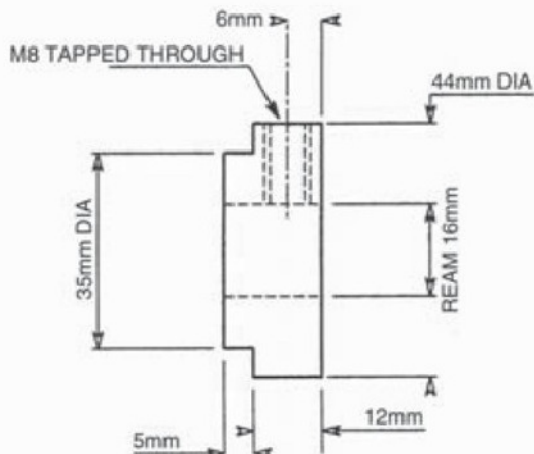
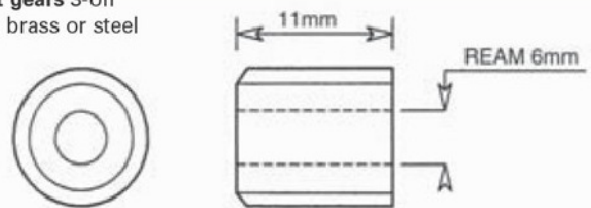
Note! When using the epicyclic gear box in high or low ratio the maximum torque transmitted is limited by the strength of the primary drive pinion. In general, install the gear unit when boring and fly-cutting. The primary drive pinion shaft as detailed is too light to drive a large HSS face mill for stock removal, however, it will happily allow a skim with a 2 inch face mill to provide a good gasket face. The design of the Compumill pushes the user into planning around using carbide tooling for most work except drilling and milling with small disposable HSS endmills. A look through the J&L catalogue will show that due to the degree to which industry has embraced carbides the prices have tumbled, and small solid carbide endmills are cost effective against HSS even for amateur use.



Cutter spindle 1 off
EN24T or mild steel

Note:
Polish 20mm spindle to suit reamed bush
Polish 16mm diameter to suit planet carrier

Planet gears 3-off
Delrin brass or steel



Planet carrier 1 off mild steel

Making the epicyclic reduction gear

The unit is divided into UPPER and LOWER sub-assemblies and the relative positioning of the groups needs to be studied. Measure the existing height from the face of the lower bush up to the inside face of the casting. Subtract this size from 50mm to give the height of the head of the upper bush. This nominal "target" dimension is shown on the assembly drawing. Make and fit the upper bush, noting that it is necessary to have clearance between the two bronze bushes. The actual fitted length of the bushes will depend on your specific castings. Use leaded bronze of 40mm dia or 1.5 inches diameter. Skimming a stock "oilite" sintered headed bush or turning from phosphor bronze is also satisfactory.

The upper assembly

The ANNULUS in its carrier is loaded from the top through the 60mm bore which locates the motor or from the side hatch. The annulus carrier sits between a pair of radial thrust bearings on the primary drive shaft. The PRIMARY DRIVE SHAFT is driven by the chuck on the motor, and it is reamed to carry a long dowel (hardened and ground) on to which fits the PRIMARY DRIVE PINION or "sun" gear.

The easiest design is to retain the motor mounted chuck to hold the primary drive shaft. This relies on the chuck giving concentric location to the 12mm drive shaft carrying the primary drive pinion. If the new chuck does not run true, then remove it from the shaft and check that the external taper on the motor shaft or the chuck internal taper are not damaged. A replacement chuck with a B16 taper is approximately five pounds from APTC or Proops.

Shortening primary chuck

The vertical space in the head casting is quite critical in this design and to help this we can shorten the primary chuck body with no loss of drive capability. Measure from the front face of the primary chuck down to the face of the upper spindle bush when the bush is fitted. The body of the primary chuck can be shortened to give the nominal dimension of 42mm. This 42mm fitting dimension is shown on the drawing 1 as dim Y. and was consistent with the three Nu-tool castings I have used. Do not be concerned if yours is not identical, make a note of your nominal size and work to this. As this turned face locates the thrust washers it should be square to the axis of the chuck. Mount the chuck on a Morse tapered arbor if your lathe has a Morse headstock. Otherwise chuck a piece of 1/2 inch steel and turn to 12.0mm dia. Clamp the chuck on this stub and tighten so that the end of the three jaws is level with the end of the bar. Now face off to give the 42mm nominal fitting dimension. This assumes that your chuck is bored through, some are, some are not. If your chuck is blind, then bore it through to 14mm and proceed as above or, turn a 12mm shaft true in the lathe and tighten the chuck onto it. Working from "behind" the chuck, face the chuck body to achieve

the 42mm fitting space for the gearbox. (An advantage of a bored through chuck is that they are easier to remove with standard extractors than the blind variety)

Reassemble the primary chuck to the motor, fit the motor to the cutter head casting and check the 42mm nominal fitting dimension. Make a note of this size as "Fitting height" for the assembled gearbox complete with upper thrust race.

Primary drive shaft

The 12mm primary drive shaft should be as long as necessary to give full engagement minus 3mm within the chuck jaws. Since full milling power is transmitted through the grip of the jaws on this shaft the contact should be a maximum. Turn the end of a 12mm dia by 38mm length of silver steel bar square and drill and ream 6mm. Alternatively, to improve the drive through the chuck, use a standard tank cutter arbor of the type which has a tri-lobed shank for optimum grip in a drill chuck and shorten/ream this. Another possibility for good grip through the jaws is to turn the drive shaft from 12mm or 1/2 inch AF hexagonal steel, skimming the minimum off the corners to allow the shaft to enter the chuck.

Chuck the standard EN24 12T primary pinion and back turn to give 11mm of full form tooth. Drill and ream the primary pinion 6mm, chamfer the front teeth to assist with final assembly and part off 11mm long.

After thoroughly cleaning these components assemble with Loctite high strength retainer on a 6mm by 40mm long hardened and ground dowel, with 10mm of the dowel protruding through the pinion to engage with the needle roller bearing in the main spindle. Do clean these components carefully and use the specified "high strength" retainer as the full motor torque is transmitted through this bond.

Annulus gear and carrier

Turn the annulus carrier from aluminium alloy. Drill and tap the M6 holes for the 3 grub screws at 120 degrees.

Turn the steel annulus gear outer diameter to 44mm diameter to give a precise location in the aluminium carrier. Thoroughly clean the annulus and its carrier and assemble with Loctite High Strength Retainer.

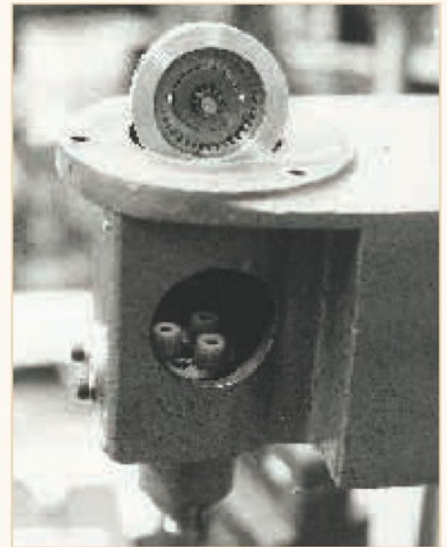
Assembly of upper components

Grease a 12mm bore radial roller thrust bearing (4mm total thickness) then fit it to the drive shaft against the primary drive pinion. Next fit the aluminium annulus carrier, then fit the second thrust race and lock the drive shaft securely into the primary chuck with as little end float as possible. This completes the upper assembly prior to adjusting the clearances.

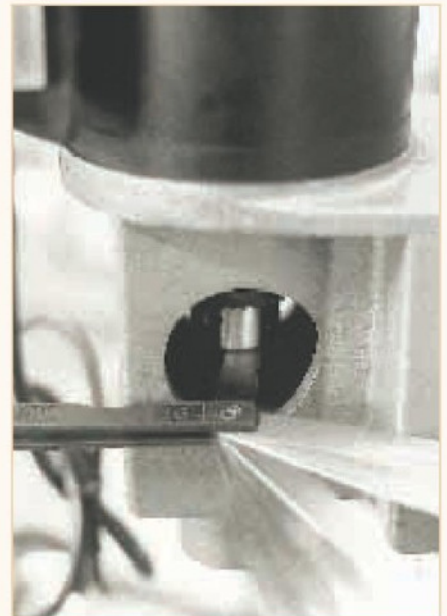
The lower assembly

The CUTTER SPINDLE, which loads from the bottom through the lower and upper spindle bushings, is firmly clamped into the planet carrier.

The UPPER SPINDLE BUSH, is turned



4. The lower components are fitted, the planet gears run on hardened and ground axles, the annulus will be loaded in from above.



5. The Motor/Primary chuck is trial fitted to the gearbox, and a check made for a running clearance of 0.5mm between the upper and lower components.

from leaded bronze and pushes into the spindle bore in the cutter head from the top. It is similar to the existing lower spindle bush. Both bushes are "headed" to give axial location for the spindle in both directions. The nominal dimension from the head of the upper bush down to the head of the lower bush is 50mm (This was detailed earlier to be carried out as the first operation)

The PLANET CARRIER, which loads from the top or side and is locked onto the cutter spindle with an M8 grub screw locating on a SHALLOW flat filed on the cutter spindle.

NOTE! I am loath to give absolute dimensions for assembled items due to the variations that one can reasonably expect with sizes of castings, chucks, headings of bushes etc. Do measure your own machine and component assembly at

each stage. As is frequently stated on commercial drawings "Check on job". Absolute accuracy is not important here, it is the careful fitting of one part relative to its mating part that gives the best result.

Turn the spindle from EN24T or mild steel if you prefer. Ideally the spindle would be hardened and ground but this requires a very well equipped workshop. Polish the 16mm diameter to give a push fit into the reamed hole in the planet carrier.

Turn the planet carrier from mild steel. The bore is reamed 16mm to locate on the spindle with a grub screw. The planet gears are carried on 6mm by 24mm long case hardened and ground (dowels) axles. These three axles are spaced equally around the 24mm Pitch Circle Diameter.

THE DRILLING AND REAMING OF THE THREE AXLE CENTRES IN THE PLANET CARRIER IS THE CRUX OF THIS JOB (and the tricky bit).

Do the best that you are able to get the planet gears matched with both pinion and annulus without being tight on either. If you have the basic kit of drill and lathe then one method that will give guaranteed useable results is:

Measure your No.2 centre drill, let's say it is 4.6mm for example. Turn a drill locator from steel to 24mm dia (PCD of planet axles) minus 4.6 (twice radius of centre drill) = 19.4mm. On this 19.4mm bar turn a spigot 16.05 diameter by 10mm long and polish this down to a push fit in the reamed planet carrier. Part off to give a 10mm length of 19.4 dia.

Chuck the planet carrier truly on the 35mm diameter. Push the drill locator into the bore. Grind a narrow angled "screw cutting" shaped tool to approx 20 degrees and turn the toolpost until the forward flank of the tool is parallel to the cylindrical surface of the drill locator. Make a "slip gauge" from whatever flat stock and feeler gauges you have to give

$$12\text{mm minus } 19.4 / 2 (9.7) = 2.3\text{mm}$$

Use this gauge to position the tool on the radius of the planet gear axle centres. Turn a fine groove on this radius. Blue the face of the planet carrier and set dividers to 12mm radius. Step around the 24mm diameter checking that the six steps are exactly one circumference. When correct, scribe the arcs to give a hexagon based on the 24mm diameter. Use a centre square to scribe bold radial lines through THREE centres at 120 degrees. These centres (1, 3 and 5) will carry the axles. Also from these centres scribe radial lines to the edge of the carrier and extend these along the 10mm length of the carrier. Centre punch on these extensions 5mm from the planet carrier face.

Fit the drill locator into the planet carrier and put the carrier into a drill vice (Photo 3) holding on the 35 diameter. Put the centre drill you measured into the chuck and line up one of the radial axle centre lines so that it is pointing straight at you. Our eyesight works well in sighting deviations from left to right, and less well in sighting in depth. Grease the shank of the centre drill where it will bear on the locator. As you drill exactly on the scribed line draw the drill vice gently towards you to keep the centre drill contacting the locator. Drill in almost to the full diameter of the centre drill to ensure maximum centreing for the 5.8mm reaming

drill. Drill and ream the three holes 6mm. This will provide an accurate PCD for the axles, and will also give adequate accuracy on the angular spacing. Mark the position of the radial M8 grub screw which will clamp the planet carrier to the 16mm spindle. Centre the screw 30 degrees from an axle centre line and mark the centre 5mm down from the planet gear locating face. Drill and tap M8.

Using a centre square through the axle centres scribe radial lines to the edge of the carrier diameter and extend them down the face. Mark 4mm either side of each line to position 8mm slots at 120 degrees. Set this up on the Compumill in the dividing head if you have one, or in the vice, or file the 8mm wide slots carefully to give an edge depth of 1.5mm. These slots will take the ends of the three M6 grub screws tapped in the casing when HIGH speed is used.

It is a help when shifting up to high speed if you have painted the 8mm slots white, this allows the grub screw insertion to be done without resorting to "feeling" the grub screw into the slot and risking burring the diameter of the planet carrier away from the slots.

Now shorten the standard planet gears by turning off the boss to leave pinions of 11mm length. Ream the planets 6mm. Turn a slight chamfer of 20 degrees for a depth equal to the tooth depth to stop the teeth scouring the carrier. Clean the planet carrier and assemble the planet gears on 6mm dia 24mm long hardened and ground dowels. Introduce the planet gear assembly into the previously assembled annulus/primary drive shaft unit. You will have to rotate the gears to give the alignment necessary for engagement. Check that the annulus can be rotated around the planets by using the cutter spindle as a handle, minor tight spots will wear in.

Turn the planets around the sun for a few revs whilst pushing the planet carrier into the annulus carrier as far as it will go. Now measure the distance between the top thrust race and the bottom of the planet carrier. This has to be approximately 0.5mm smaller than your "fitted height" size. There are two options for adjustment: if the assembly is too small, turn a washer to be inserted between the upper thrust race and the primary chuck.

If the assembly is too long then turn the lower face of the planet carrier to give the required clearance of 0.5mm. That's it, now for:

Final assembly

Assemble the cutter spindle with Molygrease in the lower bushing and locate the planet carrier from above, again with plenty of grease to allow locking the two together with minimum clearance. Knowing that we have four turned surfaces providing the location here, zero clearance to slightly tight is ideal as this fit will easily bed in with use. This is best achieved by lightly clamping across the spindle to planet carrier whilst the M8 cup head grub screw is repeatedly tightened / released to form an annular location in the flat on the spindle. This will always repeat, so get it right first time. Note, file the flat for the M8 screw to minimum depth to locate the cup-point of the grub screw.

Recap

The 'bottom located' components of spindle and planet carrier must be distanced from the 'top located' components of primary drive shaft and annulus. This clearance is nominally 0.5mm but 0.5 to 1mm is satisfactory. If this clearance is not maintained the ends of the planet gears will bind on the lower thrust race and/or the primary drive pinion will "mill" into the cutter spindle.

With the primary drive shaft, thrust races and annulus assembled in "neutral" (no grub screws), fit the upper components into the lower components by turning the the annulus carrier as the primary drive slides into the cutter spindle. Open the primary chuck on the motor to its fullest extent and lower the motor onto the cutter head casting.

After assembly, check that there is no vertical binding by inserting a feeler (Photos 4 & 5) between the upper thrust race and the face of the primary chuck. If there is no clearance then the primary chuck face or planet carrier lower face must be re-skimmed until clearance exists.

Having happily married the top to bottom units, we can set the planet gear axles in with Loctite.

Next mark the height on the front face of the head casting of the tapped holes in the annulus carrier. Do this by screwing a shouldered M6 bolt into the annulus carrier where it can protrude through a side hatch in the casting. Mark the centre height and centre punch the position of the guide bush for the anchor pin to engage the annulus. The pin is 8mm diameter so drill 10mm through the casting allowing the centreing of the bush on its own tube before final fixing. With the pin in position spot through the two holes in the flange of the bush and tap the casting M4 for fixing. Finally remove the bush and drill the casting 12mm to allow for adjustment. Use washers under the M4 adjusting screws.

The three M6 driving grub screws are removed completely for Low ratio. The correct position to allow the grub screws to enter the drive slots in the planet carrier for High ratio can be marked on the spindle nose adaptor as 3 centre punch or saw marks. Obviously, the sliding pin aligns the first position and the only mistake is to screw an M6 grub into the M8 tapping by being 30 degrees out of angular alignment. Painting the three 8mm slots in the planet carrier helps greatly here. The extended bushing for the anchor pin is long enough to go in close to the annulus carrier stopping any chance of a grub screw falling off the hex key and dropping inside.



Suppliers

Gears from **HPC Gears** Tel. 01246-268080 Part Nos. YG1-12 four off, IN1-36 one off.
Case hardened and ground dowels 6mm diameter for planet gears and driving pinion RS No. 270-647. Needle roller bearing for driving pinion RS No. 198-9358. **R. S Components** 01536 201 201
All oilite sintered bronze bushes from **Proops** Tel. 0116 2403 400
Collets in 1/8 and 1/4 diameter **J&L Industrial Supply** Tel.0800 66 33 55

INDEX FOR ISSUES 69 TO 80 OF M.E.W.

The information contained in this index supplements that published in issue 69, and brings the information up to issue 80. A computer based index is also available for those with suitable equipment to run the software.

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The columns are Issue No. containing the original item and its Page No. then the Type of Item: - A- Article, L - Letter. These are followed by the subsequent reference, together with its Issue No. and Page No.

To use the list, look up the Issue No. and Page No. of the item you are studying to see if there has been any further data. As there may be more than one letter to a page, the cross reference may refer to another letter on the same page.

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MODEL ENGINEERS' WORKSHOP PUBLICATION DATES

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5	June/July 1991	33	January/February 1996	63	November 1999
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28	March/April 1995	56	February 1999		
		57	April 1999		
		58	June 1999		

It should be noted that Issues 1 to 6 were never formally numbered and that Issues 7 to 11, although numbered, did not carry these on their covers.

MODEL ENGINEERS' WORKSHOP COMPUTERISED INDEX

As noted in Trade Counter of Issue 81, the computer based index continues to be available from CAHW Systems. Supplied on two floppy discs, it is a DOS program which runs quite happily on a Windows system. Facilities are provided for View,

Search, Sort, Edit, Update, and Print, with updates being made available every six issues, each update covering from Issue 1.

Cost is £10.00 plus £2.00 carriage on non UK orders. CAHW can be contacted at 23 Fieldway, Berkhamsted, Herts. HP4 2NX

Readers with internet access will be able to have a look at the M.E.W. index posted on Colin Usher's web site : <http://members.lycos.co.uk/Livesteam/index.htm>

A HAND PIPE BENDER

Peter Rawlinson needed to produce some neat pipework, and so came up with a versatile design of pipe bender to satisfy several differing sets of requirements.

Introduction

Approximately 9 months ago I was coming to the end of building a series of models based on Stuart Castings, these comprised in Chronological order -

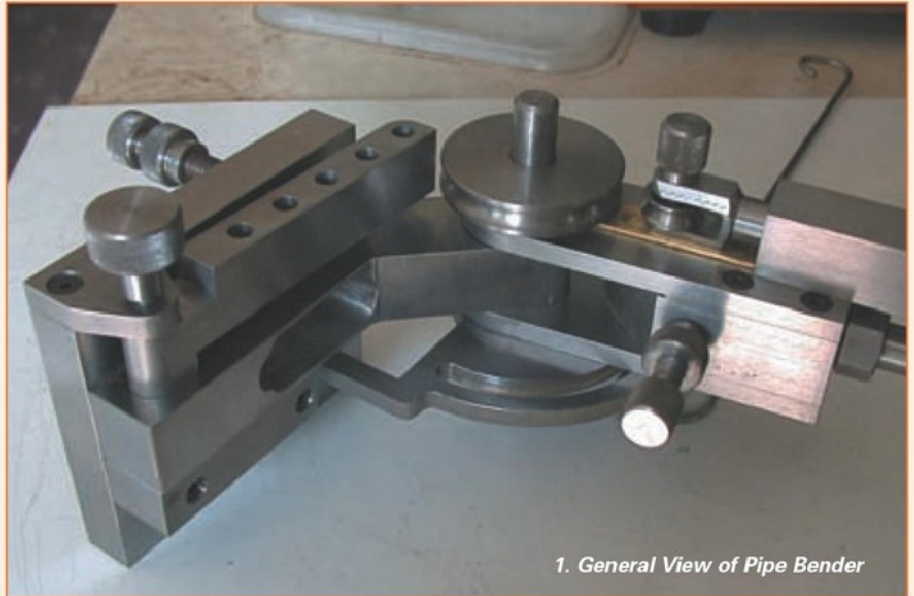
A Small Mill Engine.

A Combes Rotary Engine.

A Minor Beam Engine, and a James Combes Table Engine.

These were at a stage of requiring the copper pipe runs to finish them off. At this time it was decided that a Pipe Bending machine would be required. Although I had purchased a larger model some time previously, it was not thought that it would deliver the necessary good quality, fine finish bends on the small diameter copper tube, due to its design. This included a bar which "gripped" the tube and pulled it around the mandrel, and in doing so badly damaged the surface, it also tended to "squash" the tube on the bend.

If the bending is accomplished by using formers and pressure rollers shaped to suit the material being worked, then the "necking" experienced on the bending of the tube sections can be virtually eliminated and this was my goal in this case. It was therefore decided to build a new one which would produce a good finish on the smaller diameters. As I also planned to make a "snubber" for an



1. General View of Pipe Bender

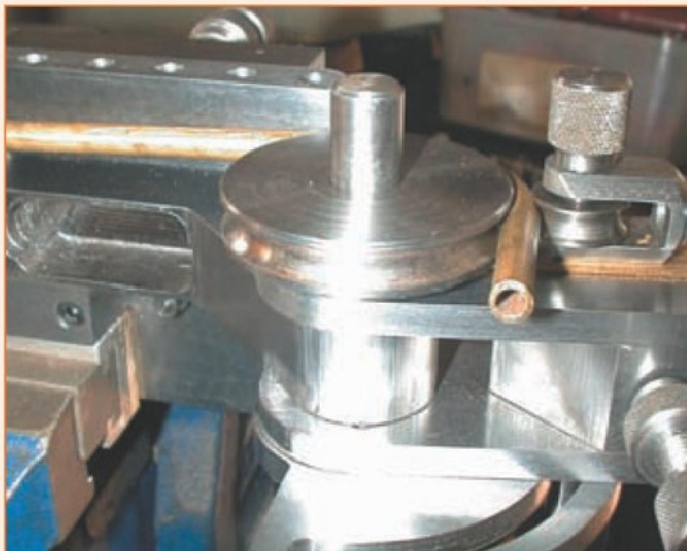
hydraulic circuit on my press an attachment was added to enable this part (a multi turn coil), to be handled as well.

A "snubber" is used to damp the oscillations in the hydraulic oil from a powered pump prior to it entering the pressure gauge which helps give a smooth reading and reduce the effects of metal fatigue in the gauge and therefore increases its life. In this modern day they are often made up using a minute orifice for the oil to "squeeze" through but in the past they were made up using a coil of fine gauge copper tube in the form of a spiral and it was decided to make the pipe bender capable of carrying out the task of bending this spiral. I have in the past used the Lathe to carry out this type of operation, or at least to wind springs.

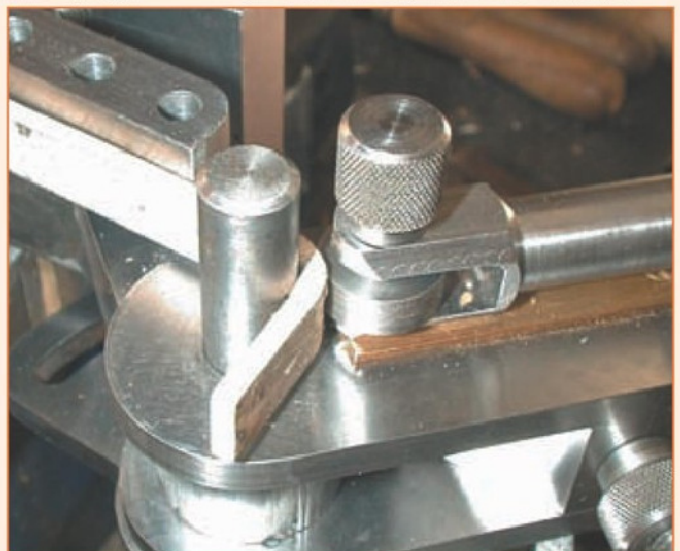
Description

My original design was similar to the final design shown on the General Arrangement drawing, **Fig 1**, but I have since added the stops so that accurate repetitive production can be carried out by setting the stops. The unit is capable of bending from 0.degrees, to 270.degrees in it's standard form, and the stops can be set at any angle between -3.deg. and +273.deg. Of course exact coverage will depend on the springiness of the material being bent.

The design consists of two major parts for the Pipe bender. By using additional mandrels and turning the handle section upside down, and then placing it on an extended mandrel above the main base



2. Bending 8mm diameter Brass Tube



Bending 0.5in. x 0.125in. Aluminium to a 6mm radius

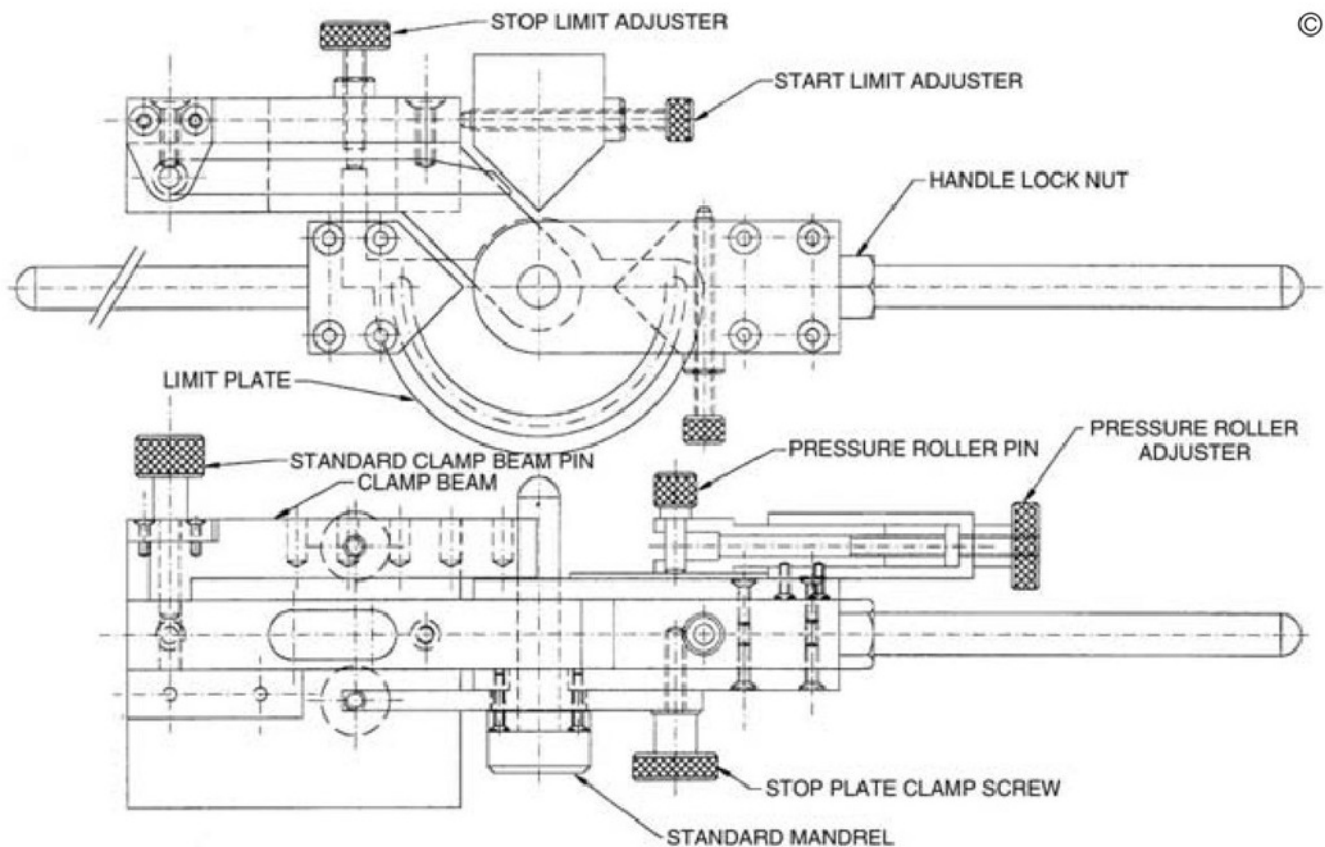


Fig. 1

FORMERS AND PRESSURE ROLLER LEFT OFF FOR CLARITY

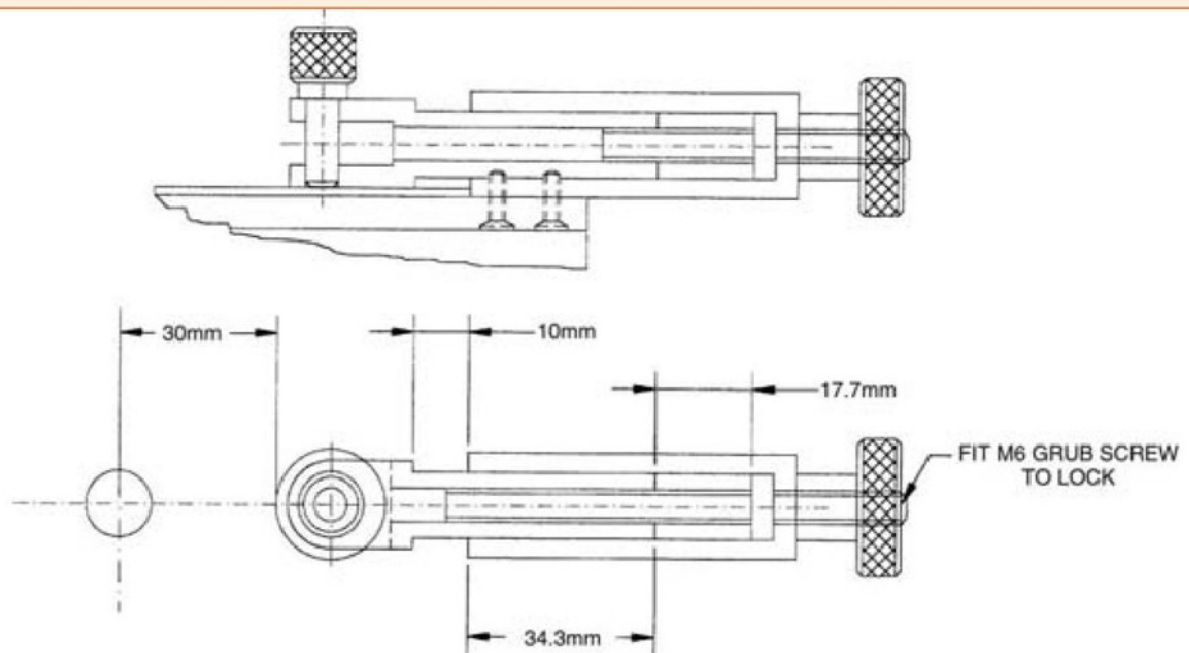


Fig. 1a Pressure roller assembly

unit, as shown in **Fig 2**, spiral bending can be carried out.

It has been designed to simply clamp in the vice although a clear space around it is required (which is a problem in my workshop). The proverbial swinging of a cat is just not on.

Most of the machining is straight forward and there is no super accuracy required, where a good fit is required then

the parts can be turned and fitted into reamed holes. All materials are standard bar stock and sizes can be varied to suit what is available (within reason). Only two reamers are required these being 12mm. & 6mm. or $\frac{1}{2}$ in. & $\frac{1}{4}$ in. Socket screws are used throughout as they can be tightened better, and one small piece of brass is used as a slide. However this could be steel, depending on what is available.

Some general advice

One or two pieces of advice are offered, at the risk of teaching grandmother to suck eggs. For components which are to be screwed together, always tap the female threads first so that the screw or die cut parts can be checked for size against the mating part. On the subject of knurling,

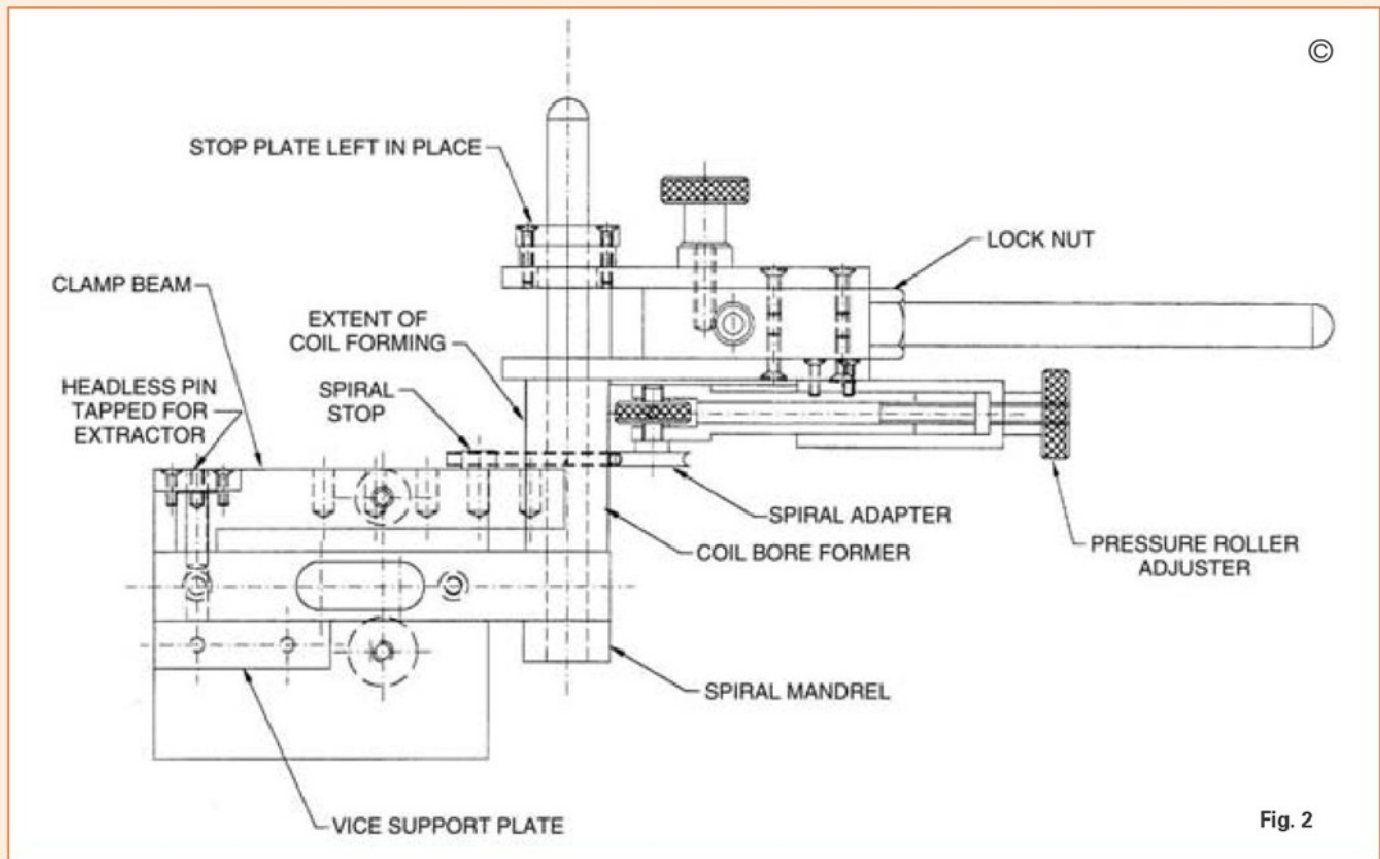


Fig. 2

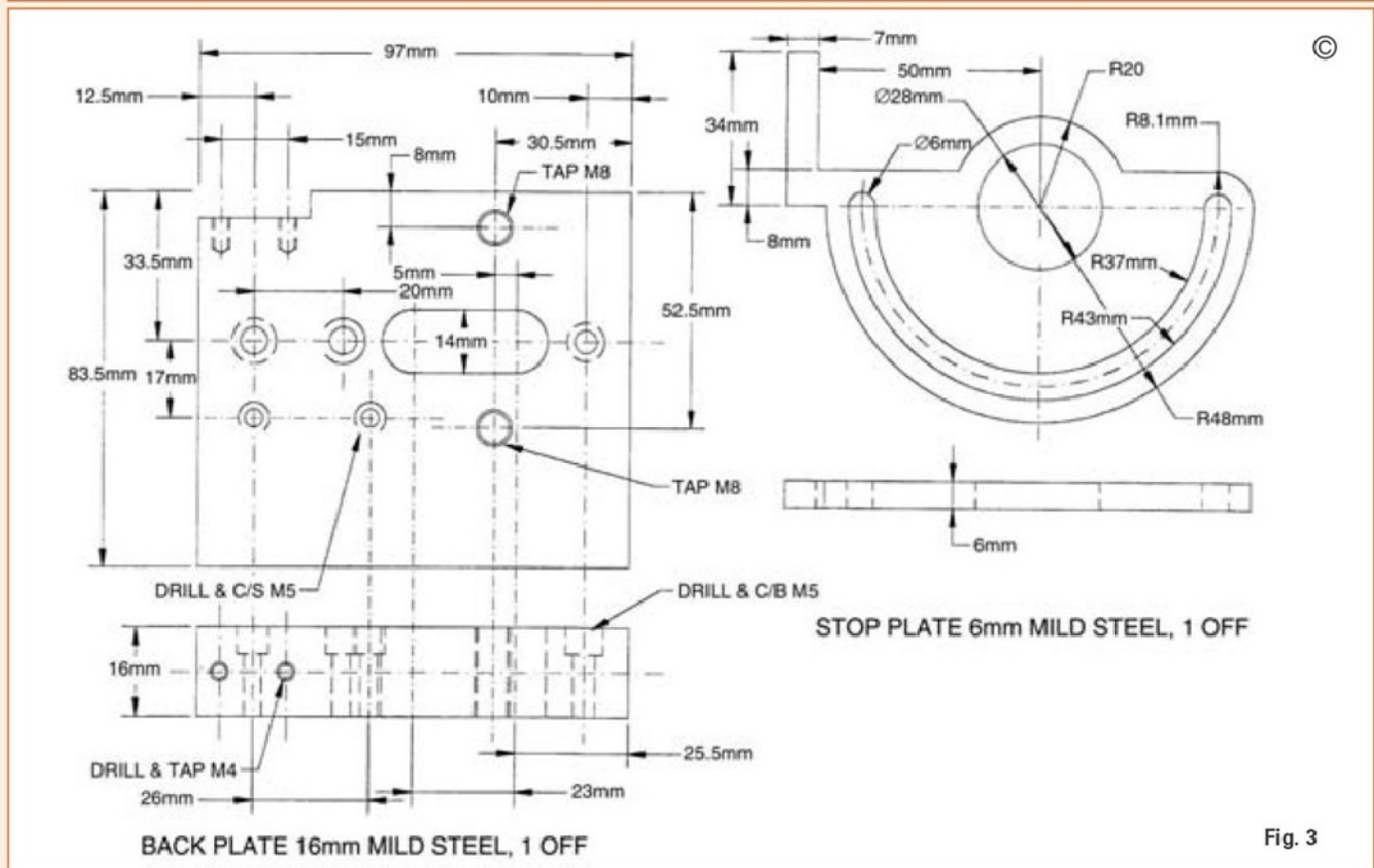


Fig. 3

much has been written about this in the past, but I feel that there is a lot to be said for using a slow speed and a slow feed, along with a copious supply of "suds" (flooded not dripped) which will wash away the displaced particles. I also prefer to polish the steel before applying the knurling tool. And last, but not least do not

force the knurls right into the work as the sharp tops produced can be uncomfortable on the fingers. For components that need to be gripped so uncomfortably hard, either a hexagon form or the provision of a set of tommy bar holes offers a better design solution. Here we have a number of knurled parts to do and it makes good

sense to organise the jobs to complete all parts at the same time.

For finishing parts, I have a small grinder and I prefer to finish parts using it wherever possible. But where this is not possible I use a small one inch wide band sander of the Taiwanese variety, which I have found to be excellent for ends, edges, shapes, etc.

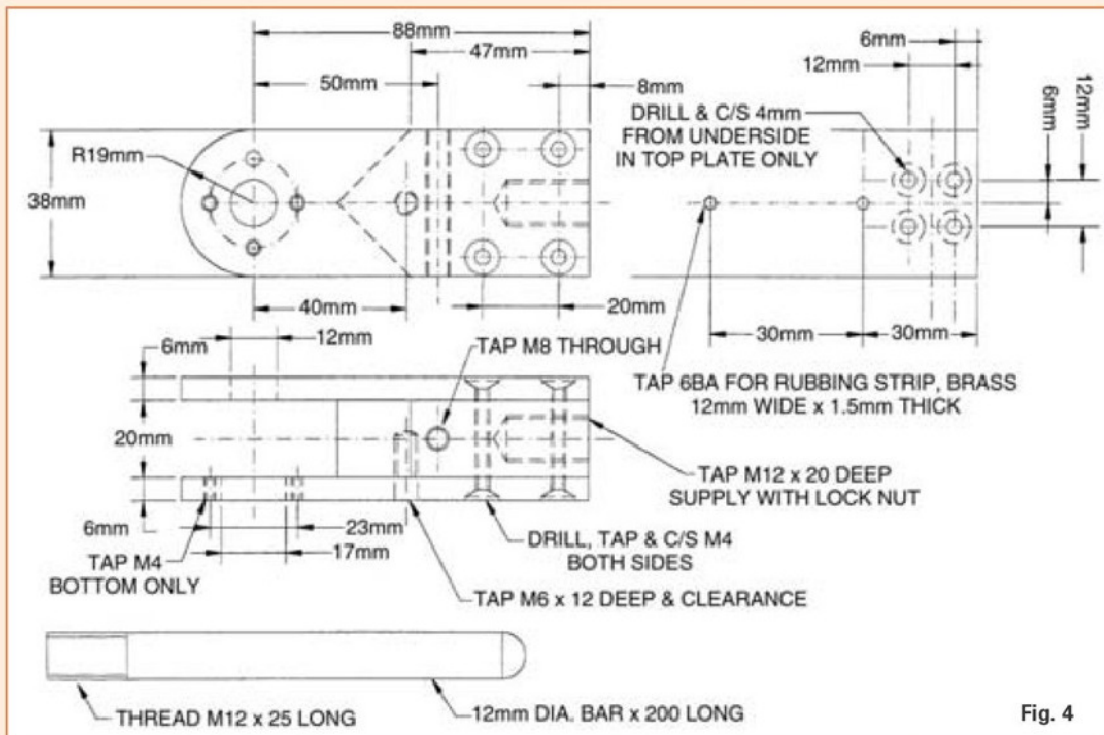


Fig. 4

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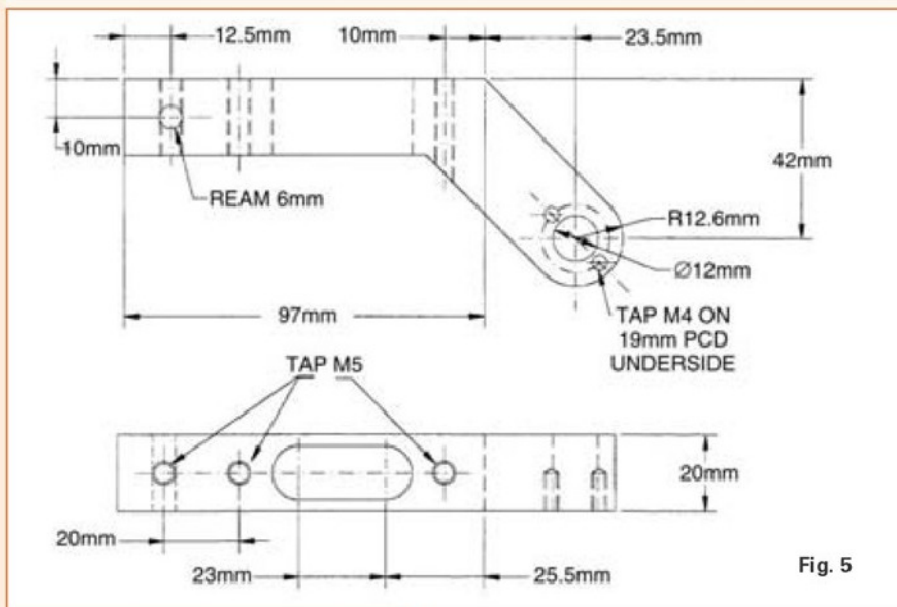


Fig. 5

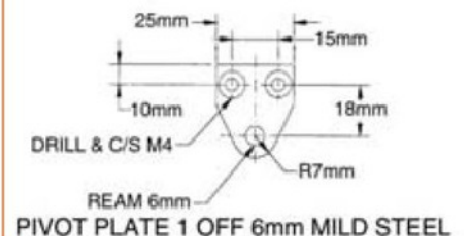


Fig. 6

Manufacturing notes

Whilst most parts entail straightforward machining work, one operation which will need careful setup is the backplate circular slot. This is the most tricky part of the machining which will be encountered. However if you have to set up a chuck on a rotary table especially for this operation then the drilling of all the holes on a radius should be carried out at the same time and the same setting where appropriate, as this will guarantee the matching of all the various parts. This circular slot is best carried out using a $\frac{1}{4}$ in. slot drill, although I used an end mill, but this entails drilling a starting hole of say 5mm diameter. I would also suggest that the depth is machined in say 2mm cuts as it is having to be fed by hand. As the cutting position is high relative to the table, it's worth tightening everything up as much as possible.

Having a long series slot drill, I machined the slot in the base unit by firmly bolting the two parts together. If you do not have one of these, then you can deal with it in two stages. (This slot is to clear the head of the start limit adjusting screw).

The fork section requires to be a good fit on the base and here I ground the two parts at the same time and the same setting, it may well be necessary to hand finish to a sliding fit the underside of the

pressure roll fork, or the brass wear strip that it rests on.

The remaining operations are considered to be relatively straightforward.

Operation

The use is simple and the photographs show various combinations that can be used. Of course the form, and pressure rolls are to the individuals requirements

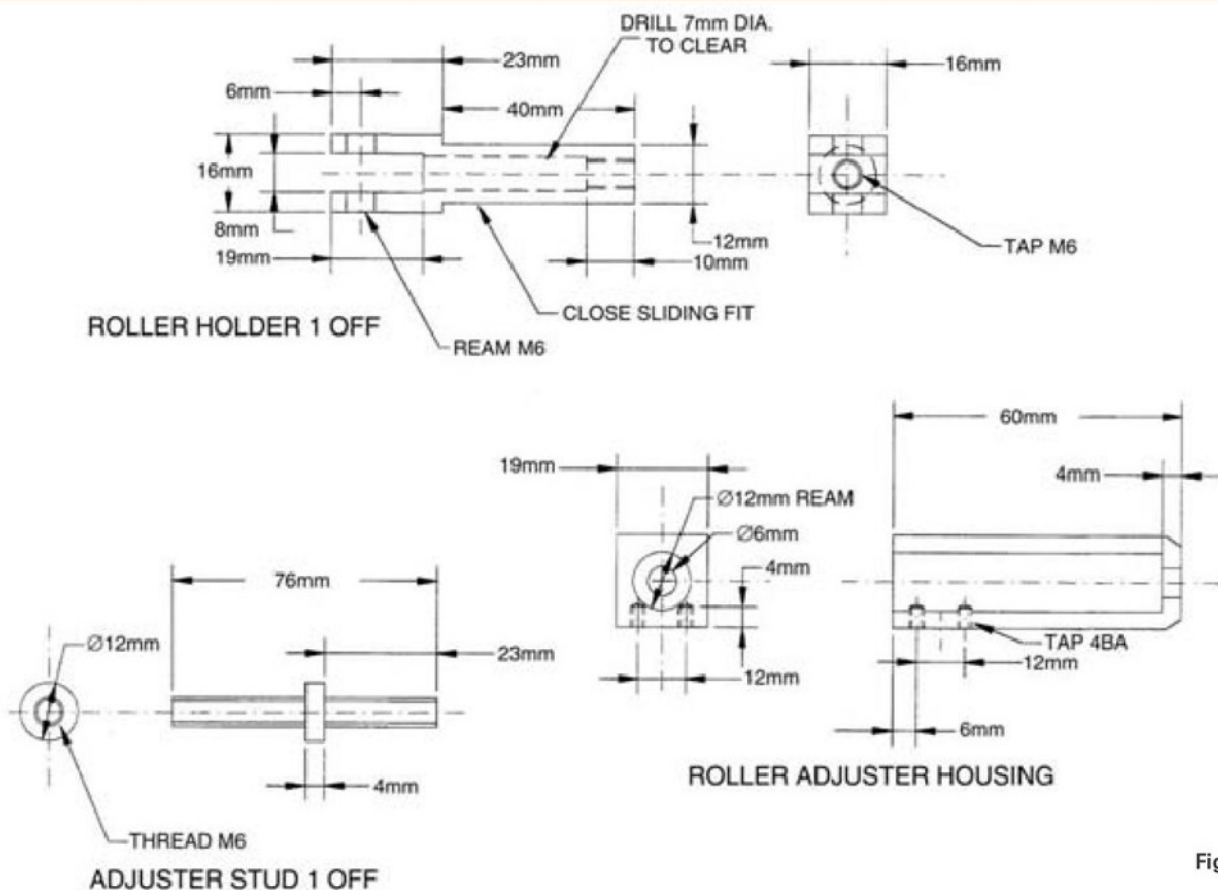


Fig. 7

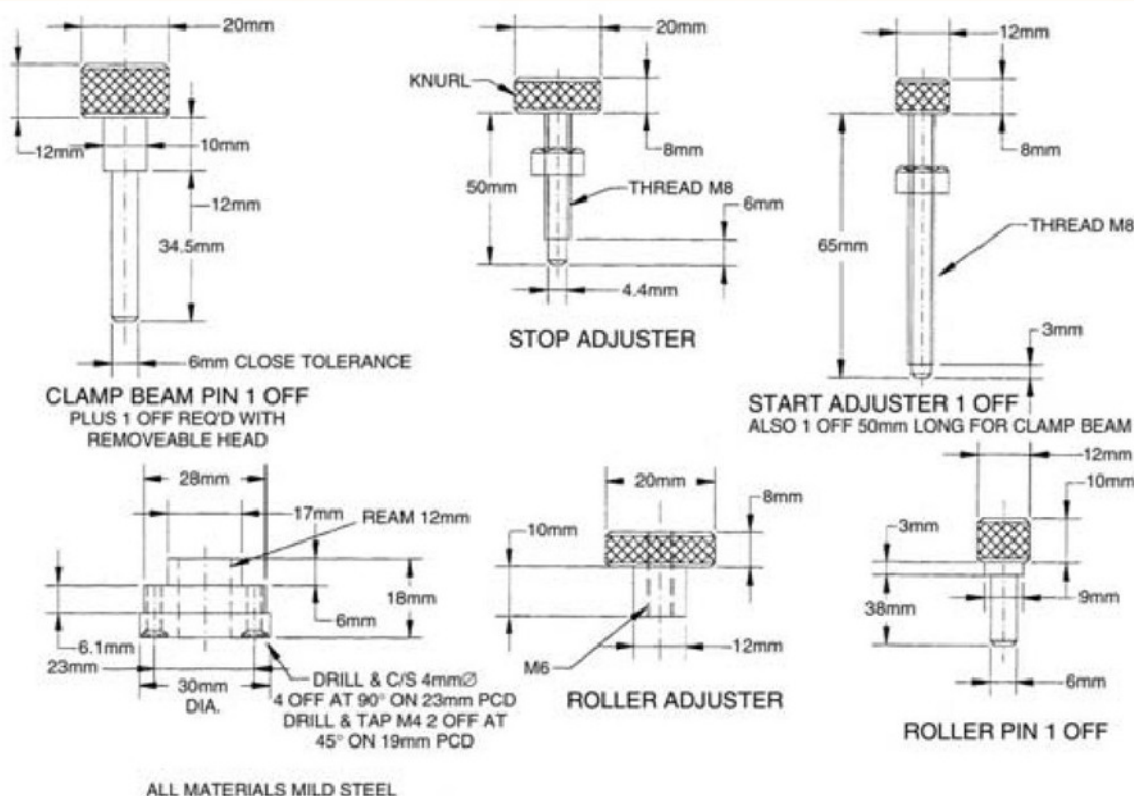


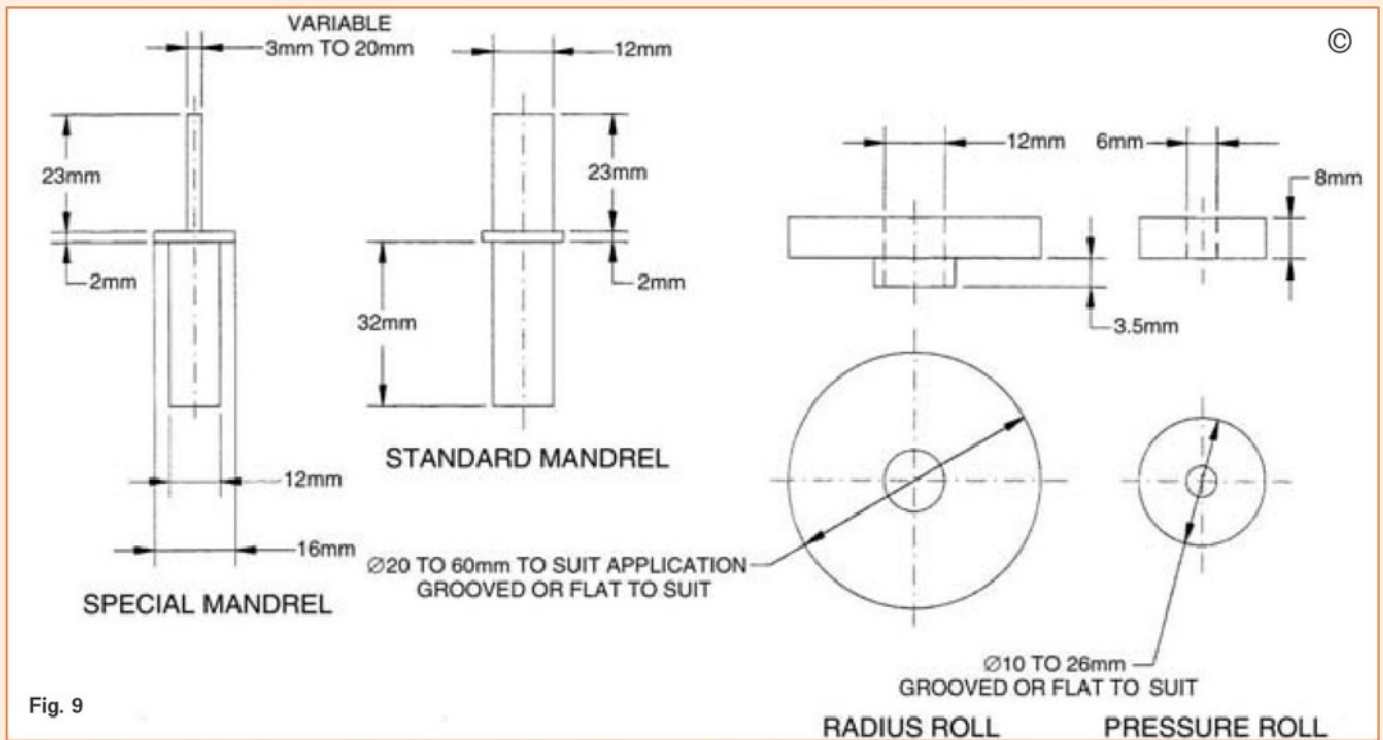
Fig. 8

and will vary depending on the radius and pipe diameter which is required. With the appropriate rolls etc. it is possible to bend down to 2mm. radius and up to 40mm. radius spirals, I would recommend a minimum of 4mm. radius, but all these sizes will depend on the cross-section of the material being bent. Detailed drawings have not been given of the myriad

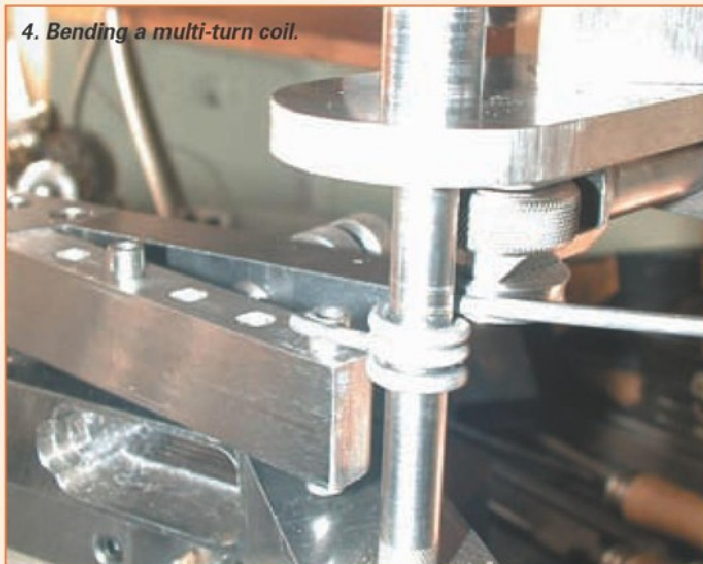
variations of rolls, formers, mandrels etc. as individual requirements will depend on the particular job in hand. A typical selection is shown in Figs 9 and 10. The basic requirement is to have a former located against the clamp beam, a pressure roller and radius roller. For tube bending each of these components should match the cross section of the tube. By

giving support to the tube in this way, flattening is minimised. It is a simple matter to design and make the parts to suit your specific requirements.

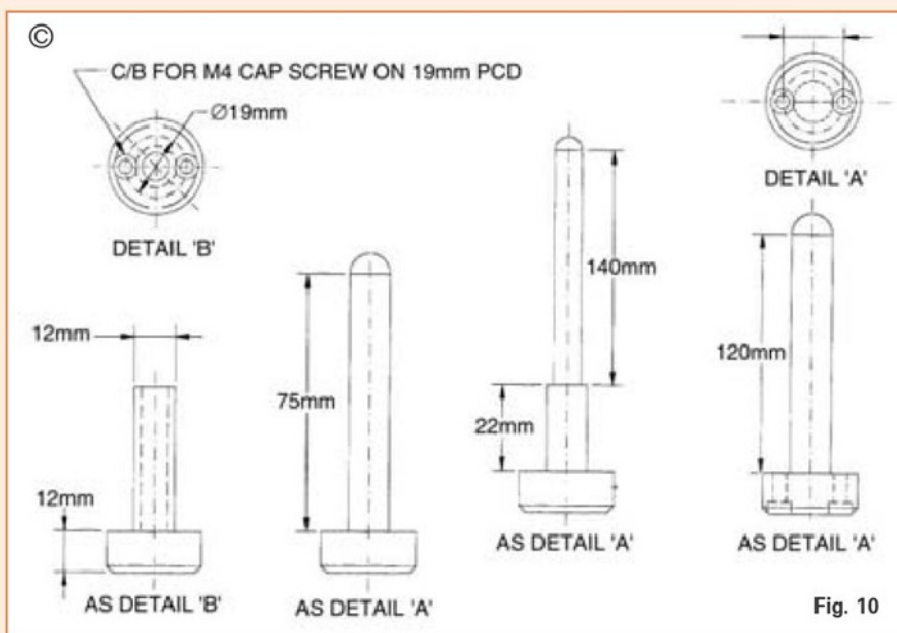
By using the special adapter for the spiral bending and turning the pressure roller section upside down on an extended mandrel, spiral bends can be made of any diameter when a suitable former is fitted.



4. Bending a multi-turn coil.

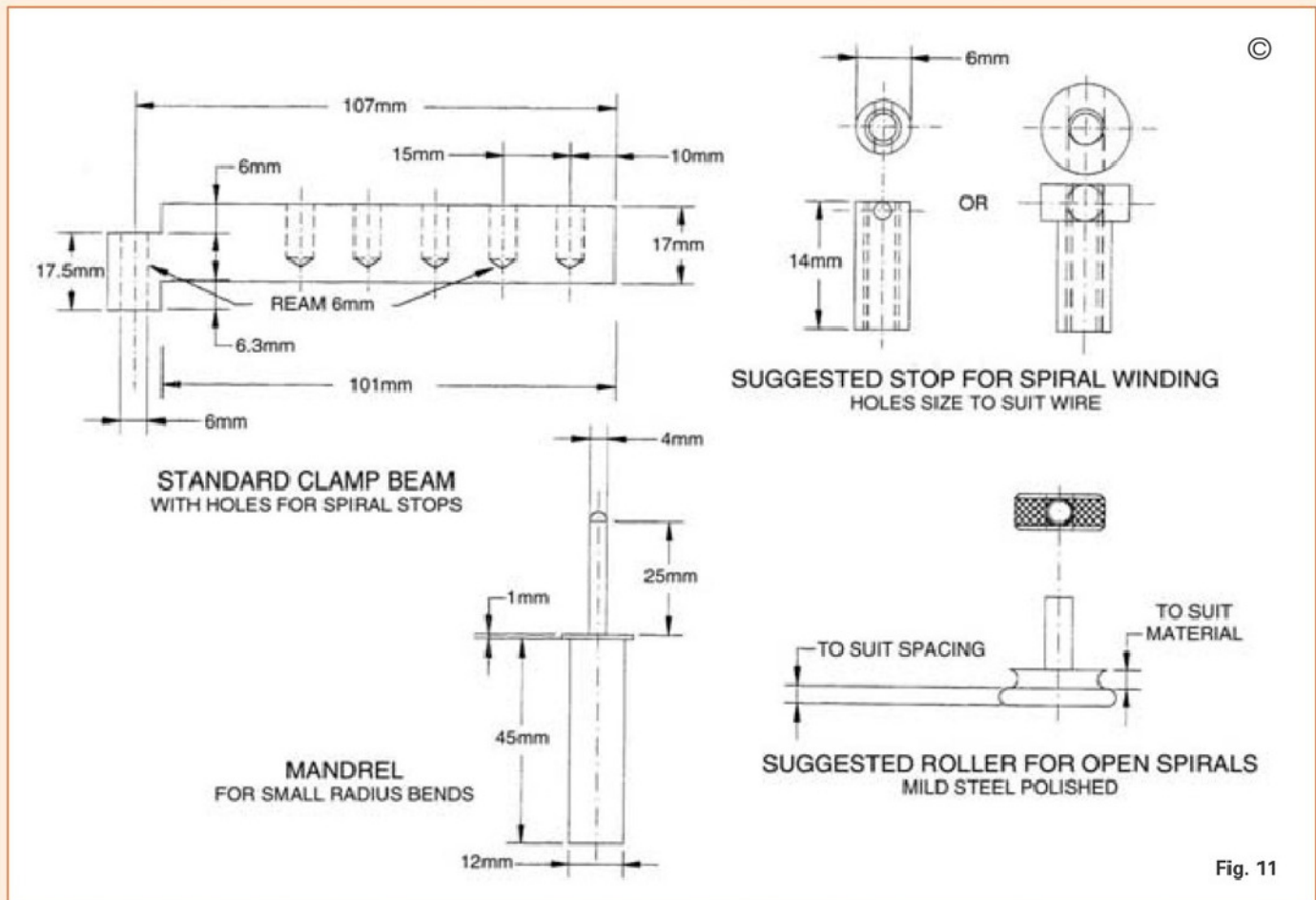


5. An Assortment of Shape and Pressure Rollers



There is of course a limitation on the length of spiral that can be made, this being is approximately 22mm. The pressure rollers that are used for the making of coils will generally be required to be narrower than the material being coiled and it will therefore be necessary to have these as form rollers or shaped to match the material being used.

The start of the spiral is a little tricky, and it has been found that a "pin" with an appropriate cross hole set at the top for the material to pass through solves this problem completely. The tapped axial hole in the pin allows for fitting a grub screw to clamp the material if necessary. A photograph is included showing coil bending, but while on this subject let me point out that the hand part must be an easy sliding fit on it's mandrel as the first coil must be "pulled" up by hand. All subsequent



6. A Selection of Mandrels

coils then follow on automatically. If a gap is required this can be accomplished by using a spacer of appropriate thickness, or making the pressure roll with the spacer added on but make sure that this spacer is polished or it will mark any type of soft material.

I am sure that many other uses can be made of the unit especially with other adapters etc.

I hope you find the subject interesting, and the device of help. Although there is a little work involved I found it interesting and more versatile than a typical commercial unit.

Again as usual I am most happy to help but telephone only please, my number is (Charing, Kent.) 01233 712158.



7. Several turned and knurled components.

ANOTHER FINGER PLATE

Philip Amos describes a simple accessory which should prove invaluable for small part workholding.



1. Finger plate arranged for cross drilling $\frac{1}{8}$ inch diameter hole in $\frac{1}{8}$ inch diameter rod. Alternative finger and Tee piece also shown.

Introduction

The finger plate is quite a well known workshop aid which is most handy in a variety of bench work to hold small pieces so that they can be worked on. In reference 1 Commander Barker points out that the design is a very personal matter and minor variations are common to suit each owner's particular requirements and preferences. This is probably why they are seldom found as commercial items, but as they are simple and inexpensive to make this scarcity is no great problem.

Design

When I set out to design a finger plate for my own use I consulted the literature and found a whole host of references, from which I selected those shown at the end of this article.

The Barker model in reference 1 is not fully dimensioned so requires some judicious scaling and guessing, but it forms a good starting point.

The proportions of the Lautard model in reference 2 yield a good source of dimensions, and it also brings forward the idea of alternative fingers; one reaches the sides and one the corners of the baseplate. The Thomas and Riley models in references 3 & 4 are only photos but give guidance on features and proportions. They are very similar to the Barker design. In reference 5 Stan Bray shows a whole variety of finger plate designs and describes a number of specific uses.

Construction

Base assembly (Fig 1)

This is built up from three components, the square base (1), the hold down stud (2), and the bridge piece (3). Part (1) is machined to 76 mm square, milled from a block of 25 mm thick mild steel with 8 mm grooves (wide and deep) around all 4 sides for clamping fingers to hold it down on a lathe or milling or drilling machine table.

On three sides there are centrally placed square notches from the top to the groove to allow clearance for a drill to pass through a workpiece. Along the fourth side is a 90deg. groove 14 mm wide in the upper surface, with a 1.6 mm clearance slot along the bottom of the groove. 20 mm from one end of this groove is a mild steel bridge piece (3) which acts as a location for a drill bush. This bridge piece is held in position using Loctite 603 or 648. Interchangeable bushes can be provided

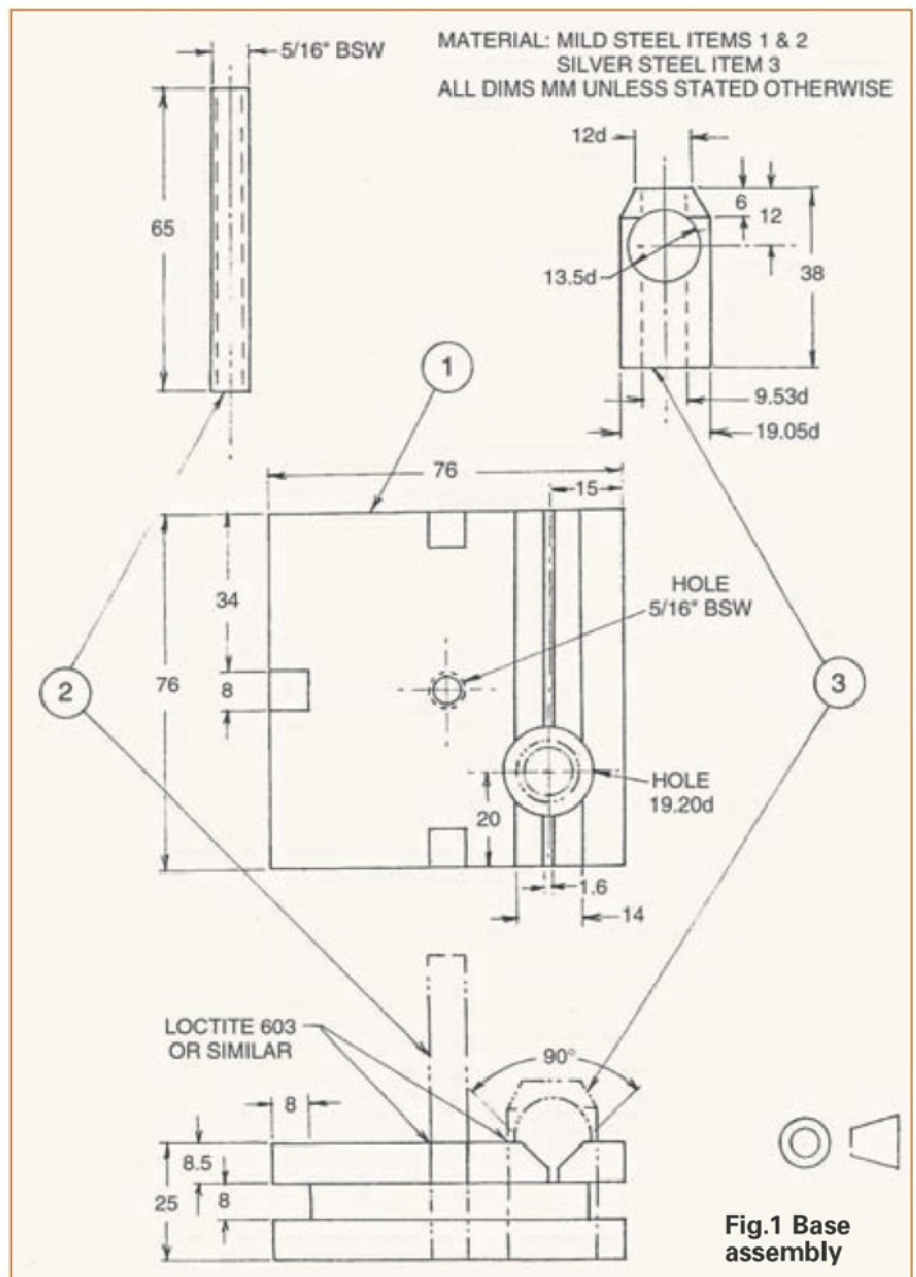


Fig.1 Base assembly

for drilling various size cross holes in rods up to ½ inch diameter clamped in the groove. I use a single drill bush (Fig 2 part 11) for a BS1 (½ inch diameter barrel) centre drill, opening this hole out afterwards if necessary (with the bush then removed). Bushes for smaller drill diameters will be made when required. Most BS1 centre drills seem to have a barrel length of 24 mm so I allowed ⅓ of this (8 mm) for the chuck to grip leaving a maximum length of 16 mm for the guide bush. If frequent use is envisaged the bushes can be case hardened, or made from silver steel, and through hardened.

The base is completed by a central ⅝ inch BSW stud (2) Loctited in place with 40 mm projecting above the top surface of the base.

Fingers (6 and 7)

Two fingers are suggested, these being similar except for length, (73mm and 83mm, respectively) and are made from 19x6 mm mild steel. On each finger one end is solid and the other end is split for accessibility.

Rocker (8)

This piece of mild steel is machined to shape from 23 mm of 19 x 6.35 mm stock. It allows the finger nut to hold the finger securely as the clamping screw applies force to the workpiece.

Finger nut (10) & clamp screw (4 and 5)

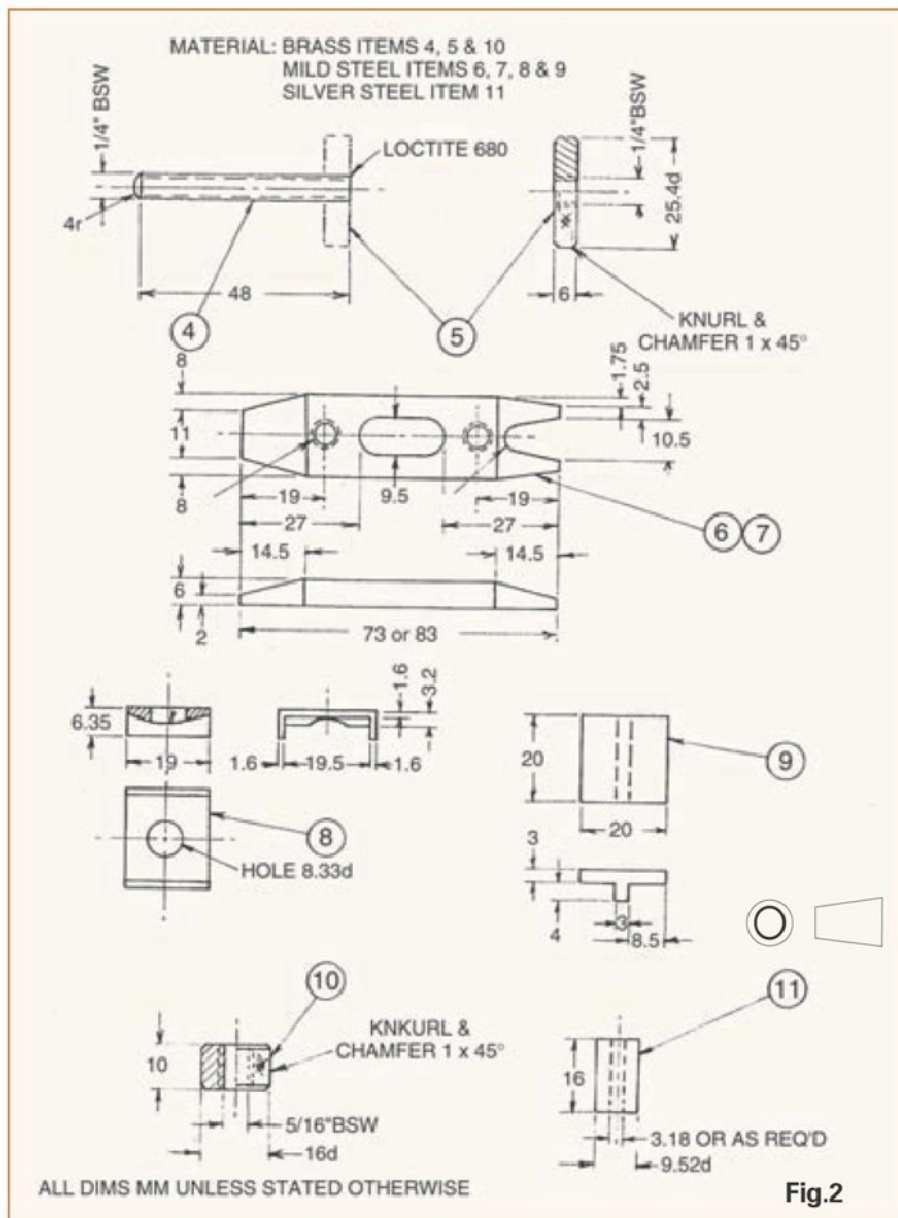
Both are made from brass with knurled rims. The clamp screw knob is held in position on the screw with Loctite.

Tee piece (9)

When thin rods are placed in the Vee groove and which do not rise above the top surface of the base, the small Tee piece can be used on top of the rod to allow the finger to apply clamping pressure.

Conclusion

I have found this device most useful in holding small pieces for drilling, milling and filing operations and I commend it to other home workshop enthusiasts.



References

1. A Forgotten Workshop Tool - W.T. Barker - ME 22 Feb 1951.
2. A Finger Plate - G. Lautard - Machinists Bedside Reader 1986.
3. Finger Plate - G. H. Thomas - Model Engineers Workshop Manual 1984
4. Finger Plate - E. Riley - NS & A Hemingway Catalogue 1994.
5. Finger Plates - S. Bray - ME Vol. 183 No 4107 18 Nov 1999.

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● Wanted, information and /or parts for a Wade C.A.V Lathe, especially a chuck to fit a 5/8in. B.S.F. Spindle. Any help appreciated, and all costs met. Please phone A. Johnson on 01633 420 462

● Help Wanted - I am having considerable difficulty in using the Potts Drill Grinding Jig. Is there

anybody in the Bristol/Bath/Salisbury area who uses one successfully. I would appreciate some help. Please phone 01373 832 681

● Wanted for Myford Super 7B, Screwcutting Metric conversion Quadrant Part No A2469, also Spindles (1485) and Gears if available. Please phone 01603 811 199 (Norwich)

● Wanted, drawings or supplier for an electric pencil or spark engraver. Please contact Ken Thornton on 01252 873663

PLASTIC STORAGE CRATES IN THE WORKSHOP



1, First project - 3 crates in a wooden framework

For some years I have been using these crates to take tools to DIY jobs "off site". They are very handy to quickly load up and pop into the back of the car, do the job and bring the stuff home again.

Numerous house and flat moves made by the offspring in their University education and employment all seem to have involved these plastic boxes. I have collected a number from several manufacturers, but never used them with any serious intent in the workshop for long-term storage because:

- There is no uniformity of design; different makes are incompatible in dimensions.
- Some styles don't seem to be in production long. A special offer in a DIY chain soon disappears.
- Some are just too big and most too fragile to hold heavy materials like steel etc. I've also found they don't make very long lasting scrap metal bins.

Although most are designed to stack by rotating through 180 degrees, they are not very stable when stacked full. You certainly can't move a full stack around the workshop and getting to the bottom crate in a stack is hard work.

My first serious use of these plastic crates is shown in **Photo 1**. This unit was

Mike Haughton suggests ways of using readily available crates to give added storage space, a decided boon to those of us who are inveterate squirrels

designed to go under the workshop bench. Three crates are slid into a wooden framework so they are suspended from their sides by horizontal rails.

This first 3-crate unit replaced an untidy pile of useful materials under the bench just waiting for me to sort through them and find a use for them. I have yet to meet a model engineer that does not hoard and how many of us have sufficient workshop space! You can see that I have used Safeway's "Green Boxes" in my design because:

- These were on special offer at 99p each and have been available for some years in the same design.
- They have almost parallel sides with a strong horizontal lip to hang the box from. Watch out for other designs that have webs moulded into the underside of the lip, which would foul the sliding mechanism.
- They are not too big. Approx. 345x525x230mm deep. My tests showed that they could hold around 20kg. Above this loading the lips distort with the weight and the crate can slip off the horizontal supports. About 10kg would, I think be a sensible maximum loading and not too bad on the back when you have to slide them out.
- These Safeway's Green Boxes are actually made by Instore in Mississauga, Canada, so there is a fair chance they will be available in North America and elsewhere.
- The construction is pretty straightforward. You will have to adjust the dimensions to suit the crates you decide to use.

From **photo 1**, you can see I have used very light timber, 33x33mm PAR (planed all round) spruce for the frame verticals and horizontals. All the halving joints were made a tight fit and also screwed and glued. After filling the countersunk screw head holes and any imperfections in the timber with filler, the filler was sanded down and the completed construction was painted with water based garden furniture paint.

This paint is quick to apply and dry and in use seems to reduce the wear on the slide horizontals caused by the plastic crates being pulled in and out; in addition to preventing oil saturation. North American readers will no doubt laugh out loud at the timber dimensions I used and

use something more substantial and better quality!

One criticism of the design is the possibility that the front verticals may spread and let the boxes slip off the horizontals. In 3 years of use this hasn't happened yet, but a simple steel tie-bar across the front legs above the lowest crate would soon prevent this. If you are handy with an electric welder the whole lot could be made from 25mm square steel tube instead of timber.

A second project

The first project functioned so well that I went on and designed and made a table with six green boxes and two drawers. See **Photo 2**. The table is on castors and also has electrical sockets on an extension lead so I can position it where I choose in the workshop and push it away in a corner when not needed. For this second design I beefed up all the vertical timbers to 45x45mm (2in.x 2in.) PAR and increased the spacing between the tops of the horizontal rails from 9" to 9½". As I like high workbenches, in this case 35" (890mm); I was left with space to fit two



2. The table with six green boxes and 2 drawers.



3. Using a mitre saw to cut halving joints in the verticals.

drawers below the worktop. These drawers have proved to be absolutely invaluable and now house some of my measuring and marking out equipment. **Photo 3** shows the halving joints being cut in the verticals with a mitre saw. The steel rule has been placed in a previous saw cut to keep all the joint cuts in alignment.

I decided to use 450mm bottom drawer runners from Screwfix as I have found they produce a very easy to open drawer. Care is needed to dimension the drawer size relative to the frame. Buy your drawer slides before you start building! See the sources list. **Photo 4** shows the frames assembled with the drawer slides fitted. The tabletop is standing at the rear.

The actual drawers are boxes made with dovetail joints using a router and a Titan dovetail jig from M&M Tools. See



4. The frames assembled with the drawer slides.

sources list. Screwfix also sell a similar jig. Once fitted to the drawer runners a separate drawer front is made and screwed and glued in place. I made the drawer fronts fit within the frame but a better appearance would have been achieved if the drawer front had been mounted on the surface of the frame as in a kitchen unit. The drawers I made were 22" (560mm) front to back. This proved to be too deep to see what is in the back of the drawer. I was unable to find a drawer slide longer than 450mm and you might want to reduce the drawer depth accordingly.

The top of the table is a 4ft.x 2ft. (1220x610mm) piece of 18mm thick MDF with an under frame of 6in.x1in. PAR spruce screwed and glued under the top. This frame has sockets to accept the tops of the six table legs. The rear legs are tied together with a low stretcher to prevent them splaying.

My workshop is always too small and I decided to experiment with a table on castors that I could push out of the way or pull forward as required. In this design the castors are 2in. diameter (50mm dia.), have a load capacity of 45kg each and came from IKEA, see sources list. The addition of castors has proved to be an absolute boon. The ones I used don't have a brake, but this does not seem to be a disadvantage in use on a relatively flat concrete floor.

A third project

Photo 5 shows the tower storage I built with 4 drawers and 3 storage boxes. The design incorporates all the features described above. The storage tower is some 55in.(1400mm) high. It was photographed before simple ply sides were fitted to keep the stored materials clean.

Conclusions

These storage solutions using Safeway's green boxes really work well for me. I'm

about to make another under bench unit that will be on castors, use a 2in.x2in. frame and have a shallow drawer at the top to hold small tools.

Footnotes

Drawers, even wooden ones, have some disadvantages when used to hold loose tools as they roll about and easily become damaged. One solution I have found useful is to line the drawers with some thick dimpled PVC sheeting called "Rationell" from IKEA. This sheeting is soft and also provides some anti roll effect. It is sold to line the drawers of kitchen units holding knives. A piece of this material can be seen on the table top in **Photo 2**.



5 A storage tower with 4 drawers and 3 storage boxes.

Sources

Screwfixdirect

<http://www.screwfix.com>
Part number 1859, bottom drawer runner 450mm.
Part number 7062, 12" dovetail jig.

M&M Tools. **M&M Distributors Limited**,
PO Box 128, Bexhill-On-Sea, Sussex
TN40 2QT. Titan TCT Cutters and
Dovetail Jig.

IKEA <http://www.ikea.com>

Part No. 966.713.00 RILL 50mm castors
45kg max loading.
Part No 8000.128.53 RATIONELL
150x50.4cm PVC drawer liner.

ELECTRONICS IN THE MODEL ENGINEER'S WORKSHOP (5)

Mike Feather considers Servo and Stepper motors, and gives suggestions for driver circuits

Clarification

Before embarking on the new subject matter, I have to express my thanks to Mr. Atkins for pointing out that Fig 16 MEW issue 81 page 43 is open to misinterpretation. For the avoidance of doubt, the wires shown crossing are not interconnected.

Servomotors and stepper motors

The most commonly used form of d.c. motor is the permanent magnet/commutator type, whose basic function is to develop a rotational power output when supplied with a d.c. voltage. Such motors find wide application in many fields and speed control can easily be achieved by the use of relatively simple electronic circuitry which can also improve the performance of the motor. These techniques were discussed in Article 2 of this series, (MEW issue 80)

Some situations demand that the speed of the motor be maintained at a precise value; a common example is the drive system for record player turntable. In a typical arrangement, the turntable is driven by a small motor via a belt drive. The edge of the turntable is provided with equally spaced optically reflective markings which are illuminated by a small lamp or LED. A photodiode or phototransistor senses the reflected bursts of light as the turntable rotates, so developing a series of pulses whose frequency is proportional to the speed of the turntable. The frequency of the pulses is compared electronically with pulses produced by a stable reference oscillator and the output of the comparison circuitry is fed to the motor

control circuit. A block diagram of the arrangement is shown in Fig. 1.

If the frequency of the pulses generated by the turntable differs from the reference pulse frequency, the motor control circuit will adjust the speed until the two become equal. Speed control systems of this type are known as servo systems and there are numerous alternative techniques for developing the speed related feedback signal. This method of comparing the actual value of a quantity with the desired value and adjusting the former if the two are not equal forms the basis of most control systems.

In another type of servomotor arrangement, the function is to control the motor's output shaft position, rather than its speed. Such systems – known as proportional movement controllers – find applications in the area of remote control of valves, satellite aerials and elsewhere. There are two basic approaches to the task of achieving proportional control – analogue and digital.

Analogue proportional control

In an analogue proportional control system, the motor's output shaft is mechanically coupled to a potentiometer via a speed reduction gearbox. The potentiometer is connected as a voltage divider, so that the voltage at its slider, V_{out} , will be proportional to the rotation of the gearbox output shaft. V_{out} therefore provides the feedback signal. A possible arrangement for a proportional control system is shown in Fig. 2.

Variable resistor VR1 is the shaft position sensor whilst VR2 is a similar

resistor used to set the desired position (it is known as the set potentiometer). It too is wired as a voltage divider so that the voltage at its slider, V_{ref} , will be proportional to the degree of rotation.

The V_{out} and V_{ref} signals are compared by applying them to the inputs of an operational amplifier chip, IC1, which is wired in *differential mode*, i.e. its output voltage is proportional to the difference between the voltages present at its two inputs (known as invert and non-invert, marked – and + in the figure). When the output shaft position matches the set potentiometer position, VR1 will be equal to VR2 and V_{out} will equal V_{ref} . There is thus no difference between the two voltages and the operational amplifier output is zero. Motor driver transistors TR1 and TR2 will both be turned off and the motor will be stationary.

Rotating VR2 will cause a change in V_{ref} so upsetting this balance and causing a voltage to occur at the output of the op. amp. and depending upon the polarity of this, either TR1 or TR2 will turn on so causing the motor to run and rotate the output shaft until the value of VR1 becomes equal to the new value of VR2, at which point the rotation of the motor will cease. Fig.3 shows an experimental set-up of the arrangement.

Note that the motor includes an integral reduction gearbox. The variable resistors VR1 and VR2 are, in this case, ten turn types (rather than the usual 270°) in order to allow up to ten turns of the output shaft. The combination of R5 and VR3 determines the overall gain (amplification) of the circuit and VR3 can be adjusted to control the speed of response of the system. Too fast a response will lead to the output shaft overshooting and possibly

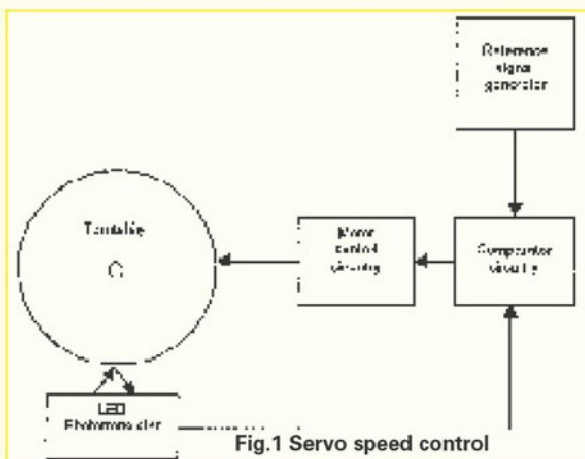


Fig.1 Servo speed control

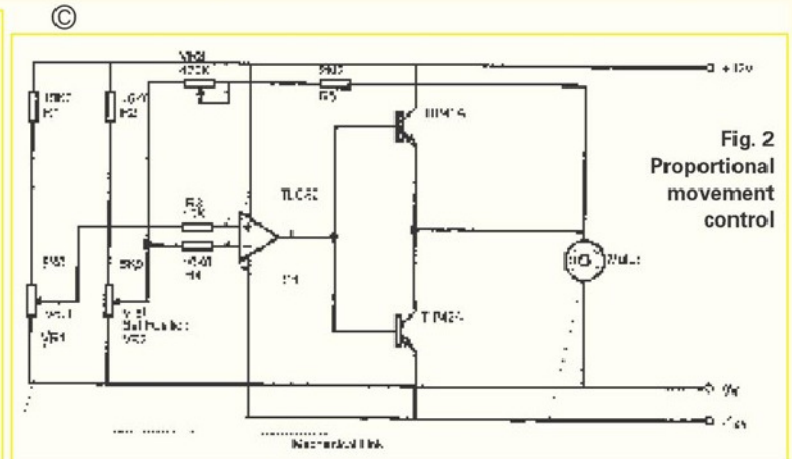


Fig.2 Proportional movement control

oscillating about the final position, so a compromise between speed and stability needs to be established.

Digital proportional controllers

Digital control is perhaps the most commonly used form of proportional position control and finds wide application in the area of remote controlled models where it is used for rudder control, aileron control, whatever. The motors used are usually simply referred to as 'servos'.

A typical small servo consists of a d.c. motor and reduction gearbox which provide the mechanical output. A potentiometer coupled to the gearbox output shaft provides the position related signal in much the same way as for an analogue system. The electronic control is entirely different however and a block diagram of the basic arrangement is shown in Fig. 4, whilst Fig. 5 shows a typical small servomotor. The position of the servo's output shaft is controlled by a variable width input pulse which is applied repetitively at a rate of about once every 15 milliseconds. The width of the pulse determines the position of the output shaft and the usual arrangement is:

Pulse Width	Shaft Position
1.0ms	Fully Anticlockwise
1.5ms	Centre
2.0ms	Fully Clockwise

Suitable control pulses can be generated using the circuit of Fig. 6. The circuit uses two 555 timer chips IC1 and IC2. IC1 develops the control pulses at a rate which can be varied from once every 12 ms to about once every 20 ms. IC2 controls the width of the pulses and hence the servo output position. With the component values suggested, VR2 allows the pulse width to be varied between 1 ms and 2ms so giving control over the full angular position of the servo's output shaft. VR3 is a trimmer type variable resistor which can be adjusted so that with VR2 in its center position, the pulse width is precisely 1.5 ms, so causing the servo output shaft to go to its centre position.

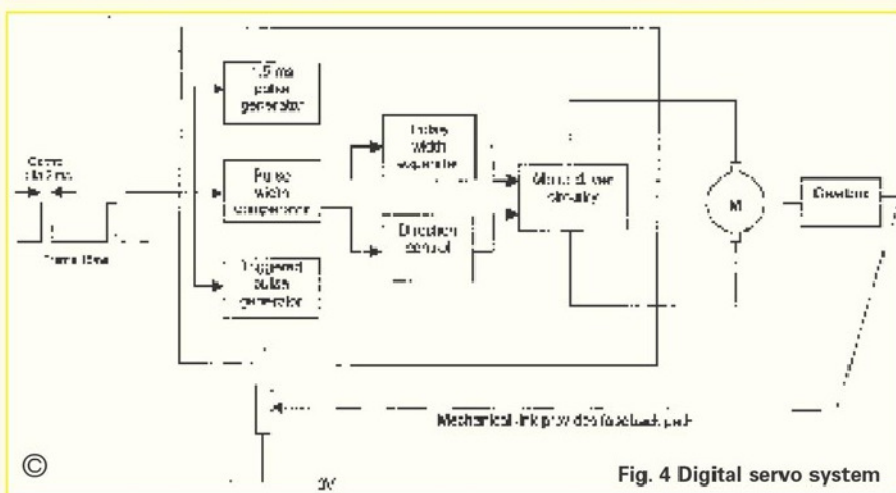
Other servomotor circuits

Several manufacturers supply dedicated servomotor control chips which employ the digital approach and may be used with conventional d.c. motor/gearbox and potentiometer combinations. A typical device is the Ferranti ZN409 chip and a suitable application circuit for a small d.c. motor is shown in Fig. 7.

The control pulse specifications are the same as those described for the model control servomotors and may be derived using the circuit of Fig. 6. In a later article, we shall look at how microcontroller chips can be used to control d.c. servomotors.

Stepper motors

Stepper motors provide an alternative approach to the task of achieving positional control by means of an electric motor. The technique used is quite



different to that of their d.c. counterparts.

As the name implies, the mechanical output of a stepper motor is in the form of discrete rotational steps, rather than the continuous smooth rotation of a d.c. motor. The size of the step is known as the step angle or angular resolution and the coarsest motors might rotate 90° per step, i.e. four steps per revolution of the output shaft. Higher resolution motors commonly offer 7.5° (48 steps/rev) or 1.8° (200 step/rev). Even smaller step angles can be obtained with appropriate control circuitry.

There are two basic types of stepper motor, variable reluctance and permanent magnet.

Stepper motors are the motive power used by Richard Bartlett's well known Computut system, and readers may wish to look over his comments in Ref 1, and related articles.

Variable reluctance stepper motors

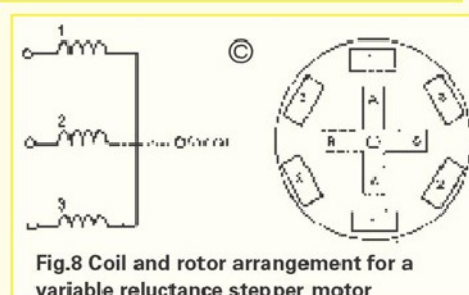
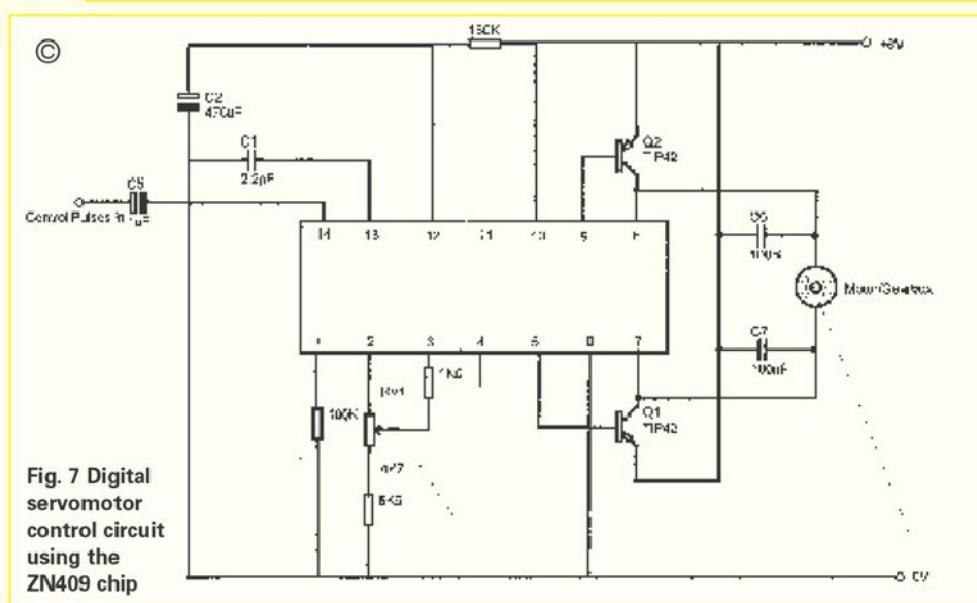
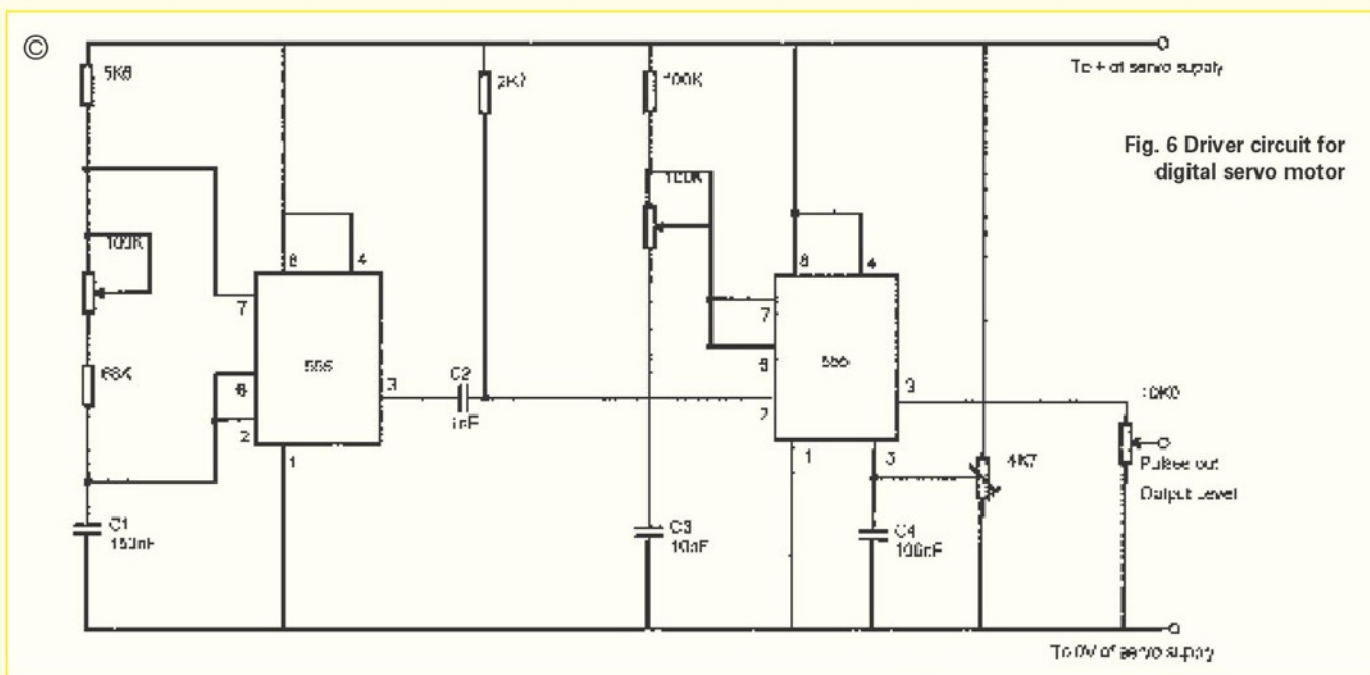
Variable reluctance motors normally have three, occasionally four, stator coil windings, with one end of each winding being joined to a common connection. The iron rotor will have a number of teeth machined into it which, together with the number of stator coils, determines the step



angle of the motor. Fig. 8 shows the coil and rotor arrangement of a simple 30° per step variable reluctance motor.

The stator has three pairs of poles (labelled 1 to 3) in the figure, each of the three coils being wound around two opposite poles. The rotor has four teeth. If current is passed through winding 1, rotor teeth A will be attracted to this pair of poles and the rotor will move to the position shown in the figure.

If the current in winding 1 is now turned off and sent through winding 2



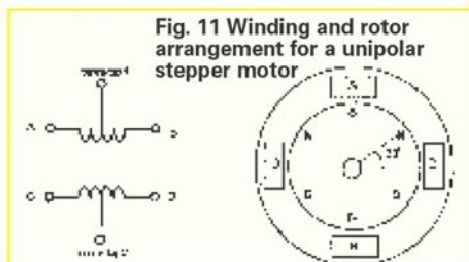
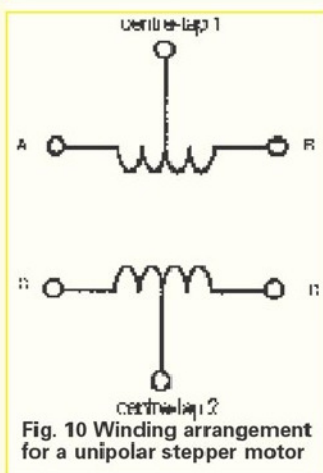
instead, the rotor will turn through 30° clockwise so that teeth B line up with poles 2. Energising winding 3 will cause a further 30° clockwise step. To achieve continuous stepped rotation, we simply apply current to the three windings in sequence. The table of Fig.9 shows this sequence, a '1' indicating that the current in a coil is switched on. Variable reluctance motors with as many as five stator windings and more rotor teeth are available, thus offering better angular resolution.

Winding 1	1	0	0	1	0	0	1	0	0	1	0	0	1
Winding 2	0	1	0	0	1	0	0	1	0	0	1	0	00
Winding 3	0	0	1	0	0	1	0	0	1	0	0	1	0
Deg. Rotation	0	30	60	90	120	150	180	210	240	270	300	330	360

"1" = current on in winding

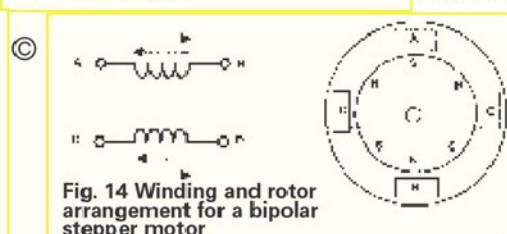
A	1	1	0	0
B	0	0	1	1
C	0	1	1	0
D	1	0	0	1
Deg. Rotation	0	30	60	90

"1" = current on



A	1	0	0	0
B	0	0	1	0
C	0	1	0	0
D	0	0	0	1
Deg. Rotation	0	30	60	90

"1" = current on



A	+	0	-	0
B	-	0	+	0
C	0	+	0	-
D	0	-	0	+
Deg. Rotation	0	30	60	90

The + and - signs indicate the polarity of windings at each step. 0 = winding off

Permanent magnet stepper motors

Permanent magnet motors usually have two independent sets of stator windings and a magnetised rotor. There are two possible arrangements of the stator coil windings, leading to two categories of this type of motor, unipolar and bipolar.

Unipolar stepper motors

Unipolar motors have two centre-tapped stator windings as shown in Fig. 10.

Motors of this type will thus normally have six connecting leads, although the two centre-taps are often connected together internally, resulting in a motor with just five external connecting leads. In use, the centre-taps are normally connected to the positive power supply rail and the two ends of each winding are alternately connected to the 0V rail in order to reverse the direction of the magnetic field generated by the winding. Fig. 11 shows the coil and pole/rotor arrangement of a simple 30° per step unipolar motor.

Winding A is shared by the top and bottom stator poles, whilst winding B provides the field for the left and right poles. The rotor is permanently magnetised with three diametrically opposite north and south poles arranged 60° apart around its circumference, as shown. In the position shown, coil A is energised, causing the top stator pole to become north, so attracting the south rotor pole. If the energising current is now switched to coil C, the right hand stator pole becomes south so attracting the adjacent rotor north pole and the motor turns one step of 30°. The current switching sequence for one complete revolution is shown in Fig. 12.

Note that only one winding is energised at a time. It is possible to apply current to two windings simultaneously and this will result in an increased output torque. The energising sequence for this is shown in Fig. 13.

The rotor positions produced by the two sequences are different and combining them results in a technique called half-stepping in which the motor stops alternately at the positions in one or the other of the sequences.

Bipolar stepper motors

The mechanical arrangement of a bipolar stepper motor is identical to that of the unipolar type, but the two stator windings are wired more simply, with no centre-taps. This makes the motor somewhat cheaper to manufacture but results in more complex drive circuitry as the polarity of each winding needs to be reversed in order to reverse the direction of its magnetic field. Some form of H-bridge circuit (see MEW issue 80) is normally employed.

Fig. 14 shows the winding and pole/rotor arrangement of a simple bipolar stepper motor, whilst the winding energising sequence is shown in Fig. 15.

Fig. 16 Typical small stepper motors

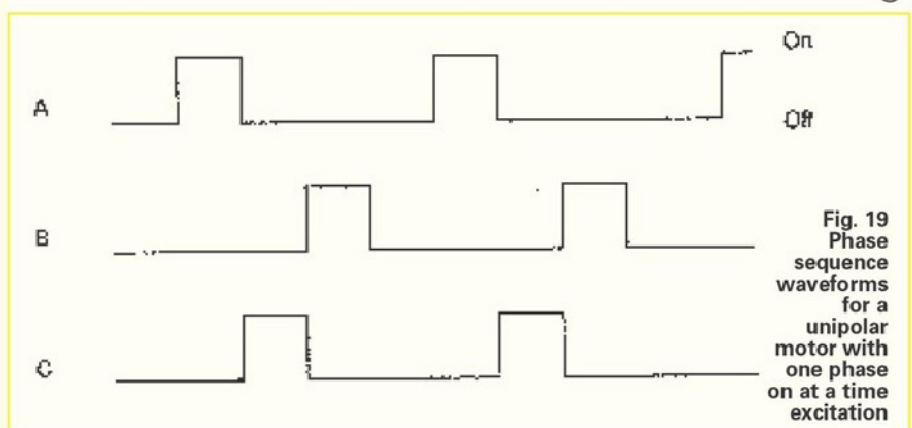
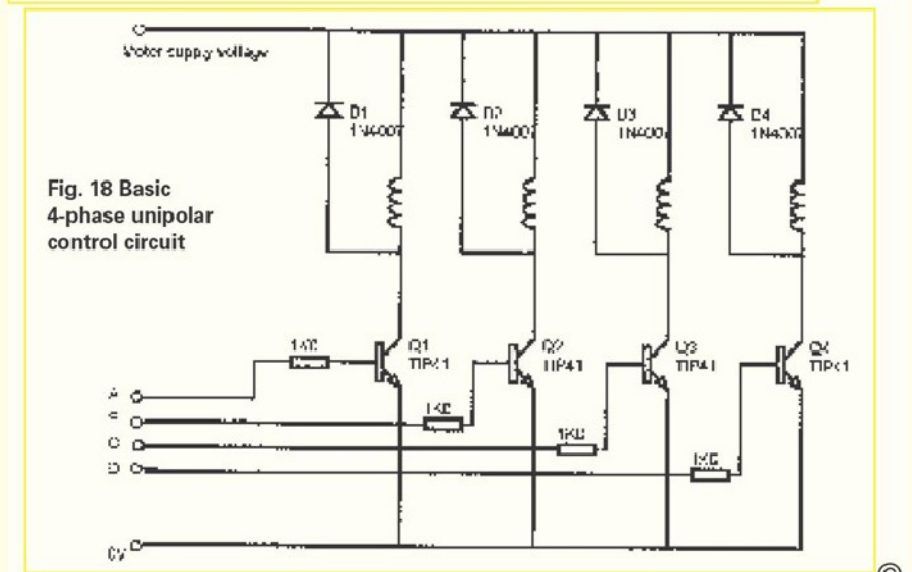
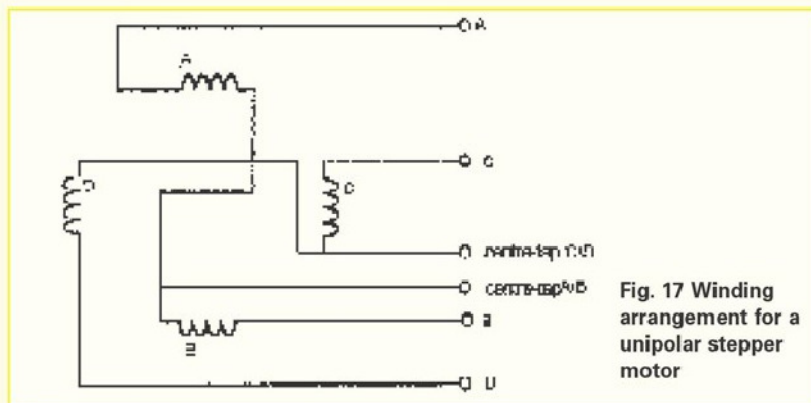
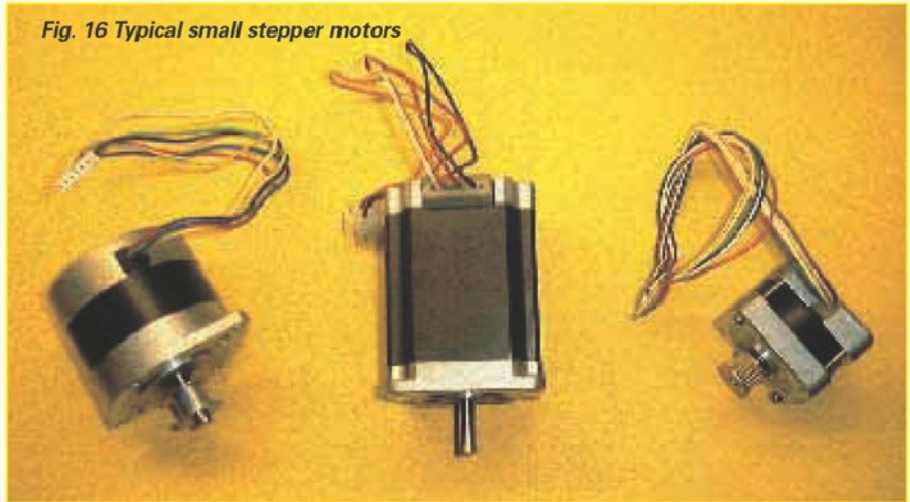
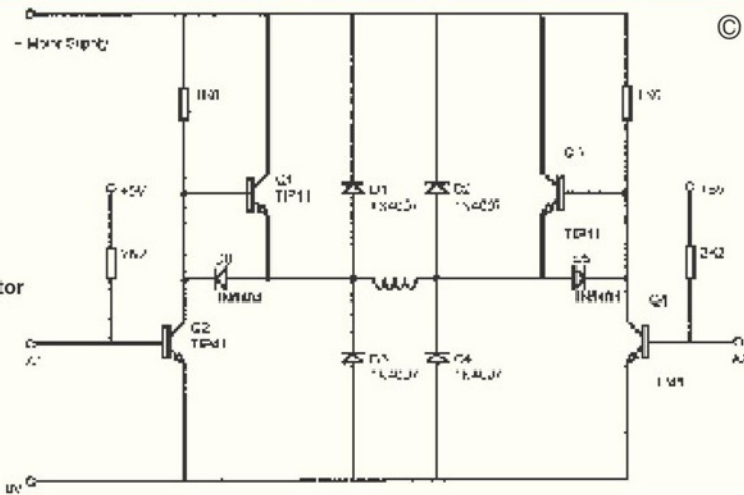


Fig.20
H-bridge
circuit for
control of
bipolar motor



For a five or six lead unipolar motor it is necessary to identify the centre-tap lead(s). Once again, a multimeter can be used. Referring to the coil arrangement diagram of Fig. 17, the centre-tap lead will be the one with only half as much resistance between it and the other ends of the winding.

Finally, it is necessary to determine the order of the windings. Connect the centre-tap(s) to the positive terminal of an appropriate power supply and connect one of the other leads to the 0V terminal. Now connect each of the three remaining leads to the 0V terminal in turn and observe the movement of the motor shaft.

Assume that coil D is the one already connected to 0V. The following table describes the effect of connecting the other leads to 0V and hence identifies the windings.

Motor Rotation	Lead Connected to Coil
Slightly Clockwise	C
Slightly Anticlockwise	A
None	B

Stepper motor drive circuits

The reader will appreciate that, whatever type of stepper motor is to be used, the driver circuitry must switch the current in each winding on and off in a predetermined sequence (known as the phase sequence) in order to achieve the desired stepping of the rotor. Transistor switches (bipolar or FET) can be used to achieve this switching action and Fig. 18 shows a possible arrangement for a four phase unipolar motor using NPN transistor switches. The phase sequence pulses are applied to the transistor bases, so turning on the transistors and the windings connected to them. For a unipolar motor operating in one phase on at a time mode and running clockwise, the required sequence of pulses is shown in Fig. 19. Diodes D1 to D4 are connected across the motor windings and are essential in order to absorb the back e.m.f. generated across the winding when the current in it is turned off.

For bipolar motors, things are a little more complex as the current direction in each winding needs to be reversed. As mentioned, an H-bridge arrangement is normally employed and Fig. 20 shows a typical circuit.

Generating the phase sequence

This task can be approached in a number of ways. At the most basic level, a suitable combination of logic gates (counters, shift registers etc.) driven by a clock pulse generator may be assembled and its outputs used to drive the transistor switch circuits of Fig. 18 or Fig. 20. This type of solution is often called 'hard wired logic' and it can lead to a fair degree of complexity. In addition to this, it is very inflexible, in that any desired change to the phase sequence would be very difficult to implement. Such systems are seldom used nowadays. At the other end of the scale, it is a relatively straightforward matter to generate the sequence using a microcomputer and an appropriate

Fig.21
Basic circuit arrangement
for the L297 chip

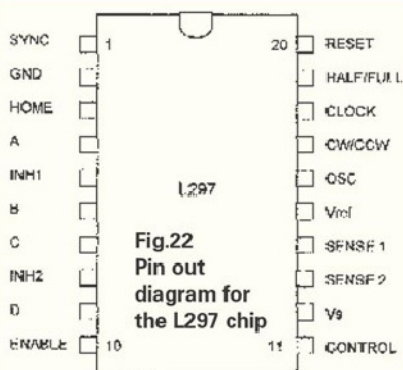
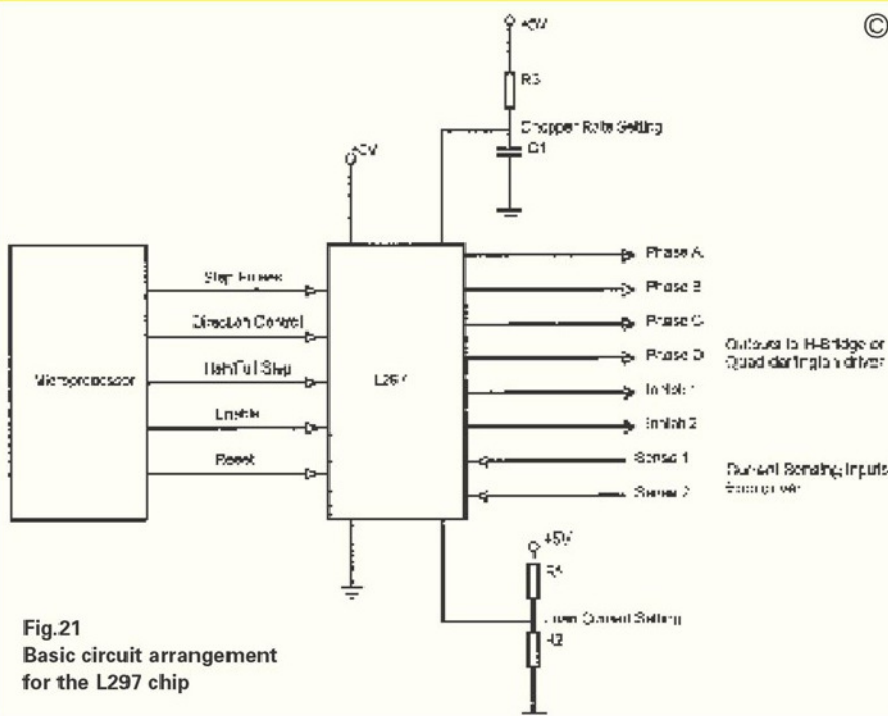


Fig.22
Pin out
diagram for
the L297 chip

standard adopted by different manufacturers. It can therefore be something of a problem in determining the type of motor and the arrangement of its connecting leads.

Turning the rotor will usually distinguish between variable reluctance and permanent magnet types. The former will offer little resistance to rotation whilst the permanent magnet variety will tend to move in 'jumps' as the magnetised rotor poles line up with those of the stator. An ohmmeter can also be used to identify the two types: variable reluctance motors usually have three (sometimes four) windings with a common connection for each. Permanent magnet types normally have two independent windings with or without centre-taps (unipolar and bipolar respectively). So:

- A motor with six leads is probably four pole unipolar: the two centre taps are often the same colour.
- A motor with five leads is probably four pole unipolar with the two centre-taps connected internally.
- A motor with four leads is either a three pole variable reluctance type or four pole bipolar: a resistance test with a multimeter will reveal the identity.

Identifying motor types

Fig. 16 shows a collection of small stepper motors, both bipolar and unipolar.

The motors do not usually carry much in the way of useful labelling other than perhaps the step angle and operating voltage and/or coil resistance. Connecting leads will vary in number according to the type of motor and, although generally colour coded, there is no particular

programme. Many variations on this approach have been devised, most employing the printer port to output the sequence to the switching transistors.

Of course, tying up a desk top computer to the task of controlling one or two stepper motors is just one approach. During recent years a whole range of small, cheap microprocessor chips dedicated to the task of control has been developed by semiconductor manufacturers. These fascinating devices are known as microcontrollers and we shall take a look at them in a future article.

In order to ease the burden of generating complicated phase sequences on the microprocessor, a range of dedicated stepper motor controller chips have been developed by semiconductor manufacturers. A very useful example of such devices is the L297 stepper motor controller chip produced by SGS Thomson. This chip integrates all of the control circuitry, including phase sequence generation and load current regulation needed to operate both unipolar and bipolar motors. It has a number of input (control) signals which would normally be derived from a microcomputer or microcontroller and, with relatively simple software, very flexible and efficient stepper motor systems can be designed and constructed. Fig. 21 shows the basic configuration of the L297 for controlling a two phase bipolar motor. An L298 dual H-bridge driver chip provides the necessary current reversal operations in the motor windings and at the same time provides sufficient power for stepper motors of up to 2A per phase. For unipolar motors, the L298 can be replaced with four switching transistors. Fig. 22 shows the pin-out diagram of the L297, whilst the functions of the pins are described in the table of Fig. 23.

Load current regulation

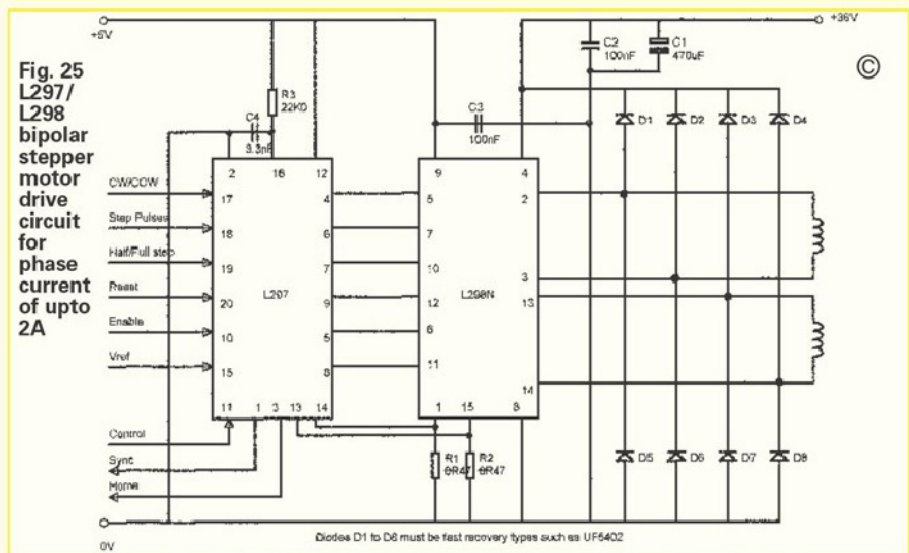
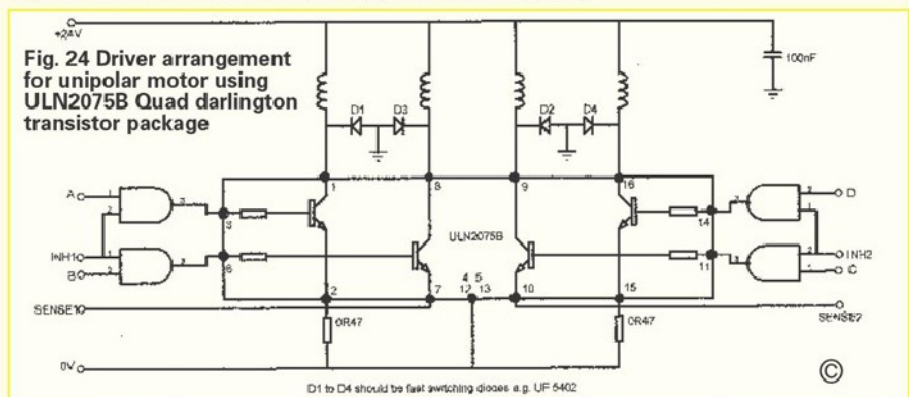
The L297 incorporates pulse width modulation circuitry (see MEW iss 80) in order to achieve good speed and torque characteristics in the motor, with the peak current being set by the voltage applied to the Vref pin. Earlier technology relied on the application of a higher voltage and the presence of a resistor in the phase supply.

A practical 4-phase unipolar motor drive circuit

Fig. 24 shows the arrangement for driving a 4-phase unipolar motor. In this circuit, a ULN2075B quad darlington driver chip provides the power interface between the L297 and the stepper motor. The chip contains four darlington transistors, each capable of handling up to 2A. Two 0R47 (yes, 0.47 ohm!) resistors carry the emitter currents for the transistors and the voltage across them is used to provide the sense inputs for the L297. Diodes D1 to D4 give back e.m.f. protection and they must be fast switching types such as UF5402. Do not use standard power diodes such as the 1N5402 in this application. Note that pins 4, 5, 12 and 13 of the ULN2075B are heat sink contact tabs and, for higher power motors, they should be soldered to a substantial area of

Pin No.	Name	Function
1	Sync	For synchronising operation of several L297's
2	Gnd	Ground (0V) connection
3	Home	Output indicates when chip is in its initial condition (ABCD = 0101)
4	A	Motor phase A drive output
5	INH1	Active low output to regulate winding current of A and B phases
6	B	Motor phase B drive output
7	C	Motor phase C drive output
8	INH2	Active low output to regulate winding current of C and D phases
9	D	Motor phase D output
10	Enable	Chip enable input: high to activate chip
11	Control	Input that defines action of current control circuitry
12	Vs	+5V supply
13	Sense 2	Load current sensing input for phases C and D
14	Sense 1	Load current sensing input for phases A and B
15	Vref	Reference voltage for current control circuitry
16	Osc	Connects to a resistor/capacitor network and determines frequency of current control circuitry
17	CW/CCW	Clockwise/Counterclockwise rotation control
18	Clock	Input for stepping pulses
19	Half/Full	Input selects half or full step operations of motor
20	Reset	Input: a low pulse sets the phase frequencer to the initial condition (ABCD = 0101)

Fig. 23 Pin functions for the L297 stepper motor driver chip



copper on the printed circuit board.

Some external logic gating of the phase and inhibit signals from the L297 is necessary in order to permit correct action of the current control circuitry. A CMOS 4011 quad NAND chip would be suitable.

The ULN2075B chip could be replaced with four individual NPN power darlington transistors such as the TIP121. If this approach is followed, then base resistors must be included: 1K0 would be appropriate.

For a bipolar motor, things are simpler

as the L298 chip contains all of the necessary current control circuitry. A suitable practical arrangement is shown in Fig. 25. Once again back e.m.f. protection diodes must be fast types and the 0R47 current sensing resistors are necessary in order to achieve good motor torque/speed characteristics.

Reference

1) CNC for Practical Engineers (4) MEW issue 44 page 31

Reader to Reader

Suction fences and vacuum cleaners

Peter Gascoyne of Wantage writes

Could I make a couple of comments on the article in issue No. 80 by Ted Wale about his suction fence. So called "vacuum" cleaners actually produce very little vacuum. Only $\frac{1}{2}$ to 1 PSI reduction below atmospheric pressure is a typical value. Really they should be called suction cleaners but no-one does. I have just done some quick tests on four cleaners that were fairly readily to hand. Three, that were bag types, gave about 4 PSI while the other, a modern cyclone type, gave 3.5 PSI. These were all measured with the pipe blocked. I suspect that Ted's vac only produces 1 PSI or less of suction which, actually, is just as well as 10 PSI would apply about half a ton load to the lid of his cleaner. This fact does not stop his fence from working. What happens is that the whole of the surface of the wood in contact with the fence is subject to suction in varying degrees. At the edges it will, of course, be zero. At the holes it will be the full value. In between it will vary between these two values. In effect it will be as though the full value had been applied over $\frac{1}{2}$ to $\frac{3}{4}$ of the area in contact with the fence. Hence the fence works.

It is also important to use a vac that has separate motor cooling for this type of duty. Most domestic ones cool the motor with the air that passes along the hose. If the hose is blocked for any length of time, the motor will overheat. Ones where the motor projects through the lid, as the one that Ted uses, should be OK but do check. Read the leaflet that came with it then block the hose and see that the flow of air into or out of the motor vents does not change.

I hope that these comments are helpful.

An electronic query

From Mr Peter Lewis

I refer, in particular, to the series of articles by Mike Feather. I am a very much retired electrical/electronic engineer and have appreciated his articles very much. I am particularly interested in the speed control of single phase induction motors around the half HP size. Looking around the options there appears to be only one. Start by changing your motor to 3 phase, procure a transformer to produce 440V or thereabouts, bridge rectify to DC roughly, then produce a piece of electronics to generate a variable frequency with 3 outputs at 120 deg. and fire three thyristors, or similar to give you a variable frequency 3 phase supply, or just buy an inverter. Can't this same logic be applied to a single phase motor. I know one has the

consideration of, shaded pole, capacitor start, capacitor start/run and may be more that I have forgotten. Is Mike going to address this in subsequent articles?

Mike Feather replies:

The present answer is no but there are rumours (and only rumours) of new developments which may make this possible. Clearly if this does become a reality then it will open up a whole range of possibilities for speed control of small machines.

Information wanted

Michel Jacot of Neuffen, Germany, writes:

I am looking for information on the "Chinese South Pointing Wagon" with a view to making one. I have been told that the wagon and its mechanism were described in "Meccano Magazine" back in the 1950's, and also in Model Engineer. Can anyone please help.

Michel Jacot, Bahnhof Str. 19, 72639 Neuffen, Germany.

Coolant comment

From Mr K. A. Willson, Fleet, Hants.

Mr D. C. Sylvester writes in issue 81 of M.E.W. concerning coolant. He correctly identifies the weakening of his soluble oil for the staining of the ways. Undoubtedly a better coolant would be a Neat Oil, which is quite easy to pump.

He fortunately has a branch of Buck & Hickman in Peterborough (usual disclaimer) where he can get advice and supplies of suitable oil. He will need to buy 25 litres and so should look around for a friend to share the costs.

A threadform query

From Mr D. Berreclough, Uckfield

I have just realised that in the tables in Appendix C of Workshop Practice Series Book No 12 (Drills, Taps, and Dies) the percentage thread engagement data is based on the depth of the nut thread, whereas I thought it should be calculated from the depth of the bolt thread as in Workshop Practice Series Book No 3 (Screwcutting in the Lathe). Would any reader who may be well versed in the subject care to offer chapter and verse.

Toolposts, fingers and elastoplasts

Mr Alan MacFarlane of Aberdeen U.S.A writes

I have just received the April issue of Model Engineer's Workshop and noted the article "Easy Changing of Lathe Tools".

The 4 way toolholder described has its good points: easy to make, of readily available materials, and at low expense. As a former user of this type of toolholder, I have found its bad points. They consist of four sharp cutting tools, any one of which can stab your fingers or back of hand in a careless moment. How do I know this? - from the supply of Band-Aids I used to carry in my toolbox that were often needed when using the lathe.

It could be said "well, you just have to be more careful" and that is probably true, perhaps I am more careless and in a hurry than the average model engineer. In any event I solved my problem by storing all my 4 way toolposts on a very high shelf and purchasing the modern Aloris-Dorian type toolpost with interchangeable tool holders. What a blessing! Tools can be changed in seconds and they are always at the proper height. No boxes of shims, no unseemly language while fumbling with the shims to obtain proper tool position. My purchases of bandages have been cut by at least 80% and I have an efficient tooling system. Yes, the downside is that they are rather costly. The US built posts are in the \$200 (probably £200 for the UK) price range, but Far East copies can be purchased for as low as \$69. This does not include the tool holder so at least one should be bought. Then you can make any number of copies from square steel or even aluminum at very low cost. I have made 9 holders at about \$2 each. Anyone with a lathe milling attachment or vertical mill and a 60 degree dovetail cutter can make as many as desired. Extreme precision is not needed, any small amount of slack in the dovetail is taken up by the clamping mechanism. I have found my aluminum toolholders have worked very well, and a lot easier to machine on my rather lightweight vertical mill.

Another option- in the May 20, 1977 issue no.3561 of Model Engineer is an excellent article on making a tool post by L. Phillips. It uses the same principle of separate tool blocks and could be made at very low cost. I found it interesting that Mr. Phillips stated he designed and built his tool post about 1953, almost 50 years ago. I do not know when the design was put on the market but the idea seems to have been lost for many years. It was, and is, a great idea, compared to the American lantern post and the English pattern, both awkward and slow. I strongly advise anyone thinking about a tool holding system for their lathe to look into one of these options. They may save you pain, aggravation and if you're like me, bloodshed!

An interference (won't) fit

Peter Rawlinson writes

My thanks to the reader who took time to phone and point out an error on the drawings for my Quick Quill Stop (MEW Issue 82 page 33) As dimensioned, the parts cannot be assembled due to a one millimetre interference between the Inner Nut and the Outer Case. If the outside

Elevating head lathes and other queried oddities

Tim Bard of Riyadh writes:

Regarding the note by Leonard Woods in ME Workshop No 80 in responding to Mr. George Mills query about elevating head lathes. The elevating head lathe does exist in production from Russia. I have a new one called an ERTEN Machining Center. If I understand what Mr. Mills is looking for, the ERTEN is probably it. A small lathe with a normal bed of about 1 metre length and a vertical column which can elevate the headstock spindle to about 0.3 metre to allow turning of pieces up to 0.6 metre diameter.

It can also be used as either a vertical miller or with an over-arm attachment as a horizontal miller. There are a number of extras available, rotary tables, swivel bases, cross slide milling attachment, etc. are of high quality (better than Taiwan). In all it is very similar to the concepts of universal machines covered in a recent MEW article. At present I am installing an independent PWM DC gear motor drive to the carriage lead screw feed as there is no gearbox and just two normal feed rates plus a gear set for either inch or metric screw cutting. I have fitted a Shooting Star (Canada) DRO to the carriage (also three axis version to my mill, excellent product).

Other Oddities - There was a short article some time back about left hand lathes. I had never seen a true left hand lathe before (one with the headstock to the operators right) but was aware that lathe carriage aprons come left and right handed. When I ordered a lathe twenty years ago for my shop the vendor asked whether I wanted a left or right carriage? The difference is that the hand wheel will be left or right of the clutch (swapped). Being left-handed a left clutch is more to my liking.

There is an amazing amount of free machining and machine shop information at the discussion forum: http://www.chaski.com/cgibin/machine_in_dex.cgi check it out!

Mr Kevin Pullen of Hobart, Tasmania writes

I was most interested to read the letter from Mr George A Mills (MEW Issue No 77) on the subject of the Astoba machine. My own experiences may be of interest.

During 1949, the University of Tasmania purchased an Astoba UW1 Universal Machine Tool for the sum of £1000 Aus. As an apprentice I operated the machine every day for three years, 1954 – 56.

I remember a wall chart of pictures illustrating every configuration of the machine; fifteen in all.

Three years ago, the machine became surplus to the University's requirements, and I had the good fortune to be in a position to purchase it. The machine is No. 307 and is the short bed model. The range of accessories acquired with it, enable it to function as a Centre Lathe, Facing Lathe, High Speed Sensitive Drill, Low Speed Heavy Duty Drill, Horizontal or Vertical Milling Machine, Slotting Machine, Surface or Cylindrical Grinder, Horizontal Borer.

Other Accessories available but not purchased in 1949 were a Jig Saw, Circular Saw (for woodwork), and a substantial power hacksaw.

The three jaw chuck has a ground scroll, and prior to the attentions of the "in house butcher", could be relied on to hold work within 0.0002 runout. One very convenient feature is that the nose design is repeated on the spindle and dividing head. This enables the chuck with turned component to be transferred to the dividing head for milling with guaranteed concentricity. The speed range extends from 75 to 4000 rpm and I believe there may have been an optional attachment to reduce this to 25 rpm. Although the section size of the main components appears on the light side compared to other machines, the rigidity is high. I believe this to be due to good design and close fit.

Changing configuration is quick and easy, with a typical time to change from Lathe to Vertical Mill of around four minutes, with half of that being required for cleaning. Whilst an apprentice, I timed myself from one most complex setup to another; seven minutes!

The machine is still in first class condition. After I left the University, the research direction changed, and the Astoba lay mostly unused for 47 years. I am lead to believe that the UW1 is still manufactured in Switzerland, by Meyer Berger AG, and is marketed in the UK by Brunner Machine Tools Ltd. (tel 020 8992 7559) Mine was made by A. Stoeckle (Switzerland) The original cost of £1000 Aus may be seen in the context of wages for a tradesman of around £15, and for an apprentice of less than £4.

It seems that the machine was available with centre heights of 4.33 or



Possibly another near equivalent to the elevating head machines described is the German Golmatic universal machine shown here in Lathe and Vertical Mill configuration. Other setups including Horizontal Mill are possible. The Golmatic is marketed in the UK by Pro Machine Tools Ltd. (tel 01780 740 956)



8.25 inches, with bed lengths giving 16.5in or 24in. between centres.

When I first used the machine in the 50's, it was a delight, and now nearly 50 years later, I still enjoy the silky smooth movements, the reliable precision, and wonderful ease with which one is able to manufacture small parts to high accuracy. Recently I made a small instrument screw 1mm dia. x 0.25mm pitch. I have also built a short stroke slotting attachment in preparation for the manufacture of ten bevel gears 0.35in. dia. x 48 dp. Such items are quite straightforward on this machine.

I would be most interested to know more about the origins of the machine. When was it first manufactured? Was it the brainchild of some brilliant designer that went straight to production or was it the result of a series of development prototypes?

diameter of the Nut is machined to 22mm, then all should be well.

Choosing a lathe

Mr George Winspur writes

Referring to "On the Editor's Bench" MEW issue 82 sparked my interest and prompted a question to our editor. When you moved to a larger lathe, did you survey the range of industrial machines available, and then make an informed choice. One issue is the three phase supply, and another is the noise of geared head machines.

Dave Fenner replies

As an apprentice, our training centre used a number of Colchester Student machines. These are a little large even for the end of the garage, but spending time on such equipment at an early age probably instils some affection for the make in later life. Some time after getting started with an elderly ML7, I had acquired a Centec mill and the need for a heavier Lathe. This coincided with the availability of several backnumbers of Model Engineer dating from the mid 1950's. One article focussed on various

toolroom lathes to which modelmakers might aspire, and the Colchester Bantam gained many plaudits. A little later I learned of a company disposing of two, and bought one. It was remoted and rewired single phase. The Bantam served well for nearly 20 years, and was changed only because a Chipmaster in fair order was offered at a good price. By this time three phase power was on hand. Gear noise on the Bantam was not a problem, but variator noise on the Chipmaster is becoming intrusive, and having made the initial enquiries, it is highly likely that an inverter drive will be added in the foreseeable future.

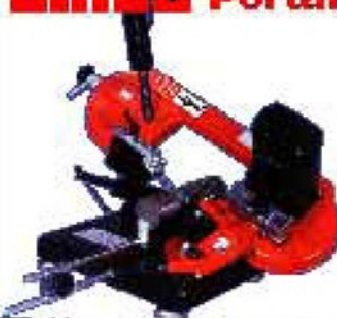
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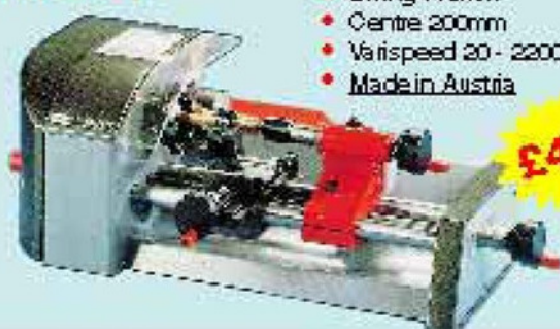


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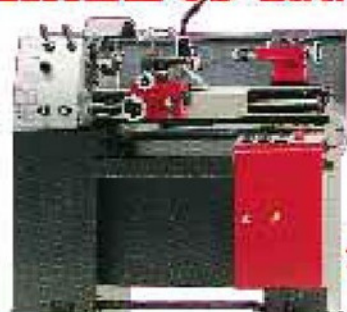
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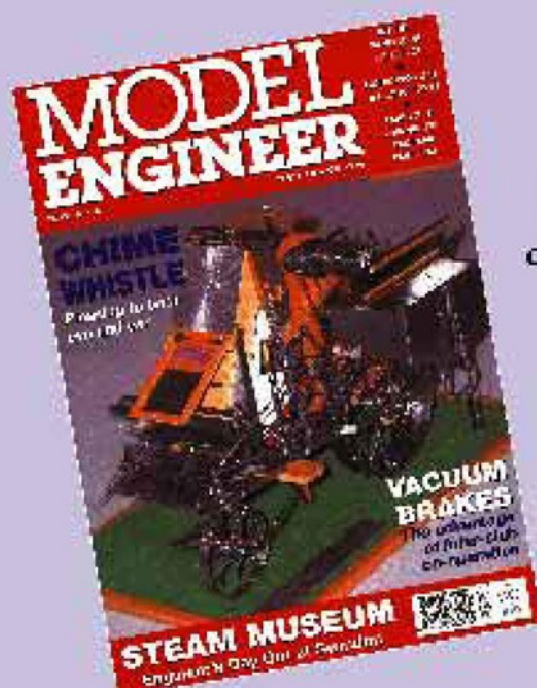
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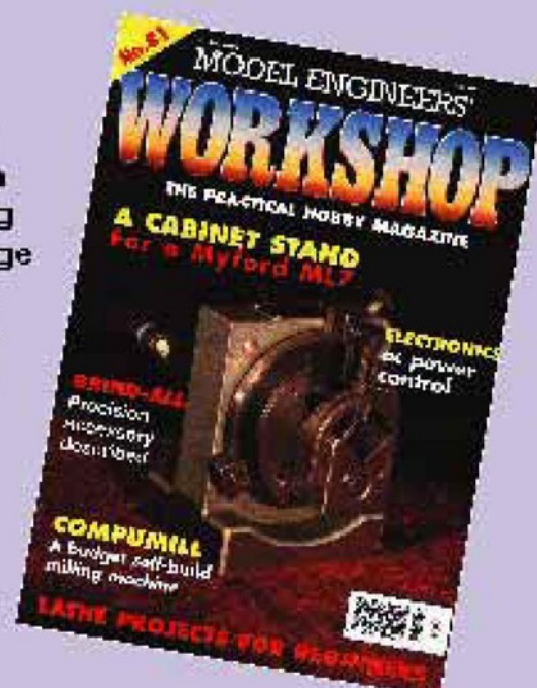


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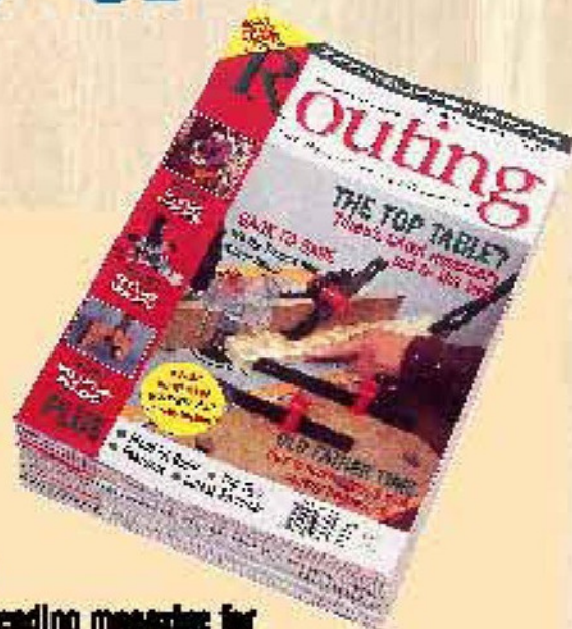
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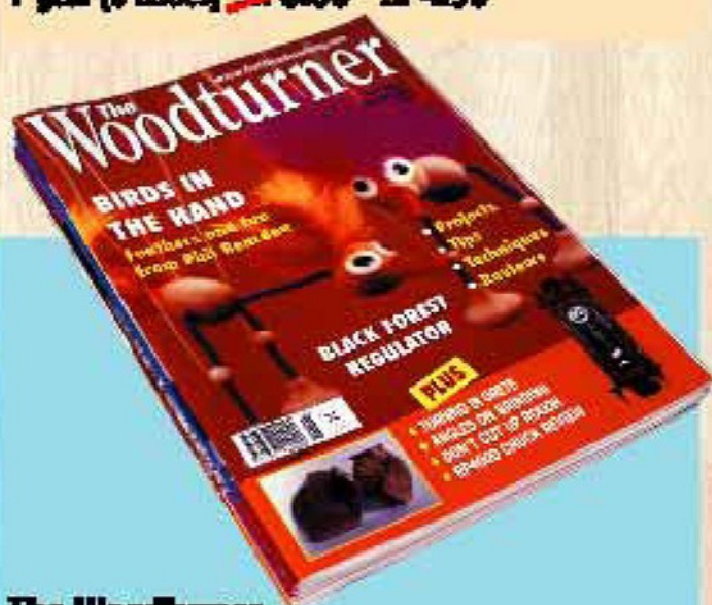
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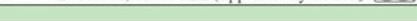
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CLAYTON UNDER TYPE STEAM WAGON rolling chassis with leaf springs, steering connected, copper boiler completed, fitted final chain drive diff, all gun metal castings, boiler fittings, materials, drawings £650.

Tel: 01483 274464. Delivery can be arranged - free within the UK.

WARCO WTM 500 lathe/milling machine, QC toolpost, 2 chucks, cabinet stand, clamping kit, 1 year old. £899 ono. Tel: 01379 641436 (Diss).

MODEL ENGINEER 82 copies 1977, 1984 to date, not consecutive £15 plus carriage. Model Engineers Workshop. Issues 41-51 inc. and 57-80 inc. £10 plus carriage. Tel: 01322 330556 (NW Kent).

BOXFORD LATHE, Model C, 5" swing 34" bed, power feed, single phase, screw cutting, 3 & 4 jaw chucks extras £750 ono. Tel: 07855 103733.

"NEW 7" x 40" LATHE 3 phase no 3 jaw list £6000. Any offers phone Alf on 01923 776136. Similar to Student. (Rickmansworth).

THREE & HALF INCH "GREEN KING" FRAMES bogie wheels done "Western" boiler drawings articles £620. O.V.N.O. Tel: 01422 256969 (Halifax).

SAND BLAST ATTACHMENT (needs good compressor) cost £250 accept £70 plus carriage. All pipes G.W.O. Tel: 01422 256969 (Halifax).

WANTED for 3 1/2" G Duchess drawings B7 H. Clarkson of York. Purchased. Borrowed etc. Any help greatly appreciated. Tel: 01626 353533 (Devon).

DUCHESS, BRITANNIA, CASTLE or similar wanted 3 1/2" - 5" G must be well built, detailed, consider unfinished project. Tel: 01626 353533 (Devon).

GUNMETAL, BRONZE AND BRASS in 12" lengths by mail order. For price list S.A.E. to PEMMSA, Unit 6, Riverbank Enterprise Centre, Dewsbury, West Yorks, WF13 3RQ.

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COLCHESTER CHIPMASTER 5" x 20" good condition 3 jaw chuck face place quick change tool post £850 o.n.o. tel: 01243 375148 (Emsworth).

WANTED Tether car parts, wheels, tyres, engines, coils, plugs, anything considered. Please telephone: 01481 726168, engineer@internet.guernsey.gg.

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MAGNETIC CHUCK Fimax 12" x 8". Full width poles. Very good condition. £250. Tel: 01425 470014 (Ringwood).

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I D STEAM SERVICES. Locos to 7 1/4" gauge traction engines to 4" to order. Tel: 01553 768578 / 07799 804671 (Norfolk).

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TOM SENIOR M1 Milling machine, horiz only, 25" x 6" table, power feed, s/p. 3MT spindle, IMP graduations, private sale. £625. Tel: 01945 780767 (West Norfolk).

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