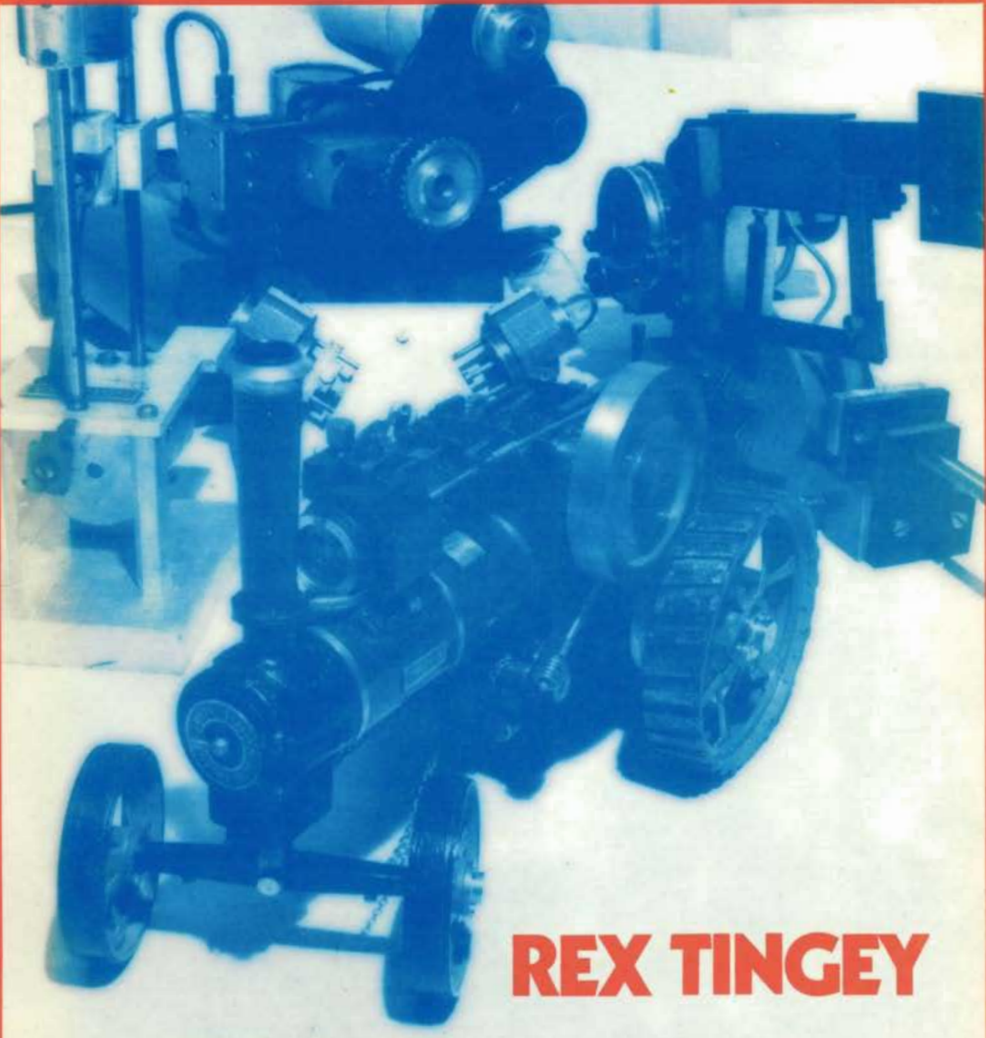
PROJECTS FOR THE UNIMAT



REX TINGEY

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Foreword

With the age of inflation, in which we find ourselves, the Unimat lathes are a great boon to the model engineer, keeping costs within the scope of most budgets as well as requiring no special workshop or facilities. The Unimats are probably the most versatile of any small machine tool on the market today, and are made to give excellent serviceability and a long and useful life.

This second book of mine on the Unimat range of lathes and accessories can be considered as a sequel to "Making the Most of the Unimat", which is mainly about various modifications and accessories. However, this book gives a range of things to be made on the Unimat, loosely based around my "valveless" engine design. In addition are some further developments to the Unimat 3, and the quick-change toolpost for use with both models.

My valveless steam engine design first appeared in Model Engineer in May 1977 where it caused not a stir. I had designed the unit to power a small traction engine after experiencing difficulty in making steam-tight conventional valve gear, and lining up and setting up the valves in the small scale, chosen so that the traction engine could be made on the Unimat. I abandoned convention and designed a "shuttle valve", concentric with the piston and much easier to make on a small lathe than any conventional valve gear since all the parts are turned and indexed. It works very well and gives plenty of power: it is included herein in several forms together with the traction engine it was made for, "Sweet Sixteen".

"Sweet Sixteen" was the first major steam project that I attempted, and it led to the making of the many improvements and accessories to my Unimat lathes, out of necessity. Thus I was a beginner when I started the small engine, but, by the time I had finished all the extras, together with the traction engine itself, I had really passed out of the beginner stage. This makes it difficult for me to assess whether the traction engine should be recommended as for "beginners". By the time the enthusiast has improved his Unimat, built a first version of the valveless engine, made some accessories, and started on the traction engine, he himself will be a beginner no longer.

The simpler versions of the valveless engine are certainly easy for the beginner to make, and they will run equally well on compressed air or steam. Once the basic design is realized it can be seen to be readily adaptable for other modes of steam engine without the problems of having separate valve gear, but the control given by some forms of external valve is of course lost in the valveless designs.

Most of the chapters will have appeared in Model Engineer or Model Mechanics, as articles, with little or no alteration, and I thank the Editors for allowing them to be used here.

1983 Rex Tingey

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Chapter One

Increasing the Swing of the Unimat 3

The bed of the Unimat 3 is a one-piece casting of cast iron, on to one end of which the headstock is bolted, being held to its correct position by the machined front rail of the bed, which is a ninety degree angle, point uppermost, and also by the machined back rail of the bed, which is flat. The point of the angle is machined to a flat and fits the headstock base to give perfect location at the front; the rear of the headstock rests flat on the back rail. Fittings such as the tailstock have bases machined to the same configuration, with clamping plates underneath the rails, to slide and clamp in small grooves either side. The headstock is secured hard by two screws from beneath.

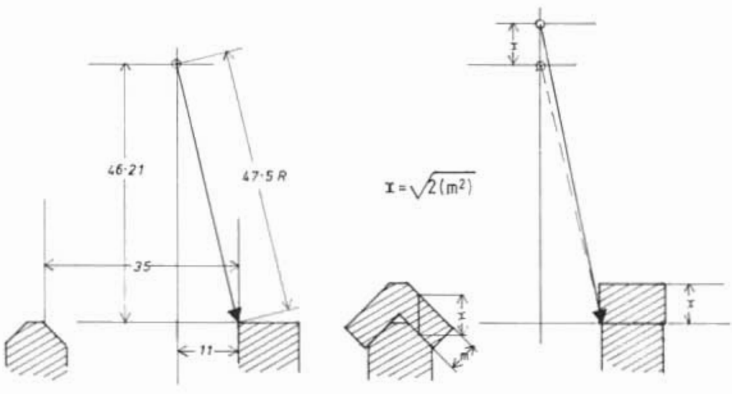
It would appear that this system of quite complex fitting shapes provides limitations to any improvement work which the Unimat owner may be able to carry out and increase the versatility of this machine tool, particularly in the lathe mode. However, after a great deal of thought it occurred to me that the "puzzle" was not a solid one, but one consisting of two separate parts. That is, if the base machined to fit the lathe were to be made in two small parts, it became very simple. This is because the main parallel line-up of parts is carried out on the triangle of the front rail and the rear rail provides positive line-up of the centres in only a small way: just loosen the tailstock under-clamp and see what I mean.

Once the complexity is seen in the light of this simplification, ways can be found to make the accessories and improvements to match those of the Unimat SL. The first major improvement is to increase the swing of the lathe, which, when used in conjunction with the improved drive can provide turning for diameters over 4in. and up to 5in. with confidence. The limitations then become the maximum size of material which the chucks can hold.

CROSS-SECTION

If a diagram of the cross-section of the Unimat 3 is examined it can be readily observed that the limitation to the maximum swing is from the front top edge of the back rail, as this is the point nearest to the centre line. All measurements are therefore to be made with this limiting point as a reference.

A perpendicular dropped from the point of a centre to meet a horizontal line across the bed is then 11mm from the limiting point, and the point of the centre itself is 47.5mm from the limiting point, being the hypotenuse of a right-angled triangle. If the centre point is raised 10mm vertically the 11mm remains a



constant in the triangle. The hypotenuse of the new triangle formed is increased by a little under 10mm, being the increase in the radius of the swing.

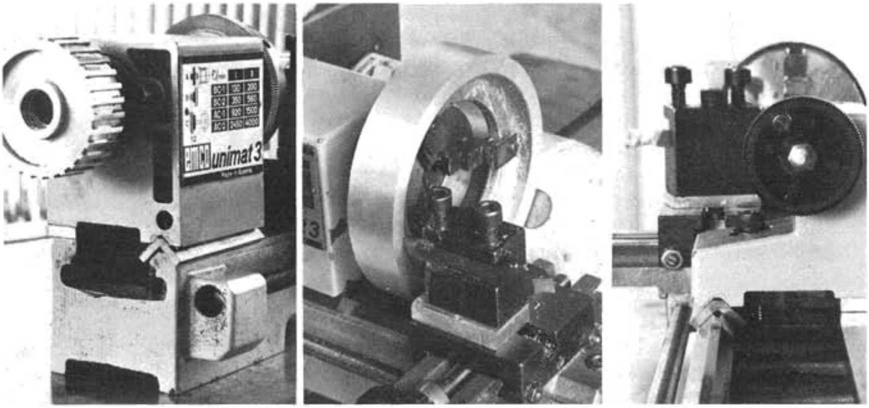
INCREASING THE CENTRE HEIGHT

The increase of swing is obtained by increasing the centre height. First the headstock height is increased with packing pieces under the front and back rails. The front package is a piece of angle iron cut to the length of the headstock, which itself is fitted with longer securing bolts to allow for the extra thickness. The angle iron fits its angle over the angular rail, which means that the augmented height is greater than the thickness of the angle iron, and can be calculated as a diagonal through the thickness at 45 degrees. For 12mm thick angle iron the increased height will be (by Pythagoras) 16.97mm, giving an increase in swing of 33.94mm (to 125.94mm or 4.95in.).

The increase of height imparted to the front rail section must, of course, be balanced by packing the space between the back rail and the headstock block to the same extent as the increased height. The packing is made by milling dural flatstock to a precise thickness, best achieved on tne milling table with careful use of the vertical feed attachment. The packing block is made large enough to fill all the space and does not need to be secured except by the clamping action of the headstock screws. These screws hold the front angle piece in place by means of cutaways, before the screws are tightened.

THE TAILSTOCK.

The tailstock is brought to the new centre height by similar means. The same angle iron material must be used so that variation in stock thickness is matched to produce an accurate result. The packing piece for the back rail to tailstock must be cut from the piece milled for the headstock. If a great deal of work is envisaged at the increased height then the back packing should be secured by a bridging piece to the tailstock or it will slide out with the constant



Left and right, the headstock and tailstock fitted for the increased swing. Centre, turning a 4 in. dia. wheel using the increased swing.

adjustments. The front angle piece is sufficiently held by the clamping screw positioned in the cutaway.

RAISING OTHER ATTACHMENTS.

An extra piece of the back packing should be milled and used to bring the toolpost to the new centre height whenever the increased swing is used. This block will require a hole drilled for the securing screw of the toolpost.

The threading attachment does not require raising to accommodate a new centre height, at least, not up to the rise given by 6mm angle iron. This is because there is sufficient variation in the possible angles of the threading tool in the attachment not to require raising the whole. The supports of the threading attachment do tend to limit the swing unless they are taken to the extremes of the bed.

INCREASED SWING, INCHES

"m"	1/8	3/16	1/4	5/16	3/8	7/16	1/2
"x"	·177	·265	·354	·442	·530	·619	·707
new swing	4·08	4·25	4·43	4·6	4·77	4·95	5·12
"m" mm	3·18	4·76	6·35	7·94	9·53	11·11	12·7
swing mm	103	108	112	116	121	125	130

INCREASED SWING, MILLIMETRES

"m"	3	4	5	6	7	8	9	10	11	12
"x"	4.24	5·66	7·07	8·49	9·9	11·31	12·73	14·14	15·56	16·97
new swing	103	106	108	111	114	117	119	122	125	128
"m" in	·118	·157	·197	·236	·276	·315	·354	·394	·433	·472
swing in	4·06	4·17	4·28	4·39	4·5	4·6	4·7	4·8	4·9	5·0

The indexing attachment, when required to be used affixed to the bed, can be brought to the new centre height with the packing pieces, and, since the tailstock is not generally used in this mode, the pieces made for the tailstock can be used in this case, without having to make more.

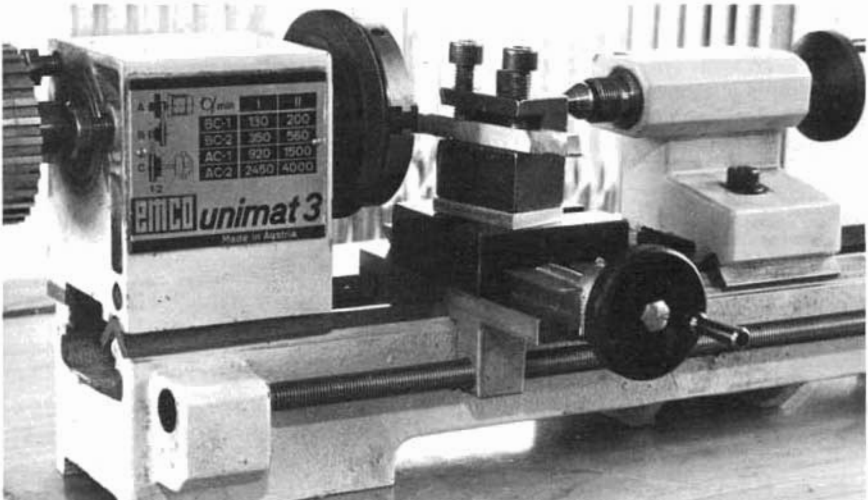
The three-point steady can be used, raised, with the raised head and tailstock, but the pass-through of the steady is only 40mm (diameter) and so only workpieces of a particular type of shape (large down to small diameter) could utilise the raised steady. Where a steady is used on larger diameters it is usually to assist on a bore from the end, and the tailstock is not brought up, so that the extension pieces for the tailstock can again be used, for the steady.

MOTOR MOUNT.

In my earlier book I described the construction of an improved drive, using a nylon toothed belt. For the Unimat 3 the drive components are mounted on a flat plate which in turn is mounted on to the headstock by two bolt heads holding against slotted holes. The motor is mounted with an intermediate drive component on this plate; the only parts to be made are the plate, the intermediate drive (incorporating a pulley to receive the normal smooth belt drive with, coaxial, a reduced, toothed section for the toothed belt drive) and a new toothed drive gear for the main spindle. The original spindle can be replaced at any time.

When fitting the improved drive you will have made your own motor plate, and so will have no reluctance to modify the plate. Lathe owners are often unwilling to alter standard manufacturers' fittings, quite understandably, and

The increased swing mode on the Unimat 3 from the front.



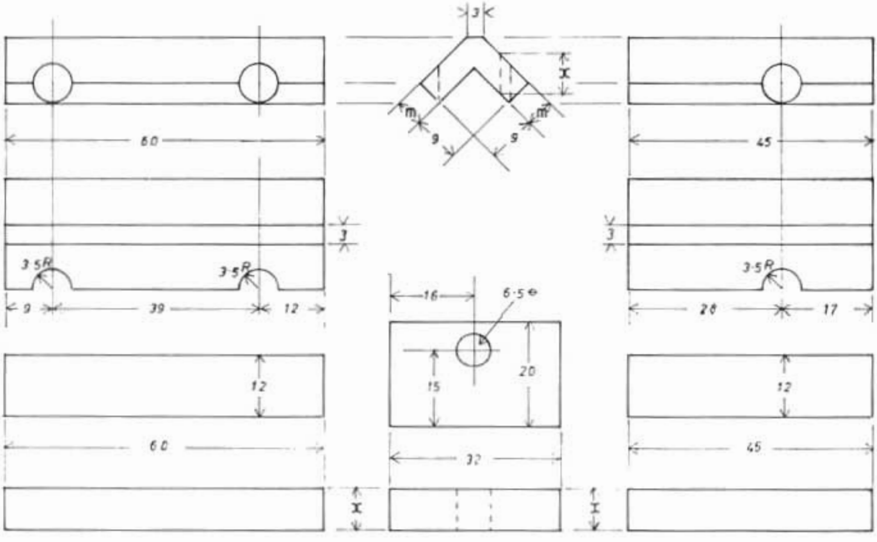
this is a good reason why most of my modifications and accessories are self-sufficient and require no alteration to the machinery.

In the case of the increased swing it will be necessary to move the motor away from the bed, if full use of the extra swing is to be made, by filing the motor mounting holes to ellipses. Before filing make sure that the flat on the side of the motor is presented correctly, to give maximum clearance. Also, move the plate around the loosened headstock plate mounting screws to get maximum clearance with the drop. Only then can the direction and amplitude of the ellipses be marked in, to take the motor just below the circle from the centre line, restricted by the back rail front edge. It will only be about 1.5mm, without taking it too far.

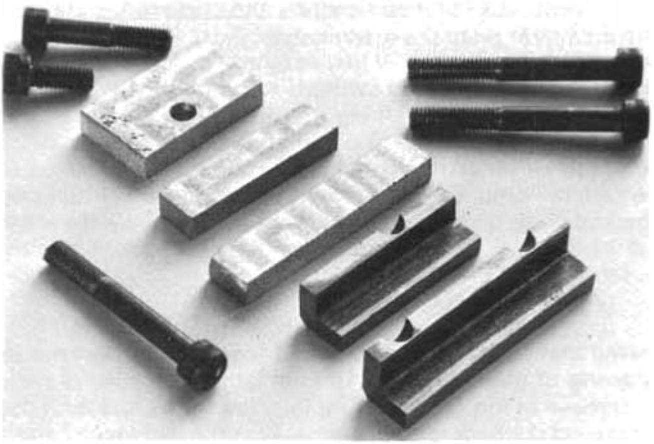
LIMITATIONS.

It must be remembered that both the three-jaw and four-jaw chucks tend to limit the maximum swing of material in the Unimat lathes, because of their small size. With no increase in the centre height the chuck jaws will limit the swing when they hit against the back rail front edge. With the increased height fittings in place it will be possible to open the chucks further when the limit of a chuck's use in holding is when the jaws are at their limits of safe holding.

With the three-jaw chuck at least two teeth of each jaw should be within the scroll or the teeth will easily break when subjected to shock. Using the four-jaw chuck in the jaws-reversed mode is precarious, since part of a jaw may readily break off, even when just tightening up on work.



HEADSTOCK EXTENSIONS TOOLPOST BLOCK TAILSTOCK EXTENSIONS



A set of increased swing components.

One way of overcoming the problems associated with the small chuck is to design the work, or introduce an order of work, where the work is held by a small diameter, or by an internal diameter, less than the outside diameter of turning. Another way which I have developed is to secure the larger workpiece to a faceplate using cyanoacrylate adhesive on flat-to-flat surfaces; the workpiece can be readily removed with modest heat. This system will not suit most circumstances.

If the work is to have a bore through it is satisfactory to drill through and fit a mandrel for all the turning work, up to a point. The mandrel should be as stout as possible and held close to the workpiece to avoid vibration chatter which can occur with large diameters in a small lathe. If chatter marks do appear they can often be eliminated by altering the cut to feed ratio, usually with a deeper cut and a slower feed rate, but the tool must be held hard, and not be the cause of the chatter. Castings, on the other hand, present other possibilities in being held for turning on the small lathe, particularly with using the surplus material for the fitting of plates and pegs for the jaws of a chuck to hcld, similar to using a smaller internal diameter. Care must be taken to ensure concentricity, but guide marking can be carried out, rather outside the limits of normal chuck use, by rotating the lathe spindle by hand whilst marking with a tool or scribe in the toolpost, before drilling for the fitting of the plates or pegs.

MAKING THE EXTENSION BLOCKS.

I made two sets of packing blocks from 1/8 in and then 3/16 in angle iron equivalent to 3mm and 5mm in metric material. The tables show the various increases gained with thickness of angle stock for both metric and imperial sizes. The 3/16 in angle iron increased the swing to just over 4¼ in which was sufficient for the job which I had to do - the 4 inch diameter rear wheels of a traction engine. The 3/16 in angle seems to be a good standard size, to start with, as the stock sizes get rather massive in other dimensions above this size.

The angle iron is all worked by hand from a length selected for having a good 90 deg angle, measured with an engineer's square. It may be found that one side of the angle is a little thicker than the other to the vernier caliper or micrometer, in which case the thicker leg must be kept to the front on all the packing pieces made from the material. Keeping the thicker side to the front will bring the centre line nearer to the front and away from the back rail. Discard angle iron which has a thickness discrepancy of more than 6 thou.

Whatever thickness you have chosen make the pieces so that the inside angle dimension is the same as in the drawing, letting the outside take its own dimension, which will depend upon the material thickness. Saw the pieces to length and saw off the surplus sides. File the ends and edges to a finish, and file off the point of the angle, the apex, to the width shown.

Secure an old large hand file in the clammed vice and gently rub the inside surface to just-clean metal. With fine emery cloth on plate glass rub down the outside to just-clean metal. Check with the vernier caliper that the cleaning up has not been overdone, and check again for the thickest leg, marking it on the lower edge. Note the measurement (m)'of the thickest leg and then use this figure to find the height increase and thus the thickness required for the back rail increase and the toolpost block.

$$\text{Height Increase} = \sqrt{2}(m).$$

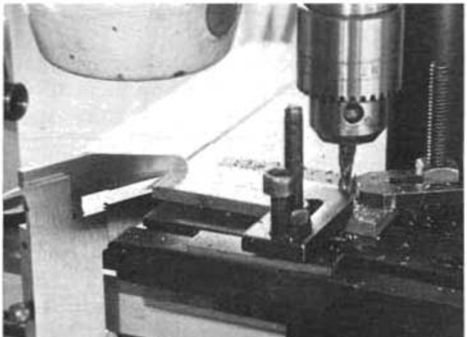
MILLING TO THICKNESS.

With the Unimat in the vertical mode and the milling table on the cross-slide clamp a piece of duralumin flat-stock hard by one end, and by one side, with the other end overhanging the milling table by about 4mm, for on-the-job measuring purposes. The piece should be about 30mm by 75mm and about 3mm overthick. The side which is down should be finished.

With a 1/4 in end mill, mill all the top surface that the clamps will allow, taking off about 1mm, and measure the thickness remaining with the vernier caliper, after winding the slide to one end of the bed. Check that the work is not sprung

Milling the back pieces to thickness.

Checking the milled thickness of the pieces.



away from the milling table with the clamping, repositioning the clamps if necessary. Bring the work back under the mill, with the cutting edge half over the back edge of the work. Switch on and fine feed the mill into the work by 1mm (10 graduations) to 1.5mm (15 graduations) and mill to leave approximately .2m to be taken off in the finishing cut. Measure again and calculate the precise setting for the fine feed to make a final cut, milling to the finished thickness.

Remove and mark out the milled part for the three blocks; the rear of the headstock, the rear of the tailstock, and the toolpost packing piece, Four longer M6 screws will now be required, increased in length by the same distance and the thickness of the piece just milled. The two headstock screws and the toolpost screw will be M6 x 40mm plus, and the tailstock screw will be M6 x 35mm plus.

FITTING AND CHECKING

File the cutaways on the unmarked legs of the angle pieces and check, fitting the longer screws and the back packing pieces, that the cutaways provide enough clearance on both the parts. Tighten up the headstock well. Oil the rails, fit the two dead centres and slide up the tailstock to the headstock to check for absolute alignment. The back packing piece of the tailstock self-retains quite well while the rail is newly-oiled and free from swarf, but the piece may slip out in working, and a retaining bridge could be made to be screwed to both parts. Alternatively a spring clip could be fitted to each end of the back packing piece so that no hole need be drilled in the tailstock.

SET OF PARTS.

The sets should be kept together in a polythene bag with a little oil to prevent the mild steel from rusting. Although I made two sets of these extension blocks, in all probability the smaller set will not be used as the medium set will cope with all eventualities, and provide good accuracy at the new height. If I find the need for a greater swing at some time I could, of course, use the two sets together after checking that they do retain the required stability, and keep in line. Otherwise a thicker set will have to be made.

DEVELOPMENTS.

It becomes obvious that further accessories can be designed for the Unimat 3, using these blocks with a firm base affixed to the top of them, or some similar idea. Two accessories which may make use of the blocks are a travelling steady, with a larger pass-through than the standard accessory, and a boring table, enabling boring work to be carried out unrestricted by the level of the cross-slide height. I have previously designed these accessories for the Unimat SL to increase its versatility in those directions.

If increases in swing greater than provided by ¼ in thick angle are required then the angle may have to be milled from square section block as thicker angle may be difficult to obtain from the suppliers. This should provide no great problem if a little thought is given to the order of milling and to the methods of clamping the material to provide a good 90 degree angle.

Chapter Two

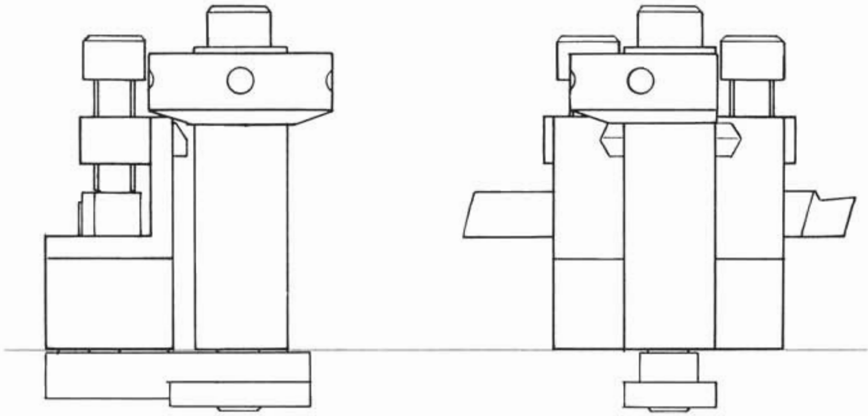
Quick-change Toolpost

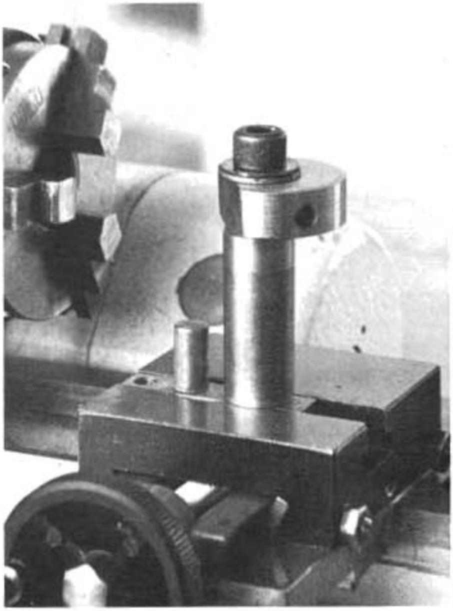
When using the Unimat, production is quite often slow due to the limitations of the single toolpost, where each time a new facet of a job needs tackling it involves changing a tool or a position, and often both. Sometimes there is the need to shim the tool to the correct height, as well as to position it accurately. The problem can often be solved on the larger lathe with a four-station turret, giving positions for up to four different tools which can be revolved into place when required, but it must be said that when using standard length tools only two or three stations can actually be used in practice.

With the little Unimat a revolving toolpost would get in the way of many operations, making the turret a nuisance, and so I have designed a quick-change toolpost with the advantages of positive accuracy with a quick change-over, but with none of the dimensional problems of a turret.

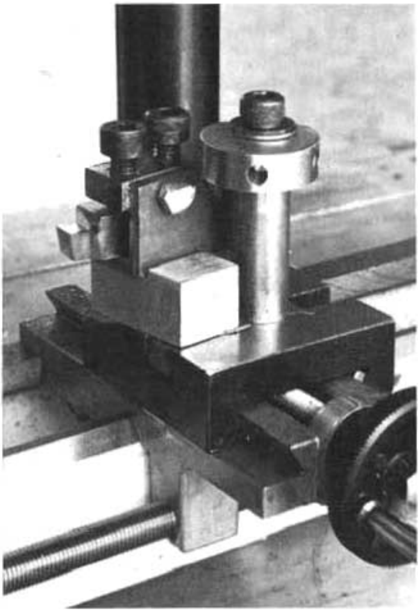
THE TOOLPOST

The standard toolpost of the Unimats SL and 3 consists of a solid block of cast iron secured flat on the cross-slide, and held, hard down, by a bolt right through the wide part, holding to a T-nut in the cross-slide slot. So, I reasoned,





The quick-change post.



The toolpost.

if the bolt were to be placed to one side and the toolholder slimmed down then the whole would take up very little more room. By utilising the flat surface the toolholder could be held easily from above; all the working thrust is downwards on the tool tip, and only the rear end of the toolholder requires holding down against leverage, and so the idea of a sort of "heavy finger" was envisaged to hold down the toolholder.

The toolholder needed accurate registration to ensure that relocation would present no problem, and the thick pin entering the base of the toolholder as a separate entity and secured hard down on the cross-slide by means of the "finger" was designed. This left the toolholder to swivel about the register pin, when fitting, and so a locating pin system was introduced so that definite fixed angles could be achieved, with intermediate angles available by angling the tool in the toolholder.

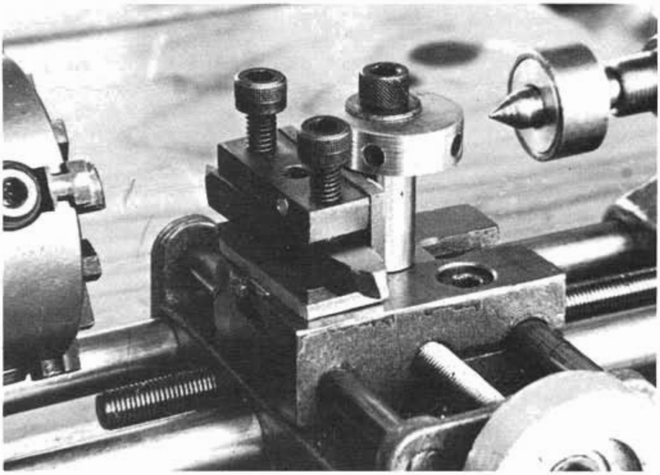
By now the design of the "finger" had been developed as an eccentric to represent a portion of a larger screw thread, making the lower, holding, surface with an angle so that the eccentric action presents an increasing downwards positioning to any one fixed point directly under the surface. I call this a cam-ramp, and when brought over the top of the fixed toolholder it bears down harder and harder as it is turned, just like a screw thread (until the centre point is passed). The relative height is such that only about a quarter turn can be given as a maximum.

The toolpost itself is a mild steel cylinder with a $\frac{1}{4}$ in BSF bolt through to secure the post to the cross-slide by means of a long T-nut. When the bolt is tightened the lower end of the cylinder is hard on the top surface of the cross-slide. The eccentric cam fits on to the top of the cylinder which is turned down to a boss to accommodate the cam. The cam is held down by a washer secured on the hex. cap head of the main bolt.

Secured to the long T-nut, and above it, is a body of $\frac{5}{16}$ in mild steel accommodated in the upper slot of the cross-slide, and into which is fitted the $\frac{1}{4}$ in diameter silver steel register pin. The top surface of the body is a little below the cross-slide surface to enable the bolt to be tightened and to give clearance for swarf which may accumulate around the pin when changes are made. The body has a hole at the end for the locating pin, drilled right through so as not to trap swarf. The assembly can be fitted either way round on the cross-slide.

The main drawback with the design is that several toolholders are required. However, I have simplified the holder considerably, making it of cheap materials, and taking into consideration the tough holding-down action of the cam-ramp on the springiness of the angle iron used.

Each toolholder consists of a piece of 1in x 1in x $\frac{1}{8}$ in angle iron cut down and mounted on a block of duralumin, with a mild steel top piece, secured with high tensile bolts, to hold the tool securing screws. The underside of the dural is drilled to take the register pin, and drilled and tapped to hold the locating pin. The high tensile bolt heads are filed away to give clearance for the toolpost and cam-ramp. There are three tapped holes for the tool securing screws so that short tools, down to 1in long, can be fitted if necessary. Several positions for the register pin can be made in the base for different requirements.



The toolpost adapted for the Unimat SL.

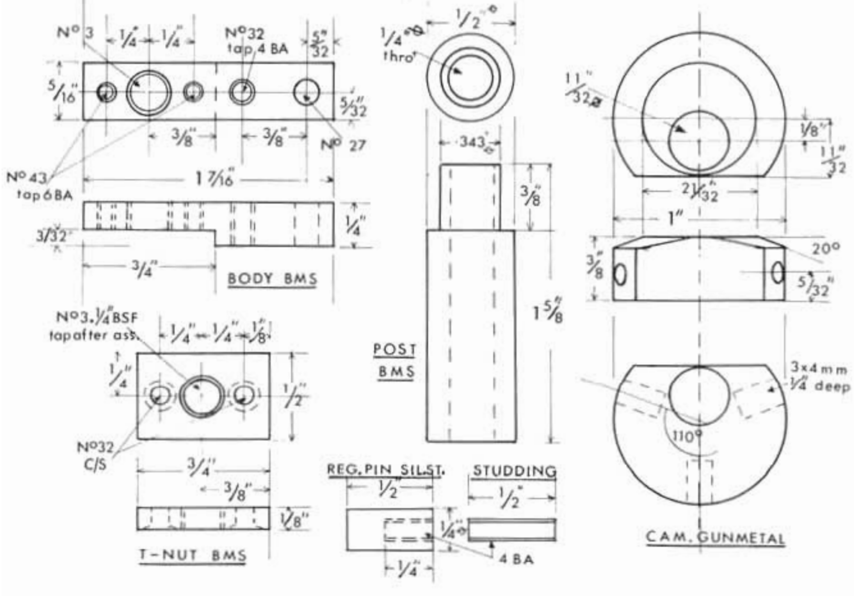
In practice it is easy to overtighten the tool securing screws, causing the angle iron to flex back, but in fact the screws need to be a little more than finger tight only, as the cam-ramp will always apply the full pressure on the tool when the toolholder is fixed in place for use.

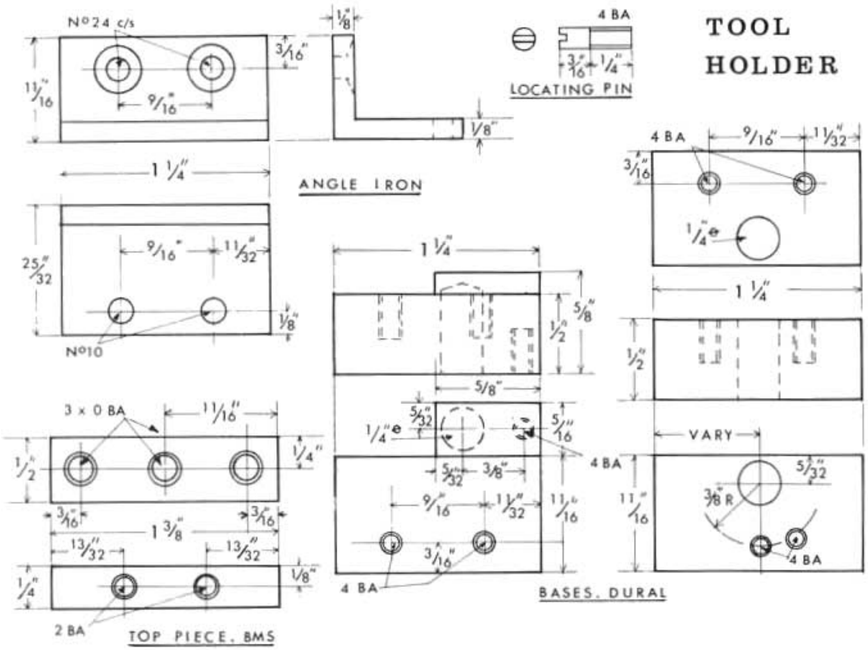
MAKING THE TOOLPOST.

First make the long T-nut, with only the two outer securing holes countersunk. Cut the body from 5/16 in x 1/4 in mild steel stock and file, or mill away, the step for the T-nut. Drill for the screws to hold the T-nut and tap 6 BA to Loctite and screw the T-nut in place. When cured mark for the hole to be drilled and tapped 1/4 in BSF, and drill with the body inverted in the cross-slide slot.

Turn the post cylinder in the lathe from 1/2 in. dia mild steel, drilling through 1/4 in and finishing the ends before turning down the boss part for the cam-ramp. The outside can be just cleaned off with emery cloth, Secure the post to the body with a 2in BSF hex cap head screw and secure both on to the cross-slide to drill the register pin hole No 32 to be tapped 4 BA immediately afterwards in situ. Drill the locating pin hole No 27. Turn a piece of 1/4 in dia silver steel to drill No 32, 1/4 in deep, and tap 4BA in the lathe. Take 1/2 in of 4 BA threaded rod (the end of a long screw will do) clean off all the threads and secure the register pin to the body with Loctite.

TOOLPOST



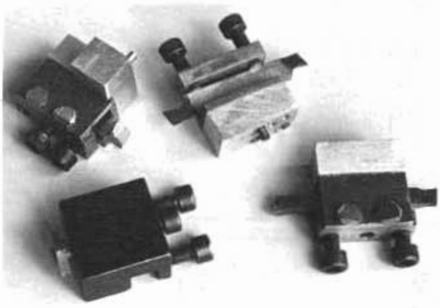


Turn the eccentric cam-ramp from 1 in dia. hard brass or gunmetal. First turn a piece about 1½ in long in the three-jaw chuck, finishing off the end before holding with the live centre in the tailstock. Bring up a pointed tool of 40 deg to the edge with the tool cutting the 20 deg ramp. Cut a few thou. forward at a time, with the cross-slide movement, taking the carriage a little to the left each time, then bringing the tool back and to the right and forward again, until the edge of the tool matches a ramp of the correct width; a light feed to the left will produce a good finish.

Use the parting-off tool after lightly turning the outside true, and part a thickness matching the height of the boss of the post, leaving the last ⅛ in or so to be sawn off. Replace in the three-jaw chuck and finish across the parted-off and sawn surface to give about 2 thou. clearance on the boss. Secure in the four- jaw chuck, eccentric, and use a centre drill in the drill chuck to mark lightly the eccentricity to be measured against the centre point. When correctly adjusted drill through ¼ in.

Still with the four-jaw, mount the work sideways on, each time, and drill the 3 x 4mm holes for the tommy bar. Remove and saw off the flat to file and just round off the corners. Use a half inch diameter, 3/64 in. washer, and mount the toolpost complete, checking that the cam-ramp swivels easily. If it is tight rub the topside down on emery cloth held on a plate glass surface.

Components of the post.



Various toolholders.

TOOLHOLDERS

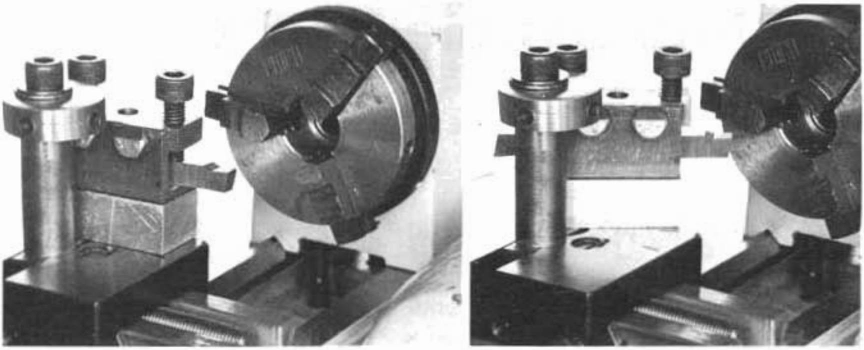
The toolholders are all made in the same way, with just the dural bases varying to suit various uses, so make, say, four at once for speed of manufacture.

Cut the angle iron first, each 1¼ in. long, and cut off the surplus from the sides, drill the holes and countersink inside the angle for the the base screws. Make the bases for the straight toolholders from ½ in thick dural, carefully marking the distance between the register pin holes and the locating pin holes and centre-punching. Drill the register pin hole right through. For the bases which are angled use a ⅝ in dural stock and mill the toolholder area down to ½ in, drilling the register pin hole just a little over ½ in deep to keep the hole blind, as it is in the other versions when covered by the angle iron. Drill the two holes in the top for the 4 BA screws and secure the angle to the base using Loctite and the screws.

The top pieces are made a little overlong so that the tool securing screws can have maximum effect of securing the tool hard at the edge of the angle iron. Drill all the holes with the Unimat in the vertical mode, holding the work in the machine vice. Secure the top pieces with 2 BA high tensile steel screws with hexagon heads which may need partly filing away to fit.

Try the toolholders in place with the post on the cross-slide to ensure that they fit and are well held by the cam-ramp. Cut short lengths from 4 BA brass screws for the locating pins, with a part unthreaded, and hold, with two nuts fitted, in a vice to have the screwdriver slot cut. Secure into a base and try out the secure positioning.

In use the toolpost provides very positive positioning. With the main bolt tightened well down, the tools can be just held down, as described, and the toolholder held with a light pull on the tommy bar in the cam-ramp, when everything will set very solid on the cross-slide. The cam holds perfectly, even with a heavy cut, showing no sign of wanting to turn with vibration.

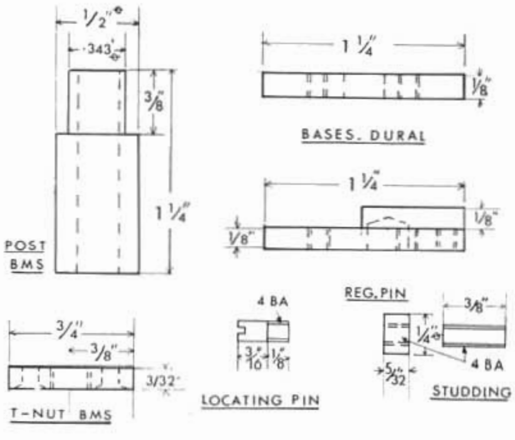


The angle of the toolpost can be varied, using the register pin.

USEFULNESS.

The usefulness of this device cannot be exaggerated for its versatility. Tools can be set up for a particular repetitive job and used, one after the other, with little adjustment necessary. A particular toolholder can be made for a peculiar application with no difficulity, and fitted right away into the system. Unlike the swinging or rotating types of holder this design enables the tool to be examined, sharpened, reground or minutely adjusted *off the lathe* and replaced with the knowledge that the toolholder will be positioned exactly as before, and the tool also if the operator knows his job!

This idea can be scaled up for larger lathes, which may be considered of value, as well as used as it is here, for the under-rated Unimat.



Variations for the SL Side Views

Chapter Three

Cutting Simple Gears

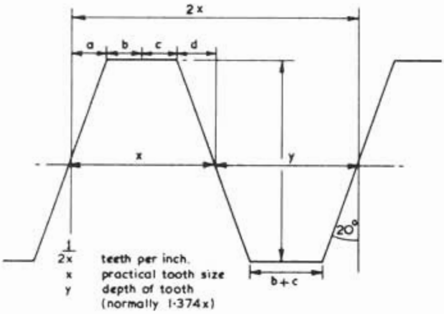
I make no apology for apparently repeating a chapter on gear cutting from my first book "Making the Most of the Unimat", but the chapter has been rewritten to cover better both the Unimat 3 and SL operations, and it has also been simplified. I have been told that even an expert model engineer would think twice about cutting his own gears, but I have had no difficulty using these methods which I developed. Those who have doubts can of course try to buy commercial gears to do the job. The chapter is repeated because most of the projects in this book require some sort of gear to be cut – square toothed for toothed belt drives for the machinery, and spur toothed for the small traction engine as well as a wormwheel and pinion for its steering gear.

INTRODUCTION

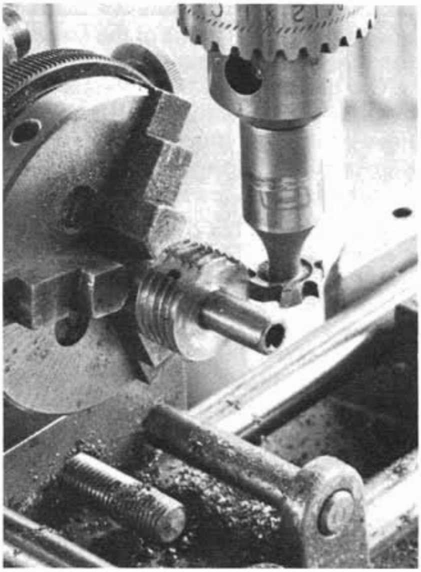
When a spur gearwheel is made to be run with another spur gearwheel the teeth should have a particular shape so that they will mesh together well, run together with the touching areas rolling rather than rubbing, one on the other, and present the maximum touching areas possible yet still escape easily. Straight teeth, hard in mesh, will lock together, and when the mesh is loosened, to enable the teeth to escape, the teeth rub along the length of the teeth on the other wheel, giving frictional loss of power. In practice a modulated straight-sided tooth form is used which has its upper half angled and made rounded. This tooth form is relatively easy to generate in straight-across spur gears with the correct form of cutter.

Among the items listed as accessories for both the Unimat 3 and the Unimat SL are gear-cutting mills, which are specially shaped side-milling wheels. These gear-milling cutters cut a gap, not a tooth, and leave the sides of the gap correctly made to form a gear tooth when the next gap is cut; the indexing attachment is used to position each cut correctly. This system limits the usefulness of each modular cutter to a certain size of tooth and to small variations in gearwheel diameter. Six of those cutting wheels are required to cover the range at a cost of over £100–plus the cost of the arbor!

A cheaper, and more extensive, method of cutting gears is to use the divisions provided by the indexing attachment, but with home-made tooth-cutting tools. The cutter takes the form of a multi-toothed hob, quite easily made on the Unimat lathe, which not only cuts a straight-sided gap into the gearwheel blank but simultaneously modifies the tooth shape being formed either side of the gap.



GEOMETRY OF THE CUTTER TEETH



Photograph at right shows the hob being grooved with a Woodruffe cutter.

This means that the cutting hob can be straight-sided with no fancy cutting pattern built in, it can deal with any diameter of blank, from large down to small, and a number of hobs can be made to give large or small tooth sizes which will run together well with other teeth of the same size which have been cut with the same hob. The hobs can be made on any other lathe, of course, and used on any milling and drilling assembly with an indexing unit.

The hobs are made from round silver steel turned on the lathe, then cutting teeth are formed using the indexing attachment and a grinding wheel in the vertical mode. Silver steel contains no silver and is quite inexpensive. It is steel which contains sufficient carbon to make it suitable for hardening and tempering, particularly for tool-making. It is produced in a range of sizes to very fine tolerances, and is easy to machine. The hardening and tempering part is not difficult and can be carried out using a small blowlamp or even just a gas-ring. Most tool merchants sell lengths of silver steel, as do many of the advertisers in the magazines.

THE HOBS

To avoid complications this system of spur gearcutting uses teeth per inch (t.p.i.) for measurements of gearwheels, which means that the old-fashioned Whitworth and BSF screw-threads can be brought in as a cutting guide when making hobs on the lathe. The disadvantage of using teeth per inch is that the gearwheels end up with odd sized diameters, due to π; however, the modern calculator can be brought into use to assist the drawing-up of tables. The

tables show the diameter of blank required for a particular number of teeth, and the working radius of the finished gearwheel for various tpi sizes, covering the range of indexing possibilites of the Unimats.

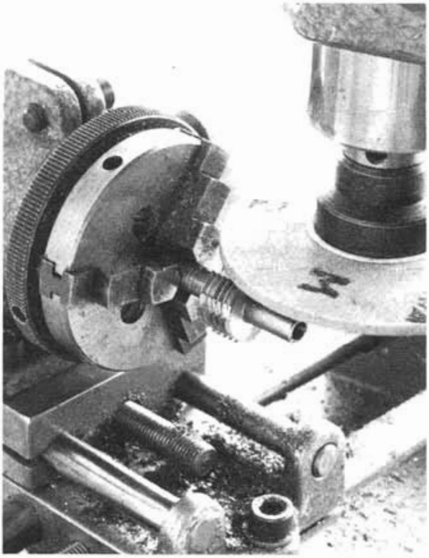
The geometry of the hob is shown in the diagram: x is a distance halfway down the tooth, if there are ten teeth to the inch then x= .05in. If a = b = c = d, then y = 1.374x; this gives a standard short tooth ; y can be increased to 1.5x to give a slightly longer tooth and allow the hob to wear and be sharpened. Figures for both are tabled to the equation:

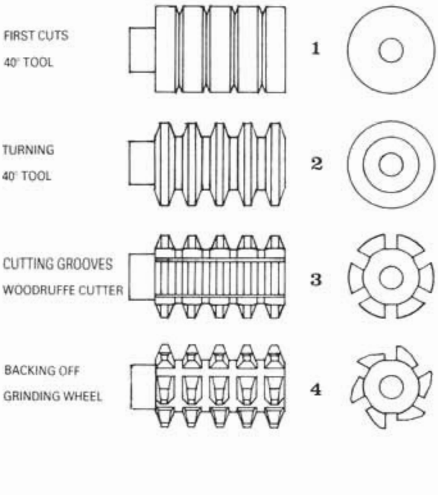
$$\frac{\text{number of teeth required}}{\text{teeth per inch} \times \pi} + (2 \times \tfrac{1}{2}y) = \text{diameter of blank}$$

The length of the bottom of the groove between the teeth when y = 1.374x is b + c ½x, but when y = 1.5x the bottom of the groove becomes .454x. The hobs have a central cutter, cutting a space, with two cutters either side modifying the forming teeth either side, mainly above x, dependent on the curve of the blank. If a tooth were to be cut instead of a space the outer edges of the two cutters would not be radial and would cut under the x line and produce a hollow tooth, and the form of tooth cut would vary considerably from large to small gears.

The four hobs which I made correspond to 1in., ¾ in., and ½ in. Whitworth, and to ½ in. BSF. These give selection of eight, ten, twelve and sixteen teeth per inch. The hobs are made from ¾ in. diameter silver steel, bored ¼ in. and secured to a ¼ in. axle for both making and using them, with a 4 BA Allen grub screw. A lathe tool is required to cut the 40 deg. angle (20 deg. either side), and

Backing off the cutter teeth.





Stages in Making Hobs

No of Teeth	Diameter of Blank								½ x D.P. of Gear Wheel			
	y = 1.374x				y = 1.5x							
5	.238	.228	.19	.143	.293	.234	.195	.147	.1	.08	.066	.05
6	.325	.26	.217	.163	.333	.266	.222	.167	.12	.096	.08	.06
8	.405	.323	.27	.202	.412	.33	.275	.206	.16	.138	.106	.08
9	.444	.335	.296	.222	.452	.362	.301	.226	.18	.145	.119	.09
10	.484	.387	.323	.242	.492	.394	.328	.246	.199	.16	.133	.1
12	.564	.45	.376	.282	.572	.457	.381	.286	.239	.19	.159	.12
15	.683	.546	.455	.342	.69	.553	.46	.346	.299	.24	.199	.15
16	.723	.578	.48	.362	.73	.585	.487	.366	.319	.255	.212	.16
18	.80	.642	.535	.401	.81	.648	.54	.405	.358	.286	.239	.18
20	.882	.705	.588	.441	.89	.712	.593	.445	.398	.318	.265	.199
24	1.04	.833	.694	.52	1.05	.839	.70	.525	.478	.382	.318	.24
30	1.28	1.02	.853	.64	1.29	1.03	.859	.644	.597	.477	.398	.299
36	1.52	1.21	1.02	.76	1.53	1.22	1.02	.763	.716	.573	.478	.36
40	1.68	1.35	1.12	.84	1.69	1.35	1.13	.843	.796	.636	.53	.398
48	2.0	1.6	1.33	1.0	2.01	1.6	1.34	1.0	.955	.764	.636	.477
60	2.47	1.98	1.65	1.24	2.40	1.99	1.66	1.24	1.19	.955	.795	.596
72	2.95	2.36	1.97	1.48	2.96	2.37	1.98	1.48	1.43	1.15	.955	.716
80	3.27	2.62	2.18	1.64	3.28	2.62	2.19	1.64	1.59	1.27	1.06	.795
96	3.9	3.13	2.6	1.95	3.92	3.13	2.69	1.96	1.9	1.53	1.27	.955
	8	10	12	16	8	10	12	16	8	10	12	16

Teeth per inch

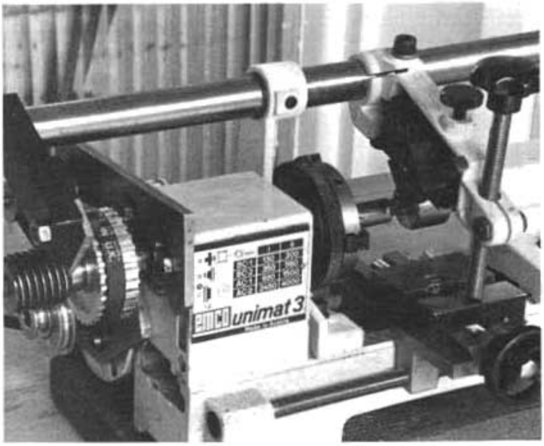
this is best made from a ¼ in. square HSS tool blank, using a grinding wheel, and a protractor set to the required angle. The tool should have an angle of 40 deg. between its two faces, which are backed off on the downward direction. The top surface is relieved back and to the left; the tool is pointed but the cut made flat-bottomed. When used the tool is fed in to match the left side of the cut, advanced, and a further cut made.

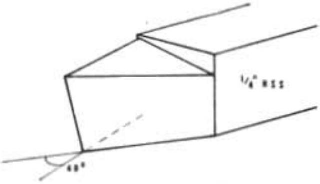
Other tools needed for making the hobs are a ⅛ in. x ½ in. Woodruffe cutter for the grooving, and a disc grinding wheel for backing off the cutting teeth of the hobs. You will also require a simple depth gauge, which I will describe later.

MAKING THE HOBS

First cut a length of silver steel, five times the overall tooth size plus ⅛ in. for the Allen grub screw, so for the eight teeth per inch hob cut a ¾ in. length. Face both ends in the three-jaw chuck, drill with a No. 3 centre drill as far as the flutes allow and then drill right through with a ¼ in. drill. Drill No. 32 for the grub screw and tap 4 BA. Run a ¼ in. reamer through the bore, fit a ⅛ in. long 4 BA grub screw and secure the blank to a piece of ¼ in. silver steel rod for turning between centres.

Take a light cut from the surface to ensure concentricity, then turn the securing screw end down below tooth level. With the 40 deg. tool make four shallow cuts between the teeth. To measure these the handwheel divisions can be used, fifty divisions equalling ¹/₁₀ in., but check with a rule before continuing; keep the appropriate BSF or Whitworth bolt handy as a quick check whilst working. Cut the two grooves, from left to right, either side of the central tooth, to the correct depth, using the geometry as explained, and a depth gauge. The width of the bottom of the cut can be regulated with the handwheel





LATHE TOOL FOR MAKING HOBS

Photograph on left shows the set-up for cutting a wormwheel.

divisions. Cut the other two grooves to form the five matching teeth, and finish by cutting the two outer surfaces to a 20 deg. angle.

To make the teeth into cutters set the work on the 1/4 in. mandrel in the three-jaw chuck, on the indexing head with the 36 division wheel in place, and lock the head onto the cross-slide. Use the Woodruffe cutter to make six slots across the grooves, at six division intervals, taking the slots down to just below the teeth. But feed in no more than five or six handwheel divisions at a time before running the cross-slide across; a greater feed causes overheating and soon blunts the cutter. Replace the Woodruffe cutter with a disc grinding wheel, set the dividing head three teeth back and grind off about two-thirds of tooth area. Set the head two more teeth back and back off finely almost to the cutting edge, all six slots. Clean off all traces of grinding from the lathe, dismantling if necessary.

HARDENING AND TEMPERING

Remove the set screw and push the hob on to a piece of copper pipe, 3/8 in. O.D., whose end has been cut and squeezed together, and place on a hearth. Have a pair of old pliers and a can of cold water handy. With the blowtorch heat up the hob to cherry red, pick up the copper pipe with the pliers, keeping the pipe upright with the hob at the top, and give a final blow to ensure redness, then dunk it in water. Include the copper pipe in the dunking or you will get a surprise when you pick it up again. Take the hob from the water and replace the water with cold. With a good file vigorously attack the flat bottomed grooves, where it should do little but remove a little blackening. With emery cloth clean the ends, including the extra surface for the set screw, and push the other end back onto the copper pipe to reheat. This time hold the pipe with the pliers and heat the copper, only, until the cleaned parts of the hob go to a nice yellow, as if the hob has been varnished, and then dunk in the water. The hob is

now finished, there is no need to clean off, and you will have burnt off the burrs with the first blow.

MAKING GEARWHEELS

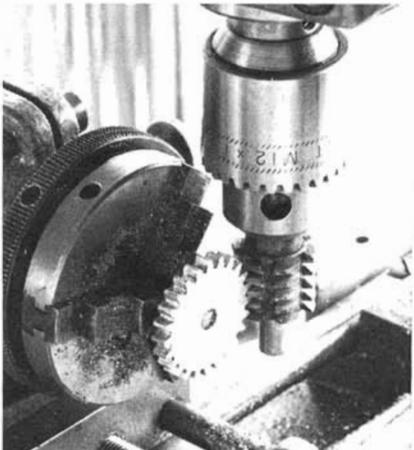
To make a gearwheel first cut the blank with a diameter a little larger than the finished diameter. Use the table to find the size of blank needed for the size and number of teeth. The effective radius of the gear is given in the last part of the table; this is the radius which can be used to draw a circle touching another circle to represent two gears in mesh without worrying about the teeth. It can be used for positioning the centres of gearwheels to be run together.

Take the blank and rub down one side flat on emery cloth on a flat surface, to remove sawcuts. Chuck the blank, finished side in, in the three-jaw and turn to a finish as much of the surface as the jaws will allow; enough of the centre of the blank needs finishing to take the mandrel, and the rest can be finished on the mandrel.

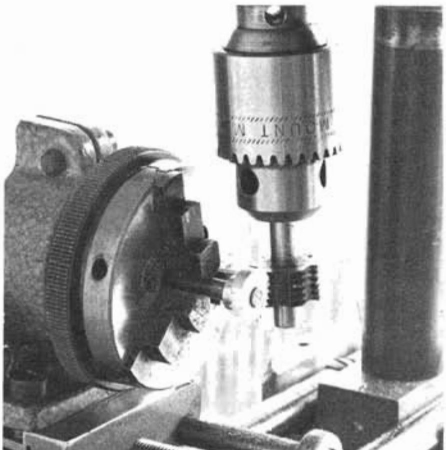
Centre-drill right through, following with a drill the diameter of the mandrel. Fit the blank to the mandrel and secure to finish the front surface and to turn down the diameter to the blank sizes, checking with a vernier caliper.

Select the correct dividing wheel for the indexing attachment; the Unimats have four sizes of dividing wheel, 30, 36, 40 and 48 teeth for the S.L., and 24, 30,

Cutting a gear with the hob.



Cutting angled teeth on a pinion.



36 and 40 divisions for the Unimat 3; the table shows the possibilities with these plates up to 96 teeth. Using this hob method to cut, say, sixty teeth with the 30 dividing wheel, you will find after cutting the spaced thirty teeth that the intermediate teeth are almost finished and require the minimum of cutting. With the indexing attachment on the cross-slide secure the blank, on the mandrel, in the chuck, and have the hob driven in the drill chuck on the vertical head. Bring the cross-slide right over, forward, and the vertical head down the column until the hob presents its middle cutting row to the horizontal centre of the blank; finalize by adjusting the quill, using the vertical fine-feed attachment if you have it. Turn the handwheel until the hob can cut into the blank, and cut through by means of the cross-slide movement. Smaller teeth sizes can be made with a single pass, forward and back, then turning for the next indexed cut; lock up while cutting. Larger teeth, and teeth in harder material, will need more than one depth of cut, in which case note the longitudinal slide handwheel setting for each cut and for the final position cut and write them down, as you may be interrupted halfway through the job. Remove the completed gear from the mandrel and rub off burrs on emery cloth.

LIFE OF THE HOB

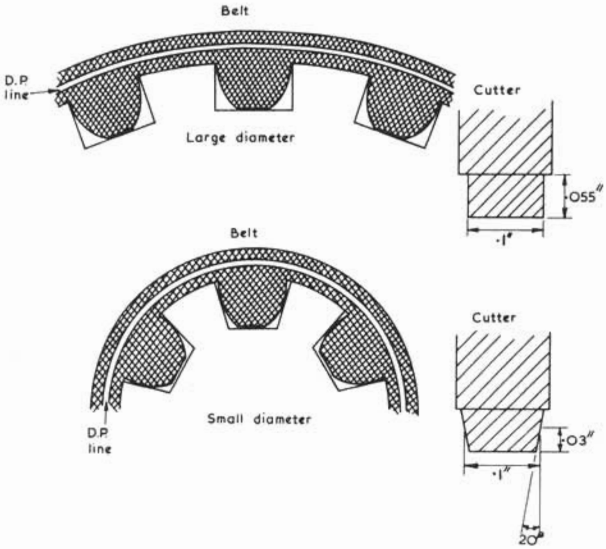
So far I have only used my hobs for cutting gearwheels in aluminium alloys and brass and the cutters show no signs of blunting. To sharpen the hobs the leading cutting edges would need a light stoning by hand, then the hobs should be turned at speed and a flat stone run lightly against the top of the teeth. There is no reason why the cutters should not be used to cut teeth in mild steel blanks, but care must be taken to avoid overheating by using less of a cut, also the hobs will need more attention by sharpening.

TOOTHED BELT DRIVES.

Toothed belt drive systems provide the same positive drive as gears in mesh, but with the flexibility of positioning that a pulley and belt system provides. A toothed belt drive is more like a chain drive, as it cannot slip, yet unlike the chain drive it requires no lubrication, and is quiet.

The toothed belt is usually from a synthetic rubber, for the belt and teeth, which are reinforced and moulded around non- stretch nylon cords within the continuous part of the belt. The nylon cords become the part about which the belt flexes, and they thus determine the pitch of the belt and teeth around wheels, and the positioning of the teeth. There is little or no information available for the model engineer wishing to make toothed wheels to run with the belts (the manufacturers of the belts supply wheels to run with them) and so I devised my own cutters to make the wheels.

I have been making and using these square-toothed wheels for over two years, to run with just one size of belt. During this time I have been using the drive system for my Unimats and for various workshop machinery I have made all with far more positive drive than previously.



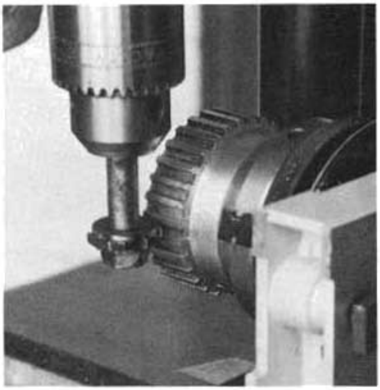
The size of the toothed belt is 100 x LO31, which is a lightweight belt with five teeth to the inch, each tooth being one tenth of an inch long with the same size space alongside. The teeth are one twentieth of an inch high, formed approximately as in the diagram. They can be readily obtained from model shops where they are a spare for a radio controlled stock car.

When the belt is manipulated it can be seen that while the teeth remain quite stable the size and shape of the spaces can be made to vary quite a lot; with diminishing diameter the gaps compress but the teeth do not. This can be seen in the diagram. Cutters for making toothed drive gearwheel are made to cut a single space between teeth, only, as that is the correct and finished shape. The cutter for larger diameter wheels has straight side, but the one for smaller wheels has to have angled sides to cut away rather more of the tooth side and so allow for the compression of the belt spaces.

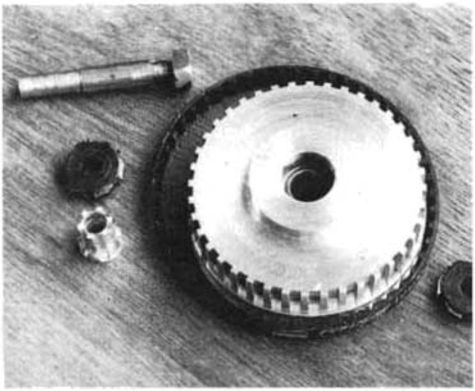
To make a gearwheel the size of the blank is calculated to accommodate multiples of one tooth plus a space, around the circumference, and although the non-stretch nylon cords will cause a need for small reduction of the straightforward diameter, in practice the effect can be ignored unless the belt is to be run without much tension, in which case the after-treatment of a few thou. turned off the toothed wheel will do the trick. The formula for the diameter of the blank is:

$$\text{Diameter of blank} = \frac{\text{Number of teeth required}}{5 \times \pi}$$

The cutters are made from ¼ in. thick slices of ¾ in diameter silver steel, with a ¼ in. bore, and they are turned, grooved and ground into cutters on a



Forming square teeth.



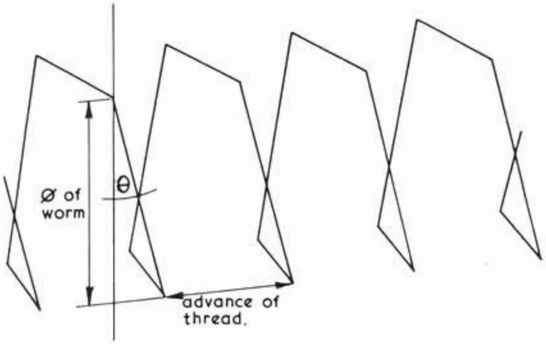
A toothed drive shown with the cutters.

mandrel made from 3/8 in. diameter mild steel, turned down to a 1/4 in. diameter collar, 3/16 in. long to take the cutters. To harden and temper the cutters, use the copper as before. The work is carried out in the same way as for the hobs, and the cutters are then used to cut the blanks with exactly the same methods.

When the gearwheels have been cut from the blanks check their accuracy with a toothed belt held tightly in place, having removed any burrs beforehand by running emery cloth against the turning gearwheel. Position the gears and belt so that the tension applied gives no more than a deviation of 1/8 in. on a straight 2in. stretch of belt . When running a toothed belt system it is usually necessary to contain the belt in some way to stop the belt running off. With a small gear driving a larger gear by means of a toothed belt it is sufficient to rim the smaller gear; this can be by means of two co-axial flanges secured either side of the cut gear.

WORMWHEELS AND PINIONS.

Whilst I was devising a way to fit non-standard threading leaders to the threading attachment I found a way to make multiple-start worm-wheels on the Unimat SL. I had made the leader from a 1in. Whitworth bolt by sawing off the head, drilling through 1/4 in., fitting an Allen grub-screw and securing it co-axially with a length of drilled brass rod on a silver steel rod centred in the lathe. The follower of the bolt's thread was a piece of 1/8 in. brass plate, filed on one side. After cutting one lot of coarse thread on the brass it became immediately obvious that, b/ simply turning the bolt relatively through 180 deg. a two-start worm would result, keeping the bolt hard against the chuck jaws both times. By using the angles of the chuck jaws as a guide a three-start worm could also be made. The same methods can be used with the Unimat 3, giving the modified bolt leader a 6mm hole, fitting it in the standard, outside, position on the threading set-up. The pulley against which it seats could be calibrated for the various starts.



SIMPLIFIED WORM GEOMETRY FOR CUTTING PINION

Since the 1in. Whitworth bolt has eight threads per inch the two-start worm becomes sixteen per inch, and a pinion of sixteen teeth per inch is needed to run with it. For this I used the cutter of ¾ in. diameter, which I had made with the other hobs. In theory the cutter should be of similar diameter to the worm-wheel so that the pinion embraces the wheel. However, as the pinion was to be comparatively thin the ¾ in. hob proved satisfactory.

To enable the pinion to run at 90 deg. to the worm the teeth have to be cut at an angle. When viewed from the side a worm- wheel presents a complexity of angles, and with a pinion whose thickness in under half the diameter of the worm it is the angle at the centre of the worm's thread which must be considered. To determine this angle it is simplest to imagine the worm as square in section, then each side of the square will advance by one quarter of the complete advance of the start. It can then be seen the angle of the teeth of a pinion to mesh with that particular diameter of worm be found from:

$$\tan\theta = \frac{.25 \times \text{thread advance}}{\text{diameter of worm}}$$

This calculation gives a compromise angle, close to the lead angle, which runs very well in practice, giving a good tight fit with no backlash. So with a worm of outside diameter ⅜ in. cut to 8 t.p.i. (the number of starts is not involved) the thread advance is ⅛ in. and a quarter of this is $^1/_{32}$ in.; .03125 over .375 equals .O83R: this is tan. theta. On the calculator this represents an angle of 4.75 deg., the angle to cut the teeth.

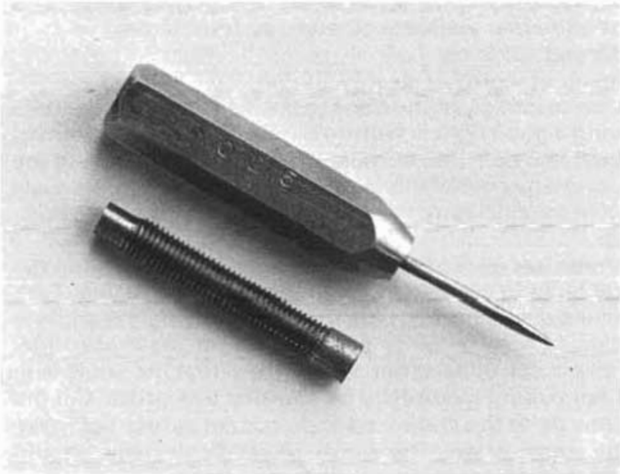
To cut the teeth of a pinion, set up the blank as before, but this time bring the centre line of the vertical head to correspond with the lathe centre line. Turn the vertical head the correct deviation from the upright, ensuring the angle is correct using the flat side of a rectangular protractor from the cross-slide. Bring the blank across and check against the worm-wheel that the angle is in the right direction, and not cutting incorrectly by a further x degrees. Cut the worm by feeding the blank on to the cutting hob; do not cut across but make the pinion hollow for the worm-wheel. The worm-wheel, by the way, should have been cut with the 40 deg. tool that you made for the hobs.

A SIMPLE DEPTH GAUGE.

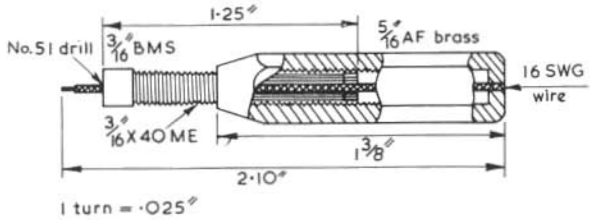
When making hobs and cutters for gearwheels, and when cutting gears, it helps to have a depth gauge on hand for getting the depth of the grooves just right. A simple but accurate depth gauge can be made by relying on the 40 t.p.i. Model Engineer series of taps and dies; either 3/16 in. or 1/4 in. can be used. The 40 threads per inch give a movement of .025in. to each complete turn on the gauge, and by using the faces of a hexagon then 4 thou. is measured as near as you will want. The one I made was with the 3/16 in. x 40, but for the 1/4in. x 40 one, just use a larger size of hexagon brass and 1/4in mild steel rod.

Take a 1 1/2 in. length of 5/16 in. A.F. hex. brass and chuck in the three-jaw. Turn both ends to finish down to 1 3/8 in., and with a No. 1 centre drill, drill into one end as far as the flutes will allow, follow this with a No. 51 drill right through, then drill No. 21 to a depth of 1 1/4 in. With the 3/16 in. x 40 second tap in the drill chuck mounted in the tailstock, tap as far as you can, loosening the quill of the SL for advancement, or adjusting the tailstock position for the 3. Remove the tap and the swarf, to tap again with the plug. Turn a taper on the hexagon until only a thin face of metal remains, to the thread. Reverse and take off the back corners.

Face the ends of a length of 3/16 in. diameter silver steel or BMS and turn the end 1/8 in. down to .09in., centre drill the end, then drill in 1 5/16 in. with a No. 51 drill. Get 1 1/4 in. protruding from the chuck, and with the 3/16 in x 40 die in the tailstock dieholder, thread 1in. past the turned-down end, first with the die wide open, and then again with the die not quite relaxed; use plenty of tapping compound to get a nice clean-cut thread. Try the hexagon on, and it should screw quite tightly with the fingers. Put a pointed lathe tool in the tool holder on the cross-slide, bring the point up to the thread and, by turning the bed-



The simple depth gauge shown dismantled.



DEPTH GAUGE

slide handwheel, score a fine line through the threads. Remove and mark off the 1¼ in. and wrap a ¾ in. wide strip of alloy around the threads and chuck in the drill chuck. Part off the 1¾ in., and face off the anvil. Push a No. 51 drill through the bore to clean away the burrs, then screw about ⅜ in. into the hexagon brass. Take a length of 16 s.w.g. steel wire (use the stuff that the model shops sell as piano wire in straight 3ft. lengths but take a vernier caliper with you to check the gauge) and grind the end to a tapered point and blunt the point straight across.

Push the blunt end into the gauge to protrude at the anvil. If all is well remove the wire and clean off to tin with Comsol at the 2in. to 2.1in position, rub the solder down flush. Smear the hole in the hexagon brass with Comsol paste, and push in the wire to the 2.1in. Solder in the wire with a small flame or large soldering iron, touching the joint with Comsol wire to consolidate. Allow the joint to set and cool naturally, and with a small hacksaw cut off the surplus wire, place in the vice and flush with a fine flat file. Remove the threaded part and clean both parts. Smear the threads with grease and screw right home, unscrew and take off the surplus lubricant.

To zero the gauge rest the anvil on a dead flat surface and hold it upright and still, turn the hexagon slowly, and the needle will lift the anvil from the surface as the zero point is passed, back off the hex. until the needle coincides, level, with the anvil, and, mark the position of the line cut into the threads onto the taper of the brass. To finish off stamp .025 on the brass, on the opposite side to the line, to remind you. To protect the little gauge beg one of the small tubular boxes that hold small twist drills from your tool merchant; it will accommodate the gauge neatly.

Remember that each complete turn of the gauge equals .025in., and in use complete turns need to be counted to get correct length of needle protruding from the anvil, or can be counted back from where the anvil has lifted on measuring the depth of a tooth cut.

Chapter Four

An Air Compressor

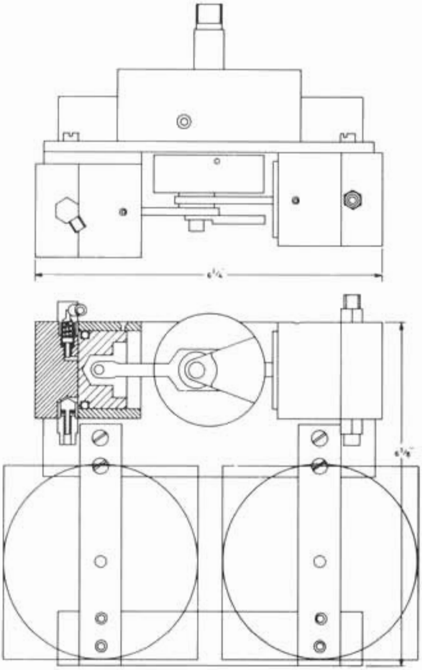
Airbrushes are being used increasingly by the model maker to obtain variations in a first class finish not obtainable by other methods, and whilst the airbrush is moderately priced, obtaining the air to drive the brush is becoming prohibitively expensive. The aerosol dispenser, the cheapest form of propulsion, may seem reasonable until used for a sizeable area, when the can will be empty in a very short time. Diaphragm compressors of the smaller type are available around £40 and require a range of accessories if they are to work correctly.

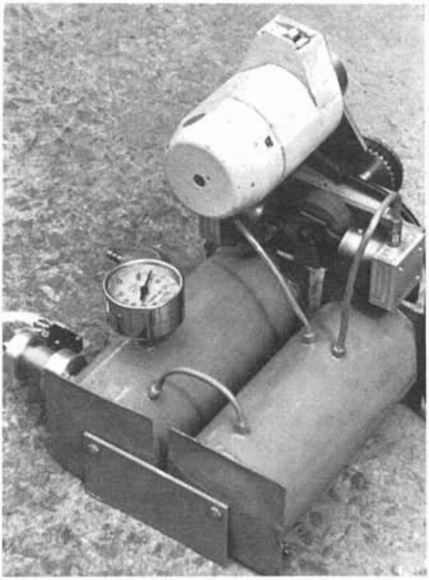
I decided to design and make a small compressor to supply the requirements of an airbrush, capable of being made on the Unimat lathe, SL or 3, and of being powered by the drive unit of the Unimat, all in the name of economy.

COMPRESSORS.

There are two main classes of air compressors - rotary and reciprocating. The modern rotary compressor can be a sophisticated piece of machinery efficiently producing high pressure air flows, but to make them they require complex, high precision component machining, outside the scope of the Unimat man. The format of the simpler type turbine compressor, which may be considered, rules it out simply because in small size the necessary clearances provide a large leakage, which in a massive size is only a minute loss.

Thus the reciprocating type of air pump must be considered for a small, simple design such as this. These may be classified into two groups, diaphragm and piston. The diaphragm compressor can be the simplest, consisting of a diaphragm of a flexible material, such as reinforced rubber, being pulled and pushed from a flat plane by a crank or a solenoid. The pulling draws air in through a valve, and the pushing expels the air through an outlet valve. By careful design the diaphragm compressor can be made quite efficient, but the two drawbacks are firstly that on drawing in air the diaphragm goes conical, thus drawing in less air at a time where there is little work-load and maximum air should be taken in. Secondly, at the end of the compression stroke the diaphragm flexes back rather than fully compressing the air.





The completed air compressor unit.

Left, general layout of the compressor.

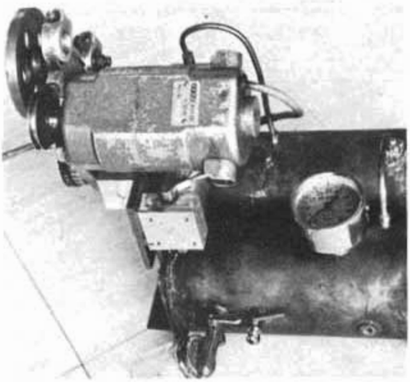
The piston compressor does not suffer from these defects, but, consequently, requires more power for a given size of chamber to drive it, producing more efficiently its output of air.

THE PISTON AIR COMPRESSOR.

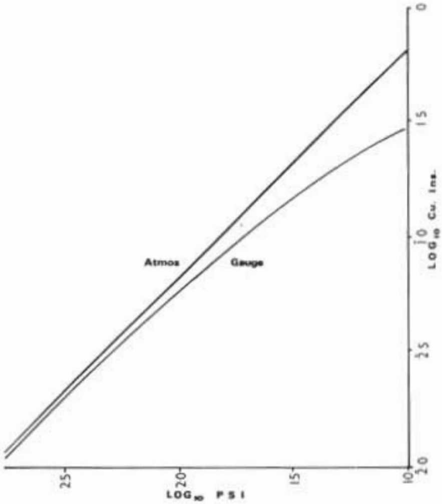
To start from basics, Boyle's Law is considered. A volume of air is in a cylinder with a piston at one end and closed at the other; the air can be measured for pressure. If the piston is pushed halfway in the air pressure will have doubled. So if the air was first at atmospheric pressure, considered here as 14.7 psi, the air in the half volume will be at 29.4 psi. If the piston is pushed in halfway along the remaining length of cylinder, the pressure will again be doubled, to 58.8 psi. Since the gauge will be zeroed at atmospheric pressure it will read only 14.7 at half volume and 44.1 at the quarter volume (58.8 - 14.7). On continuing the halving of volume the doubling of pressure will make it possible to obtain very high pressures.

DELIVERED AIR.

It must be noted that as the pressure increases the volume of air becomes smaller, so that if the high pressure air is delivered it will be in minute



Photograph above shows the compressor being driven by the Unimat SL motor.



quantities: this is shown on the graph. Effects due to temperature and water vapour, which may affect pressure, are not considered here.

There are two considerations involved with delivered air. First the dead space within the inlet and outlet passages which limit the top pressure reached, even when the piston travels to touch the cylinder head. This dead space provides inefficiency as the air compressed within it is decompressed on the backward stroke, and is not delivered. The second consideration is that, with delivered air, the air is only compressed sufficiently to overcome outlet valve spring and air loading, when it will pass through the valve. But at a rising pressure, into an air receiver, the top pressures can be eventually reached, requiring great effort from the drive motor, unless a limit is placed on the top pressure.

In the reciprocating piston compressor the pistons are usually driven by means of a crankshaft and connecting rod, and, ignoring effects of connecting rod angularity, will travel back and forth with sinusoidal acceleration and deceleration, the maximum speed being attained at the points halfway

TABLE FOR PISTON. 1⅜ in DIAMETER. STROKE 5/16 in.

Remaining Part of Stroke	PSI ATMOS		PSI GAUGE		CUBIC INCHES		
	Number	Log	Number	Log	Number	Log	Cal log
·3125"	14·7	1·1673	0	–	·4640	$\bar{1}$·6665	–0.3334
·15625"	29·4	1·4683	14·9	1·1673	·2320	$\bar{1}$·3655	–0·6344
·078125"	58·8	1·7694	44·1	1·6444	·1160	$\bar{1}$·0645	–0·9355
·03906	117·6	2·0704	102·9	2.0124	·0579	$\bar{2}$·7634	–1·2365
·01953	235·2	2·3714	220·5	2·3434	·0289	$\bar{2}$·8624	–1·5375
·00577	470·4	2·6725	455·7	2·6587	·0145	$\bar{2}$.1616	–1·8383
·0049"	940·8	2·9735	926·1	2·9667	·0073	$\bar{3}$·8619	–2·1381

Table showing relationship between remaining part of stroke, pressure and volume of air under pressure.

Graph above illustrates, this table and is used to select particular required gauge pressure to find volume of air in cylinder, and, by calculation, CFM.

forward and halfway back, deceleration starting just past these points. With a continuous applied rotary force at the crank the sinusoidal deceleration of the piston on the forward stroke increases the power at the piston at a time when it is required for the increasing air pressure. By running a pair of pistons, directly opposed, an even-running compressor can be made with twice the output of a single cylinder, and using quite a small amount of power up to a receiver pressure of around 60 psi.

COMPRESSOR DESIGN.

As the compressor is to be made on the Unimat the design is kept as simple as possible, and, as it is to be powered with the Unimat drive, a single ended drive is adopted, away from that often used of single cylinders driven each end of a motor shaft. A common journal drives two connecting rods to horizontally opposed pistons in cylinders, one of which is stepped out of line to avoid cranking the connecting rods with two angles. The cylinders are made from heavy brass tube to minimize machining and finishing, and the cylinder heads are simple blocks of light alloy. The valves are made part of the head, with screwed brass fittings. Pistons are machined to be an exact fit in the cylinders, and are fitted with silicone rubber "0" rings close to the piston head, which is made to travel and just touch the cylinder head.

The big ends are ball-races Loctited in place and running on a journal which is the unthreaded part of a 1/4 in BSF hex. cap head bolt. The small ends run on phosphor-bronze gudgeon pins, screwed into one side of the piston. The main drive shaft is driven by a toothed belt drive, as previously described, and runs in two large ball-races within a bearing block, to a brass crankwheel, which drives the common journal for the connecting rods.

The drive motor unit is supported on the bearing blocks, for the Unimat 3 drive, by two screws, and for the Unimat SL drive by a 35mm collar extended from the block. Other types of drive motors can be easily adapted to fit. The bearing block is secured to a 3/16 in gauge steel plate, on the other side of which are the cylinder units, one of which has an extra thickness of plate as a step.

The compressor unit is supported upright on two steel legs fixed on to the receiver cylinders.

LENGTH OF STROKE.

To minimize angularity effects, where acceleration and deceleration are not sinusoidal, either the connecting rod can be made long compared to the length of the stroke, or the stroke can be made short so that the connecting rod can be made compact, as in this case. The stroke is 5/16 in, and the bore of the cylinder 1 3/8 in. With a longer stroke larger volumes of air are produced at pressure and proportionally more power will be required. With the Unimat 3 drive adapted for the toothed belt drive, the compressor can be made to run at 2000 rpm up to a pressure of about 40 psi, when it will start to slow on the increased load. This basic speed of running of the compressor gives the cubic capacity of operation in cubic feet per minute (C.F.M.) and at 20 psi this is approximately .45 CFM.

AIR VALVES

The inlet and outlet valves were designed empirically, commencing with balls on "O" ring seats, then trying out various flap valves, through to the "bob" types as fitted. The idea is to keep the valves as simple as possible without resort to big holes, thus keeping dead space to a minimum, a 5/16 in x 40 thread and its appropriate aperture being the maximum valve working area aimed for.

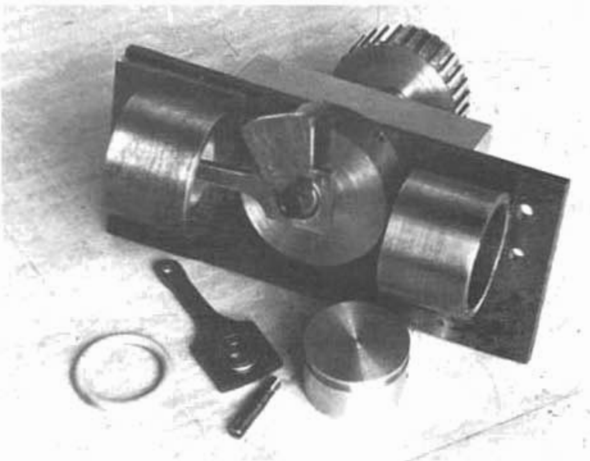
The flap valves were in too small an aperture to be effective. The original ball valves worked well at low pressure but as pressure built up the ball became stuck in its "O" ring seat or unseated the "O" ring sideways. So the bob valves were designed, with the inlet valve working by gravity and the outlet valve being lightly spring loaded to minimize bounce.

The inlet bob is like an inverted spinning top, the brass bob top being turned to fit the space left by the letter L drill, and having a tail of a length of 1/8 in. diameter phosphor-bronze as a guide, with an "O" ring fitted to seat on to the flat end of the hollow brass screw fitting. The outlet bob is a brass disc central on a length of rod, with the "O" ring fitted on the lower part and the upper part being spring loaded into the brass fitting. This "O" ring seats on the bottom of a standard angle drill hole.

The tails of both inlet and outlet bobs have filed flats, to let the air get by, and they have a lift of approximately 1mm.

AIR RECEIVER.

When air is compressed it experiences a rise in temperature, and since air expands when heated, a rise in pressure occurs. Air in the atmosphere over damp old Great Britain has an average of around 50% relative humidity for most of the year, which means that the air contains a great deal of water



The compressor with one piston removed.

vapour. When air is compressed so is the water vapour. Upon decompression the air cools rapidly and the water vapour will often fall out as water droplets. If compressed air is passed directly from a compressor to a spray gun droplets of water will emerge with the air, spoiling the spray of paint.

By allowing the compressed air to pass first into an air receiver, pressure is equalised, eliminating pulsing, the temperature is allowed to drop overall, allowing some of the water vapour to condense, and the reservoir of air, albeit quite small, allows air to be collected at a certain pressure and retained with the motor drive switched off, giving the motor a rest period when air is not being used continuously.

The air receiver can be used as a strong base for the compressor mechanism and all fittings of pressure gauge, inlet and outlet bushes, water drain taps, and pressure relief valve or pressure switch. In my design twin tanks are used of 16 SWG copper 3½ in diameter x 7½ in long. The tanks have 16 SWG plates brazed on each end, stayed with a single phosphor-bronze rod right through each tank.

WATER TRAP.

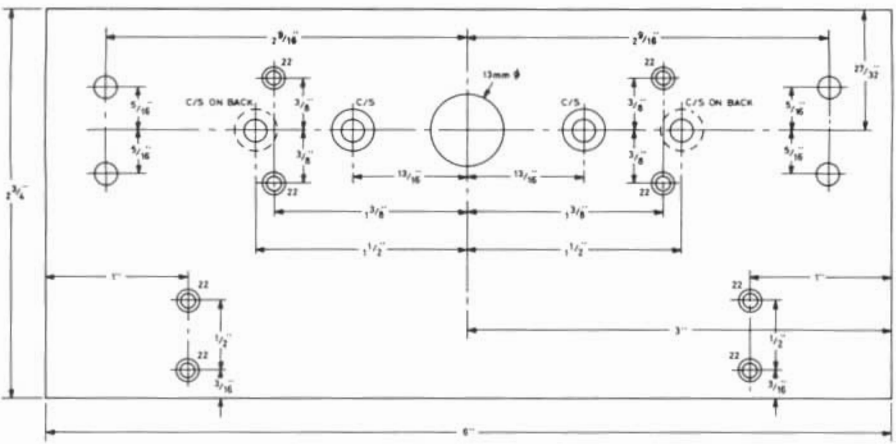
To rid the air of water before it is used a water trap is fitted where the air first expands after the outlet tap. The trap consists of a glass jar into which the air all passes before delivery to the air hose. In this design a large diameter plastic hose is used as a further water trap, intermediate between the glass bowl trap and the small diameter functional hose to the airbrush. In use the glass bowl retains minute droplets of water on its walls, and the plastic hose appears internally cloudy in use, and proves very effective.

PRESSURE SWITCH.

The Unimat 3 motor has an intermittent usage of 80%, and should be switched off for 5 minutes every 20 minutes use, or it overheats. Apart from this, if the compressor is left running when little or no air is being drawn off, the pressure will rapidly build up with the pressure gauge needle going right off the scale – unnecessarily high and putting a great load on the drive mechanism. I have had an estimated pressure of 80 psi from the compressor with the drive mechanism still running, though rather laboured.

To eliminate the gradual build-up of high pressure I designed a simple pressure switch to switch off the motor when top working pressure has been reached, without wasting air. The switch consists of a piston in a cylinder, the piston being spring loaded against air pressure, and the backward movement of the piston, overcoming set spring tension, operating a microswitch directly, with no linkage. The microswitch itself has a roller on a spring-loaded bar, and the roller falls into a channel on the piston, seen through an aperture cut in the cylinder wall. The effort to push the roller out of the channel is greater than that of it falling in, and so a pressure difference is realized between "off" and "on" of the microswitch, and hence the motor drive to the compressor. If the spring-loading on the piston is adjusted so that the piston moves back and operates

BED PLATE 3/16" GAUGE PLATE



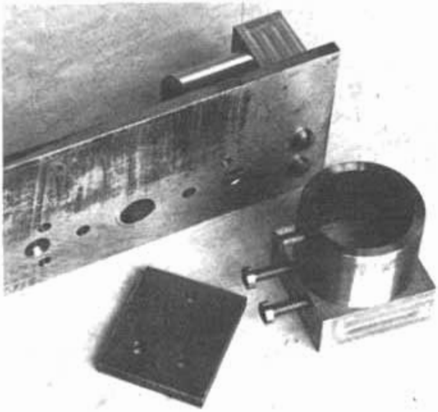
UNMARKED HOLES - No 10 HOLES No 22 - TAP 2BA

the cut-out at 30 psi, then the piston will not move again until the receiver pressure has dropped to around 20 psi, when the compressor will restart.

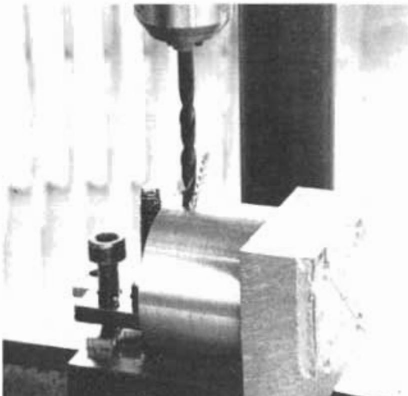
By adjusting the microswitch position relative to the groove the spring pressure on the roller can be made to give a varying differential of between 7 psi and 15 psi.

If the switch fails to operate and the motor keeps running then the piston continues to be pushed back until its head is at the microswitch aperture, when pressure will be released as through a safety valve.

The bedplate and step.



Drilling after milllling the flat.



OTHER SIZES

The table and graph are worked out for the one particular size of piston diameter, but this air compressor can be made with other sizes of piston, using the same stroke, with modification of the drive shaft only: the drive shaft requires increasing in length by the same amount as the radius increase of the piston. This may be necessary for several reasons, the most likely being the unavailability of the thick brass tube for the cylinder. The cylinder may alternatively be made of thinner tube fitted into a thick sleeve of duralumin and Loctited in place, allowance being made to the main shaft for dimensional variations which may be necessary.

If a change is made to the piston dimension then the volume of air at a given pressure will be different from that in the table, and, for those who like to keep up with the times, the modern calculator can be programmed for all variations in this field.

MAKING THE COMPRESSOR

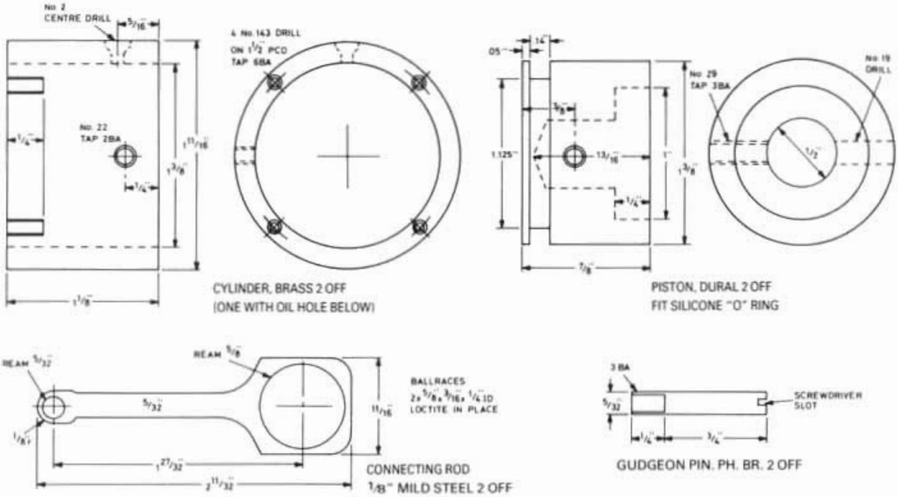
The first component to make is the bed plate, which is of 3/16 in gauge plate to make sure that everything lines up with the least amount of bother. If the gauge plate is difficult to come by you will have to make do with mild steel section, from Messrs Reeves most conveniently. Cut out the piece carefully to file and finish to size before covering the front surface with marking out blue, made from French polish coloured with aniline blue dye. For marking out you will need a sharp scriber, a well-etched 6 in rule, spring dividers, a small engineer's square, two sharp centre punches (one ground at 60 degrees, one to 90 degrees), and a medium weight hammer. Later a protractor will be needed.

Start with the horizontal line and scribe this, find the precise centre of the line and, using the square, scribe a line down. Lightly pop the cross with the 60 deg punch to take the leg of the dividers and mark the horizontal line with the various positions, each side of centre, and then the circle. Check before drawing in the vertical lines with the help of the square, then the other lines. Lightly centre punch for all the holes with the 60 deg point, and examine all indents for their correct positioning before going over them all with the 90 deg punch. Drill all the holes carefully on the milling table, with the work clamped down each time, leaving the large centre hole until last.

CYLINDER UNITS

First obtain the brass tube. If you have difficulty in obtaining the right size there are two alternatives. Use thinner section tube and bore out some dural to house the tube, adjusting the drive shaft length for any internal radius difference. Or use solid brass and bore out the cylinder, using a between centres boring bar and toolbit. Remember that the wall must be of sufficient thickness to take the 6 BA screws.

Gripping the bore internally with the three-jaw chuck, square off the ends of the tube, bringing it down to the correct length. With both cylinders made, set



CYLINDER, BRASS 2 OFF (ONE WITH OIL HOLE BELOW)

PISTON, DURAL 2 OFF FIT SILICONE "O" RING

CONNECTING ROD 1/8" MILD STEEL 2 OFF

GUDGEON PIN, PH. BR. 2 OFF

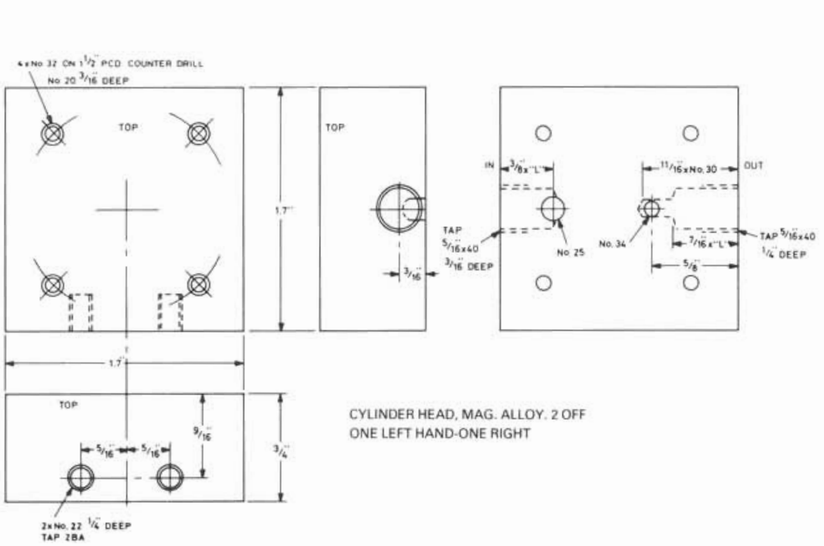
up the dividing head with the 36 position plate, and, with the Unimat in the vertical mode, drill the four holes to be tapped 6 BA, first staking the positions with a No 2 centre drill. Tap the holes.

The cylinder heads are made from magnesium alloy section, and are quite big, giving plenty of cooling area. In use they do not overheat at 50 p.s.i. over half an hour, so they do not really need fins milled on them. But if overheating is experienced there is plenty of room for fins to be machined and the cooling area increased. The head is kept very simple and is easily removable, should the need arise.

First cut the two squares a little oversize and scribe diagonals. Lightly punch the centre and draw in the circle for the 6 BA clearance holes; punch and drill the holes. The head is fitted to the cylinder with four hex. socket cap screws, and the heads of these are sunk into the cylinder head by counterdrilling. Fit the heads to the cylinders.

Set up the Unimat for milling and secure one cylinder unit to the cross-slide with a clamp in the bore, using a piece of 20 gauge alloy to protect the bore. The head should butt against the side of the slide, approximately square and level, for the milling of a flat reference surface with a 1/4 in end mill as a "T" right over one side, making a flat, ·2 in wide on this side of the cylinder. Swing the head out of the way and measure and scribe a line 1/4 in from the front edge of the cylinder, scribe a cross line down the centre of the "T". With a No 2 centre drill in the drill chuck stake the cross and then drill through No 22 into the bore. Repeat for the other cylinder. Punch numbers on the cylinders and heads, "0" and "1" respectively.

Set up the milling table and, "T" reference surface down, mill the side of the head, parallel. Clamp a length of 1 1/4 in square material to the milling table and



CYLINDER HEAD, MAG. ALLOY. 2 OFF
ONE LEFT HAND-ONE RIGHT

G clamp the unit with the reference surface against the block, tube parallel to the surface, and mill the top side of the head, repeating for the last side. Tap the cylinder holes 2 BA. Remove the heads and clean down the mating surfaces on fine emery cloth held flat on plate glass, before replacing the heads tightly.

Secure one cylinder to the bed plate, square up the head with the plate end and scribe a line across. Mark the cylinder head securing screw holes through, remove and measure that the securing holes are in the correct position, according to the drawing, before drilling. Clamp the block to the milling table and drill the holes a little over 1/4 in deep and tap 2 BA. Cut screws to length and fit the cylinder to the bed plates; punch the number of this cylinder on the bed plate. Remove and repeat for the cylinder head on the other side, using the same screws. Make the step plate and fit this to one side, making longer screws to fit. Always number both sets of components on a dual job like this as it saves searching for a number which may not be there.

Drill the oiling holes with No 2 centre drill on both top surfaces Clean off the burrs from the two holes in each cylinder bore. Fit the two units completely and tightly, using the correct size screwdriver which fits the heads, and ensure that it is all in line, then remove the heads and put them to one side. Use small transparent polythene bags to store parts which may not be needed for a little while.

BEARING BLOCK

The size of the bearing block was decided by the longest piece of 1 1/4 in dural which the four-jaw chuck could turn on the Unimat 3 and on the Unimat SL with the extension block fitted. Centre in the chuck and drill through 9mm first, then bore out with the boring tool in the toolpost to fit a pair of ball-races with a

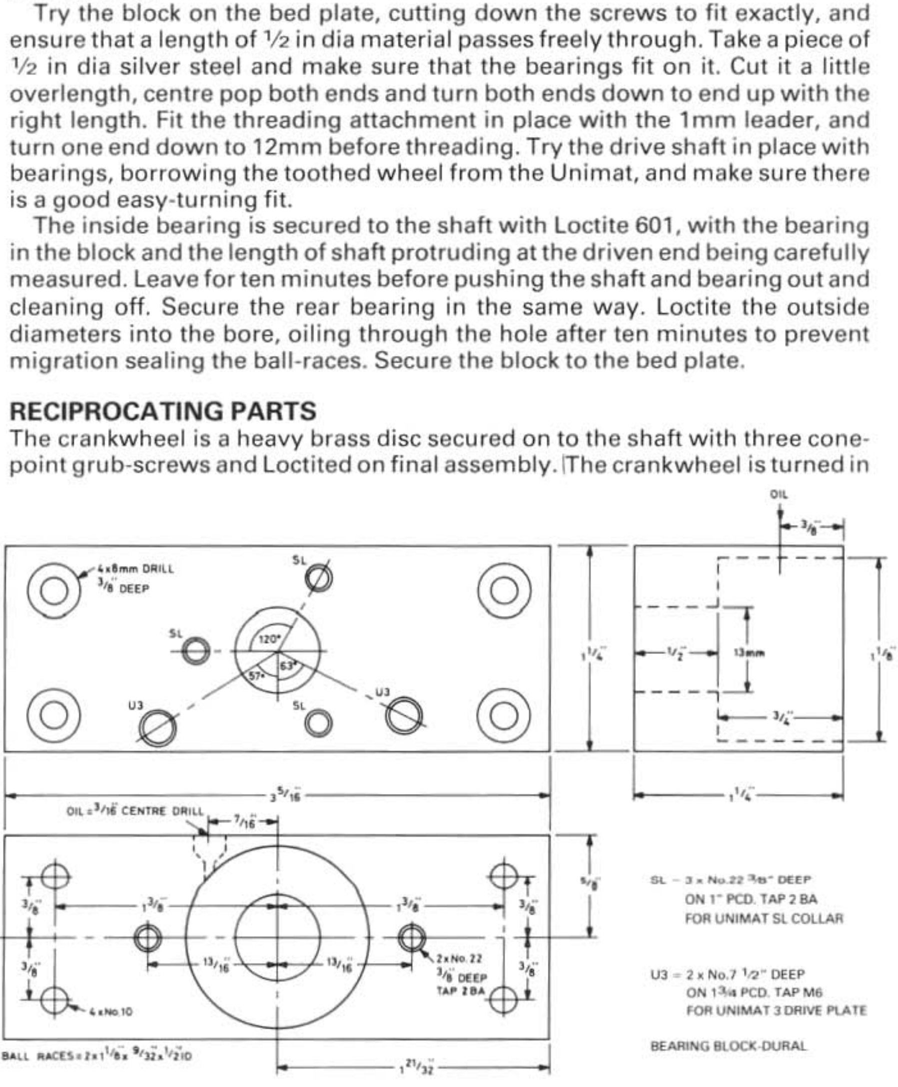
½ in internal diameter; allow a separation of about ⅛ in between them when in position. Centre up the block lengthwise, lightly centre-drill and turn the ends to a finish. Mark out for the other holes, punch and drill, counterdrill for the hex. cap heads and finally drill out the centre to allow clearance for the ½ in drive shaft.

Try the block on the bed plate, cutting down the screws to fit exactly, and ensure that a length of ½ in dia material passes freely through. Take a piece of ½ in dia silver steel and make sure that the bearings fit on it. Cut it a little overlength, centre pop both ends and turn both ends down to end up with the right length. Fit the threading attachment in place with the 1mm leader, and turn one end down to 12mm before threading. Try the drive shaft in place with bearings, borrowing the toothed wheel from the Unimat, and make sure there is a good easy-turning fit.

The inside bearing is secured to the shaft with Loctite 601, with the bearing in the block and the length of shaft protruding at the driven end being carefully measured. Leave for ten minutes before pushing the shaft and bearing out and cleaning off. Secure the rear bearing in the same way. Loctite the outside diameters into the bore, oiling through the hole after ten minutes to prevent migration sealing the ball-races. Secure the block to the bed plate.

RECIPROCATING PARTS

The crankwheel is a heavy brass disc secured on to the shaft with three cone-point grub-screws and Loctited on final assembly. The crankwheel is turned in

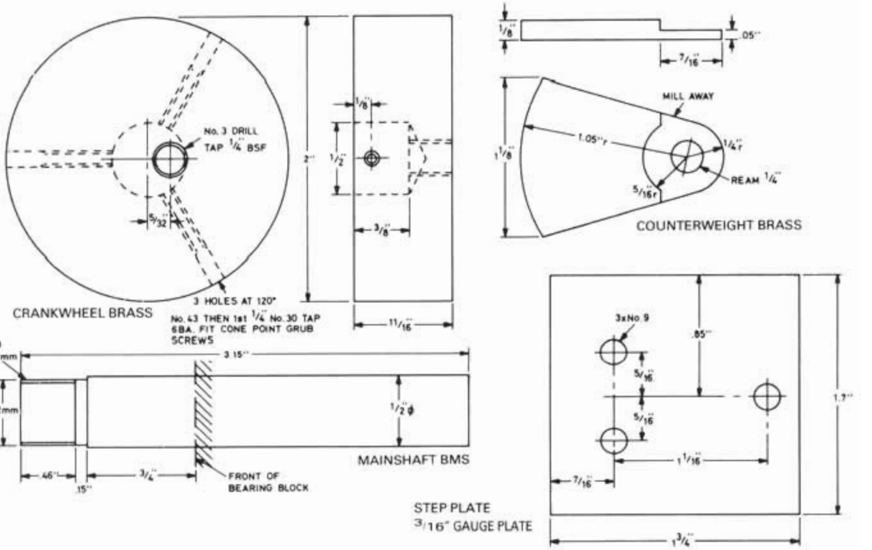


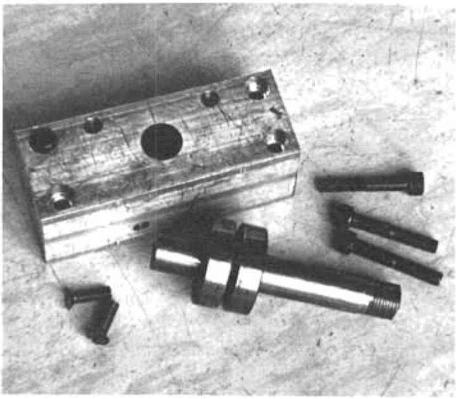
the three-jaw chuck, jaws reversed, and finished true, back and front, before being transferred to the four-jaw chuck, jaws reversed, for the drilling of the crank screw hole, 5/32 in off centre found by adjusting in situ against a sharp centre in the tailstock.

Turn the pistons from light alloy, finishing them to fit the bore exactly, using very light cuts with a knife tool. The vernier caliper should feel the metal both sides when finally tried in place. The piston is best turned from a piece a little oversize, the end is turned true and drilled 8mm so that a boring tool can take out the 1in bore, made so that the three-jaw chuck can grip internally, and the piston be turned down accurately and the groove cut for the "O" ring. Turn the work around and finish the part of the back end which could not be reached, and drill in for the small end recess. The "O" rings fitted are white silicone rubber, 1 1/4 in O.D., stretched to fit in this application.

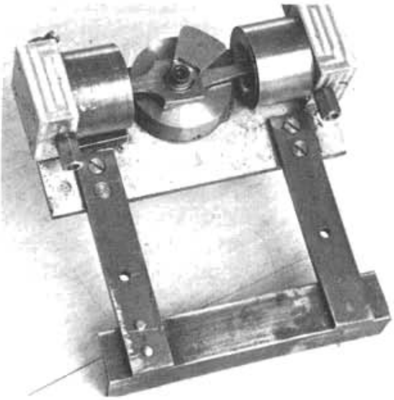
Drill each piston precisely 3/8 in from the front end, right through No 29, using a V-block to ensure a diagonal, then drill the top half for tight 3 BA clearance, and tap right through.

Take a piece of 1/8 in mild steel flat stock for the connecting rods and blue over to mark out carefully the small to big-end centres, lightly centre-pop, check and draw in the circles, then fully punch. For the big end holes a cone-cut can be used up to 1/64 in each side of the correct diameter as drawn, then reaming through 5/8 in. Drill the small end No 27 before reaming through 5/32 in, reamer in the drill chuck. Now the outline of the connecting rods can be drawn in, to be cut out and filed to shape.





The bearing block and main shaft.



The pump assembly.

Make the gudgeon pins from phosphor-bronze, 5/32 in dia rod, turning down the end in the lathe, threading 3BA, and parting off to the correct length. Secure them in turn in the vice, upright, and make a saw-cut for a screwdriver slot. The counterweight is made of brass, the piece being marked out, cut out, clamped down on the cross-slide for milling, and then drilled for the 1/4 in hole.

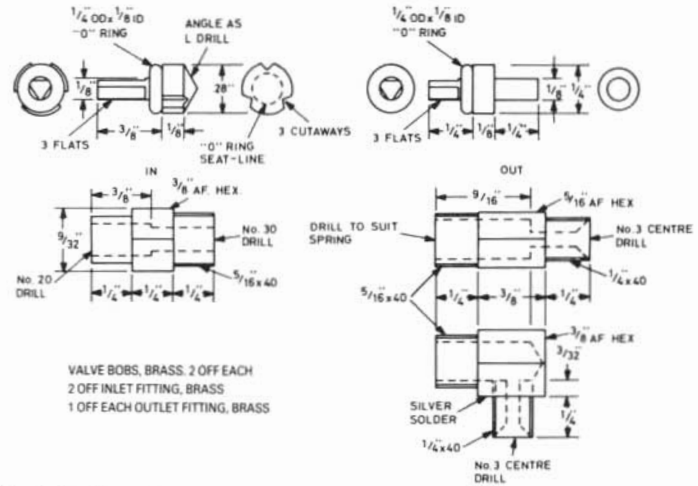
Press a ball-race into the hole on one connecting rod and fit the small end into the piston, minus the "O" ring, and secure the gudgeon pin in place. Pass the connecting rod through the head and secure the big end to the crankwheel, using a 1/4 in BSF hex. cap head screw with about 3/8 in unthreaded. Turn the main shaft over and check that the piston-top comes level with the cylinder end, as it should, exactly. If it is a fraction over try it in the other side first, before thinking of taking any off. When a fitting combination is reached stamp the numbers on the bottom ring of the piston and the connecting rod. Fit together again and check for the correct position of the 1/8 in thick connecting rod on the 3/16 in wide ball-race to centralise the small end in the piston head. Remove the assembly and Loctite the bearing in with 601.

AIR VALVES

Before making the valves, or the holes for the fittings, secure the heads to the cylinders and bed plate and write "OUT" on the top of each with an arrow to the cylinder, and "IN" underneath, with a soft pencil. The heads are removed and the letter L holes, et cetera, are drilled in the top and bottom with the head clamped to a square block, which is clamped to the milling table. Each time the head is clamped with its smooth mating surface towards the block.

With the mating surface uppermost, and the head clamped with a T-slot clamp on a protecting slip of cardboard, drill the holes through to the valve bores, having marked the spots and lightly centre-punched for the drill point.

The easiest way to make the bobs is to turn the bodies from brass and drill them, then insert the tails using Loctite 601, filing the flats and triangles when



cured. The tails do not have to be of phosphor-bronze – brass will do. Fit Viton black rubber "O" rings, which are harder than the silicone rubber type.

Turn the fittings from brass, threading them in the lathe using the tailstock dieholder. When inserting the valve screw down on to the bob and "O" ring until they are just held, and then unscrew the fitting about two turns to give the correct lift. On the final fitting Loctite 222 is used to make the valve threads airtight. Remember that the bottom, inlet valve works by gravity and that the top valve is lightly spring-loaded.

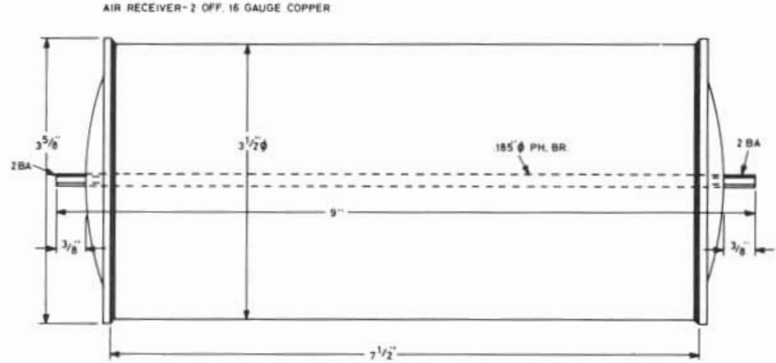
After assembling the crankwheel tight on the shaft, the pistons with rings, and connecting rods down on to the journal, secured with the counterwheel in place, opposed to the big end bearings, fit the completed cylinder heads with a gasket of Loctite 222. Leave for ten minutes before turning the shaft over and checking for suction in and high pressure blow out.

RECEIVER TANKS

The air receiver tanks are made from 16 gauge copper and are brazed together with Phosphalloy; quite a lot of heat is required for this size of job. Flanging is avoided by the use of Phosphalloy which gives an excellent fillet on copper, and no flux is required. A phosphor-bronze stay is threaded into both end plates, and the protruding threaded stay is used each end to complete the tank/compressor assembly.

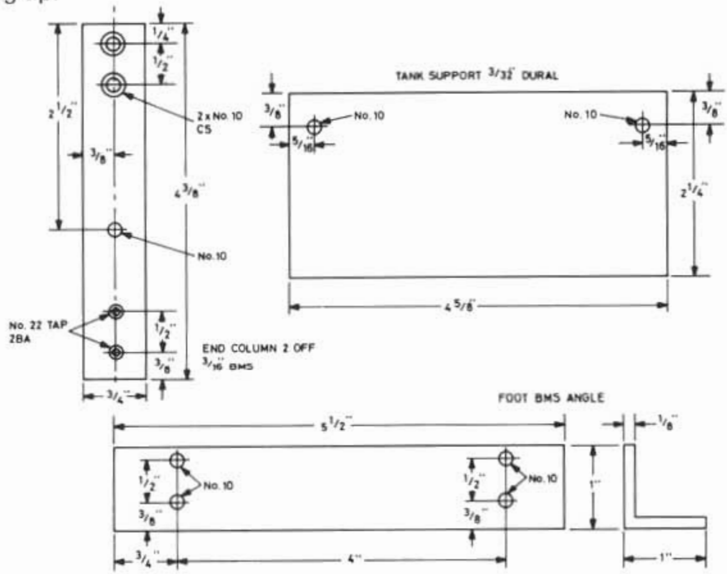
Cut the copper tube to size, carefully, using the finest hacksaw blade for the job. Cut out the four squares from sheet for the end plates and drill the centre of each No 22; anneal just the plates. Taking a collar of the 3½ in tube as support gently hammer the centre of each end plate into a dish. Tap the holes 2 BA, and cut two lengths of phosphor-bronze rod to be threaded each end in the lathe, ½ in x 2 BA. Clean off the areas to be brazed with emery cloth.

Take one copper cylinder and find a domed plate to fit, tapping the plate to get a surface-to-end fit with gaps no more than .02.in. Place them on the



brazing hearth, dome down, and cut a ⅛ in piece of Phosphalloy and lay it in the middle of one corner. Direct the blow on to this corner but at the join of the cylinder to plate, moving the flame back and forth over the join. The corner will soon go red hot and the Phosphalloy flow as a silver looking metal, at this stage. Take the long stick of braze and run it towards the flame at the join, removing the stick and bringing back the flame as flow occurs. For any reluctant runs use a pointed steel rod, made red hot, to promote the flow to a fillet all around the join.

Do NOT make the joint by ringing the line with Phosphalloy braze before heating up.



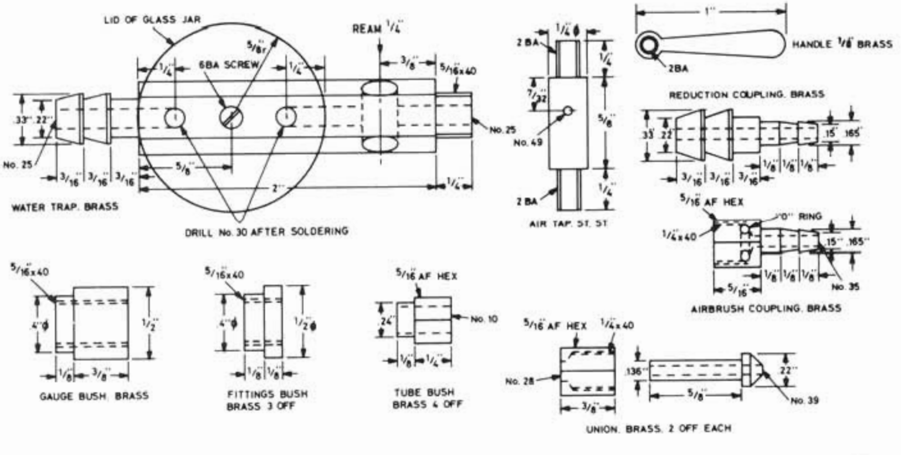
Dunk the cylinder in cold water, or preferably sulphuric acid pickle which cleans up the metal nicely. After washing look inside, and a good fillet of braze will be seen all around. Braze the one end of the other cylinder to get more practice at the job, before going on to the closed ends, which cannot be internally inspected.

Screw in the length of stay-rod, and screw on the other end plate, when the fit will be easier as the plate is pulled down, tight. Tap down any gaps and braze as before, by now a straightforward task. When the hot cylinder is dunked it will now float, and the only water to get in will be drawn into the stay threads, which will require sealing with Comsol solder, with the higher melting point. This can be carried out when fitting the bushes, as can any caulking of leaks, although leaks are unlikely if the tanks have been brazed as instructed.

Make the bushes from brass hexagon and rod, and decide where you would like the fittings to before drilling the tanks. There is plenty of scope for resiting the fittings. The bushes are all Comsol soldered in place, as are the tubes, using the correct flux. There is a spare bush for an extra tap, which does not have to be fitted. A standard cylinder drain cock, threaded 3/16 in x 40, is fitted to the first tank.

FIXING AND FITTINGS

Make the tank plate from dural and secure the back end of the tanks with 2 BA brass nuts. Construct the steel legs and angle for the foot, and secure the assembly on to the bed plate, and then on to the tanks again with the brass nuts. Now the tubing and unions can be organised and fitted, the pressure gauge fitted, and, with blanks in the other bushes, the little compressor can be tested for operation before proceeding. The pressure gauge fitted on the protoype is 0 - 50 psi and the needle on this was taken right round to the zero

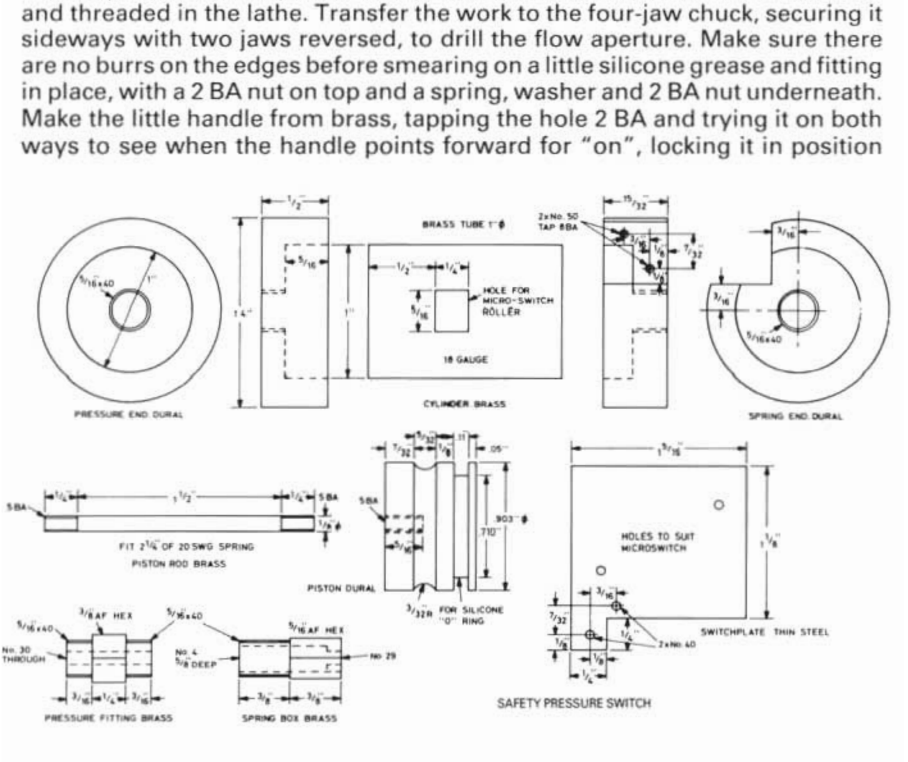


(about 75 psi) before switching off and listening and feeling around for any leaks.

The water trap tap is made from hex. brass stock, turned in the lathe for the tubing rings, made with a 60 deg pointed tool, and threaded the other end in the lathe. The hole for the tap is drilled letter B before reaming through. The holes are drilled in each end to where the water trap will be, and the space between is drilled centrally for the lid retaining screw. The little jar is a 30 ml specimen bottle and may be obtained from a chemist who deals in microscope spares; other types may be used. The lid is drilled in the middle and cleaned off, then secured to the fitting with a screw after fluxing between. Bring up a small flame and heat the brass hex. only, until the flux browns and runs when the stick of Comsol can be applied – leave to set and cool naturally.

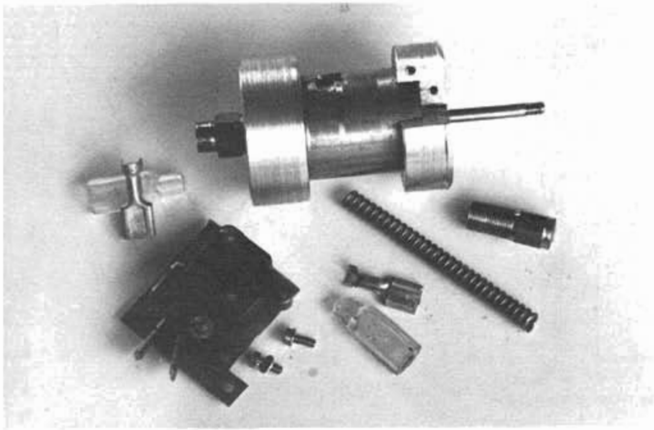
Drill through into the lid and hexagon to meet the air passages. Clean off with very fine emery and make a new gasket for the lid out of an old inner tube, cutting an oval out of the gasket. Check with the bottle in place that the lid has not distorted; screwing the bottle tightly in the distorted lid will crack the solder.

The spindle of the tap is of 1/4 in dia stainless steel, turned down each end and threaded in the lathe. Transfer the work to the four-jaw chuck, securing it sideways with two jaws reversed, to drill the flow aperture. Make sure there are no burrs on the edges before smearing on a little silicone grease and fitting in place, with a 2 BA nut on top and a spring, washer and 2 BA nut underneath. Make the little handle from brass, tapping the hole 2 BA and trying it on both ways to see when the handle points forward for "on", locking it in position



SAFETY PRESSURE SWITCH

Components for the safety pressure valve.



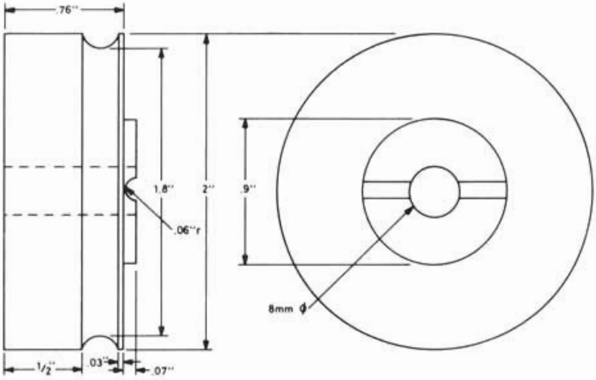
with the nut. The gauge, tap and switch are secured to their bushes on the air receiver with Loctite 222 or "O" rings may be used instead.

PRESSURE SWITCH

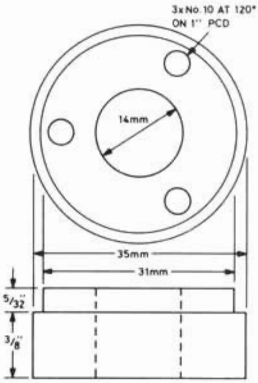
The pressure switch end caps are turned from dural and permanently secured to the cylinder with Loctite 601 after fitting the piston with its "O" ring. There should be no wear on the "O" ring in this slow moving mode. Make sure that the hole in the brass cylinder for the microswitch roller is chamfered on the internal surface, in all directions, as the "O" ring may have to pass the aperture, with no damage.

The end caps are made from solid, and the cylinder holes bored out. The spring end cap is carefully marked and sawn for the width of the microswitch, half marked one side of a radius, and the L shape sawn out before drilling and tapping. Because the piece remaining is the width of the microswitch the microswitch plate can be of any thickness. I used thin stainless steel. Make the holes to suit the microswitch a good clearance, so that its position may be adjusted relative to the roller groove.

A microswitch has three terminations marked COM for common, NO for normally open, and NC for normally closed. The two terminations to use in this application are NO and COM and to wire in the microswitch Lucar connectors are used, sometimes called spade connectors, together with the plastic covers. Use a spare covered connector for the NC termination, unwired, and wire the other two into a 13 amp flatpin socket, the type used for extension leads. In the socket one wire goes to the L (line) terminal, and the other to a plastic block termination, where it is connected to the brown lead of the mains three-core cable. There is plenty of room for the block inside the socket, by the cable securing screws; the plastic block is bought as a strip from which one is cut. Use plastic insulation tape to cover the microswitch wiring and preferably slip a rubber cover over.



MOTOR PULLEY UNIMAT 3. DURAL



DRIVE COLLAR-SL. DURAL

DRIVE UNITS

The bearing block and main spindle are designed to take the drive motors of both the Unimat 3 and the SL, with adaptation by means of a collar for the SL. Both motors will drive the compressor using the standard vertical drive pulley of the 3, and making a pulley to fit the main shaft for the SL, and then mounting the drive units with rubber belt drive. However, it is to be recommended that the improved drive for both models is fitted, and used for more positive effort. The improved drive is for a toothed belt, and the making of the wheels for these drives has been described previously.

The Unimat 3 toothed belt drive runs with an output of about 1200rpm at its fastest, and so a new motor pulley is made and fitted, with a ratio of 1.8:1 to the intermediate group, bringing the compressor drive shaft rotation up to the required 2000 rpm. This speed is maintained on load up to and just over the working pressure for the airbrush. Fit a Hoover drive belt, the type for the upright vacuum cleaner, for the first drive as it gives a more positive effort than the smaller Unimat belt. The Unimat SL first drive belt can be adjusted to give a faster speed, but the motor is less powerful and may not cope with the increased load, at this speed.

AIR FILTERS

Initially I did not fit filters to the air intakes, just to see what would happen, but have since fitted them. The easiest form of filter is a short length of polythene tube containing a plug of expanded soft plastic foam secured in place with a pin across. If a filter is not fitted a black deposit of dirt forms and builds up around the outlet valves, eventually making them leak.

FAULTS IN THE COMPRESSOR

If the compressor speeds up, and the pressure rises more slowly than usual, the fault will be in one of the inlet valves. If the compressor slows down, with only a slow rise in pressure on the gauge, an outlet valve will be failing to seat properly.

In either case the side upon which the fault occurs can be found by removing the air filter and, with the finger-tip, feeling for the suction in one side with the compressor running. If that side is working correctly a definite speeding up of the drive motor will be heard as the inlet is blocked off. If this occurs the other side will need dismantling to discover what is wrong – a simple task with these heads.

THE AIRBRUSH

The Paasch airbrush had been advertised and I purchased the Model F1 for use with the compressor, making the coupling ¼ in x 40 and using a length of silicone rubber tubing rather than buy the hose. The coupling needs a ¼ in O.D. "O" ring inside the threaded hole. None of the hose fittings need clips, push fits are sufficient at the pressure used.

The airbrush is a good buy and works as well as the more expensive models. An advantage with the model F1, which may at first seem a disadvantage, is that the amount of paint supplied is controlled by a screw-set needle valve, and the finger button supplies only the air. But this requires less expertise to use than does the airbrush with the single push-for-air, pull-back for paint control, as well as less effort in use.

The main advantage of the airbrush over the paintbrush is that very thin coats can be sprayed on, over and over, gradually building up the colour without pulling up the previous coat. Being sprayed with an evaporating medium, air, a coat of Authentic Railway colour dries almost as it is sprayed. I would advise mixing in 30% of S6 thinners for an easy spray, although it takes a little longer to cover. Advantages are to be found with the use of stencils for good edges, easy access to inaccessible corners, and the use of the brush at an angle to get surface effects. The F1 airbrush is also capable of giving a fine line of under 1/16 in width, with reasonably defined edges; The finest line is obtained with the bottom, front edge of the nozzle touching the work, and a fine needle setting.

When using the Humbrol enamels a slower technique must be used, with a few minutes between each application, but an excellent finish can to obtained without thinners as no clogging occurs.

SAFETY

Although there is very little airborne paint debris with the directional airbrush, the use of a mask is to be recommended when spraying indoors, together with adequate ventilation for the dispersal of the vapour being very necessary.

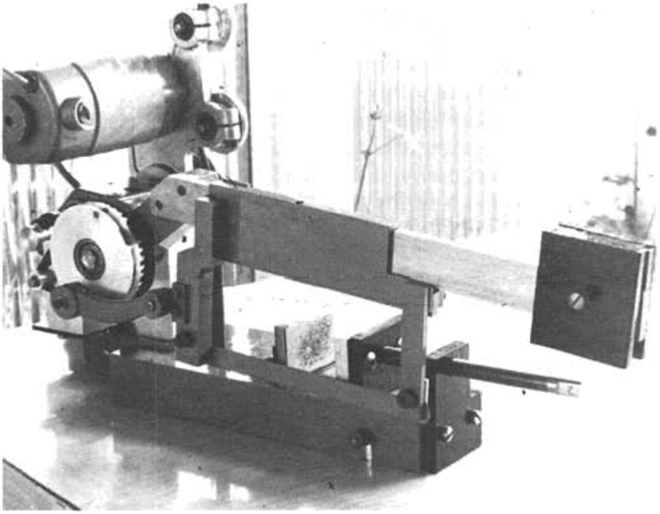
Other makes of airbrush and associated equipment are De Vilbiss Aerograph, Humbrol and Badger.

Chapter Five

A Small Power Hacksaw

This hacksaw was first designed as an "accessory" to my Unimat equipment, and was originally made to be powered by the Unimat head driving through a rubber belt, but the belt drive stretched and slipped on the forward stroke, and relaxed on the return. This made the saw jump around the room which was interesting but not entirely satisfactory. I redesigned the drive using a toothed belt system, which cut out all tendency to leap around, and provided excellent power drive. Later a sewing machine motor was fitted instead of the Unimat head, so that I now have the use of the lathe whilst sawing is in progess.

The advantage of this little saw is that, while it does not cut particularly fast, it saws very straight and gives an almost finished surface to the cut requiring little further attention. It cuts up to 2½ in. dia. round material and about 2 in. square bar; it will cut copper tube for boilers with sufficient parallelism for working, but the weight must be removed when cutting down the tube sides. The saw uses a standard 12in. high-speed hacksaw blade broken in two. Blade life is long as cutting is controllable by the amount of weight on the saw arm to suit the different materials, shapes and sizes.



The complete power hacksaw, which can cut up to 2½ in. diameter material.

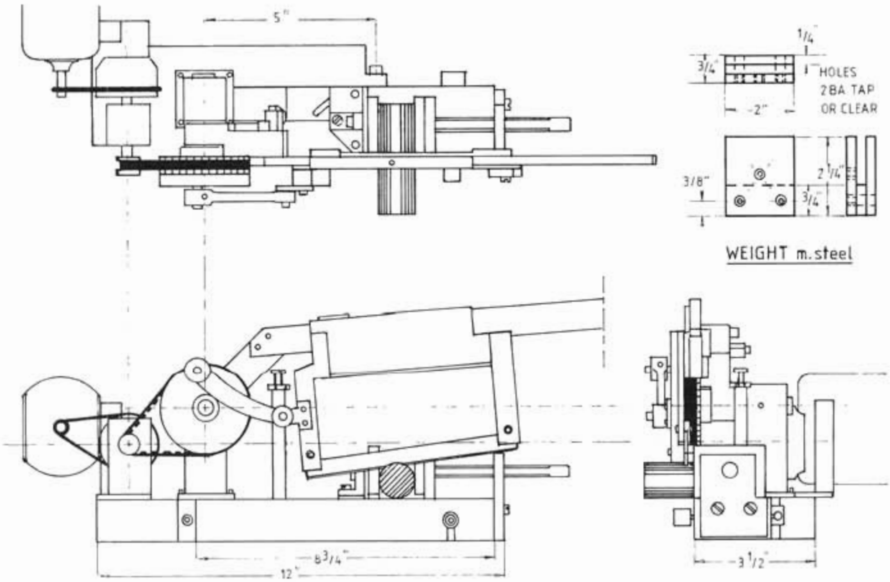
The main consideration for the speed at which the saw will cut down is whether the swarf is cleared fully from the kerf, and, with the stroke of 2½ in., lengths of cut of up to 1½ in. are cleared well. Cutting lengths above this do not completely clear the kerf of particles and cutting down is slower. However, since the machine can be left working away unattended in safety this is no problem. There is a cut-out incorporated which operates when material is sawn through.

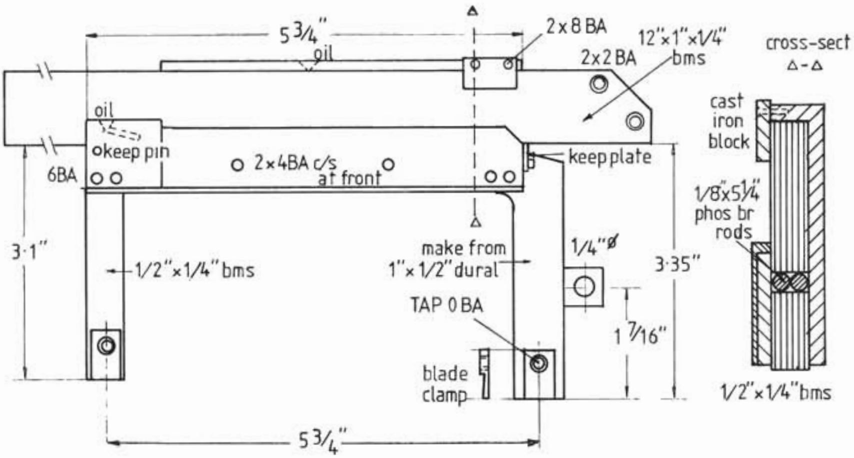
Construction is in three main units:

1. Bed, made from square section duralumin, fitted with a steel vice, limiting rod, and integral cut-out.
2. Drive unit, consisting of motor drive to the fly-wheel via a flexible rubber belt, driving shaft with two ball-races and a toothed drive wheel; mostly of dural with a brass flywheel.
3. Saw Unit. A column-mounted weighted arm along which a small saw reciprocates by means of a connecting rod driven by a large toothed wheel turning on a twin ball-race.

THE SAW

The most interesting unit to make is the saw. Start with a piece of angle iron (mine was a piece of old iron bedstead.) placed against a nice straight foot-length of ½ in. x ¼ in. b.m.s. Cut off all but ¼ in. of the top side of the angle and file to a clean fit of the arm.





SAW SLIDE ASSEMBLY

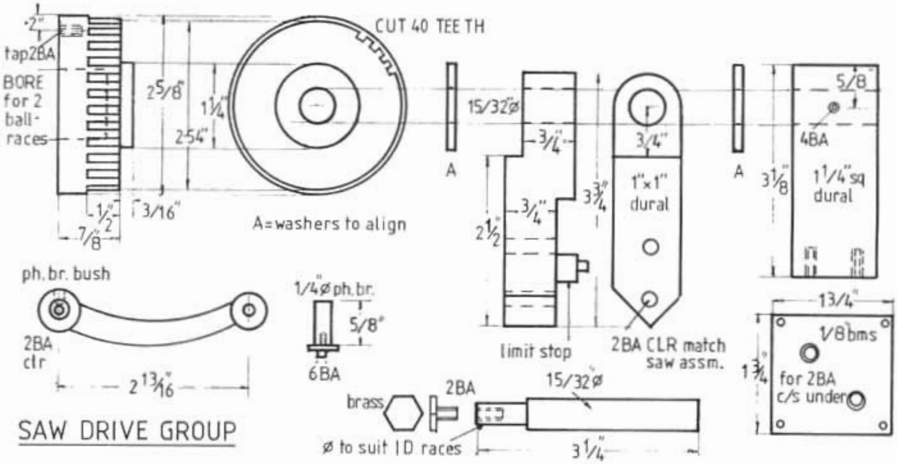
The secret of the easy running of the saw is the twin lengths of 1/8 in. round phosphor-bronze upon which the saw moves; cheap, easy to replace, but giving a smooth action. Put these in place with the 1/2 in. x 1/4 in. b.m.s. tight up to them, place the side plate on top, overlapping the arm, and clamp together holding the 1/2 in. x 1/4 in. piece then slide out the arm and phosphor-bronze. Drill through No. 24 in two places 1 in. either side of centre 1/4 in. from bottom. Drill out the angle and bar No. 13, countersink outside of angle, tap side plate 2 BA. Bolt together with countersunk screws, cut off surplus and file flush, remove screws, clean up with CTC, and secure permanently with Loctite 270.

Make the bearing block for the top of the slide from a scrap of cast iron. File it clean and square on all sides, drill the two holes No. 43 and counter-sink. Mark out for corresponding holes on the thin edge of the angle, centre punch, clamp to the cross-slide of the Unimat, or to the bed of the drilling machine, and carefully drill No 50, 1/4 in. deep. Tap 8 BA and secure cast iron block in place. Place phosphor-bronze rods in their channel, hold, and slide in saw arm, oil well and the arm should slide as if on runners.

Make the oiling plate from a piece of dural, drill and countersink the oil hole and mill out the line of the well. Secure a 3/32 in. pin protruding 1/4 in. into the well side to keep the ends of the bearing rods.

The front leg is 3 1/4 in. of 1/2 in. x 1/4 in. b.m.s.: clamp this and the oiling plate either side of the slide front. Drill through No. 43 for the two holes of the hexagonal cap head securing bolts, tap the leg holes 6 BA and drill out other holes with a No. 33 drill. Clamp in place with 1 in. long 6 BA bolts.

Make the back leg from 1 in. x 1/2 in. dural sawing and filing to shape as shown. Clamp into position behind the angle and drill through with a No. 33 drill. Tap the leg 4 BA, countersink inner surface of the angle after drilling out



SAW DRIVE GROUP

hole No. 27. Secure with a 4 BA countersunk screw, checking that the head is well in the countersink. Drill two holes, No. 43, and complete as the front leg.

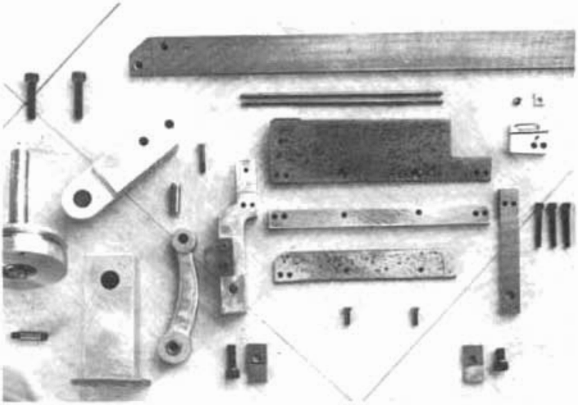
Remove the legs and drill a 6mm hole central in each leg ½ in. from the bottom. Drill the oil hole in the top of the angle, No. 55 countersunk with a ¼ in. drill. Drill a No. 43 hole in the back end of the ½ in. x ¼ in. b.m.s. and tap 6 BA, make a small plate with a No. 33 hole and secure with a 6 BA cheesehead to keep the rods from sliding out backwards. Put everything together with Loctite 270, after cleaning well; saw off protruding threads and file clean.

The blade clamps are made from 3/32 in. mild steel: clamp flat in a vice and file half away, at an angle as shown. Drill through No. 10 almost at the cutaway and tap 0 BA. Use short 0 BA hex. cap head screws to secure blade.

The connecting rod is duralumin with a ⅜ in. dia. big end bush and a ¼ in. dia. swivel pin, both of phosphor-bronze. My rod was made from an old winding handle, already shaped: it can be made straight remembering that the centre distance is important. Loctite the bush in place with 601 and drill a No. 55 oil hole through, then a ¼ in. hole in the dural only. The small end swivel pin is secured with a 6 BA grub screw, and runs in the swivel plate, made from ⅛ in. b.m.s., and fitted when positioned from the drive wheel.

THE SAW DRIVE

The saw is driven from a toothed wheel, turning about a spindle, on twin ball-races. Use whatever bearings you can obtain easily and cheaply, under 1 in. O.D. Sealed for life bearings are preferable as swarf is excluded and oiling unnecessary. The size I used were 24mm. O.D. x 8mm. I.D. x 10mm. and cost only 30p each. For the drive wheel use 2¼ in. dia. dural rod 1⅛ in. wide. To turn this on the Unimat you will need a 20mm. thick separation piece under the headstock and a similar block under the toolpost. The separation piece is

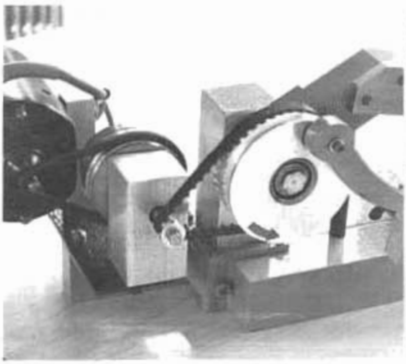


Parts of the basic saw frame and drive.

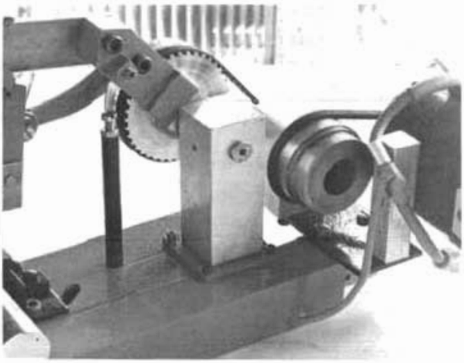
"Adaptor", catalogue No. U1311, or it can be made from two lengths of 1 in. square dural bolted together with two 2 BA hex. cap head bolts 1½ in. long. Bore out 20mm., right in the middle, then swing mill to the correct thickness. The toolpost block is approximately the size of the toolpost, but 20mm. high and with a ¼ in. hole in the middle, secure with the longer T-bolt from a claw clamp, with a nut on top of the post.

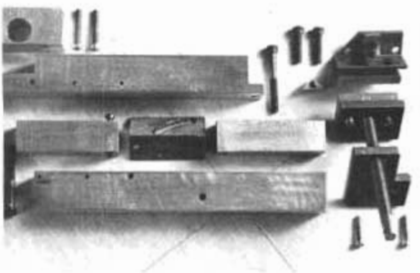
To bore the hole for the bearings use a tool as illustrated which starts well in a 9mm. hole. Cut the hole both down the bore and across the bottom with the tool but avoid cornering the tool until the depth of the bore is correct, then take care to avoid biting in. When the bore is finished and the bearings a good push fit face the front surface, turn down the circumference available to a finish. Reverse in the chuck and take down the hub, then turn the part to be toothed down to 2.54 in. dia., for the 40 teeth.

The drive arrangement.

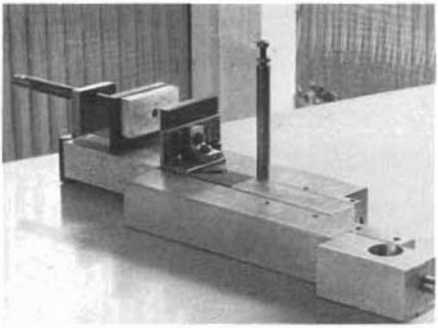


The crank arm and pillar.





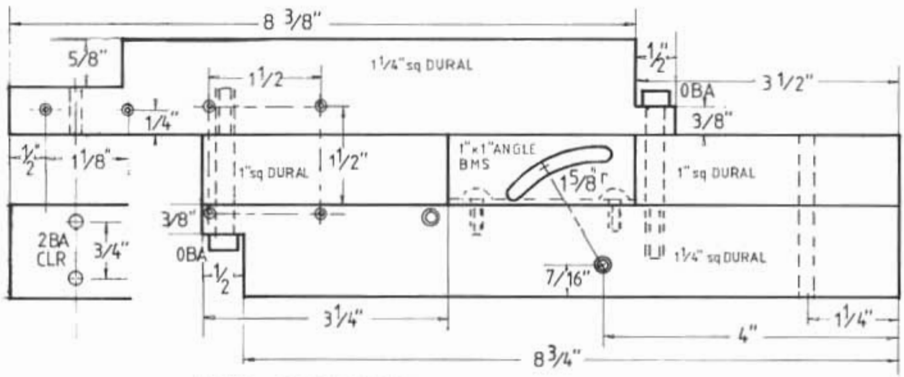
Parts of the bed.



Basic bed assembly.

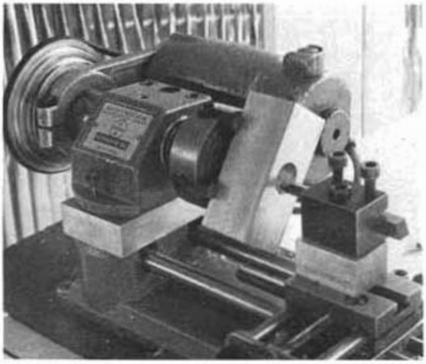
The saw swivels on a crank arm made from 1 in. square dural as shown: bore a hole centrally, ½ in. from the bottom end, 12mm. in diameter. Saw off the diagonal from the b.m.s. saw arm, drill the two 6mm. holes and match to the crank arm at 45 deg. Drill the crank No. 10 and tap 0 BA. Saw off the odd 45 deg. bits from the crank arm, and file to a finish.

The pillar is 1¾ in. square dural: flycut the bottom dead square, then make the mounting plate from ⅛ in. mild steel. Drill the plate with a No. 26 hole in each corner, and two in line, countersunk, No. 12 holes to secure it to the pillar with 2 BA screws. Drill the pillar No. 24, 1 in. deep, to match, and tap 2 BA. Bore a 12mm. hole, centrally, 2⅜ in. from the flycut end, drill a side for the grub-screw to secure the spindle, and tap. Make the spindle from 12mm. or ½ b.m.s., turning one end down to a good fit in the ball-races, and tapering to the large diameter so that the taper is in the hub. Drill the spindle end No. 24 and tap 2 BA, turn a screw from 7/16 in. AF brass to fit.



BED ASSEMBLY

Cutting the slot in the centre bed angle.



Boring the pillar for the races.

Put the lot together with two washers, 1/16 in. thick, between the elements. Mark the position of the big end boss and the driveplate to give a 2 1/2 in. throw. Remove ball-races and spindle. Then drill and tap the drive wheel for the boss, which is made from silver steel. Drill and tap the back leg for the driveplate. Secure the wheel in the 3-jaw chuck on the indexing attachment and cut 40 square teeth, as shown previously.

Clean up the wheel with CTC, run a cloth damped with CTC around the outside of one ball-race and secure race in the bore with Loctite 601. If you are using sealed bearings secure the second race in the same way: if the bearings are of an open type the second race must be left a push fit for the cleaning and lubrication of both.

Assemble the saw arm on the drive, position the drive plate with 6 BA bolts, connect up the rod, oil, and it is ready for fitting once the bed is completed.

The bed is made from two outer sections of 1 1/4 in. square dural, with an inner section of 1 in. square dural, bolted together with O BA hex. cap head bolts, and secured at the front end with the vice screw plate. The only complication is the integral vice, on which the back half only is made to swivel up to 45 deg. by means of a pivoting bolt and a lock screw travelling in a slot milled in an angle plate. The screw locks by means of a triangular nut beneath the angle plate, enabling travel to extend to near the walls. The front half compensates for the set angle with half round fittings dowelling into the front plate of the vice.

The bed is fitted with a microswitch and arm at the front end. When the saw has cut through, the blade descends on a hardened runner on the end of a spring-loaded arm, which runs through the bed block and is swivelled at its far end by a 1/4 in. rod in a block. The arm, when pushed down, contacts a microswitch bolted to the bed and cuts off the supply to the motor. For safety all wiring and soldered terminals are thickly epoxied in place. The runner is made of silver steel and hardened right out, and it runs freely on the arm. The bed is cut away beneath the runner to avoid collection of swarf in the hole.

When the bed is complete, with a limiting rod fitted with an adjustable screw head, mark out for the position of the columns to give the saw blade $^{3}/_{16}$ in. clearance from the side of the bed, exactly parallel, with the centre of drive 5 in. from the back face of the vice when it is at 90 deg. With these conditions satisfied the back leg of the saw will not strike the workpiece but provide maximum stroke length. The position of a limiting stop block on the crank can now be marked and a block fitted.

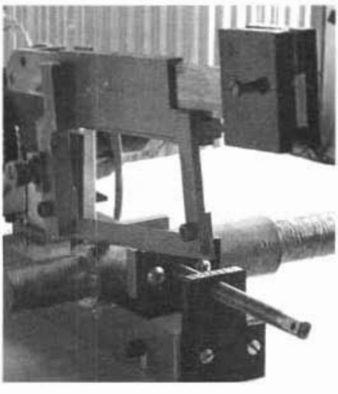
To drive the saw with the Unimat head make the extra bed block and the drive pulley which has an outside thread to fit the grinding wheel adaptor; the thread is made on the threading attachment. To fit the head use the 20mm. thick adaptor beneath the head and the screw as shown.

THE FLYWHEEL DRIVE

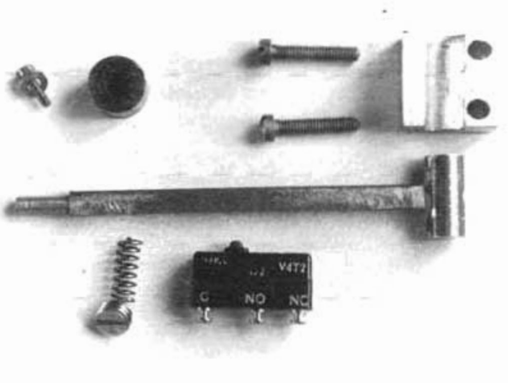
This consists of a $^{1}/_{8}$ in. thick steel plate on which are mounted the motor support and flywheel column containing twin ball-races through which runs a shaft with a flywheel at one end and a small toothed drive wheel at the other. The flywheel is grooved to be driven with a rubber belt by a sewing machine motor, mounted on a $^{5}/_{32}$ in. square support, or by the Unimat head. The motor support is secured to the plate with a single 2 BA countersunk screw and Loctite 601.

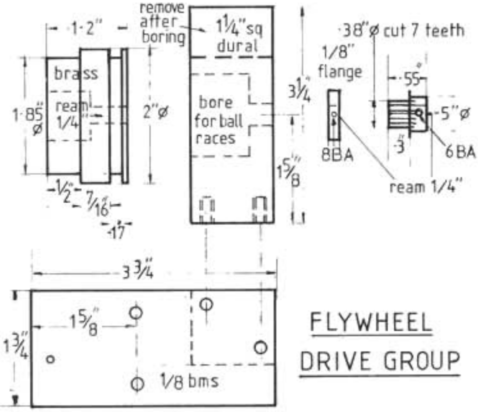
The flywheel column is bored for bearings the same as the drive wheel, using the raised headstock. The column is made from $1^{1}/_{4}$ in. square dural, $3^{1}/_{4}$ in. long secured in the 4-jaw chuck. The bore is made in the middle of the piece and the surplus top sawn off afterwards; this is to prevent excessive vibration whilst boring. Bore out for the twin bearings from a 9mm. hole; if open races are to be used give an extra $^{1}/_{16}$ in. depth. Cut off the surplus top, and flycut the bottom square. A $^{1}/_{4}$ in. spindle is fitted, so if the I.D. of the bearings is greater than this a dural sleeve must be made to fit. Clean sleeve and bearings and

Cutting bar on the finished machine.



The components of the cut-off switch.

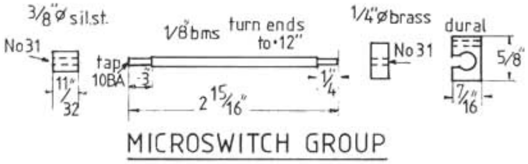


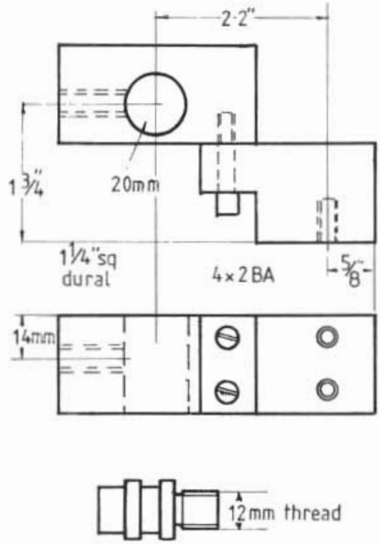


Loctite together with 601: with open races fit a small washer between races and drill oiling hole into top of column to correspond with the gap. Loctite the races into the bore. Make brass flywheel, shaped to avoid hitting the motor, bore out ¼ in. and Loctite on to spindle; run a piece of cloth down between flywheel and column to keep Loctite from bearing. File a thin washer to fit small wheel teeth, as a flange, and make an annular flange secured with a 6 BA set screw, for the other side.

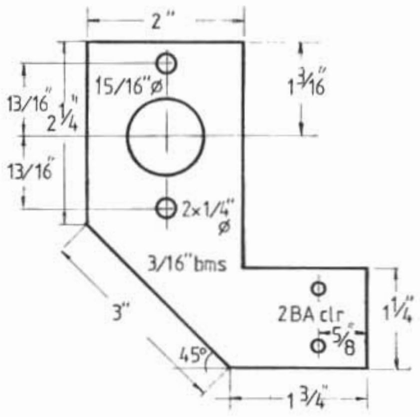
The column is secured to the steel plate with two 2 BA hex. cap head bolts; the holes in the plate are slightly slotted. Drill the holes in the plate, No. 12 for the bed screws, fit toothed belt drive after setting screws in the slots close to the saw side, pull tight and mark position of the holes on bed, drill No. 24 1 in. deep and tap 2 BA. Secure the plate to the bed with cheesehead screws. Loosen the two cap head screws and pull column over to tighten up the belt, tighten screws, side away from saw first.

Fit the motor, if the Unimat head is used line up the pulleys with the headstock lever, fit a flexible rubber belt with a round section, such as the Hoover cleaner small rubber belt. If another motor, such as the Jones sewing machine motor, is used, fit direct to the support, and run the belt, as described, directly from the motor spindle to the flywheel pulley.





UNIMAT SL ADAPTORS



UNIMAT 3 ADAPTOR

Make the weight from 1/4 in. or 5/16 in. mild steel to weigh about one pound, for general work purposes. The cutaway of the slide allows extra weight to be fitted; for example, the small Unimat vice, inverted and clamped to the bar, makes a simple extra weight.

In use the speed of cutting indicates when the saw is cutting correctly. When cutting correctly the saw cuts more slowly; if the saw speeds up it means that the saw is not cutting efficiently, perhaps due to oil in the kerf, or sawdust causing the teeth to plane in a long cut. For block cutting use 18 teeth blades; for thin or angle sections use 24, and for copper tube use 32 teeth, with some variation in weight to suit material.

This is an easy saw to make on small lathe; it is cheap to make and construction can be varied to suit the material available. But above all, in use it saws with little waste, saving expensive materials.

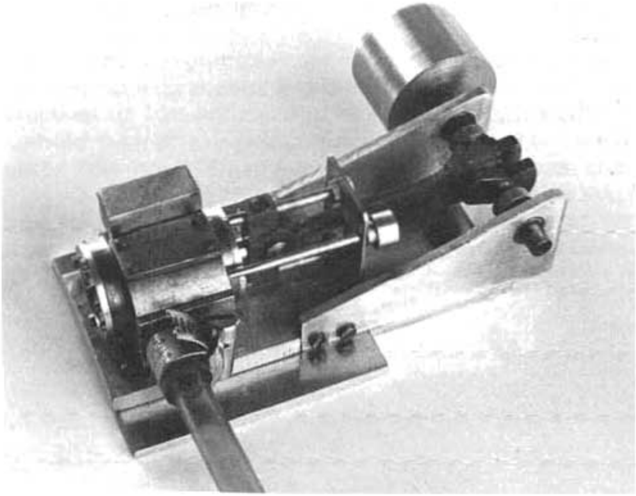
Chapter Six

A Valveless Steam Engine

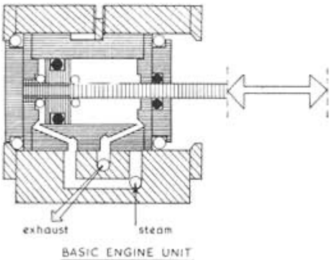
With the general availability of "O" rings I decided that it would be a good idea to construct a steam engine with valves simplified or eliminated by the use of these rings. I toyed around with the idea of using the rings on pistons passing over ports but found I could not avoid slicing up the rings. I abandoned the scheme and thought out this idea instead. This engine started out as a complex double-chamber change-over piston, but simplification became obvious, and I ended up with this protoype, which runs well.

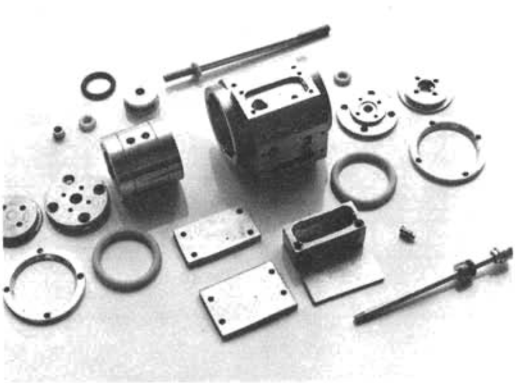
This system employs no valves, as such, and could be loosely described as a valveless, double-acting, engine but in fact the cylinder moves to make the change-over from steam to exhaust and back. This means that there has to be a cylinder and piston, and a cylinder block. The cylinder is a sleeve with two bores and not complex, yet it eliminates all the need for a valve gear and eccentrics which all too often lead to over-scaling and complications in the smaller gauges.

The "O" rings carry out more functions than usual. They act as packing seals for the moving parts, the larger cylinder rings are hermetic seals to keep a



The completed prototype engine as first tested on air.

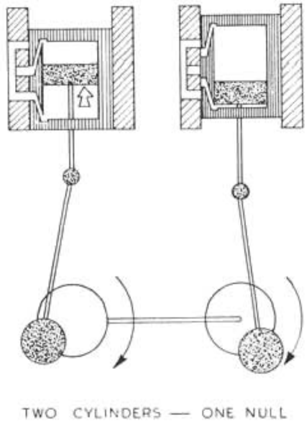




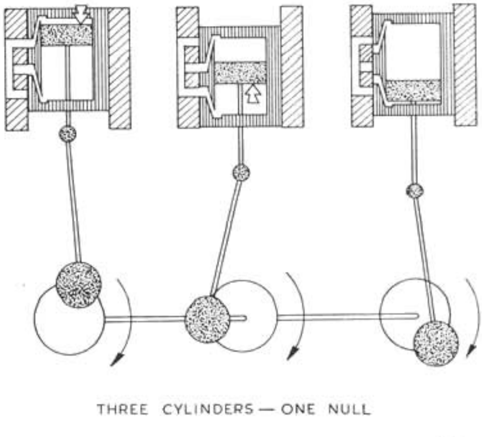
Right, the components of the basic cylinder/piston assembly.

general pressure within the cylinder system, and in the third place they are used as buffers both for the piston to move the cylinder and for the cylinder to stop in the block. The "O" rings pass over no ports so that damage and wear are minimised.

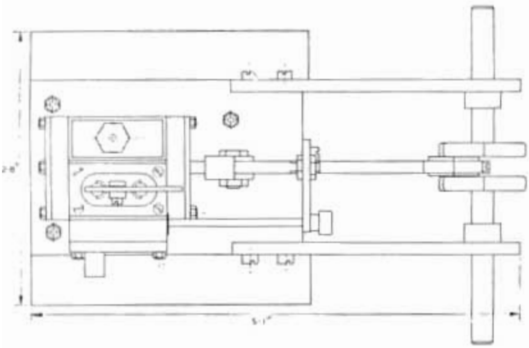
This steam engine was envisaged as a simple engine capable of being machined on the Unimat without difficulty, as indeed this prototype was. Small inaccuracies can be tolerated; for example any leakage between the cylinder block and cylinder is kept within the system by the "O" rings and goes finally to exhaust. The optimistic way to view this is that it does away with the need for a blower. The single-cylinder version needs a flywheel but this is less necessary with multiple-cylinder versions. In fact the multiple-cylinder versions are self-starting in all positions and the direction of rotation is determined by giving the crankshaft a half-turn in the required direction which sets up the cylinders correctly, before running.

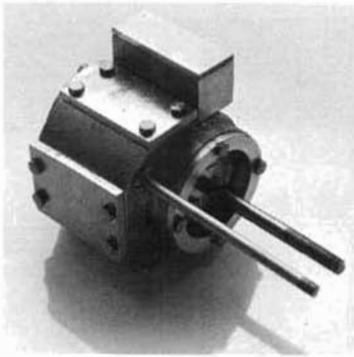


TWO CYLINDERS — ONE NULL



THREE CYLINDERS — ONE NULL





The assembled cylinder group with regulator.

THE MOVING CYLINDER PRINCIPLE

The single-cylinder prototype consists of a piston with an "O" ring as a piston ring, moving a piston rod and having an "O" ring back and front to buffer it from contact with the cylinder covers; the rod is sealed in the front plate, with another "O" ring. The piston moves within the cylinder for only two-thirds of its travel. For the other third the piston moves the cylinder, changing over ports in the cylinder from steam to exhaust and vice versa, relative to the cylinder block. The cylinder has plates over its covers holding "O" rings which seal the cylinder-to-block space from atmosphere. It has a milled slot in which a grub-screw locates to keep the cylinders from turning. The cylinder block has flanges at each end tapered to take the cylinder "O" rings and buffer the travel. Steam and exhaust ports are drilled and milled in the block, and a simple piston type regulator is fitted, complete with an "O" ring seal. Provision is made for fitting a safety valve and a lubricator.

THE STEAM CYCLE

The steam cycle starts with the piston and cylinder at one end of the block when steam will be passed through the passages into the cylinder, driving the piston for two-thirds of its travel when its forward "O" ring will butt against the cylinder cover pushing the cylinder for the final third, changing the port from steam to exhaust and the other port to steam, driving the other side of the piston for the double action.

There is some lead, in fact the steam port is fully open by top dead centre, but the change-over is sudden; there is also exhaust clearance by the same token. However, cut-off occurs after the end of the power stroke so there is no expansion after admission, but this could be rectified by bringing the piston rod through the back cover and fitting springs and stop collars back and front to initiate the cylinder change-over whilst the power stroke is still under way. This is something for future experimentation.

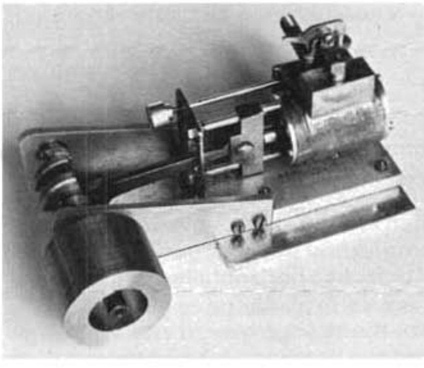
THE PROTOTYPE ENGINE

The prototype engine was constructed very economically, the most expensive items being the "O" rings. All parts were machined on the Unimat or worked by hand and adaptability was taken into consideration as each part was made. The version I ended up with is intended for use on a small traction engine, using it as a test bed, hence the provision for the regulation, lubrication, and the safety valve. Before final fitting the steam inlet has to be blocked off, a saddle fitted and the steam dome milled out.

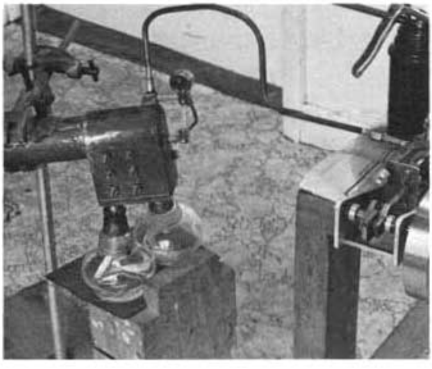
The engine was constructed from the solid, the engine moving parts being made from good quality aluminium alloy. A dural piston runs in a dural cylinder; these parts change direction rather a lot and need to be light in weight. The cylinder block is machined from solid brass and a hard brass should be used; gunmetal or bronze would also be suitable but more difficult to machine with the Unimat. Phosphor-bronze is used as a bearing surface for all fast-moving parts of the motion, but in the most economical and easily-made way. Stainless steel is used for the piston and regulator rod as they are in contact with the steam. The connecting rod and crosshead are of mild steel and the crankshaft is of silver steel. The crosshead is a little taller than is usual, but it runs on two phosphor-bronze rods for cheapness plus smooth running. The bed is constructed of aluminium, but duralumin is to be recommended due to the difficulties encountered in tapping the soft aluminium with small BA sizes, even with over-sized holes.

The "O" rings used are of two types. For use in hot oily steam with fast-moving parts the black Viton rubber "O" rings are to be recommended, as they retain their size and hardness and wear well under these conditions; they are also obtainable in very small sizes. On the other hand silicone rubber "O" rings are used for seals where they may get less lubrication and heat, and as buffers. The silicone "O" rings swell and soften very easily, when they are easily damaged, but they are excellent as buffers and where oil may not immediately reach as they are slippery in their own right.

Prototype engine with small flywheel.



Prototype engine on steam test.



TESTING THE PROTOTYPE

After construction, the engine was given a pneumatic test and ran readily with an air pressure of 30 p.s.i., stopping work when the pressure fell below 15 p.s.i. The regulator worked well providing from full-speed running to total cut-off. The most promising part of this test run was that no parts were finally tightened up or sealed and yet the engine ran with only a little leakage to exhaust. At this stage neither the safety valve nor the lubricator were fitted, so the next task was to complete and fit these. The safety valve is the Ramsbottom type, but fitted with balls, and the lubricator is to my own design working by gravity, steam pressure, and displacement.

Before running the engine in steam, I tightened down all the nuts and bolts, sealing them with Loctite, and gaskets were fitted where needed. Then I gave the engine another test on the air compressor, fitting the larger flywheel. The compressor was run up to a pressure of 40 p.s.i. and the little engine opened up, when it ran easily and very fast. I checked the speed with a stroboscope and found that it was running in excess of 1000 r.p.m. The large flywheel twisted itself off when the regulator was closed to slow up the engine, but the engine continued to run. It was vibrating badly and would not speed up. I was pleased with this test and was covered with a film of light oil as I had used 3 in 1 in the lubricator as a running-in oil.

To run on steam I used the small boiler for the traction engine, to which the engine was to be fitted later. A steam pressure gauge and water gauge were fitted and the various unions and pipework made steamtight. As the boiler had no steam dome the "backhead" top fitting was used for this purpose so that the boiler had to be run in a nose-down position to obtain something like dry steam. This is not an ideal position to get a good draught for steam pressure, but with the smokebox and chimney removed, two spirit burners heating the firebox end, and a spirit blowlamp heating the front end, a pressure of just over 25 p.s.i. was recorded on the pressure gauge, and the engine run on steam. A few leaks became apparent and the pressure soon dropped, but it had proved my point. With the leaks secured I ran the engine again on steam and it ran easily in either direction, but not very fast as there was insufficient pressure.

Surprisingly the engine runs very smoothly without any knocking, considering the movements involved.

DEVELOPMENTS

Being a self-contained engine these units are envisaged as being capable of running in any position, with just the cylinder block changed or modified to suit the design requirements and number of journals on the crankshaft. With a short motion the unit has only to be pointed in the right direction and secured, the length of connecting rod being determined by the configuration desired. For example it is easy to imagine a pair of units as a horizontally opposed twin-cylinder engine, and three units, in line, as a vertical marine engine.

When I chose one-third as the period for the change-over, it was for design convenience, and it happened to work, but the position of the ports and their

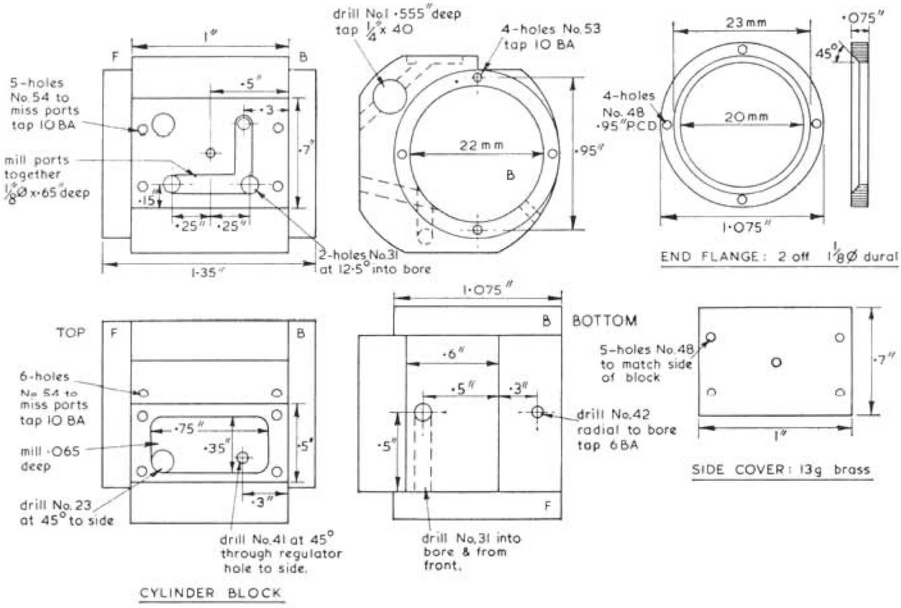
size was given considerable thought. The cycle could possibly be improved by altering the timing; this is something for experiment.

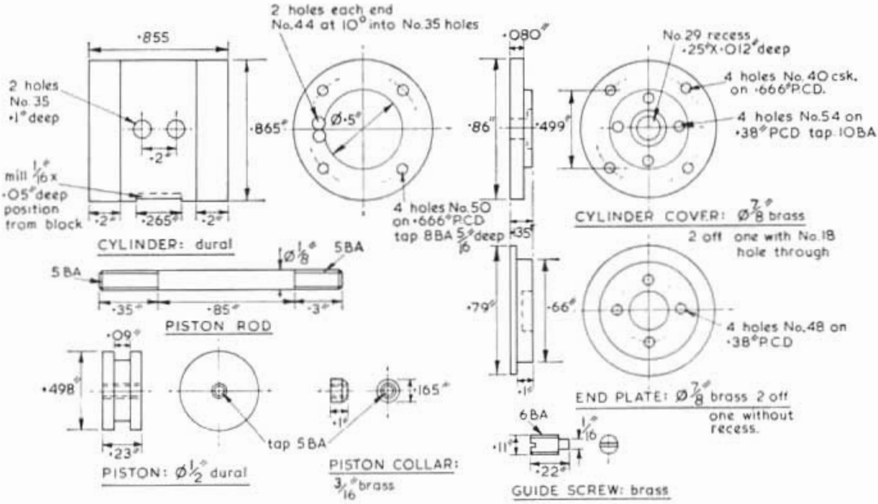
The size of construction of this prototype was detemined firstly by the scale requirements of the crankshaft stroke, and also by the volume of the steam chambers, but another consideration in the smaller gauges is the cross section dimension of the "0" ring which is quite massive if scale is considered. Larger gauges can have the advantage of only needing a cylinder sleeve no thicker than that of the small gauge. Cylinder blocks need not be bulky if the steam chest, regulator and safety valve are placed elsewhere, such as with a locomotive with outside cylinders, so that something like scale appearance may be achieved.

This engine is something between the full valve gear type and the oscillating cylinder engine, and is a good in-line, high-speed energy converter, running well on steam, air or gas pressure and may well be of use in pneumatic tools, or for use where a sparking electric motor would be hazardous.

CONSTRUCTION

After the design considerations, the essential dimensions of the prototype were decided by the size of "O" ring to hand and the tools and materials already in the workshop. For example I have a 22mm. reamer, but no ⅞ in. reamer, so the cylinder block became 22mm. bore but the "O" ring used is ⅞ in. The cylinder is reamed ½ in. and a ½ in. OD "O" ring is used, a dural piston





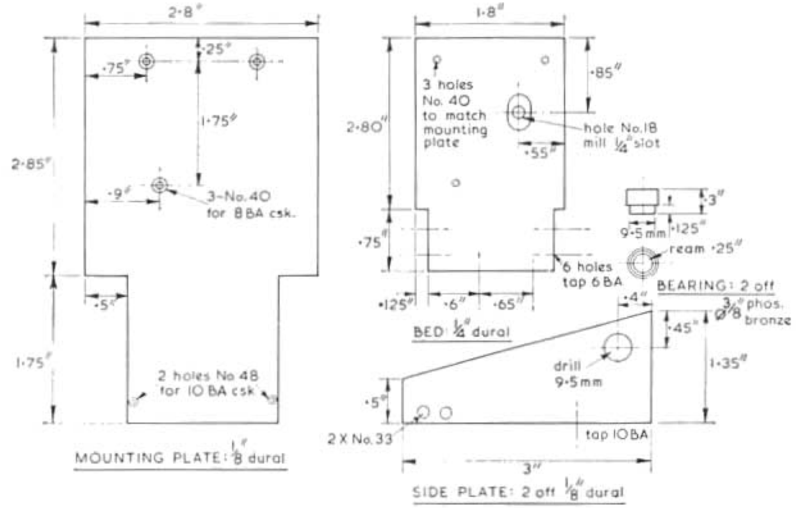
runs in the dural cylinder but only the "O" ring is touching if it has been made correctly; so let us proceed with the making.

THE CYLINDER GROUP

First make the cylinder group, leaving all the drilling until later so that the holes all match up. The cylinder is turned from 1 in. dia. duralumin, cutting a piece 1 1/4 in. long and centre popping one end. Chuck the other end in the three-jaw, jaws reversed, and centre drill with a No. 3. Drill through No. 20, bring up the live centre and turn as much of the outside as you can down to 24mm. Reverse and true up with the live centre to turn down the rest to 24mm. and drill through 7mm, then 12mm., the drill held in the four-jaw chuck (if the drill is too long for the Unimat grind off an inch or so off the shank). Hand ream the bore 1/2 in. This may leave a faint rifled pattern in the bore but this we polish out later.

Hold the best end lightly in the three-jaw, centre with the large bore running centre, and tighten up. Sharpen the right-hand knife tool, set the vernier caliper precisely to 22mm., and carefully take the outside down. Use soluble oil very dilute and one handwheel division until nearly there, then reduce the cut to a half a division to exactly 22mm. Cut the two lubricating grooves with a pointed tool, face off the front and part off at exactly .855in.

Chuck a piece of 1/2 in. dural for the piston in the three-jaw and centre drill lightly, No. 1, then drill 1/4 in. deep No. 37 and tap this hole 5 BA in the lathe at the slowest, controlled, speed. Face the front surface, then with the parting-off tool turn down to .498 in., start to part off at .23 in. so that the position of the groove can be centred, and cut the groove. The wide groove allows the "O" ring to roll a little and provide a good seal. Angle the tool and take the corner



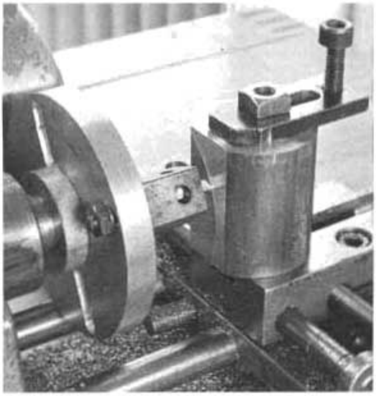
off each side of the groove to avoid damage to the "O" ring before parting off. Cut a piece of stainless steel for the piston rod, file up the ends and thread both ends in the lathe using the tailstock die-holder. Do not attempt to thread by hand, and use Rocal RTD compound to get nice clean threads. Make the collar from 1/4 in. dia. brass turning the outside down, finally, on the piston rod held in the drill chuck.

The cylinder covers and end plates are made from 7/8 in. dia brass; drill right through No. 30 and recess, drill out, turn and part off one after the other, from the same piece. The front end plate will need its hole fitted with a threaded stub of brass soldered in place.

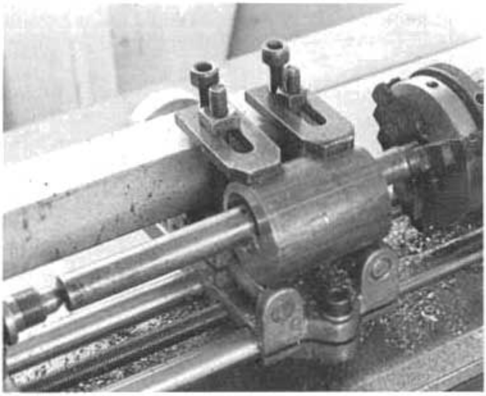
THE CYLINDER BLOCK

The cylinder block is made from 1.4in. or 1 13/32 in. dia. hard brass. Clamp the block between the back of the carriage and the cross-slide, not quite touching the cross-slide bars, with a piece of 22 gauge alloy at the rear; use two clamps and lock up tight, also locking the cross-slide. This will put the bore in the right place with no measuring needed. Centre drill and drill right through No. 30 followed by a 1/4 in drill, then a 1/2 in. drill to give clearance for the between centres boring bar. Bore out to 21.5mm Put the block upright in the vice, no clams fitted – don't worry about the outer surface – and ream through 22mm., only rotating the reamer in the cutting direction.

Grip the bore from the inside with the three jaws and centre up with the large bore live centre. Run the lathe at under the fastest controlled speed to minimise vibration from the eccentric workpiece. Use a flat topped pointed tool of just under 40 deg. which will turn brass in both directions, and turn down each end round, to leave 1 in of main block. Clamp the block upright,



Flycutting the side of the engine block.



Boring the cylinder block.

with the clamp through the bore and flycut the side at the thickest part; use this flat down on the cross-slide to cut the top and bottom flats.

Make the two end flanges from dural, boring out a little after drilling 1/4 in. Turn down the bevel before parting off.

STAKING AND DRILLING

With a centre drill in the drill chuck, the headstock on the column, and the indexing attachment on the cross-slide, the Unimat makes a fine staking tool; no need for marking out and centre popping.

Use the 40-tooth index plate and the No. 2 centre drill. First grip the cylinder block, upright, and manipulate the position to stake the top hole, and the other three at ten-tooth intervals. Check that this is a diameter of .95 in., and correct if necessary. Slip out the centre drill and replace with a No.53 to drill the four holes 5/16 in. deep. Reverse the block, and repeat, then stake and drill the end flanges with the same set-up but this time with a No. 49 drill.

Use the same procedure for the cylinder, end plates and covers. Tap all the holes which require it, but before dismantling the set-up stake the ends of the cylinder for the two steam portholes. Remove the indexing attachment and fit the vice, fitted with alloy clams. Centre punch the side of the cylinder for the two steam ports, .2in. apart, and drill these No. 35, .1in. deep. Set the head to 10 deg. and drill the ends with two No. 44 holes down into the appropriate side hole.

POLISHING THE BORES

Now is a good time to perfect the bores by lapping them with a polishing compound. To make the laps make lapping cylinders of a number of calico discs on a mandrel of aluminium rod, secured between aluminium self-locking nuts. The polishing compound is Brasso domestic metal polish, quite sufficient for this job unless bad scoring has occurred.

The calico discs are made from a yard of unbleached calico from the draper; the yard makes a few years supply when converted into small circles. With a pencil and a coin mark out the material and cut out with scissors; when a small pile has accumulated punch a hole and push them on the mandrel. About 30 discs are needed for sizes up to ¾ in. and 40 for up to 1 in. to give a firm cylinder for short bores. For ½ in. bore cut a 1p (19mm dia) and for the 22mm. a 2p (25mm dia) size disc.

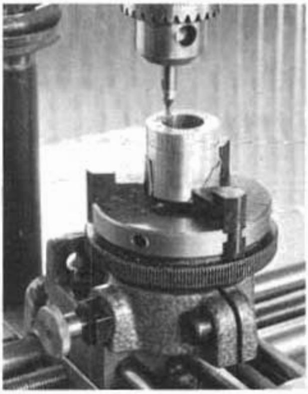
Use the Black & Decker for lapping, but if you have to use the Unimat run at a high speed and clean up well afterwards. Polish with plenty of Brasso, and take time as not much metal is being removed. Clean up the job well afterwards, and a good cleaner for the hands is "Swarfega".

FIRST FITTING AND ASSEMBLY

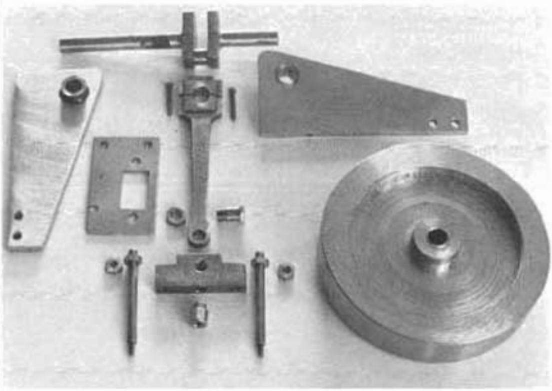
Remove burrs from all parts completed and fit the "O" rings to the piston, oil the cylinder and slide in the piston on its rod: it should not feel tight. Check the covers for fit. Remove the covers and, with a bright light in front, look through the cylinder at all angles, holding the rod central, and at all positions. If any light is apparent a piston with a slightly larger groove diameter will have to be made. Remove the piston and try the cylinder in the block, oiled for the occasion. It should need a little pressure to take it through; for oiling grooves may stick and will need a little rubbing down with Brasso. General reluctance to pass through must be tackled by re-lapping the block.

With a flat needle file carefully take away some metal between the steam holes at the cylinder ends, at 45 deg., and also from the cylinder cover where they coincide. Clean the cylinder group and screws with CTC and use Loctite 270 for this assembly. First secure the piston and collar on to the rod, the bevel of the collar towards the piston. Wipe off the surplus Loctite and push ⅛ in. ID silicone rubber "O" rings fore and aft of the piston. Secure the rear cover, with Loctite on the cylinder end, with four 8 BA screws. Push in the piston, fitted

Staking the ends of the cylinder.



The motion parts and side plates.

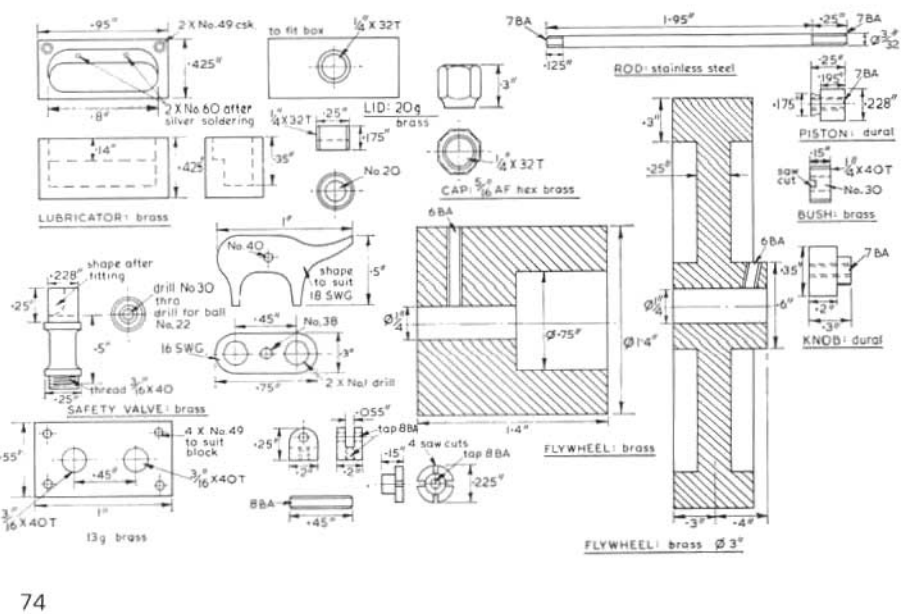


with the ½ in. O.D. Viton "O" ring, the rod passing through its hole in the rear cover, and fit the front cover, its larger hole to take the collar, and secure with its countersunk screws and Loctite, as before. Fit the front plate, with the blanked-off hole, with four 10 BA screws and a touch of Loctite. Slip a ⅛ in. ID Viton "O" ring over the piston rod and secure the rear end plate with cheesehead screws, making sure that no Loctite gets into the recess. Leave for an hour, then place a drop of oil into both steam holes and move the piston and the oil will suck into one and blow out of the other. Ensure that oil enters both sides when the piston should feel very easy-moving. Check that the complete assembly slips into the block.

MILLING AND DRILLING THE BLOCK.

First mill the shallow cavity to be covered by the safety valve if you are fitting one here, and mill away the top of the lubricator. Drill the No. 1 hole for the regulator, and the two holes at 45 deg., drilled from the top into the side panel. Turn the block upside-down and drill straight down into the bore and from the front end into this hole for the exhaust. The under hole, tapped to hold the engine to the bed, can be filled in later if necessary.

The steam inlet ports are drilled at 12½ deg. from the side panel to be in line, in the bore, with the exhaust port. Note that the holes are elliptical in the bore, presenting large areas for the ports in the cylinder. Drill the side for the cylinder limiting screw. Run the lap through the bore to remove burrs from the drilled holes, clean, oil, and slip the cylinder in to the block keeping the ports



lined up and mark, through the hole, for the position of the milled slot of the retaining screw. Mill the slot with a 1/16 in. end mill. Drill all the holes for the covers to miss any holes and avoid entering the bore, and tap.

THE LUBRICATOR

Basically the lubricator is a box full of oil with two drain holes from a step halfway up in the box. Firstly the oil will lubricate the cylinder in the block by gravity. Secondly, steam pressure will enter the box via the cylinder groove and force oil down the other groove, and third, the steam condensate will raise the level of oil in the box to continue lubrication by displacement.

The lubricator is cut from a piece of ¼ in. square brass. Mill the large area down to the step, then, with the smaller mill, down to the bottom. Drill No. 49 and countersink for the two securing screws, locate on the cylinder block and mark the positions of the holes through, drill and tap the block 10 BA. Paint the brass screws and mating surfaces with silver solder, paint and screw the lubricator to the block. Silver solder in place using a little Easyflo No. 2 at the base when the paint runs. Avoid heating the thin side of the block or this will buckle. Pickle and clean off.

Drill the two holes into the bore, from the shelf, No. 60, directly opposite the steam inlet holes. Make the lid and fittings and Comsol solder this in place before fitting the lid, also with Comsol. The cap is turned from hex. brass, tapped ¼ in. x 32, and fitted with a silicone rubber "O" ring, after which it should screw on to the lid no more than 2½ turns; it doesn't need to be spanner tight as the seal of the "O" ring increases with the steam pressure.

THE REGULATOR

The regulator is a simplified job, consisting of a piston with a steam slot, opening diametrically opposed ports; one end of the piston is missing and a Viton "O" ring substituted, saving space. The "O" ring acts as a steam seal for the regulator rod and bore only, the alloy piston in the brass being sufficient to cut off steam. Steam pressure keeps the "O" ring away from the steam ports when the piston is pushed in, and the regulator opened. After making the piston, rod and bush tap the hole for the regulator just five complete turns ¼ in. x 40.

THE COVER PLATES

Make the side and safety valve cover from brass, modifying them to suit whatever way you intend to run the engine. For running with gas or air the safety valve cover can be fitted plain, and the side plate fitted with a simple brass nozzle, coincident with the inlet hole, to fit an air line. For steam the inlet nozzle will need to be threaded for a steam union, and a Ramsbottom type safety valve made and silver soldered to its cover plate. Gasket the plates with Loctite 275 and secure with 10 BA cheesehead screws. But be warned, if the threads get Loctited and you have to remove them it is very difficult to avoid shearing off the heads in 10 BA size.

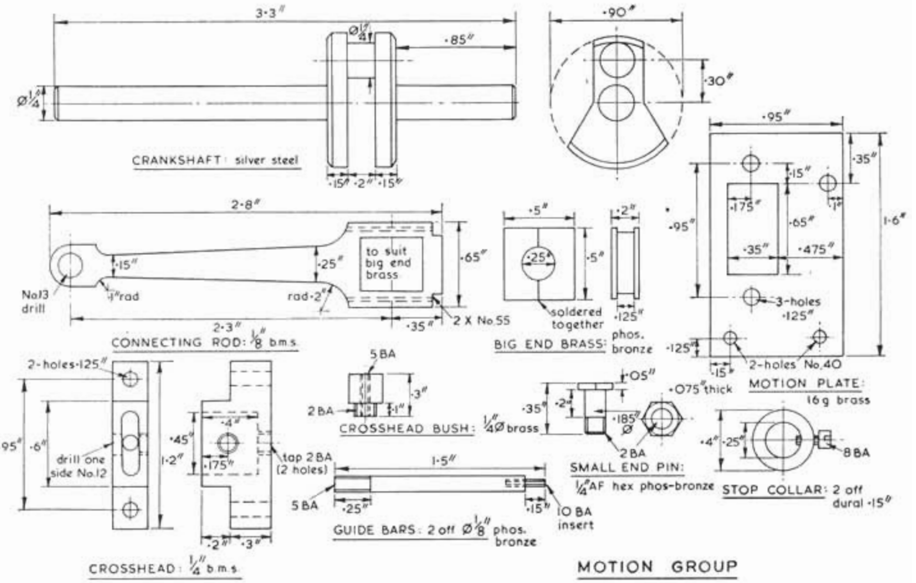
THE MOTION

The cross head is made from a small block of mild steel, first drilling out the parallel 1/8 in. holes precisely .95 in. apart. Using the same drill, drill each end of the slot for the small end then mill away between. Drill the side through for the small end pin, No. 22 then drill one half No. 10 and tap 2BA. Drill and tap the front for the bush and file off the corners. Make the bush from brass rod and tap 5 BA for the piston rod. Fit the crosshead to the assembly, first slipping the bevelled ring on the rod. Drill one end of each of the slide bars No. 53 and tap 10 BA to take short lengths of 10 BA studding; thread other ends 5 BA.

Fit a 7/8 in. O.D. silicone "O" ring on to the piston rod end of the cylinder, line up the ports, and push the other end into the cylinder block, ensuring the ring slides into the bore without being trapped. Push the cylinder through until the other end is just in the open and fit the other "O" ring before pushing the cylinder back. Fit the limiting screw, and the bevelled flanges can be secured in position with 10 BA hex. bolts, plus the two slide bars at the rear end, top and bottom, through the crosshead. Now measure the travel of the crosshead, which should be .6 in. (+ .05 in., − .00 in.). If it is under, take of a little off the bevel from the end flanges.

For the crankshaft use 1/4 in. and 7/8 in. dia silver steel. For the webs cut the larger diameter, about 1/2 in. will do, and face both ends in the three-jaw chuck and centre lightly with a No. 3 centre drill. Re-chuck in the four-jaw, eccentric, and adjust until the centre drill starts exactly .3 in. away from the centre, centre drill, then drill through 6mm. Return to the three-jaw chuck and drill through the centre; ream both holes 1/4 in. File a good flat on one side, cut in half and face each cut side to size, and bevel. Assemble on the full length of the crankshaft with 1 in. for the pin, and with eight rings of silver solder, fluxing well. Place flats down on an asbestos board and heat up until the solder runs, then use more silver solder, fluxed, and a pointed rod to ensure good joints; leave until cool, do not dunk in water or pickle. Saw out the crankshaft from between the webs, protecting the crankpin journal with a sleeve of alloy, and saw off the crankpin ends. Turning the shaft between centres, clean up the shaft and the other surfaces of the webs. Saw the webs to counterbalance shape and file the pin and inside carefully.

The big end brass is made from 1/4 in. square phosphor-bronze, two pieces being soldered together with Comsol paint. A 1/8 in. slot is then hand filed around the edge of the square, and the connecting rod made with a square hole filed to take the brass, measured with the vernier caliper. Finish off the rest of the mild steel connecting rod to the two No. 54 holes drilled in the end and then cut the big end across the middle of the square with a fine slitting saw; drill out the small part No. 49 and tap the large 10 BA. Press the big end brass into place, cuts all aligned, and secure with 10 BA screws, Centre punch the middle of the brass and drill through 6 mm., ream 1/4 in. Hold the connecting rod in a vice and file each side of the big end brass until it will be a tight fit between the webs. Remove the screws and put the small end in the vice so that heat can be applied to the big end until the half falls off; clean off on emery cloth. To run the bearing in, secure it to the crankpin, apply Brasso and



run the crankshaft in the drill chuck, holding the connecting rod against rotation; clean off well and oil.

THE BED

The bed is a straightforward construction job; make the side plates as a pair, clamped together. The only trouble which may be experienced is with tapping the alloy 8 and 10 BA when the tap tends to clog up within the hole and strip the thread on removal; it just needs removing more often during the job. Secure the bearings with Loctite 270.

The motion plate screws on to the end of the main bed and it is the relative adjustment of the motion bars to this which correctly positions the engine together with the securing screw in the slot under the bed.

For test purposes the smaller of the flywheels is sufficient. The larger one is difficult to make on the Unimat; it is like a gyroscope, when turning, and objects to being disturbed by a tool.

So assemble everything and turn the crankshaft to see if the throw takes the cylinder equally to each end of the block; adjust this by screwing the piston rod in or out of the cross-head bush, working in some Loctite 221 when it is correctly positioned. Oil the moving parts well before testing; for a pneumatic test put 3 in 1 in the lubricator, and for steam Valvata. The motion will need a little running in before giving its best.

Chapter Seven

A V-Twin Valveless Steam Engine

After fitting the single cylinder prototype engine and successfully driving the complete "works" of the traction engine, I decided, before proceeding, to make the proposed two cylinder version of the valveless engine, which was to be a marine version.

Instead of the horizontal twin at first envisaged the engine became a marine V-twin, with the cylinders at approximately 120 degrees, the advantages of this being:

a. It takes up less room athwart a boat than a horizontal engine.

b. Both big ends can run on the same crank journal simplifying crankshaft fabrication.

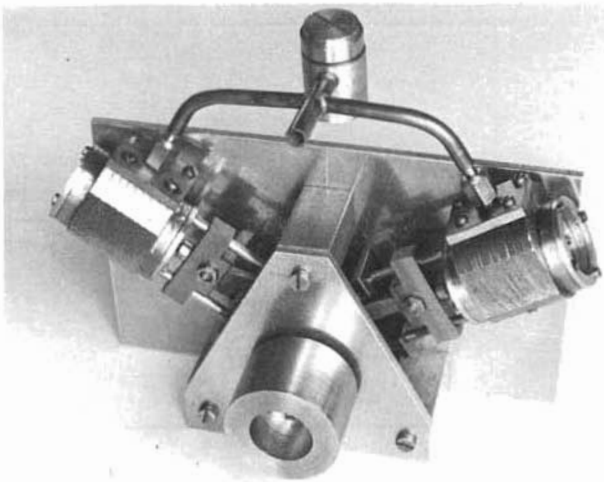
c. The bed could be vertical and adapted as a strong bulkhead in a boat design.

VARIATIONS FROM THE PROTOTYPE

The basic engine unit employs a changeover period of ⅓ of each half cycle, with power for ⅔ of each half cycle, plus the extra bits due to the size of the ports, opening and closing. This is brought about by having two thirds of the crankshaft throw, or piston movement, employed in the power stroke, and the other third employed in changing over the ports by moving the cylinder. In the prototype the total piston movement is 0.6 in., the changeover being 0.2 in. of this. For the twin units, by way of experiment, the changeover of the ports remains the same, but the throw of the crankshaft has been increased to 0.68 in., giving a 20 per cent longer power stroke, relative to the previous version.

The variation is brought about without any major alteration to the drawings by simply slimming down the piston and the cylinder covers a little, and, course, increasing the throw of the crank.

A significant alteration to the unit configuration is the shortening of the connecting rod so that the big and small end centres are 1.4 in. apart, approximately twice the throw, which is really quite short, the ideal connecting rod being infinitely long. With an engine employing eccentrics and valve gear a short connecting rod can lead to the engine running unevenly, particularly at low speeds. With the "valveless" engine the crank is virtually the valve eccentric and the connecting rod the eccentric rod, so that the moving cylinder does not experience outside angularity differences, and the discrepancies tend to travel together. This can be examined in more detail graphically.



The complete engine, designed with model boats in mind.

Minor variations are made to the cylinder block and covers, the blocks being much simpler in this version, having no extra functions to perform or hold.

An angularity effect of the short connecting rod is examined in Figure A, using the centre of the null points at both ends of the crankshaft throw (the prototype 0.6 in. throw is used throughout). It can be seen to occur at 56 degrees from the piston rod end and 44 degrees from the cover end. This angularity effect will cause a difference for each event, different at each end.

By drawing out, to scale, the complete cycle of the angular displacement the linear displacement can be measured and plotted as a graph, giving a curve of linear displacement due to angularity, for this length of connecting rod and stroke, or any other to this ratio. See figure Bi and Bii. One half of the cycle only is plotted on Bii, the other half being a mirror image, descending.

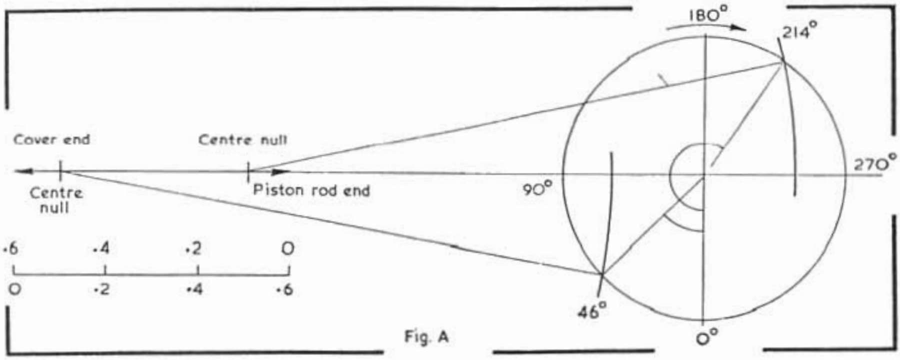


Fig. A

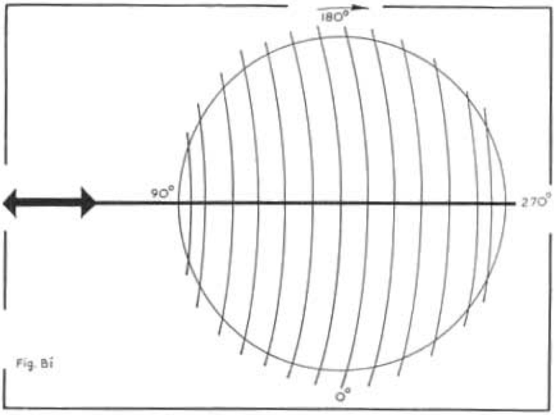


Fig. Bi

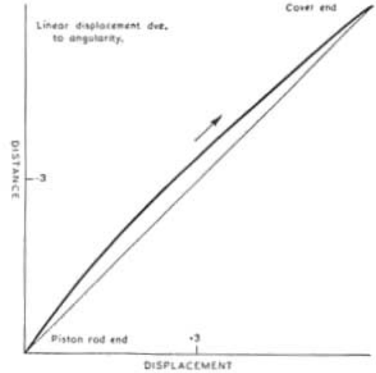


Fig Bii

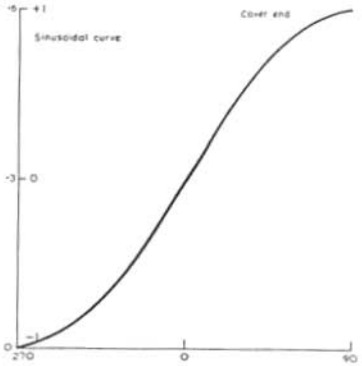


Fig C

With an infinitely long connecting rod the flywheel and crankshaft, moving at a constant speed, will always impart a sinusoidal rate of change to the piston. That is, the piston will decelerate from its centre point, and accelerate up to its centre point, stopping at top and bottom dead centre, with a precise sine wave curve. In figure C, the position of that piston about a mean is plotted against angle (or relative time). Only half of the cycle is plotted, the other half being a mirror image.

THE QUADRANT DIAGRAM

To compare the way one complex circumstance reacts when working with another, the quadrant diagram can be used. This consists of two, or sometimes three graphs plotted against each other to produce a further curve to show what is happening. If two curves are used to produce a third curve the fourth space is made a transfer quadrant, with a straight line at 45 degrees. In

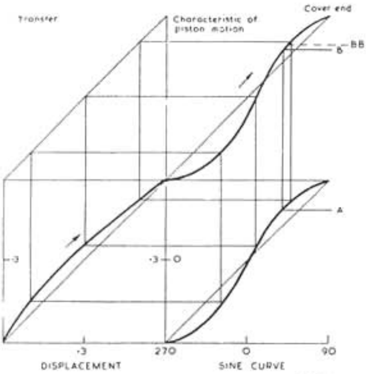


Fig Ci

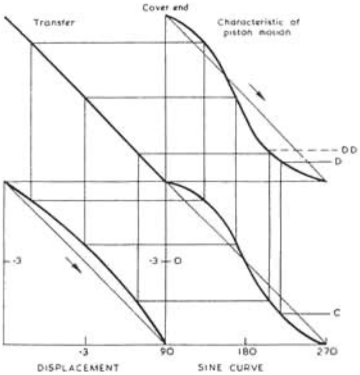


Fig Cii

this case the ideal sinusoidal motion has the linear effect of angularity plotted against it to show the actual rate of change of the piston movement. See figures Ci and Cii.

Figure Ci shows the effect of angularity of the piston going from the piston rod end of the cylinder to the cover end, and Figure Cii shows the reverse movement. The piston movement curve peaks at the cover end and flattens out at the piston rod end. If the valve event, opening to steam, was externally controlled, the positions A changing to B and C changing to D, would be as plotted, varying considerably one end from the other. However, this first opening of the steam port in this engine is controlled by the piston, and the events are marked in at BB and at DD, and are not very dissimilar; this gives a clean, even beat at slow running speeds.

Further to this is the effect of using a round steam port, opening over an elliptical port. The way this occurs is shown in Figure Di with the effective area of the port increasing against the ellipse, and the characteristic curve of this is plotted as Figure Dii. The equivalent plot of the usual rectangular valve opening over a slot is, of course, a straight line at an angle greater than 45

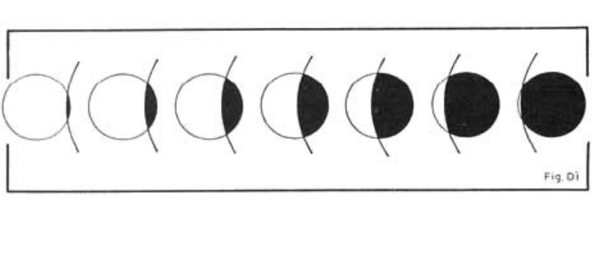


Fig. Di

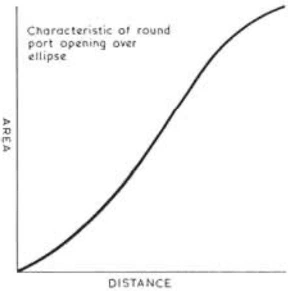


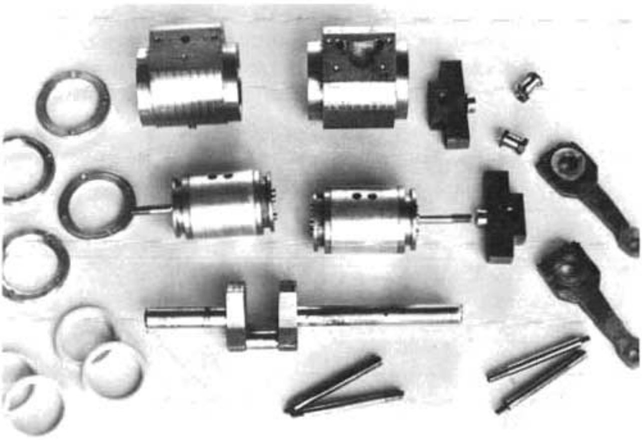
Fig. Dii

degrees. The much slower and controlled opening of the round port to steam can be seen to provide effective assistance to deceleration of the piston at this end of events. This again obviously adds to the slow running characteristics without affecting fast running. Remember that the quadrant diagrams represent the situation when the connecting rod is only twice the throw, and that an improvement can be expected with a longer effective rod length.

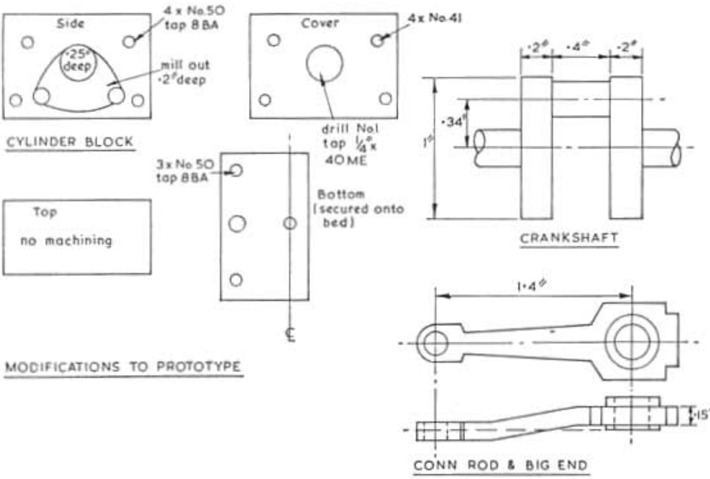
THE TWIN CYLINDER ENGINE

The angle adopted for the "V" formation was just under 120 degrees to take the one cylinder further into its power stroke while the other is changing over; 116 degrees in fact. Simplicity and low cost of manufacture were major considerations. All components were made from stock materials, either by hand or machined on the Unimat, and great care was taken to ensure first class fitting of all the parts. Particular care was taken over the cylinder to get a perfect size of bore and outside, and to obtain the best possible finish (I made four before I was satisfied with two). I had taken less trouble on the single cylinder version, and it did tend to leak steam to exhaust a little, but only at certain places in its travel. With two cylinders these places would be impossible to eliminate unless the fit was first class.

The cylinder blocks are much simplified, with no lubricator, regulator, exhaust passage or safety valve, just a hole for the cylinder, and steamways to two faces. With two basic units to hand (one left and one right) they are fitted to the vertical alloy bed. A front plate is supported by three pillars. The front plate and the bed are drilled out, while clamped together, for the pillars and the bushes for the crankshaft. The three pillars are flycut in the lathe while clamped together, to get them square and the right length. All positions are scribed on the vertical bed as shown, using the extremes on the throw to



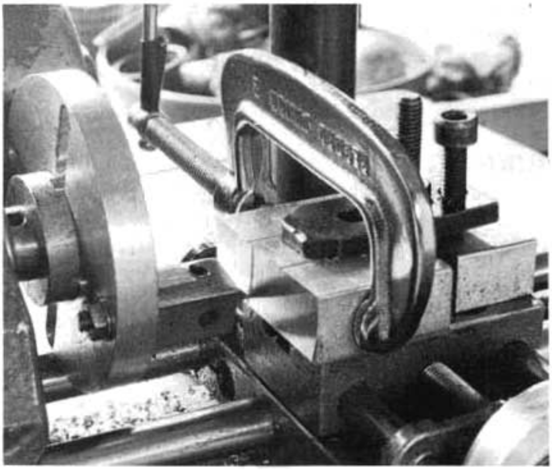
The main components of the two engine units.



position the units on the scribed angles, with the hole on the centre line of the exhaust face of the cylinder block being used to position each unit.

The crankshaft is made as before, but with slightly larger webs to take the longer throw, and a longer crankpin for the dual big ends. No trouble should be experienced in brazing this if the flat is cut on the piece for the web after drilling and before slicing through; the crankshaft sits on the now two flats for brazing up, all in line.

The connecting rods are made from ⅛ in. b.m.s., by hand, after drilling the big end and small ends. They are then bent in a vice before fitting the big end brasses.



Flycutting the three clamped-up pillars which support the front plate