How to Make a Simple 16th Century Style Clock

by

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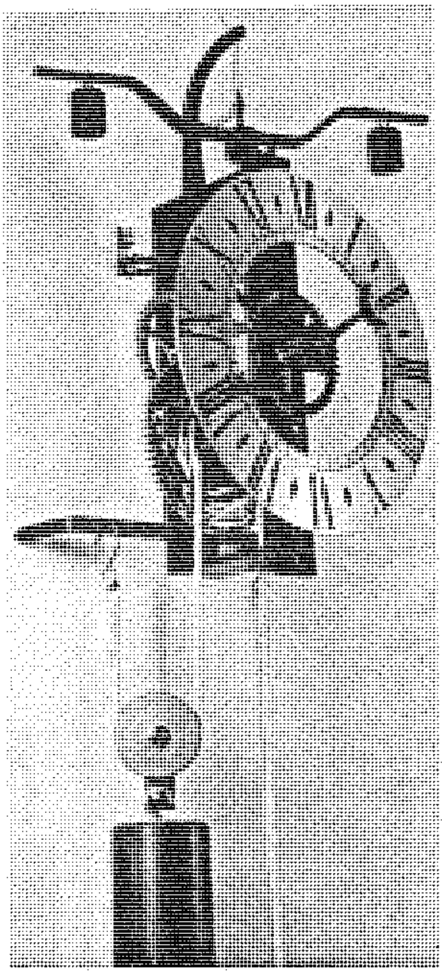
Chapter 1
Introduction

IN previous books that I have written on the construction of various types of clocks, the machining has been illustrated using the ML7 lathe. It is a particularly suitable size of lathe for work on clocks and also for the construction of the many special tools and fittings required in both clock repairing and making.

Fig 1 General view of clock



However the ML7, together with even a modest selection of accessories, involves a fairly expensive outlay and I thought it would be appropriate to show how to make a clock using a lathe in a cheaper price bracket.

The Unimat 3, which is the tool I have chosen is quite suitable for this work. It is well designed, extremely versatile in that it can be converted for drilling and milling in a matter of moments. The dividing attachment can be fitted in no less than three different positions and this feature is of great value in the cutting of wheel teeth and drilling lantern pinions.

It is capable of swinging a 3 in diameter blank which takes care of the main wheel in an English longcase clock, and therefore any other clock wheel likely to be required in the normal run of repair work.

The Unimat 3 comes into the category of the student or hobbyist's lathe and as such it is quite probable that it will be the owner's first machine tool. I am assuming this, and in the description I shall be dealing with matters of elementary lathework including "tooling up".

I would like to thank Nathan Shestopal Ltd, who kindly made the equipment available to me for the purpose of this project.

The clock

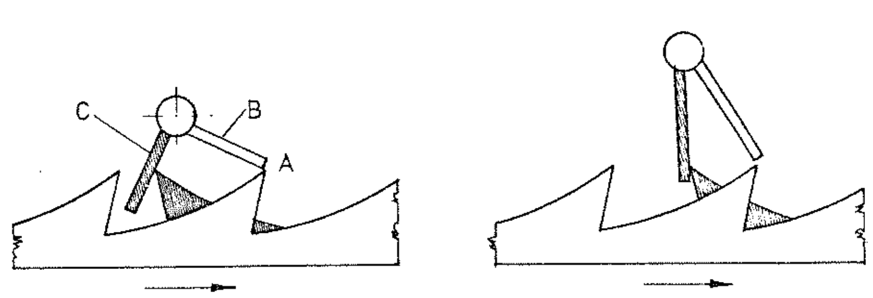
Figure 1 shows the completed clock. It is based on the style of the 16th century, and would, at that time, have been made of iron throughout, using the methods of the blacksmith, ie fire welding for joining metal, swaging and upsetting for shaping it, and filing to form the teeth and pivots. It is not my intention to follow these traditional methods in the construction of this clock. The type has been chosen for its simplicity and suitability as a beginner's project.

I have used mild steel for the general structure, but all the wheelwork is in brass. The contrast of the polished brass and the blued steelwork makes it a most attractive piece.

The escapement

The escapement is a verge with a foliot as the oscillator. Regulation is

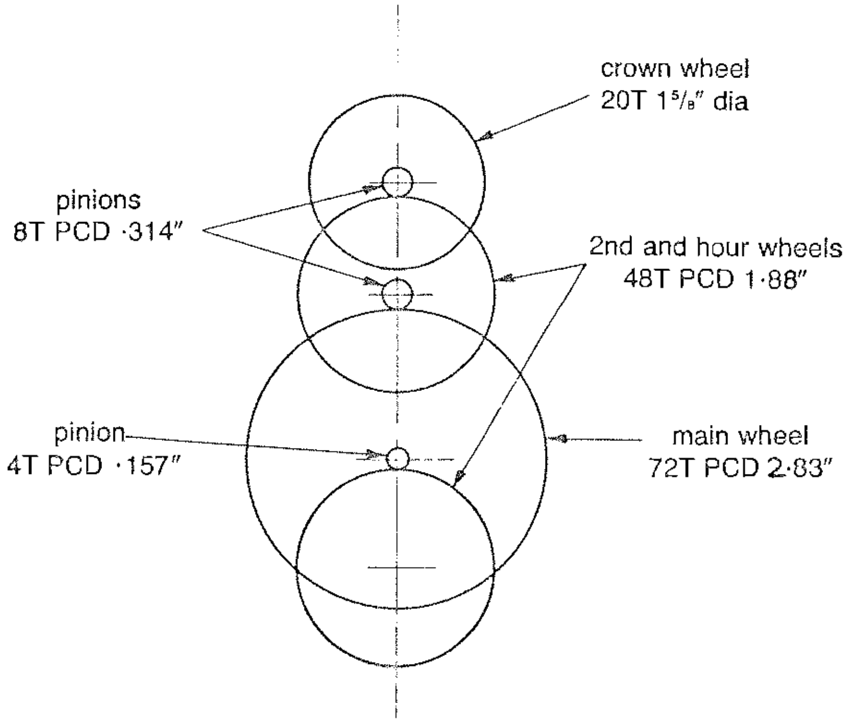
FIG 2 VERGE ACTION WITH DIFFERENT PALLET ANGLES.



INCLUSIVE PALLET ANGLE of 90°

INCLUSIVE PALLET ANGLE OF 30°

FIG 4 DIAGRAM OF WHEEL TRAIN



carried out by moving the foliot weights either in or out on the arms. If this action is insufficient then the driving weight can be altered, increasing it will accelerate the action.

In the traditional form of verge escapement, the pallets were usually set at 90° to 100° apart, but in this design I have reduced the angle to 40°. The disadvantage of a large pallet angle is the severe engaging friction which is encountered on the recoil. Figure 2 illustrates this. On the left, the tooth A has just escaped from the pallet B, and the shaded tooth on the other side of the wheel has impinged on the pallet C. But the momentum of the foliot is causing the verge arbor to continue to rotate in an anticlockwise direction forcing the wheel backwards. This action is common in all recoil escapements, but the angle of contact here is particularly bad as you can see. It will be all right as soon as the recoil is over and the rotation is in the other direction. Clockmakers describe this as the difference between engaging and disengaging friction. In his book *Clockmaking past and present,* G F C Gordon describes the difference in the two frictions with the illustration of a pedestrian who trails his walking stick on the ground as he walks along the pavement. This is easy to do, but if he holds the stick out in front of him and pushes it along the ground it will catch in every small obstruction. If we look at the right side of fig 2 where the pallet angle is 30° you can see that in the same situation the action is much nearer the line of centres and the engaging friction will be very much reduced.

Another interesting feature in this escapement is the number of teeth in the wheel. With the verge passing across the centre of the wheel there must be an odd number of teeth otherwise the escapement cannot function. However the Unimat division plates do not offer a suitable odd number in the range required and so an even number (20) has been chosen and the verge is displaced 1/16 in off centre. It functions perfectly well in this manner and the anomaly is not noticeable.

Figure 3 is a side view of the general arrangement of the movement.

The wheel train

I was determined that I was going to design a clock that could be made entirely with the standard Unimat accessories and without having to import special attachments of another make (such as a division plate).

The wheels in this train can all be cut with the standard division plates supplied with the dividing attachment. In fact only three of the four are needed, (the 24, 36 and 40 hole plates). Figure 4 is a diagrammatic arrangement of the wheels which is the simplest way to show it for computing the train.

In order to find out how many vibrations the foliot will make in a minute, and how far the weight will fall in say an hour, we must "prove" the train which involves making a simple calculation in the form of a fraction.

On the top line of the fraction we put down all the tooth numbers of the wheels, from the hour wheel which carries the hour hand up to the escape wheel.

$$48 \times 72 \times 48 \times (20 \times 2)$$

You will notice that the escape wheel tooth count is multiplied by 2, as during one revolution each tooth is engaged by both pallets.

On the lower line of the fraction we put the pinion numbers.

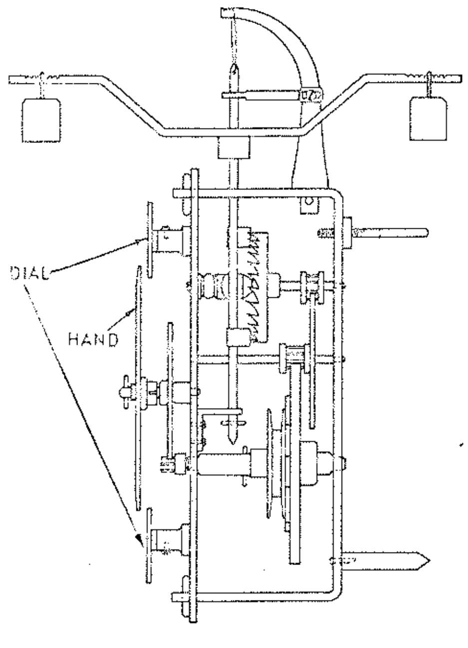
$$4 \times 8 \times 8 \times (12 \times 60)$$

As the fraction relates to a wheel that revolves once in 12 hours and we require the number of vibrations a minute, the fraction is further divided by 12 and 60. The completed fraction therefore appears as shown here.

$$\frac{48 \times 72 \times 48 \times 20 \times 2}{4 \times 8 \times 8 \times 12 \times 60} = 36$$

As you can see, it resolves to 36 being the number of vibrations a minute. Apart from anything else it is convenient to know this figure for the purpose of regulating the clock when it is finished, as we simply count the ticks over a period of a minute and adjust the foliot weights accordingly.

FIG 3 GENERAL ARRANGEMENT



The drive pulley is mounted on the same arbor as the main wheel and this is geared with the hour wheel via the four tooth pinion and so the pulley revolves once an hour. The effective diameter of the pulley is 1¼ in and so applying π we find that 3.9 in of line will pass round the pulley each hour, or 117 in in 30 hours, or if we used a double fall 58 in. So we see that the clock has a 5 ft weight fall over 30 hours and should therefore be hung about 6½ ft above floor level for the full running time to be obtained.

When I mentioned this project to colleagues, doubts were expressed as to whether it was a practical proposition to make a clock on this class of lathe. "Will it be accurate enough?" they asked, "What about rigidity?" and "Is there enough power in the motor?" The answer to these questions is to be found partly in the choice of "set-ups" and in the proper sequence of the operations together with an intelligent appraisal of the capability of the tool and working within that limit.

I can assure the reader that I had no difficulty in carrying out all the machining in the construction of this clock on the Unimat using a really quite modest selection of accessories.

It goes without saying that I assume the reader will make a thorough study of the instruction book supplied with the lathe. Another useful book published by MAP is *The Book of the Unimat* by D J Laidlaw-Dickson.

Materials

I am giving a list of the main materials required in order to construct the clock. I am specifying mild steel for the main frame and general external structure but brass could be used or even light alloy if preferred. However I think there will be a loss in character if the latter two materials are employed.

The mild steel is all listed in Whiston's catalogue[1] although it may be shown in metric sizes. For instance the 1 in wide strip for the frame and front plate is listed as 25 mm width which is 0.4 mm undersize, but this will not make the slightest difference.

The brass can be purchased from Smiths of Clerkenwell or any of their branches[2].

The pivot steel required for the lantern pinions together with all the special horological tools such as piercing saw blades, broaches, can be obtained from Nathan Shestopal Ltd, 1 Grangeway, London NW6 2BW.

Materials required

Mild steel flats

1 in x 1/8 in	2	12 in lengths	main frame and front plate
¾ in x 1/8 in	1	12 in length	foliot
1½ in x 1/8 in	1	12 in length	foliot bracket
¼ in x 1/8 in	1	12 in length	lower frame support
¾ in x 1/16 in	1	12 in length	hour hand, verge pallets and click

Round mild steel

5/8 in dia x 12 in	foliot weights and height gauge
5/16 in dia x 12 in	main arbor, hour wheel post
3/16 in dia x 12 in	pulley spindles
1/8 in dia x 24 in (2 x 12 in)	verge, arbors, hanging hook, taper pins

Brass blanks BS2870 CZ120

3 in dia x 1/8 in	1 off	great wheel
2 1/8 in dia x 1/16 in	3 off	second wheel, hour wheel and ratchet wheel
1¾ in dia x 1/16 in	2 off	pulley flanges

Round brass BS 2874

1 5/8 in dia x 7/16 in	1 off	crown wheel
1 in dia x 3 in	1 off	
5/8 in dia x 3 in	1 off	
½ in dia x 12 in	1 off	various collets, pillars, etc
3/8 in dia x 12 in	1 off	
5/16 in dia x 12 in	1 off	

Brass flat BS 2874

1/16 in x ½ in x 6 in	click spring and pulley frame

Square

¼ in x ¼ in x 6 in	verge bearing bracket

Angle

¾ in x ¾ in x 1/16 in x 6 in	lower verge bearing

Getting started, A chuck board, Tooling up, Grinding the tool bits, The lathe tool honing jig, Twist drills, A height gauge for the lathe tools, Lathe accessories required.

Chapter 2

Getting started

IT is a popular misconception with beginners that having purchased the lathe and some of the essential accessories, they are then all set to start on the project. "Let's put something in the chuck and get turning!" Although such feelings are understandable, the beginner must be patient and undertake the preliminaries. Failure to do this will almost certainly give rise to disappointment in the first attempts at turning.

A chuck board

The lathe bed is "sacred" and every effort must be made to protect it from accidental damage. When work is being filed or burnished in the lathe it is very easy for the tool to slip off the work and damage the bed. Another common cause of damage is the leaving of a chuck key in the chuck and then starting the lathe. Dropping chucks on the lathe bed when changing them is a further cause. The consequence of these occurrences can be greatly reduced by the construction of the simple chuck board illustrated in fig 5. This little protective cover is made from a $2\frac{3}{4}$ in square of hardboard with two wood strips glued one at each side to straddle the lathe bed. It is placed as shown whenever any fitting is changed on the mandrel nose and whenever any hand work is being carried out on work rotating in the chuck.

Fig 5 The chuck board in position on the lathe bed

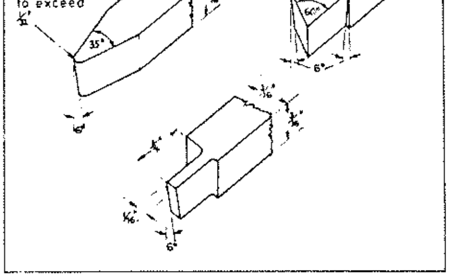
Tooling up

The manufacturer can supply a set of lathe tools in a box for this lathe. Don't buy them. I have several similar sets of lathe tools in my tool cabinet and the majority of them are unused. In general they are too large for horological turning and the shapes are not satisfactory. Furthermore they are ground with top rake which is not required when turning in brass.

I suggest that the constructor purchases 4 Eclipse high speed steel tool bits $^{3}/_{16}$ in square and a length of $\frac{1}{4}$ in round silver steel.

In the making of a clock most of the turning will be in brass, ie collets, pillars, barrels, pulleys, wheel blanks, etc. The two basic tool shapes which will accomplish most of the turning are shown on fig 6. They are the round nose tool on the left and the right hand knife tool on the right. For turning the pivots on arbors we also require a right hand knife tool and this differs from the brass one in that the top of the tool should slope away from the cutting edge whereas tools for brass have flat tops. A parting tool is required for use on brass and this is also shown on fig 6. The width of the cutting edge should not exceed $^{1}/_{16}$ in in this size of lathe and the relief behind the cutting edge should be minimal otherwise the tool is weakened at the neck. Other shapes will of course be needed but these will get you started. There is certainly no need for "roughing" tools with a lathe this size; we are not concerned with the speedy removal of large quantities of metal. "Little and often" is the best policy on a light lathe.

FIG 6 SUGGESTED TOOL SHAPES FOR HOROLOGICAL WORK



Grinding the tool bits

The Eclipse tool bits are already shaped obliquely at the ends which lessens the amount of grinding required.

The Unimat grinding attachment is excellent for the purpose of grinding the tools. The grinding rest, however, is a little small for the comfortable manipulation of the tool bits and I enlarged mine by clamping a section of 16 gauge steel plate on the standard rest with a pair of toolmakers clamps. This is demonstrated in fig 7 and suitable dimensions are shown on fig 9. A more permanent arrangement would be to secure the extension with 5 BA countersunk screws fitting into tapped holes in the Unimat rest.

The beginner should realise that the grinding of tool bits is carried out in order to form the shape. After this has been done the tool tip is honed with an Arkansas slip stone[3], in conjunction with the lathe tool honing jig. As a matter of interest, having shaped my lathe tools as illustrated in fig 7, no further grinding was carried out on any of them during the construction of

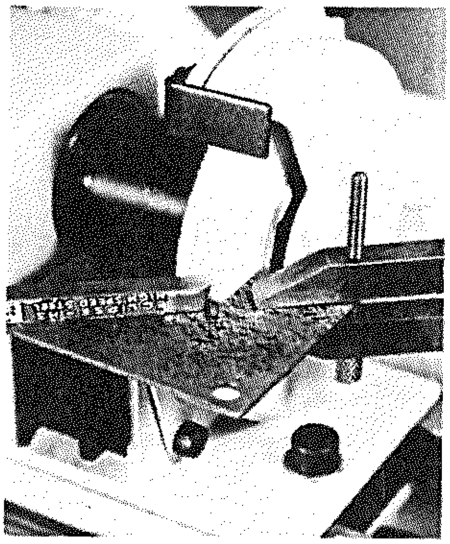


Fig 7 The extension piece fitted to the Unimat grinding rest

this clock. I mention this fact for the benefit of those on a tight budget, as apart from this initial use, the grinding attachment will hardly feature again in the construction of the clock. The subsequent sharpening of the lathe tools will all be done on the honing jig.

The lathe tool honing jig

It is not satisfactory to hone lathe tools in a freehand manner. The little jig in fig 9 enables the slip stone to be presented to the cutting edge of the tool in a precise manner. You can see that 6° is the angle selected for clearance under the cutting edge of the tool. In order to minimise the work of honing, the grinding should form the clearance angle to an angle somewhat less than 6°, then the stone will only have to engage the actual cutting edge.

Six degrees is not critical, the angle may be between 5° and 10°; however, if excessive, the tool tip is weakened and if minimal, the setting of the tool at lathe centre height becomes more critical.

It will be found that if the Unimat grinding rest is set horizontally and the extension as described is fitted in place, then a $^3/_{16}$ in tool bit when ground on the periphery of the wheel will have a satisfactory angle formed for use with the honing jig illustrated here.

This little jig is simple to make and will ensure consistent tool sharpening. The body of the jig is formed from a short length of 2 in x 1 in wooden batten to which the side plates are secured. The dimensions are given in fig 9. Almost any stiff material can be used for the side plates. I have used brass, but steel, formica, paxolin, etc, would all be satisfactory.

Fig 8 shows the basic tools required for marking out. It is convenient to colour metal with a dye which will then show up the scribed lines more clearly. Layout blue as it is called is available from all good tool shops, and a make that I have used for years is Talbot Blue. It dries almost instantly and does not easily rub off.

The external shape is marked out for one side plate, and after cutting this out with the hack saw, it may be used as a template for cutting out the second plate. Then the two can be clamped together for filing to the line. I have not shown the positions of the screw holes which are not critical, but they can be sized for a No 6 wood screw and positioned $\frac{1}{4}$ in from the edges. Fig 10 depicts the two plates clamped together and held in the vice for filing.

Fig 11 illustrates the Unimat set up for drilling the screw holes. Drilling is always started with a centre drill as shown here and then followed with the twist drill. The circular marks visible round the hole were caused by the swarf from the drill.

The next stage is to offer up the plates to the wood body and secure them with a "G" clamp as shown in fig 12. You can see here that I am using the engineers square to check the positioning of the plates. Finally, in fig 13, I hold the body of the jig in the

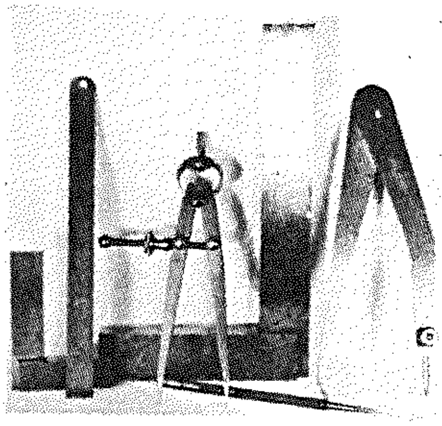
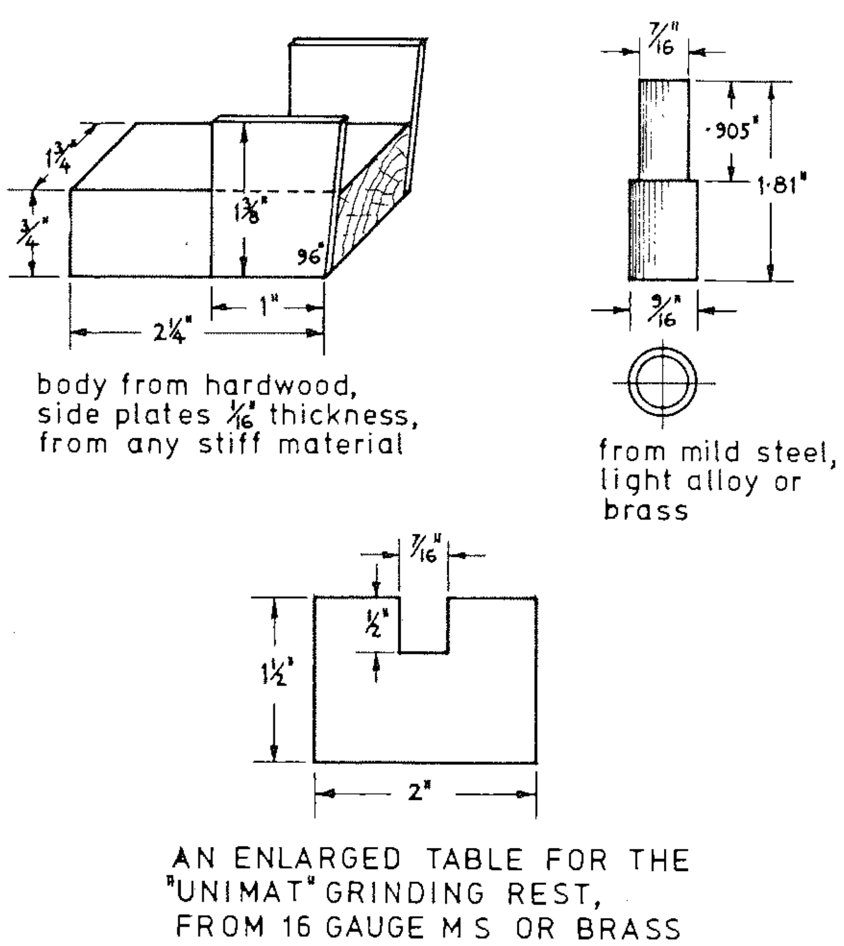


Fig 8 Basic tools required for marking out

FIG 9 LATHE TOOL HONING JIG & HEIGHT SETTING GAUGE



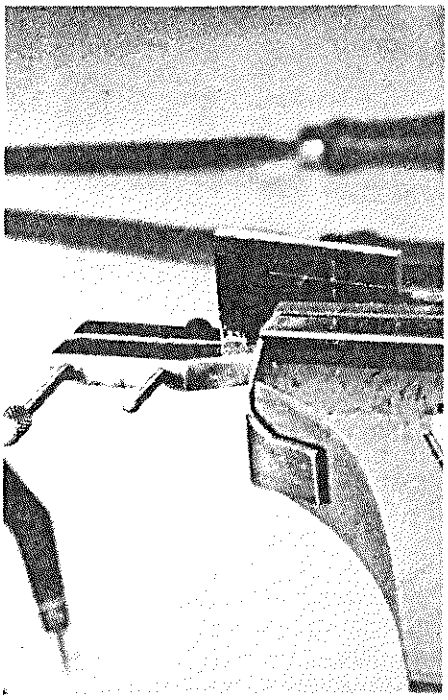
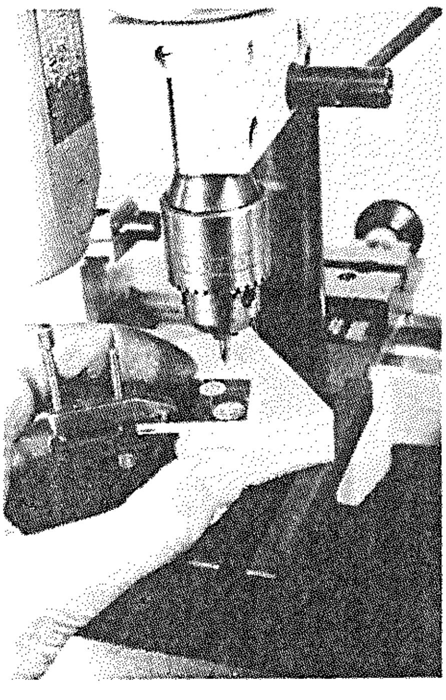


Fig 10 The side plates of the honing jig clamped together for filing the edges

Fig 11 The Unimat set up for drilling the side plates



vice and using the hand drill spot through the plate holes for the wood screws. Figure 14 demonstrates the jig in use for honing the general purpose brass turning tool. The slip stone is moved in close contact with the front guides of the jig while the tool is swung round to present the length of the curved tip to the stone. An Arkansas stone is essential, any other will be too soft and quickly become grooved. Finally, the tool is taken to the bench stone where it is honed on its upper

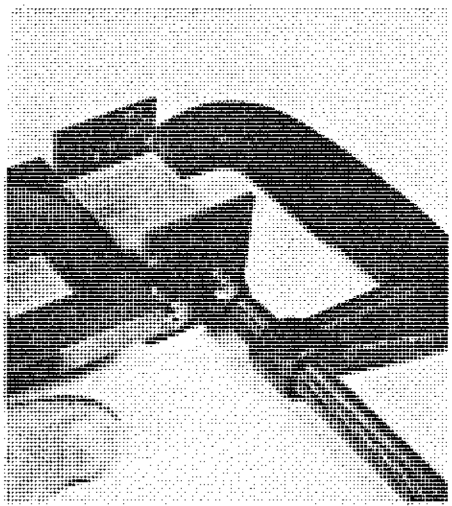
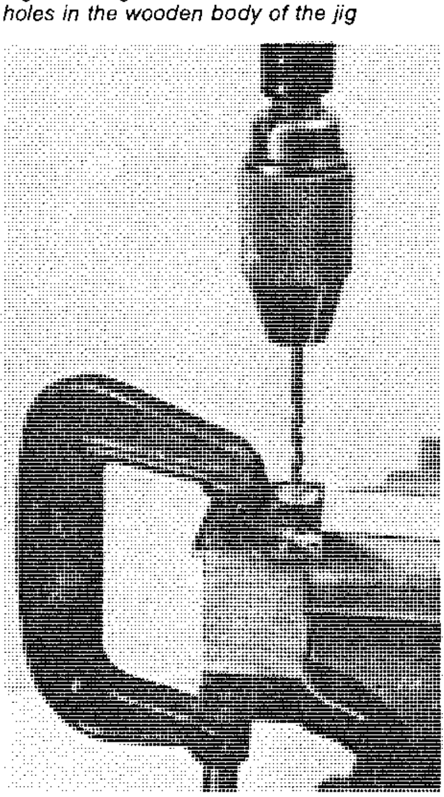


Fig 12 Using the engineer's square to check the positioning of the side plates

Fig 13 Using a hand drill to form the screw holes in the wooden body of the jig



and side surfaces by holding it well down with heavy finger pressure in the manner shown in fig 15. In the background of this picture you can see two Arkansas slip stones, the rectangular one is used with the honing jig and the triangular for other purposes.

It is customary for horological tools of this sort to be designed for holding in the vice. This allows both hands free. The honing jig can have a $\frac{3}{4}$ in square piece of wood glued underneath for this purpose.

Figure 15a shows the four basic tool shapes which will accomplish nearly all the turning in this clock. The one

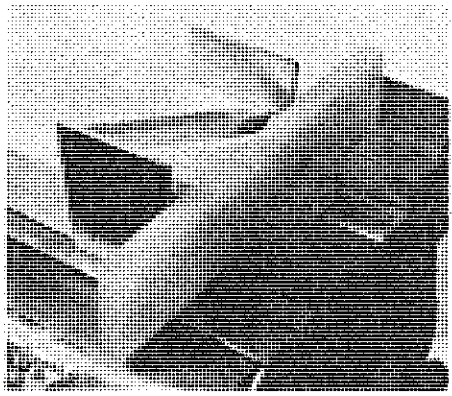


Fig 14 The jig in use for honing the general purpose brass turning tool

on the left is the knife tool for steel, the others are for brass.

Twist drills

While discussing honing, I must stress the importance of removing the rake angle on these before they are used on brass. As previously stated, brass tools work better without any top rake but the normal twist drill has a built in rake angle formed by the spiral flutes. If this is not removed the drill will tend to grab when drilling a soft material like brass. The rake angle can be negated quite easily with the aid of a triangular slip stone as demonstrated in fig 16. The drill (a large one for the purpose of illustration) is laid on the bench with one of the cutting edges parallel with it and the stone is applied in the manner shown. Only half a dozen strokes will be required to form a small flat on the

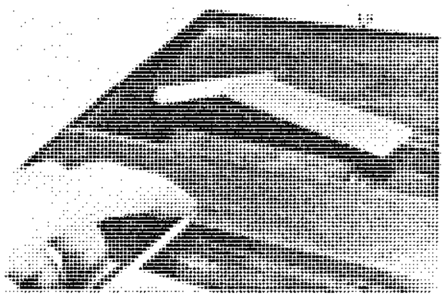


Fig 15 Method of honing the top and side surfaces of the lathe tool on the benchstone.

cutting edge. The drill is then rolled over 180° to hone the other cutting edge. Figure 17 attempts to show the "white line" which is in fact the reflection of light on the honed flat.

It is not really possible to hone drills in this manner which are much less than $^1/_8$ in diameter. This doesn't matter as it is in the larger sizes where it is more important.

It is possible to buy straight fluted

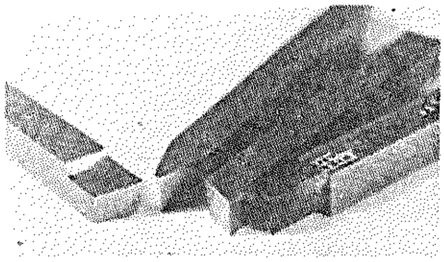
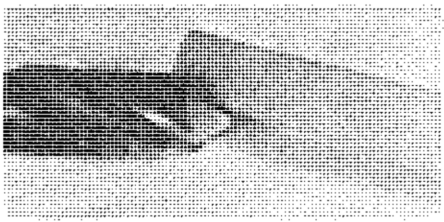


Fig 15a The four basic tool shapes which accomplished most of the turning in the construction of this clock

Fig 16 Method of negating the rake angle on a standard twist drill



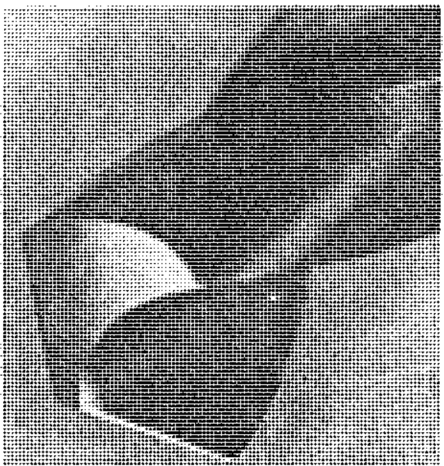


Fig 17 The 'white line' illustrating the flat on the cutting edge of the twist drill after honing

drills but it is hardly a practical proposition to equip the workshop with complete sets of both types of drill.

A height gauge for the lathe tools

We are nearly ready to use the lathe now. Having honed the lathe tools it is important to set them in the tool holder at centre height. It will be found with the Unimat 3, that a $^{3}/_{16}$ in tool bit which still retains its original thickness will require a piece of packing under it $^{1}/_{16}$ in thick. Although the height of the tool tip may be checked against a lathe centre, this is not always convenient or possible if the chucks are in position. The surface gauge can be used, but again this is not very convenient being large and bulky on a small lathe.

The simple height gauge shown on the drawing fig 9 will be found convenient in this role. It is a two position gauge and is designed for placement

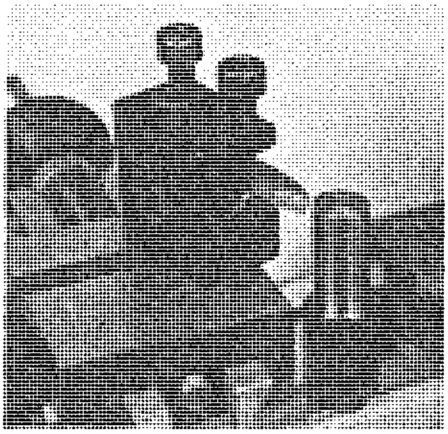


Fig 18 The two position height gauge in use on the lathe bed

either on the lathe bed or cross slide whichever is convenient as demonstrated in fig 18 and 19.

It can be machined from mild steel, brass or light alloy, preferably the former. The diameter is not critical and in the pictures which follow I show mine being machined from a scrap piece of hexagonal stock. A sufficient length that will hold up to the measurement on the drawing is cut off with the hacksaw and held in the 3-jaw chuck where one end can be faced true. It is then removed from the chuck and the 1.81 in dimension marked off using the oddleg calipers (set from a steel rule) as illustrated in fig 20. The stock is returned to the

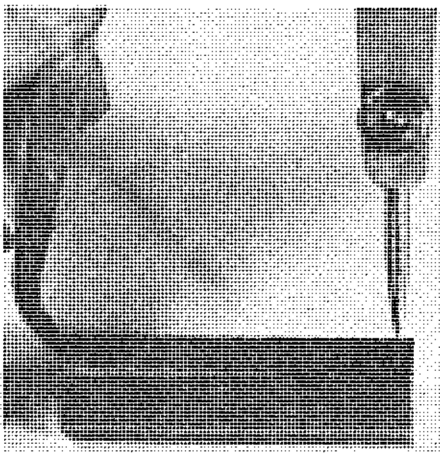


Fig 20 Using the odd-leg calipers to mark out the length of the height setting gauge

chuck for machining to length and the accuracy can be checked with a vernier slide caliper as shown in fig 21, the stock being returned to the chuck for further machining if necessary. This work could be carried out between centres, and if the machining involved concentric accuracy on the diameter of the work this would be the proper way to do it. Here, we are only concerned with accuracy in the linear dimension and the 3-jaw chuck

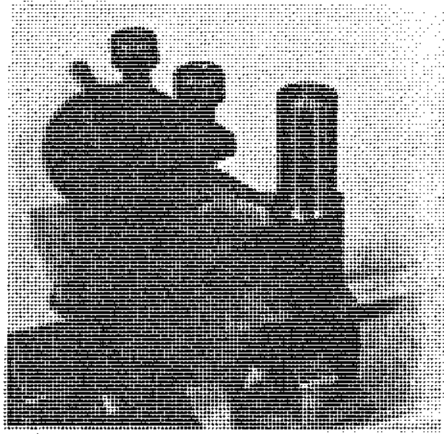
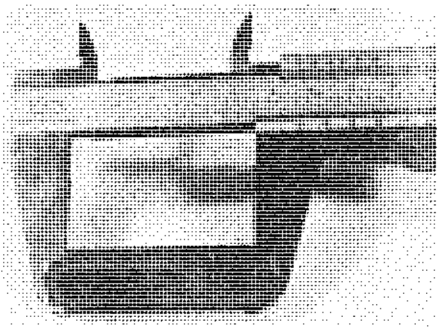


Fig 19 The two position height gauge in use on the cross slide

Fig 21 Checking after machining to length using the vernier slide calipers



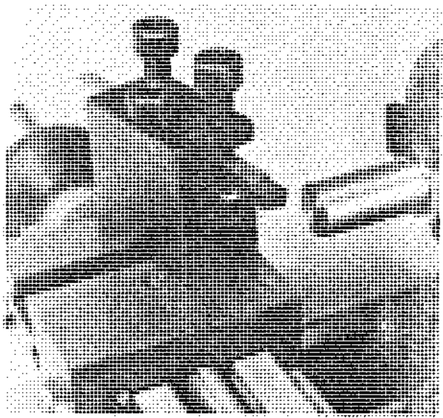


Fig 22 Turning the step on the height gauge using the right-hand knife tool with top rake

is satisfactory for this purpose. After marking the 0.905 in dimension in a similar fashion, a step is turned as shown in fig 22. To ensure that the gauge seats squarely on its base it is advisable to machine a slight recess, or relief, on the under side.

There will be other accessories required later on in the work, such as holders for both the wheel cutter and a circular slitting saw. A lathe filing rest will be needed as well. But these can be constructed at a later date.

Lathe accessories required

If the wheelcutting is to be undertaken[4] then the constructor will need the following accessories:-

Vertical drilling and milling attachment.
Vertical fine feed attachment.
Indexing and dividing attachment with the set of plates.

Other accessories which are necessary for the general machining of the clock are three chucks (3-jaw, tailstock and 4-jaw), the top slide for taper turning and the tool grinding attachment. If the lathe is required for drilling then the milling table together with the milling table support will be found more convenient than using the cross slide as the drilling table.

The main frame and front plate, The taper pins

Chapter 3

The main frame and front plate

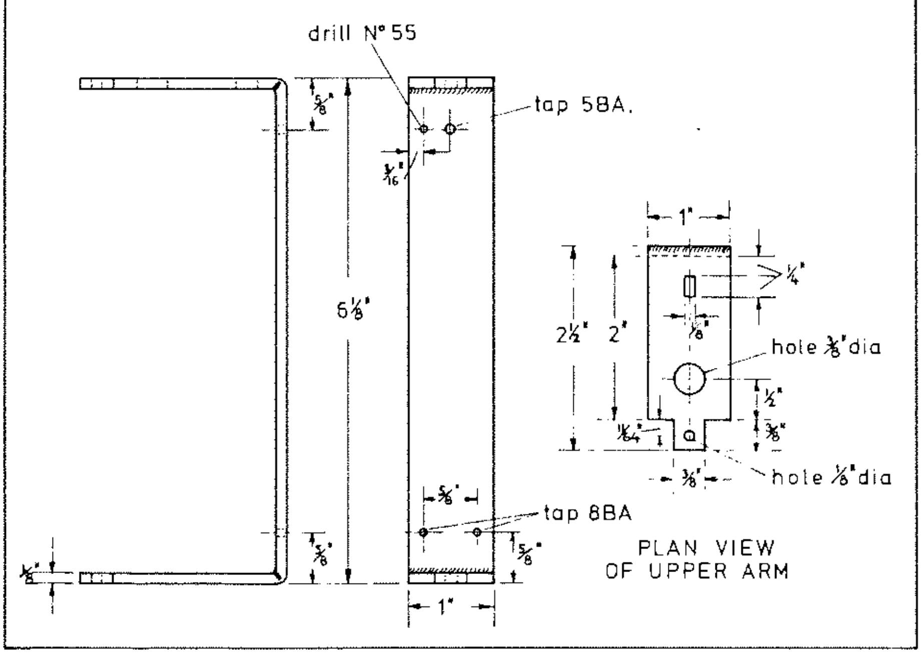
IT is both customary and logical to start the construction of a mechanical clock with the plates and pillars as they form the backbone of the movement. In this clock we have no pillars, instead, the back plate is bent to a U shape and the front plate is fitted to the horizoutal arms using mortice and tenon joints, the whole being securely locked together with tapered pins.

A drawing of the main frame is. given in fig 23 from which it can be seen that the main part of the construction involves the forming of two right angle bends in the mild steel strip.

It is difficult to form really tight, neat bends in this thickness without the assistance of a bending jig, even if the metal is brought to red heat. However the work can be accomplished quite easily in the manner shown in the accompanying photographs. This method has the advantage that the process is completely under control and corrections (to a limited extent) can be made during the bending.

The work is started by taking a 12 in length of 1 in x 1/8 in mild steel strip and coating one side with layout blue, after which the approximate centre position of the strip is marked. Positions 3 in above and below this point are marked out and lines scribed across the strip; these will of course be 6 in apart. A sawcut is made on the line to a depth of about three quarters of the thickness of the strip. The sawing should not be attempted with the saw blade parallel with the stock. Start on one edge with the blade at an angle, gradually dropping the handle of the hacksaw frame and stopping frequently to check the straightness and direction of the cut. The cut is now closed up by bending the strip, and this can be done quite easily with the fingers. A second saw cut is now made in the same position removing the metal which has been pinched together in the closing of the original cut. This stage is illustrated in fig 24.

FIG 23 MAIN FRAME — FROM 1/8"×1 M S



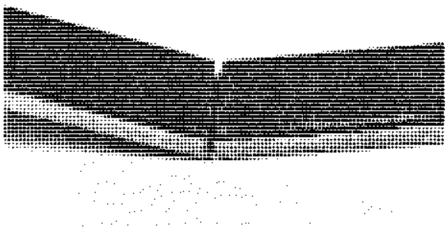
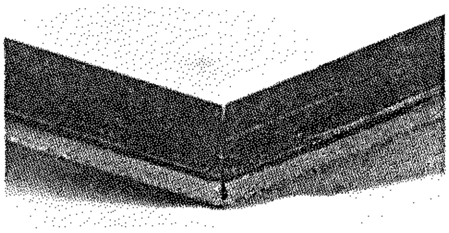


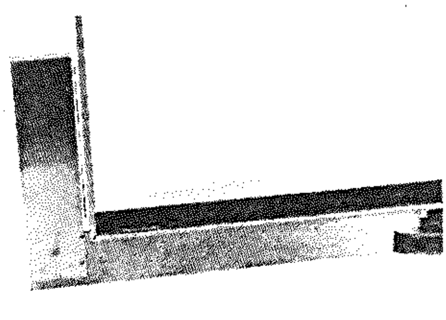
Fig 24 Illustrating the principle of sawing and bending in order to form a right angled bend

Fig 25 Closing the sawcut in preparation for the next cut



Again the cut is closed up by bending as shown in fig 25, and the process is repeated until a right angle has been formed. This is checked with the engineers square as demonstrated in fig 26. The second bend is formed in precisely the same way. The accuracy of the bends will depend to a great extent on the original saw cut so do try

Fig 26 Checking the accuracy of the bend with the engineer's square



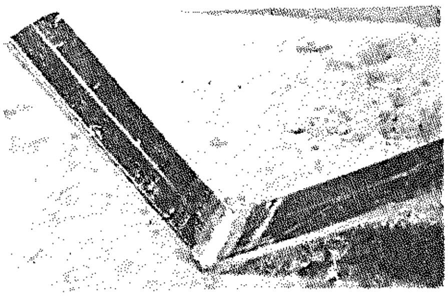


Fig 27 Filling the saw cut with a soft solder fillet

and make that at right angles to the strip. Check each bend after it is made and if you can see any untruth or twist, this can possibly be corrected by holding one part in the vice and applying corrective pressure with a large adjustable spanner or mole grips on the other section. Finally the corners are filled and strengthened by running in a fillet of soft solder. You can see mine being done in fig 27 where the stock is resting on a fire brick for warming with the gas torch. Make sure the solder fills the saw cut completely and runs out at each end.

We shall require heat for various operations in the construction of this clock and the type of torch, such as the Ronson blow-torch, which attaches to disposable gas containers, is very suitable for this work.

Although an outside measurement of 6 1/8 in is shown on the drawing this is not critical and the front plate is made to match the frame.

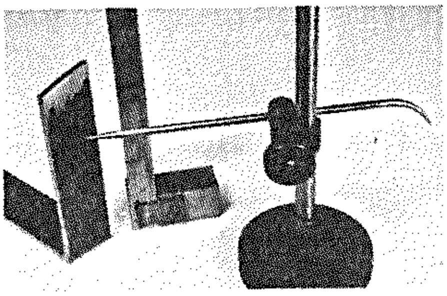
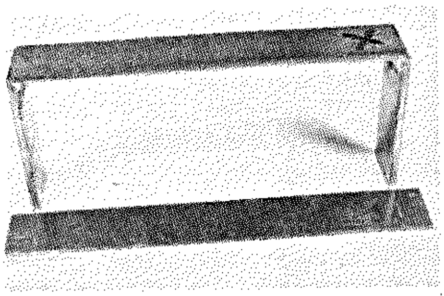


Fig 28 Method of marking out dimensions on the arms of the main frame

Fig 30 Showing how the arms themselves are used to locate the positions of the mortices on the front plate



The next stage is to mark out the lengths of the two arms, that is the 2 in and the 2 3/8 in dimensions. This can be accomplished in the manner demonstrated in fig 28. The scriber of the surface gauge is set to the correct height with a rule and with both the work and gauge standing on a flat surface the distances are scribed.

The surplus stock is removed with hacksaw and file. We are now ready to mark out the front plate. Although I give linear dimensions between the mortices in fig 29, these should be 'checked from the job' as shown in fig 30. Here you can see that the frame has been placed over the front plate and the positions of the two mortices marked by scribing across the front plate each side of the frame arms.

When marking out the 3/8 in width of the mortice, work from the centre of the stock. To do this a centre line should be scribed on the material by setting the odd leg calipers to ½ in and forming a centre line locating the odd leg from each side of the strip in turn. Unless you are very lucky this will result in a pair of 'tram lines' close together but adequate to establish the centre of the stock. From this centre line you can mark out 3/16 in each side.

To cut out the mortice, drill a hole of some 3/32 in near one end of the slot and thread the piercing saw blade through this, clamping it tightly so that the blade is under tension. Piercing saw blades are available in various thicknesses and numbers of teeth per inch. In the Eclipse range I suggest you buy a dozen M2 and M2/0. Use the former in this case. You will also require a vee notched sawing board about 9 in x 6 in. This should have a 4 in block of wood 2 in x 2 in underneath at one end so that the board can be held in the vice.

The blade is secured in the frame so that it cuts on the downward stroke and the work can be seen in progress in fig 31. You must persevere with the piercing saw if you don't succeed

Fig 31 Demonstrating the use of the piercing saw and the vee notched sawing board

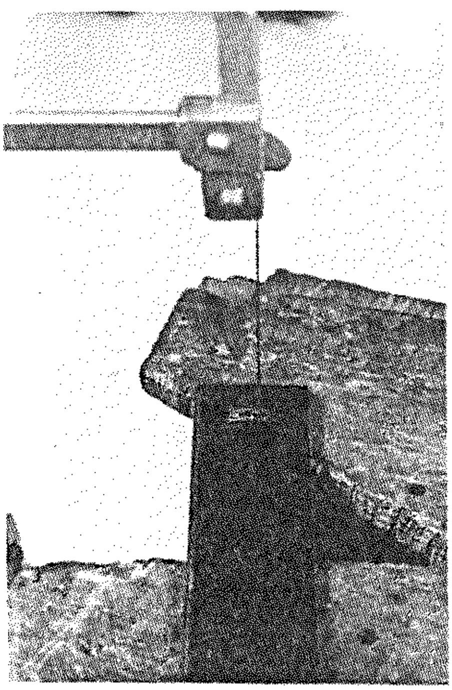
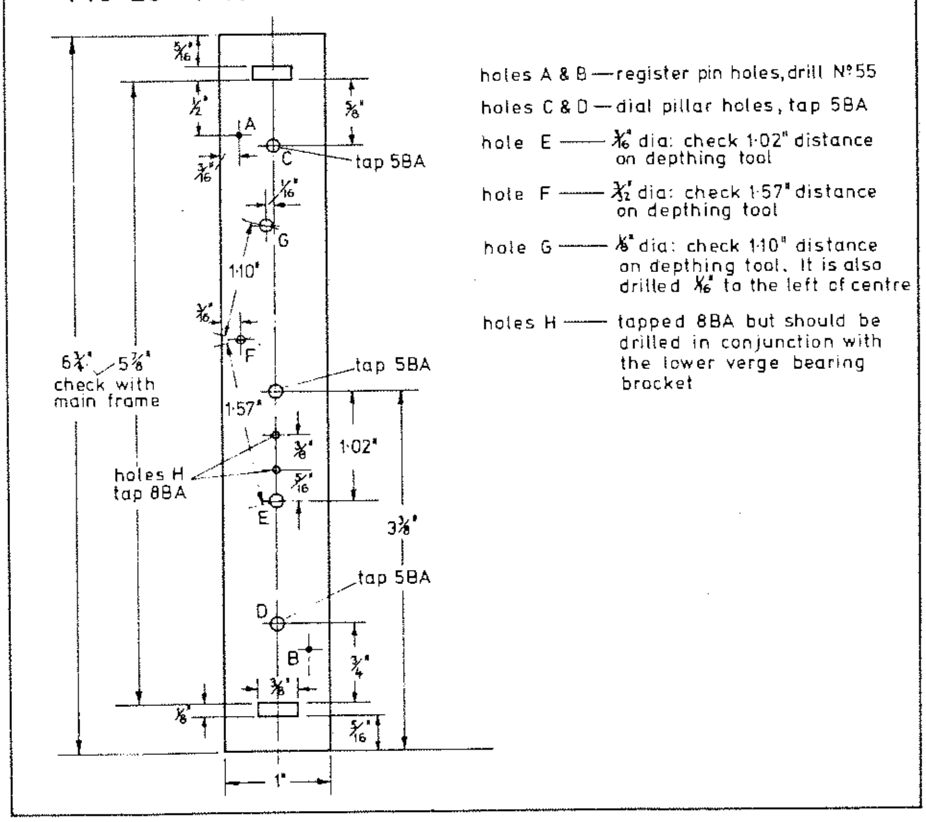


FIG 29 FRONT PLATE FROM 1/8" x 1" M S



straightaway, it is a vital tool in horological work. Use slow firm strokes without excessive pressure. When going round corners the blade must behave like the soldier on the inside position of a long rank carrying out a wheeling manoeuvre, ie, he must mark time. It is usually best to keep the frame pointing in the same direction and move the work on the board.

The hole is filed to the line using square and rectangular needle files of No 2 cut. Needle files must be regarded as expendable items. When purchased they have cuts on all surfaces and in use it is frequently necessary to have safe edges on one or other of the sides. Old or part worn files should be modified in this manner by removing the cut on the grinding wheel or carborundum stone. In this particular case you will need a square file with opposed safe edges and a rectangular or pillar file with safe sides to it. Only if this is done will it be found possible to obtain sharp corners to the slot. The sort of result you should achieve is shown in fig 32.

Leave the front plate now and form the tenons. These are marked out in a similar fashion and the surplus metal removed with a small hacksaw in the manner demonstrated in fig 33. The work is then filed to the line using, firstly, a file of about No 2 cut and finishing with a No 4 cut. A convenient size of file in this situation would be 6 in in length.

It may horrify the beginner to be informed that it is good practice to keep separate sets of files for brass and steel, as a file that has been used on steel will not cut brass efficiently. In practice I have two drawers of files, one for brass and the other for steel. New files are put in the brass drawer and relegated to the steel drawer after they start to lose their bite on brass. The same principle can be used with the hacksaw. My frames are colour coded blue for steel and yellow for brass (coloured plastic tape). It may appear extravagant but I can't remember when I last bought a hacksaw blade and I can't remember when I last changed the general purpose blade in the steel frame. Blades do last an incredible time if they are segregated in this manner.

When filing the tenons on the frame it is permissible to form the suspicion of a taper on the sides to facilitate fitting. The front plate must fit closely on the frame tenons but without force and excessive wriggling. When carrying out the filing to achieve this, it is better to work on the hole, enlarging where required rather than to reduce the size of the tenon.

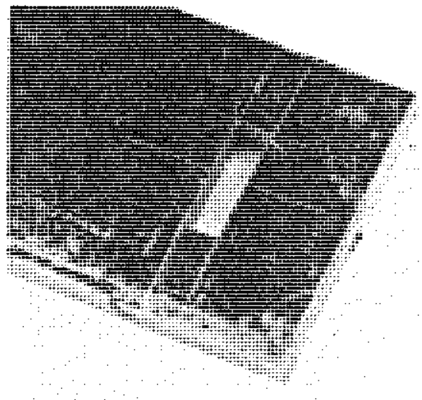
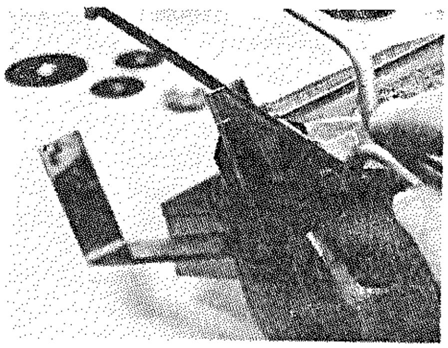


Fig 32 The mortice in the front plate after filing to shape

Fig 33 Sawing out the tenons on the arm of the main frame



Although the shoulders of the tenons are shown to be at right angles to the frame, in practice it is customary to undercut them in a situation like this. It is an accepted principle in horological fitting that where wheel collets and pillars abut against a mating surface, as they always do, the shoulder is always slightly undercut so that coutact is at the maximum diameter. Although I do not have a close-up illustration of this feature you may just be able to see it in fig 34 on the limb being drilled.

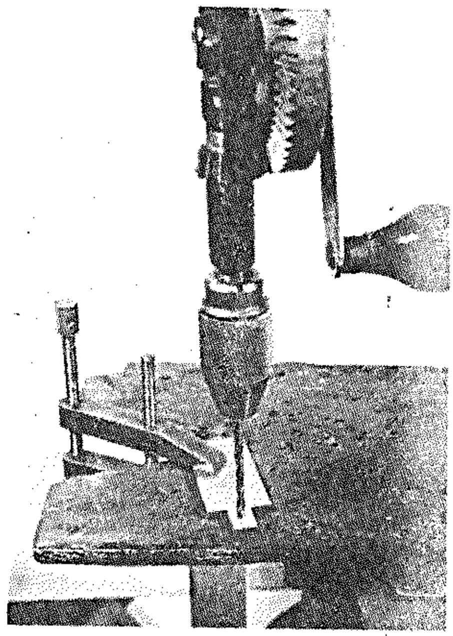
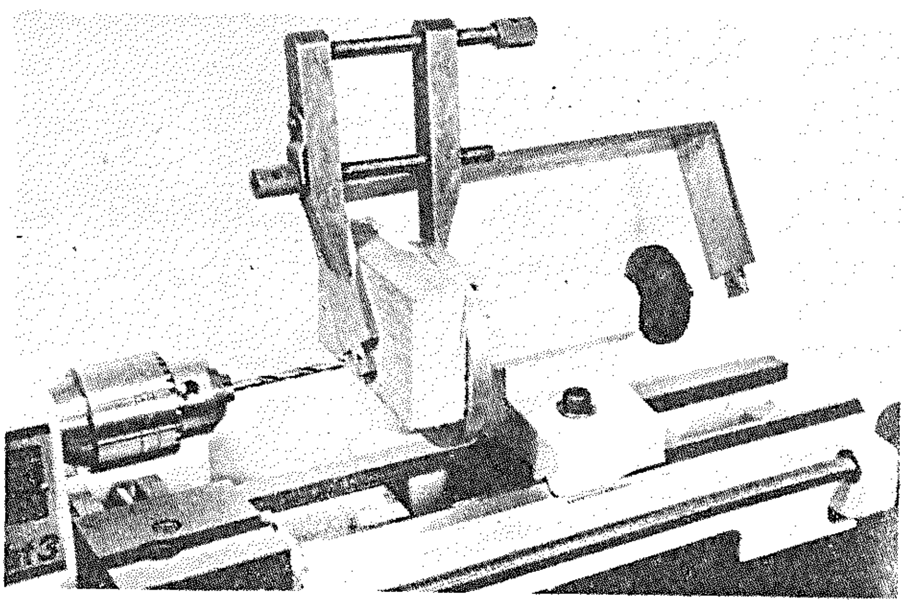


Fig 35 Drilling the pin holes with the hand drill. Note use of sawing board and toolmaker's clamps

When the front plate fits closely and without rock on the frame arms, they should be assembled and a line scribed on the teuon close up against the front plate. We now have to drill the pin hole in the tenon and it must be formed so that a small segment of it is inside the mortice. In this manner, when the tapered pin is pressed home, the two components will be held tightly together. The hole position is carefully marked out as indicated on the drawing fig 23 and centred with the centre punch.

In this instance there is not sufficient clearance to carry out the dril-

Fig 34 Method of drilling the pin holes in the Unimat lathe



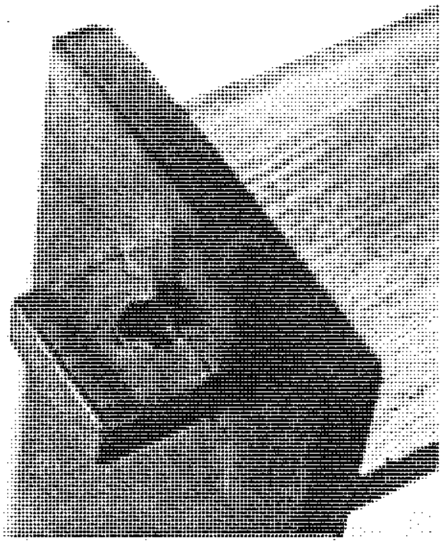


Fig 36 Illustrating one of the mortice and tenon joints. Note the partial occlusion of the hole

ling in the Unimat when set up as a drilling machine. The work can be accomplished either by hand as depicted in fig 35 or in the lathe set-up as shown in fig 34. In either case the drilling is started using the centre drill with a body diameter of 1/8 in. In fig 34 you can see that the lathe face plate has been fitted to the tailstock (the nose being identical to that of the headstock mandrel). The work is clamped as shown and initially it would be centred by inserting the headstock centre and bringing up the tailstock so that the position of the work could be aligned with the point of the centre. The result of the drilling should appear as in fig 36.

It may well be that the beginner has not been entirely successful in the accomplishment of all this work and the sides of the front plate do not align as well as they might with those of the frame, and even if they do, it will be desirable to pass a file across all the edges to clean them up. Fig 37 illustrates how the frame may be held in the vice using only moderate pressure of the vice jaws. The file here is a 10 in one of No 6 cut but a No 4 cut would be all right.

The taper pins

The taper pins are formed from 1/8 in diameter mild steel. The taper which is only nominal can be filed with the work in the lathe chuck (remember the chuck board), and the end of the pin should be rounded. In horological work the rounding of such items is not carried out to equal the radius of the component at that point but rather to equal the diameter of the stock.

The rounding at the large end is carried out by hand as it is bad practice to grip non parallel stock in a lathe chuck. Fig 38 shows the set-up. Here a filing block (a piece of wood with a notch filed in it) is held in the vice. This particular filing block is made especially for work on pins and has a groove formed as shown so that the end of the pin can be worked on with the file. The pin itself is held in an Eclipse pin vice and twisted in the fingers while the rounding is carried out using a clockmakers pivot file[5]. This is the file shown in this illustration and on its opposite face it is a burnisher. It is normal practice to burnish all surfaces of clock pins especially large ones like this. I shall be dealing with the 'making' of burnishers when we come to the matter of polishing pivots.

The frame and front plate may be cleaned up to remove the layout blue, scriber marks and general blemishes using wet and dry paper of about 180 grit. This is best cut into 2 in wide strips and wrapped round half a wine bottle cork. It is used wet. The procedure is shown in fig 39.

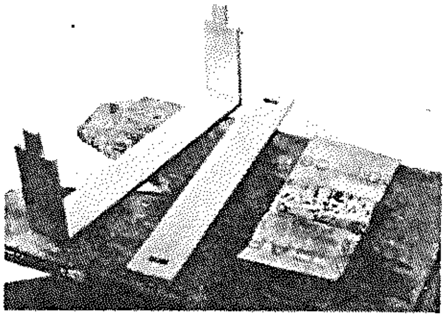
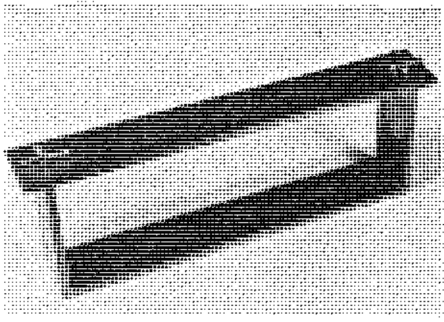


Fig 39 Illustrating how 'wet and dry' paper may be cut into 2 in wide strips and wrapped round a half section of a bottle cork for cleaning the frame and front plate

Fig 40 The completion of the main frame assembly and the first stage in the construction of the clock



The assembly at this stage is illustrated in fig 40. Of course many holes have to be drilled in both components but we can leave the frame at this stage and start on the wheelcutting.

NOTE Pivot files are not just fine needle files, as I understand, some readers imagine. They are properly shaped for forming clean shoulders; they are thick enough to prevent flexing and are of a superfine cut especially for forming pivots on tempered steel.

Fig 37 Method of holding the frame assembly with moderate vice pressure for cleaning up all edges

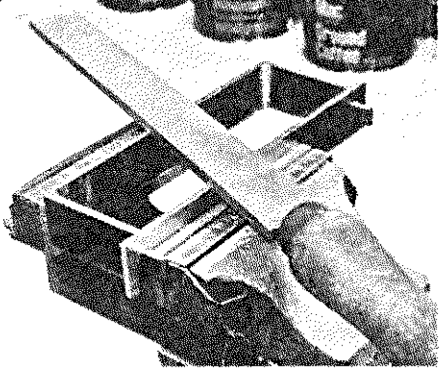
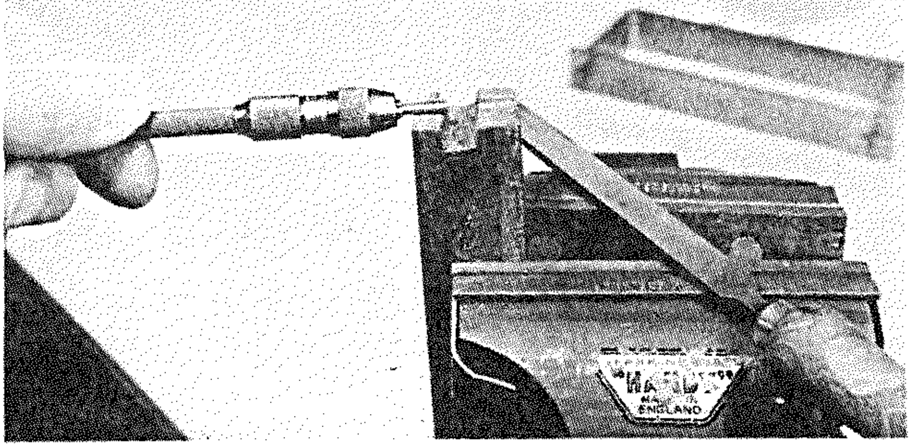


Fig 38 Method of holding a taper pin for filing and burnishing the head in conjunction with the wooden filing block



Preparation for wheel cutting, Alternative methods, The cutter, Hardening the cutter, A cutter holder, The wooden faceplate, Turning speeds, Boring the centre hole

Chapter 4

Preparation for wheelcutting

I THINK this subject – wheelcutting – causes more concern than any other in clockmaking.

There are several reasons which give rise to this. Firstly, the majority of professional clock repairers do not undertake the work. It is one of those jobs which are usually 'put out'. Naturally, if the professional doesn't do it, the amateur is led to believe that it must be very difficult. Secondly, an enormous amount has been written on the theory of wheel teeth. Every text book has its chapter and I think the beginner feels that the subject is so technical and critical that there isn't much point in attempting it. Thirdly, the normal centre lathe requires adapting in various ways before gears can be cut. Special attachments must be bought or made and this again is perhaps a deterrent. Lastly, there is the purchase of the cutters themselves, quite expensive items.

Dealing with these difficulties in order, it is strange that professional clockmakers rarely undertake this work. A mechanical clock is after all a gear box and it seems odd not to be able to produce new gears for it on the premises if required. Perhaps it is, that in the past, clock repairers did not have sufficient training on the general use of the lathe, and there also appears to be a thinking that clock wheels can only be cut on a traditional wheelcutting engine. Regarding the matter of the theory and the shape of the addendum curves, etc; fortunately this is not nearly so critieal as one might imagine, especially when lantern pinions are being used as most of the action takes place after the line of centres. The function of the curve is little more than that of providing a relief or clearance so that the wheel tooth can 'let go' of the pinion trundle as the two part company. (Trundle is the term used to describe the pins in a lantern pinion). The actual driving is done by the flank of the tooth. A visit to any museum will show the large variations in tooth shapes. The reader need not be worried by the special attachments to enable wheelcutting to be carried out as they are all available as standard Unimat accessories and I have enumerated them in chapter 2. As to the cutter, we shall use a simple fly cutter which we shall make ourselves. This is very easy to do as it is in fact just like a parting tool.

In forming the teeth we shall simply cut rectangular slots round the edge of the wheel and then form the addendum curves by filing. Again, this is not difficult nor critical and I shall be showing you a picture of a wheel in the process of having the teeth filed in which you will be able to observe irregularities and differences quite clearly. I can assure the constructor that in a clock of this type and with such a coarse tooth pitch (deliberately chosen), this method of producing the wheels is perfectly satisfactory.

Another point over which some readers may be concerned, is the fact that the main wheel has 72 teeth and there isn't a Unimat dividing plate giving that number. In fact we use the 36 hole plate and go round twice, resetting the blank for the second cut. This may cause raised eyebrows among those with an engineering training, but such procedures are perfectly workable in clock gearing. The same method will also be used with the 48 toothed wheels using the 24 hole plate.

At one shop where I worked the 80 hole circle on the dividing plate of the wheelcutting engine was so badly worn that it was impossible to be certain when the indexing detent was properly engaged in the hole. When cutting a wheel with this number we always used the 40 hole circle and went round twice.

Alternative methods

The Unimat is so versatile that it is possible to carry out the work in two different ways using the standard accessories. I illustrate both ways in

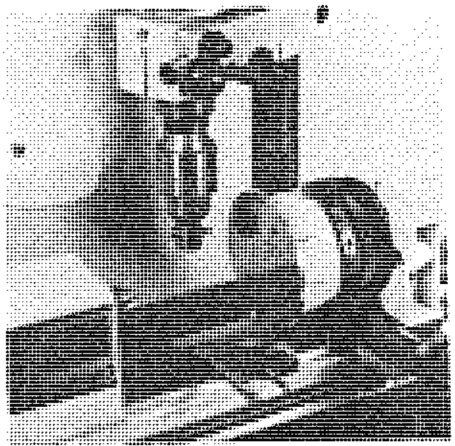
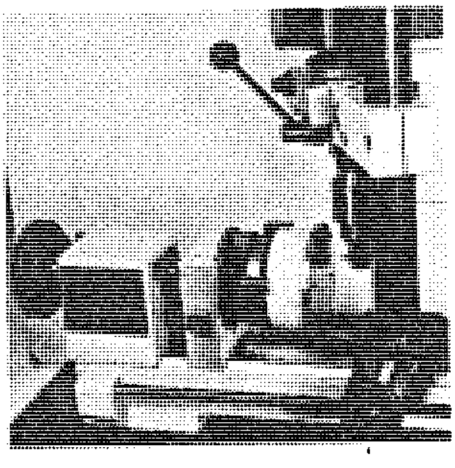


Fig 41 A method of wheelcutting where the dividing head is secured to the cross slide and traversed across the path of the rotating cutter

Fig 42 A method of wheelcutting where the dividing head is secured to the lathe bed and the cutter becomes the moving party



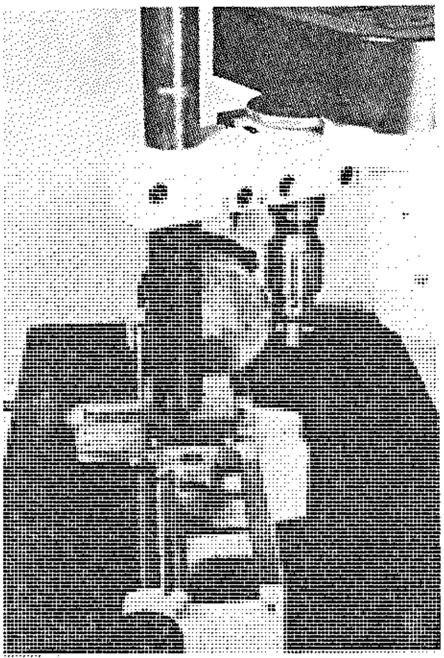


Fig 42a Another view of the arrangement depicted in fig 42

fig 41 and 42. In fig 41 you can see that the vertical column of the milling attachment is fitted in its seating at the rear of the lathe bed and the dividing head together with the wheel blank is mounted on the cross slide. In this case the cutter remains stationary and the wheel blank is traversed through its path.

In fig 42 the situation is reversed. Here the dividing head is clamped to the lathe bed just in front of the headstock and the column of the vertical milling attachment is fitted to the cross slide.

I have used both methods and each is perfectly satisfactory. It might be thought that there would be more rigidity in the former method, where the vertical column is secured in its vee shaped bed at the rear of the lathe, as opposed to its position in the second method where it seats on its end on top of the cross slide. In practice there did not appear to be anything to choose in the matter of rigidity between the two methods. However, the disadvantage of the first system is that owing to the direction of rotation of the cutter, the direction of feed must be from behind the blank outwards and this means that the thrust of the cutter instead of being against the wooden face plate is away from it and against the screw heads which hold the blank. This also means that the wooden face plate must be thick enough (about 1½ in) to allow room for the cutter behind the wheel blank so that it doesn't foul the chuck jaws and is still well clear of the blank itself when the latter is indexed for the next cut. In my illustration (fig 41) you can observe a pair of toolmakers' clamps attached to the lathe bed. This was to form a temporary stop so that I didn't run the cutter back into one of the chuck jaws.

It is this method which is illustrated in the sales literature on the Unimat where a gear is shown being cut. In this case the gear appears to be some 1½ in from the chuck jaws to give the necessary room for the cutter illustrated. An overhang or projection of this amount is not ideal, but can in this instance possibly be excused by the fact that the pitch of the gear being cut is quite fine.

I am recommending the second of the two set-ups (fig 42).

The cutter

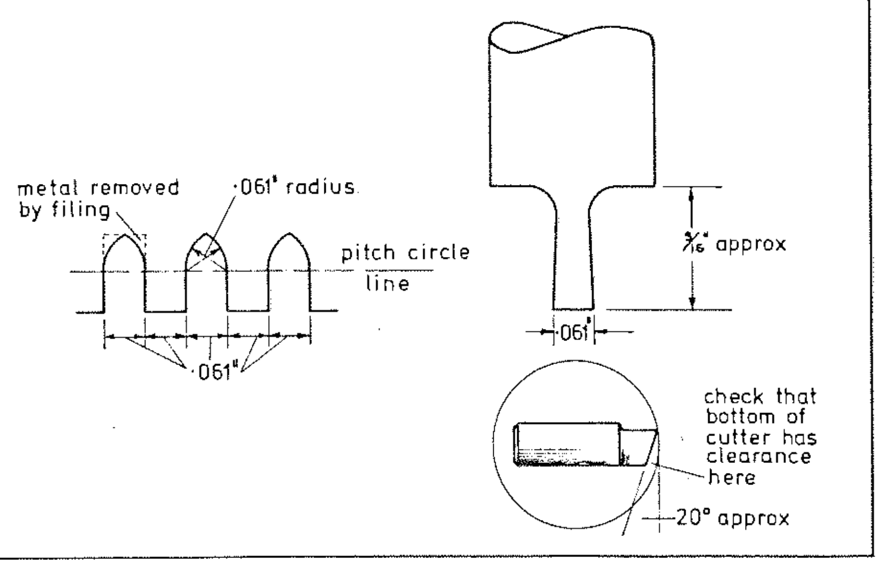
I am not going to cover the theoretical side of clock gearing in this book. As I have already mentioned, this subject is dealt with in almost every other text book. Whether wheel teeth are coarse or fine is designated by the diametral pitch of the wheel which is the number of teeth in each inch of diameter. In this clock the dp is 25.4 or No 1 module. To make the cutter we need to know the circular pitch of the wheel. This is the distance between two adjacent teeth measured at similar positions. To find the circular pitch we simply divide the diametral pitch into π. In this case 3.142 divided by 25.4 = 0.123 in. As the wheel teeth and the spaces between them are equal in clock gearing we divide this number by two and we have the figure 0.061 in as the width of a tooth or tooth space. The matter is illustrated in fig 43. You can see from this drawing that the process of cutting the teeth involves the removal of a series of rectangles from the edge of the blank just under 1/16 in wide. The depth of the rectangle (or the length of the tooth) is not critical and is usually made deeper than necessary. The usual reason given for this is that it provides room for dust and particles of dirt.

A plan view of the cutter is shown on the drawing (fig 43) and a side view demonstrates the necessity of sufficient clearance under the cutting edge.

It is made from a length of ¼ in diameter silver steel and the first step is to file a flat at the end to a depth of about 1/16 in. This will represent the top face of the cutter. With a Junior hacksaw remove the bulk of the metal from each side. If a grinding wheel is not available, the whole of the formation of the shape can be carried out by filing. However, it is easier to put the embryo cutter in a square block as illustrated in the following pictures. This is simply a ¾ inch square of mild steel in my case but light alloy or brass would do. A ¼ in hole is drilled to accommodate the cutter and a 4BA clamping screw is provided.

With the cutter secured in this block it can be presented to the grinding wheel in a positive manner and in a variety of ways. We can put the cutter on its side for instance and by presenting the top face to the side of the grinding wheel we can form this flat and true. By slackening the clamping screw and rotating the cutter very slightly first one way and then the

FIG 43 TOOTH FORM AND FLY CUTTER



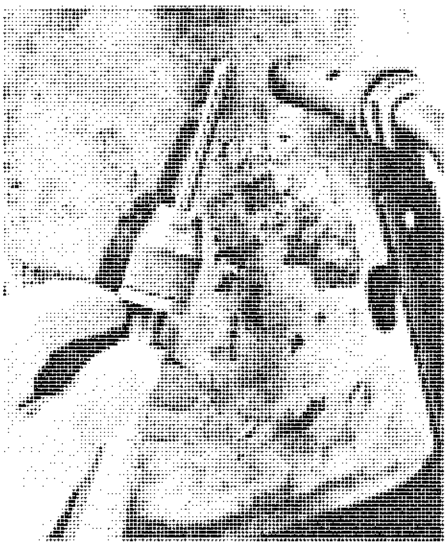


Fig 44 Bringing the cutter to red heat before quenching in water

other we can form the sides with a slight clearance. With the shape roughly formed, it can now be hardened.

Hardening the cutter

At this stage the embryo cutter is still attached to the parent stock and may be gripped in a large pin vice as illustrated in fig 44. In this illustration it is being held close to a fire brick and brought to red heat with the gas torch. At this temperature it is quickly quenched in cold water. The cutter should now be dead hard and a file should skate off it. It would be too brittle to use in this condition so we temper it by further heat treatment. To do this it must first be cleaned with emery cloth or sticks[6] to brighten the metal so that we can observe the colour changes. When this has been done the stock is again heated but this time with the flame turned down low and the heat applied about an inch from the tip. The colour changes are carefully watched and when pale straw is reached at the tip it is again quenched.

The cutter can be separated from the parent stock with the hacksaw now, by cutting in the area where it has just been heated as the temper at that point will have been lowered sufficiently for this to be possible.

The final grinding can now be carried out measuring the width of the cutting edge with a micrometer. Lastly the cutter still in its square block is taken to the honing jig for honing the cutting edge. As the clearance angle in this case is more than that for which the jig was made, the block must be tilted slightly. You can see in fig 45 that I have placed a matchstick under the front edge of the

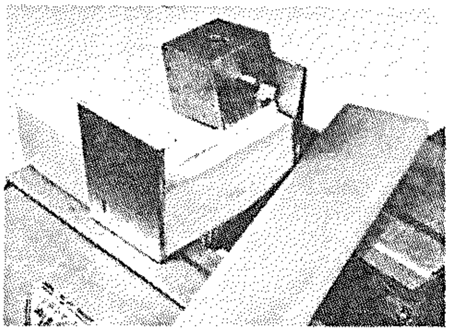


Fig 45 Honing the tip of the cutter in the honing jig. Note the matchstick under the holding block to give increased clearance

block for this purpose. The topface of the cutter is honed with a triangular slip stone as demonstrated in fig 46, and the general appearance at this stage can be seen in fig 47. The dark area at the top of the end of the cutter is the area that has been touched with the stone and is in fact polished to a mirror finish by the Arkansas slip stone.

A cutter holder

A cutter holder is illustrated on drawing fig 48 together with a suitable mandrel for a slitting saw which we shall require later on.

The holder is made from $\frac{1}{2}$ in diameter mild steel and the cross drilled hole is perhaps most easily formed in the Unimat by cutting the stock slightly overlength and then holding it crosswise in the 4-jaw chuck for drilling the $\frac{1}{4}$ in hole from the tailstock. Two of the chuck jaws will have to be reversed in order to provide a secure holding. After the hole has been drilled the stock is then held in the 3-jaw chuck for turning the shank to $\frac{1}{4}$ in diameter.

The wooden faceplate

The method by which the wheel blank is secured to a hardwood faceplate is standard practice for large wheels as it enables the outside diameter and the centre hole to be machined, together with the cutting of the teeth, all at one setting.

In this instance the diameter of the faceplate should be some $2\frac{1}{2}$ in to give maximum support to the blank and the thickness about 1 in. It is held in the 3-jaw chuck with the jaws reversed for holding large diameter work. The beginner should read the instructions carefully regarding jaw changing. These are not inserted in the same slots from which they came. The locations are reversed and the order in which the scroll engages the threads is important. The matter

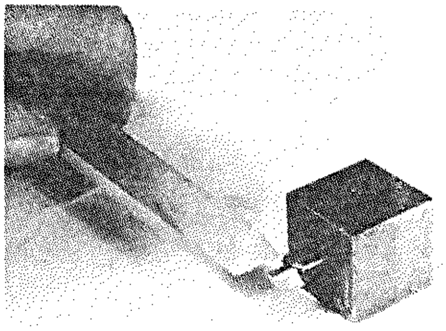
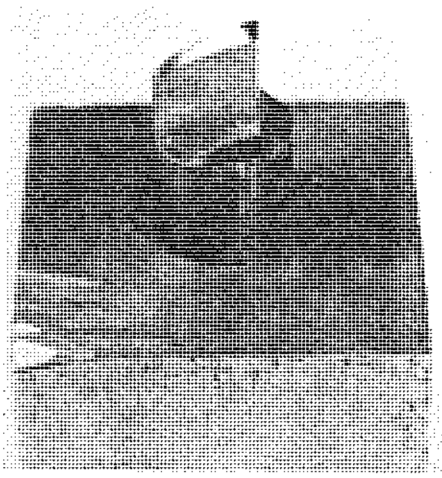


Fig 46 Honing the top face of the cutter with a triangular slip stone

Fig 47 The cutter ready for use



needs a little practice. In fig 49 you can see my wooden faceplate being faced. The centre part of the disc is very slightly recessed to ensure a firm support at the maximum diameter.

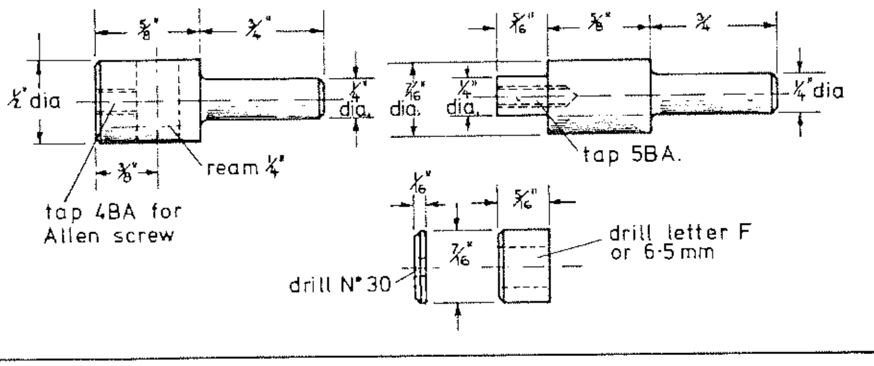
Fig 50 gives the drawings of the wheels from which you will see that the outside diameter of the main wheel blank is 2.95 in. The first step is to find the approximate centre of the blank and you can see this being done in fig 51. The odd leg calipers have been set to slightly less than $1\frac{1}{2}$ in and the odd leg is positioned on the edge of the blank while a short arc is scribed at the centre. This is done four times as shown, thus forming a little square. A fairly deep centre punch mark is formed in the centre of the square.

Four screw holes are now drilled $^1/_8$ in size and these are formed at a radius of 1 in and roughly equidistant from each other. In this way they will occupy the part of the wheel which will be cut away during crossing out.

The blank is now held against the wooden face plate while the tailstock centre is brought up to engage the centre punch mark in the middle.

With the tailstock locked to the lathe bed, a pointed tool such as a bradawl is put through the $^1/_8$ in holes to form a start for the wood screws.

FIG 48 CUTTER HOLDER AND MANDREL FOR SLITTING SAW — IN MILD STEEL



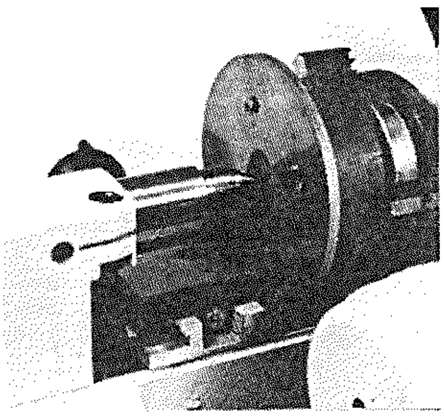


Fig 52 Using the lathe tailstock centre to locate the wheel blank while the wood screws are inserted

Fig 53 Machining the outside diameter of the blank to size

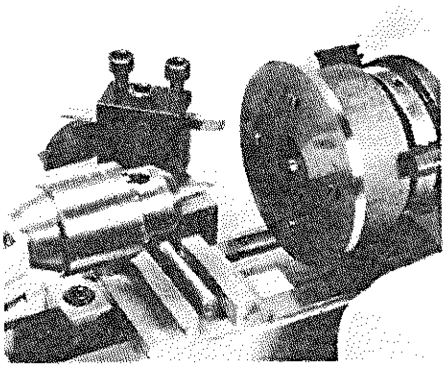


Fig 49 Carrying out a facing cut on the wooden faceplate

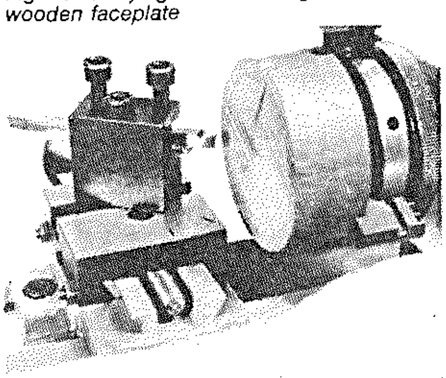
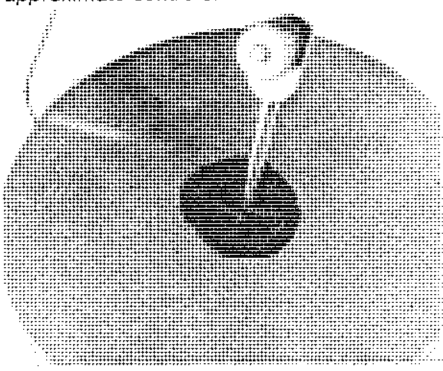


Fig 51 Using the odd-leg calipers to find the approximate centre of the blank



These can be ½ in x No 2 size and it will be found that a long handled screw-driver is convenient for inserting them. This operation is depicted in fig 52.

It may be found that when the screws are tightened the blank is pulled slightly off centre. This doesn't matter as there is sufficient metal in the diameter to allow for this.

Fig 53 demonstrates the machining of the outside of the blank.

Turning speeds

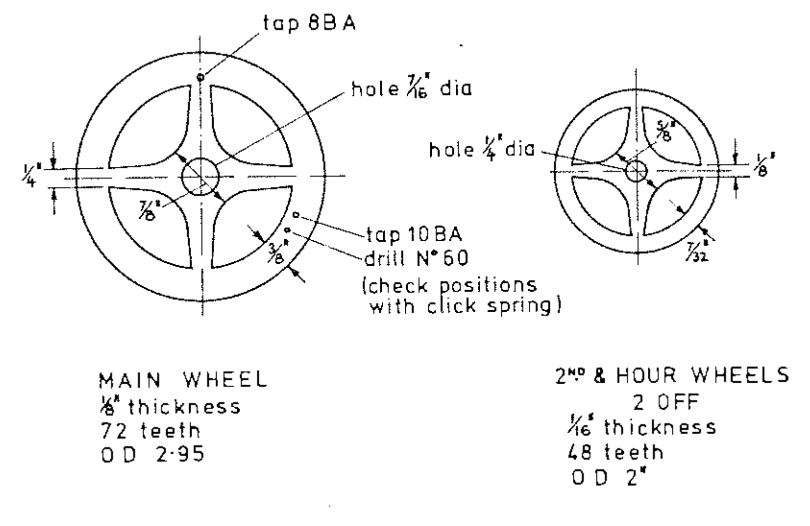
In the instruction book with the lathe a table of turning speeds is given for various diameters and in different materials. The beginner might imagine that he should have a calculator on the bench in order to compute each turning operation. This is not so and such instructions may be regarded as a guide. I found that with the belts fitted for the slowest speed and the motor used in the fast running position (ie 200 r/min), this provided a speed that was satisfactory for nearly all the turning in the construction of this clock. Certain operations such as grinding need the maximum speed and in wheelcutting the fly cutter also requires this.

If when turning this blank for instance you experience chatter or a squeaking noise, reduce the depth of cut and if you are still in trouble, reduce the motor speed. If this doesn't cure it check the play in your lathe slides and finally if all is in good order then you probably have too large a radius on the tip of the general purpose tool thus presenting too big a contact area with the work.

Boring the centre hole

As in all boring operations, the hole must be initiated with a drill proceeded by the centre drill as shown in fig 53. Be very careful when starting the centre drill especially if the centre punch mark has been pulled off centre by the wood screws. The tailstock barrel should be retracted as much as

FIG 50 WHEELS — ALL N° 1 MODULE IN "COMPO" BRASS



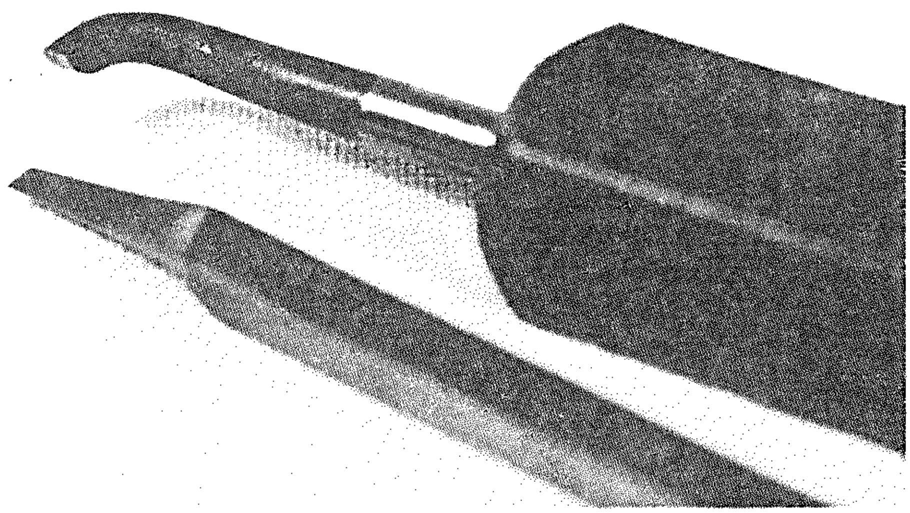


Fig 54 Two types of boring tools

possible to give the minimum extension. Drilling can follow with ascending sizes of drills in increments of 1/32 in up to 5/16 in, the maximum capacity of the tailstock chuck. There should be no difficulty in the drilling if the rake angles on the drills have been negated in the manner previously explained.

The hole should now be enlarged with a boring tool. Two of these are illustrated in fig 54. The near one is for truing small holes of about 1/8 in diameter and is ground from 1/8 square tool steel. The other tool is a commercial boring bar in a holder and very suitable for this type of work. It is shown in action in fig 55. It must be set to lathe centre height like any other lathe tool and when used on brass the top should be horizontal. This is achieved by a combination of twisting in the holder and packing underneath.

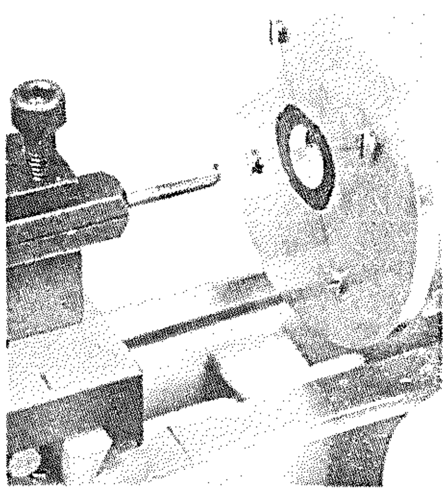


Fig 55 Boring the centre hole of the wheel

After what must appear a rather long protracted procedure we are now ready to cut a wheel.

The beginner must appreciate that preparations of this nature are normal practice in lathe work. However one soon accumulates a great variety of special jigs and fittings which can be used or adapted for other purposes.

Wheelcutting, Cutting the second and hour wheels, Marking out the wheel crossings, The crossing template, Filing the addendum curves

Chapter 5

Wheelcutting

WE are now ready to cut the main wheel which is a comparatively quick and simple operation. As is so often the case, it is the preparation which takes the time.

The Unimat should be set up as shown in fig 42. The first step is to fit the cutter in its holder and grip the latter in the drill chuck. One advantage of fly cutters is that it is not vital to rotate them truly as would be the case with the multitooth type of cutter. The fine feed attachment must be fitted, and using this, the cutter is adjusted to lathe centre height as depicted in fig 56. The belts should be set for the fastest speed and we are ready to go.

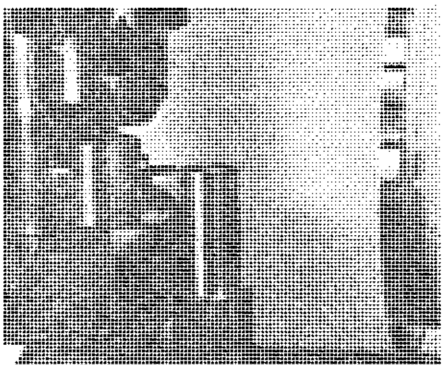


Fig 56 Setting the cutter to lathe centre height with the home made height gauge

Constructors may have noticed that the Unimat division plates are engraved on the front with angle markings in increments of five degrees. As there are therefore 72 markings, why cannot we use these instead of the holes in the plate or in conjunction with them?

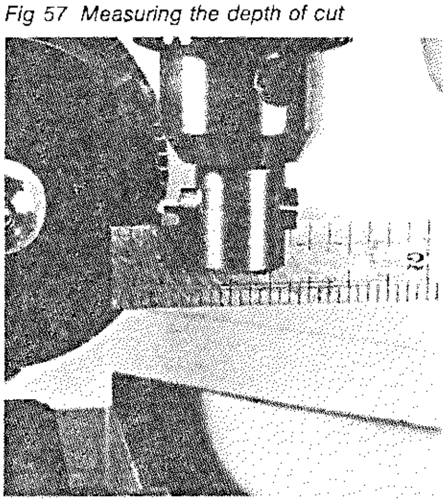
I did in fact try this and it is a workable proposition, but did not produce such an accurate wheel as the method of going round twice.

What I did was to index with the spring plunger every second tooth and use the angle marking for the alternate teeth, but it is very difficult to set this accurately even using an eye glass. The matter was aggravated by the fact that on my plate the engraved markings did not quite match up with the holes on the other side of the plate, so I had to make a slight allowance for this on each alternative tooth.

Rigidity is of vital importance on a small lathe especially in the case of wheelcutting. When setting the position of the milling attachment on the vertical column, position it as low as possible. *Don't* place it high up then use the feed lever to bring the cutter down to centre height. When the cutter has been set to the correct height, lock the fine feed position so that it cannot move under vibration. Partially tighten the carriage locking screw so that the movement of this component is stiffer than normal. When the depth of cut has been established, lock the cross slide clamping screw so that it cannot move.

As I mentioned in Part 4, the length of wheel teeth is not critical and the cutter here may be fed in to a depth of $^1/_8$ in. Figure 57 shows how the depth of the cut can be measured, using the steel rule. The cutter should take this cut in one pass quite comfortably and the general sequence of operations is as follows.

Fig 57 Measuring the depth of cut



Set the indexing plunger in the hole in the dividing plate, start the motor, traverse the cutter through the blank, stop the motor, traverse the cutter back again to the front side of the blank, pull the spring loaded indexing plunger back and move the blank round one position, start the motor and repeat the operation 36 times! The appearance of the wheel should be as in fig 58, where you can see the segments of the uncut wheel are some ¼ in in length.

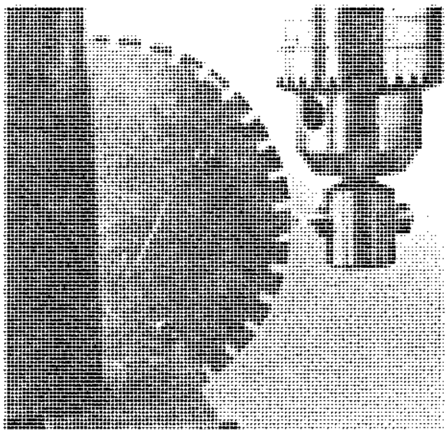


Fig 58 Setting the cutter for the second series of 36 cuts

With the indexing plunger engaged in one of the holes in the division plate, slacken the chuck jaws slightly and move the wooden faceplate round the equivalent of half a tooth space. This can be done reasonably accurately by positioning the face of the cutter close to the wheel blank and making a critical observation. Tighten the chuck jaws, retract the cutter well away from the wheel blank, start the

motor and bring up the cutter until you hear it just making contact with the wheel. Stop and examine the "nick" the cutter has just made. If it is not central between two teeth previously cut make the correction with the *vertical fine feed adjustment*. You will find that you can do this extremely accurately. Don't worry if you have several attempts at this operation, remember that the tips of the teeth will all be filed afterwards and your "trial and error" marks (providing they are only on the edge of the blank) will all be eliminated.

When satisfied with the new position for the second set of 36 teeth, lock or tighten all unused slides etc, and go round for the second time. This is the position in fig 59 where I am nearing the end of the work.

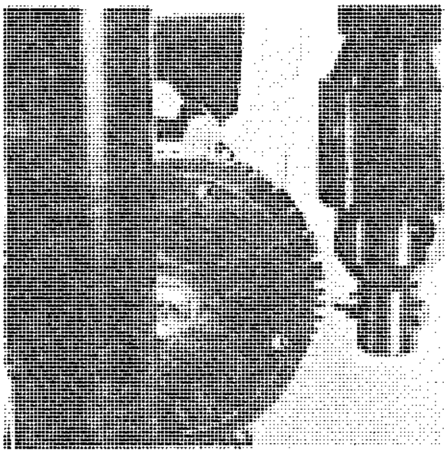


Fig 59 Nearing completion of the second series of cuts

Remember to switch the motor off when bringing the cutter back to the starting position each time. Do not traverse it back through the blank while rotating. Apart fom anything else the Unimat motor is not continuously rated and likes frequent rests.

Cutting the second and hour wheels

The procedure is the same as for the main wheel only we use the 24 hole division plate and go round twice so obtaining 48 teeth.

As the two wheels are identical they may be cut together.

They could be attached to a wooden faceplate in the same manner as the main wheel, but in this size it is, I think, more convenient to secure them with a ¼ in BSF screw through the centre of the wooden face plate. In this case the wooden faceplate, which should be reduced in size now to about 1½ in diameter, is drilled from the tailstock with care to $^{7}/_{32}$ in size and finally brought to size with the

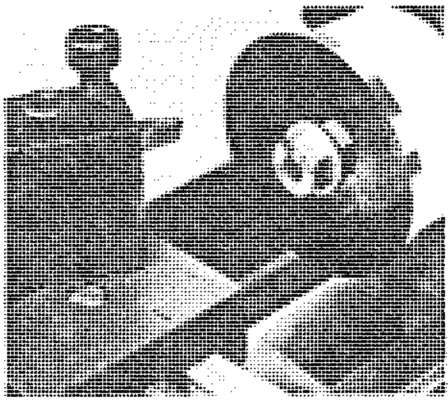
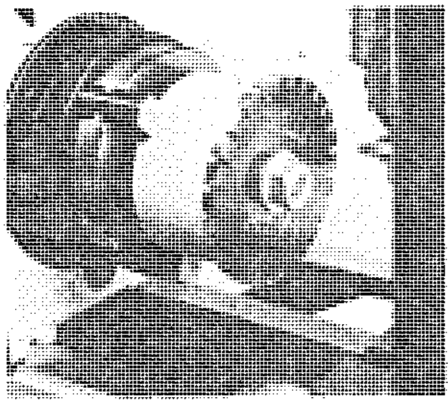


Fig 60 Turning the blanks to size for the second and hour wheels

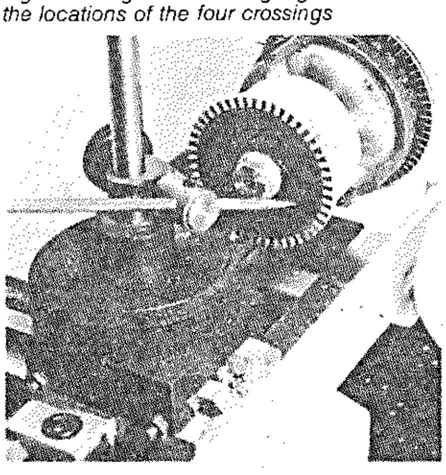
Fig 61 Showing the appearance after the first series of 24 cuts



boring tool previously shown in Part 4. This will ensure a true hole. Figure 60 illustrates the two blanks being turned on their outside diameters. And in fig 61 you can see that the first 24 cuts have just been completed.

I do hope that I have been able to dispel some of the difficulties which the constructor may have imagined to exist in cutting clock wheels. I know that we have not completed the operation yet, but the hardest part is done. There really is nothing very difficult in it and you will have the enormous satisfaction of having made the "heart" of the clock mechanism. In fact more than that, because you have made the actual cutter with which to carry out this work.

Fig 62 Using the surface gauge to mark out the locations of the four crossings



Marking out the wheel crossings

When a wheel is set up for cutting, it is a convenient time to mark some of the guide lines for the wheel crossings.

These wheels have four crossings or spokes and in fig 62 I show the surface gauge positioned on the cross slide. It has already been set to lathe centre height with the assistance of our little gauge. A horizontal line is *lightly* marked on each side of the wheel which can then be rotated 90° using the indexing arrangement for marking the other two lines.

I should perhaps mention that all dimension lines should be marked very lightly as it is quite surprising how deep a scriber will go if used under pressure. When you come to finish the work it is most annoying to find that you have perhaps obtained a nice grained or polished surface which is marred by scribed lines. These will involve a lot of hard work with the cork block and wet and dry paper to remove.

We have now finished with the dividing attachment for the moment and the chuck can be unscrewed and repositioued on the headstock spindle for marking the circular lines which indicate the termination of the crossings.

Some constructors like to do this with a keen vee-pointed tool in the tool post thus forming positive engraved lines. If you do this you are committed! It means that you must work to these lines because the delineation is so definite it cannot be ignored. I prefer to use a lightly scribed line which can be disregarded in the event of an error in the sawing or filing at the later stage.

The radii of these lines is shown on the drawing of the wheels (fig 50). A satisfactory way to mark them is to measure the distance using a rule and make a pencil mark which should show clearly when the wheel is rotated in the chuck. Then taking the scriber and resting the hand on the cross slide, let the scriber point make contact with the rotating wheel at such an angle that it trails against the wheel. It is only necessary to just touch the wheel for the briefest period in order to produce a circular line.

The crossing template

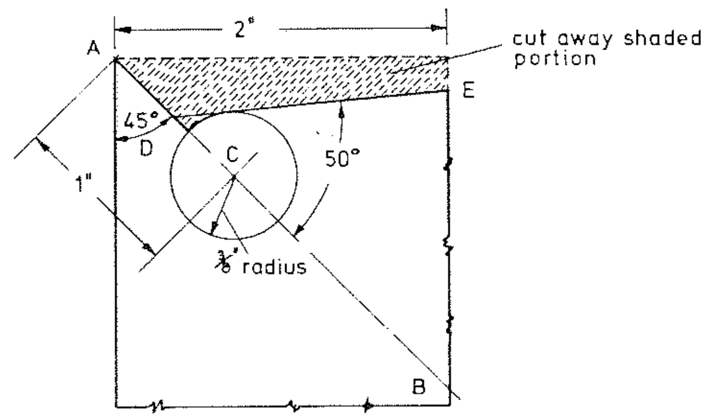
A crossing template, which I designed years ago, is a valuable means of marking wheel crossings in the traditional design.

It is dimensioned on drawing fig 63 and can be made from almost any thin stiff material even a postcard for those who require it only for this one clock.

In this case take the card and bisect one corner with with the line AB. Mark the point C 1 in distance from A. With centre C draw a circle $^3/_8$ in radius. Draw the angle BDE of 50° making the line DE tangential to the circle whose centre is C. Cut away the shaded portion.

Figure 64 demonstrates the template in use. It is positioned so that the portion of the line AB passes through the centre of the wheel; the remainder of the positioning will be obvious from the picture. The template is turned over to draw the other half of the crossings.

FIG 63 A TEMPLATE FOR DRAWING WHEEL CROSSINGS, FROM THIN SHIMSTOCK OR A POSTCARD



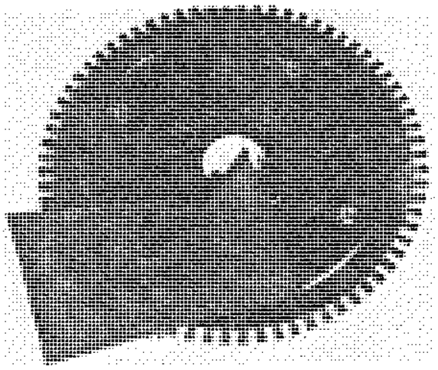


Fig 64 The crossing template in use

Filing the addendum curves

I hope that in Chapter 4 I was able to convince the reader that in this class of clockwork the addendum curve on the wheel teeth is not critical especially when lantern pinions are employed. You can see that in the drawing I show this curve to be ogival in form, like a Gothic arch.

In fig 65 I show an enlarged view of a wheel in which some of the teeth have been filed to shape. I think you can discern the irregularities in the addendum curves quite clearly. If not then you must take my word that they are there. At a later stage when the lantern pinions have been made and we mesh the wheels and pinions in a testing jig you will be able to examine the action with an eyeglass and observe what a small part the addendum curve plays in the transmission of the power.

Figure 66 demonstrates the work of filing in progress. The file in use here is a barrette or ridge back file of No 4 cut[7]. This is one of the few needle files which comes with safe edges on the two ridged surfaces. It is designed so that these may be ground to produce a sharp junction with the cutting face for getting into tight corners. In this case it is used in its normal state but the plain smooth ridges prevent the file cutting where it is not wanted. Needless to say a half round file could be adapted to give a similar action by removing the cut on the curved back.

In use, literally only three or four strokes of the file are required on each side of the tooth. Concentrate on keeping the file at right angles to the face of the wheel.

In Chapter 6 we shall cut the crown wheel and then all the wheels may be crossed out.

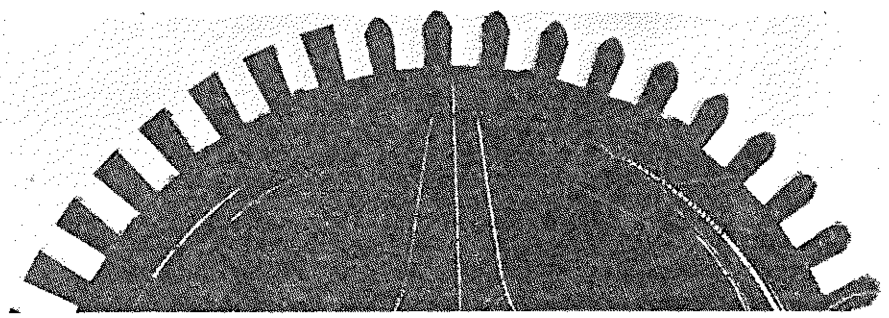
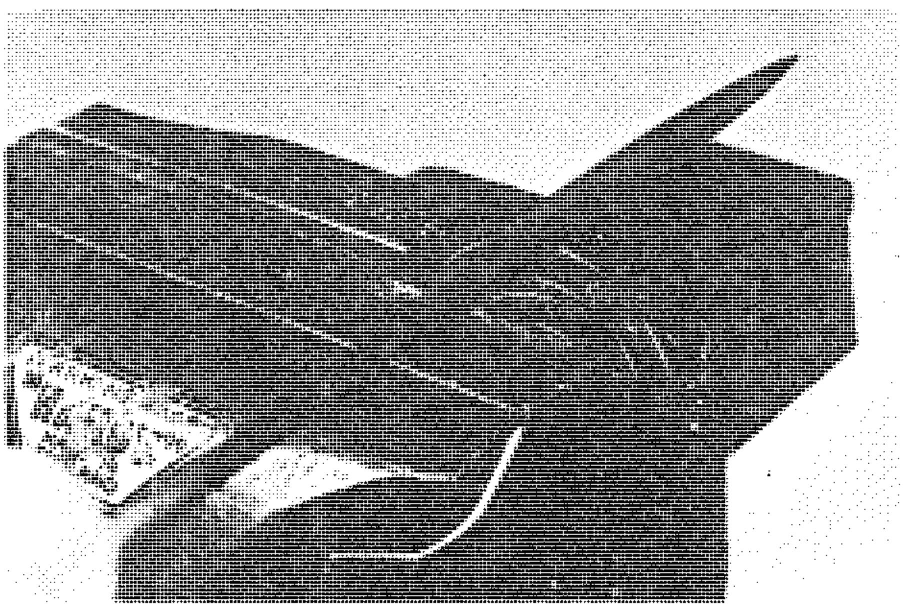


Fig 65 Showing the appearance of the wheel teeth after filing the addendum curve by hand

Fig 66 Using a barrette file for the purpose of forming the wheel teeth



The crown wheel, Forming the undercut tooth face, The slitting saw, Crossing out, Filing the crossings, Burnishing the crossings

Chapter 6

The crown wheel

IN escape wheels we are really concerned with the leading face of the tooth, the rear profile is designed only to produce a well proportioned tooth and, a space that will give clearance for the action of the pallets. It is usual to remove the metal in the tooth space with a form tool. However this results in a rather heavy cut with this type of tooth shape which is undesirable on a small lathe. I have chosen an alternative method of making the wheel in which a circular slitting saw is used to form the front undercut face of the tooth, while the back curved surface which is not critical is formed with the use of the piercing saw and filing. In this manner we use the Unimat in order to obtain the accurate spacing of the 20 teeth and for forming the angled acting faces. We do the unimportant part of the work by hand.

FIG 67 THE CROWN WHEEL

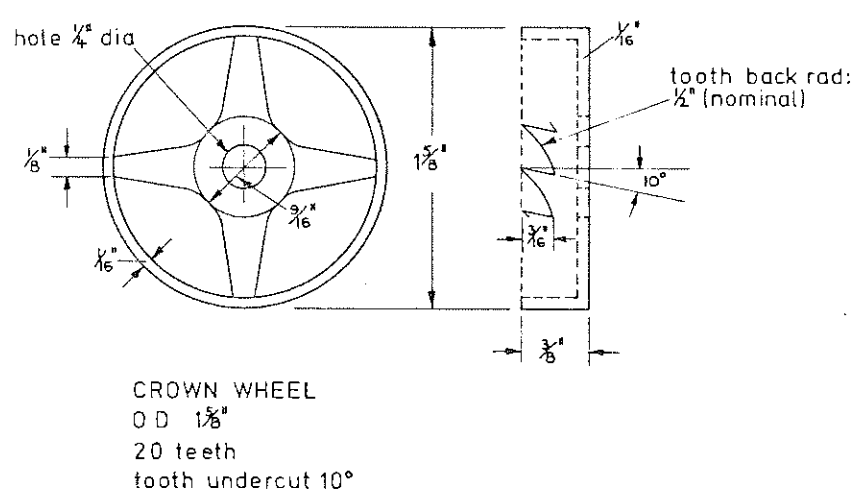


Figure 67 shows the drawing of the wheel. We start with a $^7/_{16}$ in length of $1^5/_8$ in diameter round brass of the machining type. In Part 1 I specified the grades of brass to be used in the construction of this clock. It is most desirable that this advice is followed. I find that some constructors are tempted to pick up the odd piece of brass from a local scrap yard. It is both difficult and unpleasant to machine brass which is intended for riveting. There is a tendency for drills and small taps to jam and possibly break, and wheel-cutting is especially laborious when using soft brass. There is really no point in making the work more difficult than it need be.

In fig 68 you can see how the stock is held in the 3-jaw chuck with the jaws reversed for large diameter work. After taking a facing cut to true the surface, the centre hole is drilled from the tailstock. If a reamer is available this should be used, drilling the hole to letter D size (or the equivalent metric size) prior to using the reamer. The advantages of the reamer are firstly that the hole will be accurately sized (at least more accurately than with the drill) and secondly the surface finish will be better than that obtained with the drill.

After the hole has been formed, the disc is recessed to a depth of $^5/_{16}$ in. I have a special toolholder designed to hold round cutter bits for this work and you can see this in fig 68. But the work can be done equally well using a right hand knife tool which has been ground with more than the usual side clearance. This is depicted in fig 69.

Fig 68 Starting the recessing of the crown wheel

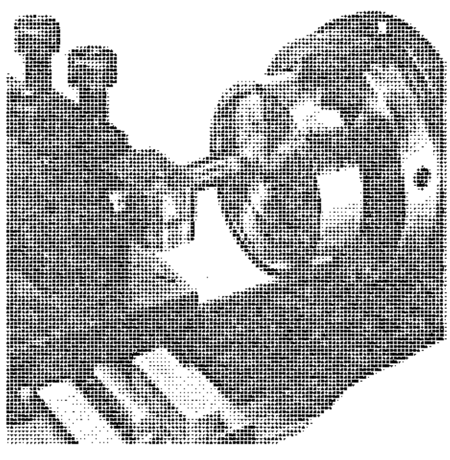
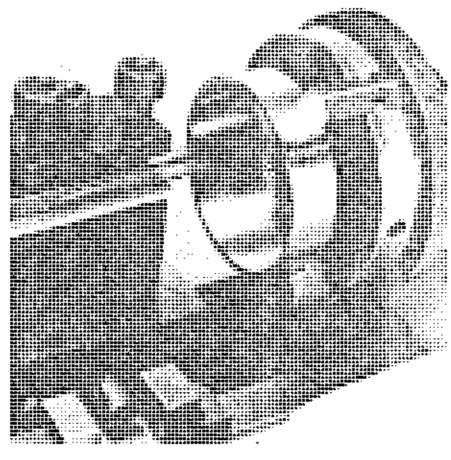


Fig 69 The completion of the first stage in the making of this wheel



Forming the undercut tooth face

As can be seen from the drawing the teeth are undercut 10°. The work is carried out on the Unimat by fitting the vertical milling attachment in its seating at the rear of the lathe bed and angling the head to 10°. The embryo wheel, still held in the 3-jaw chuck, is fitted to the dividing attachment with the 40 hole plate, and mounted on the cross slide.

The slitting saw

These can be obtained in a variety of thicknesses and are about 1 in in diameter[8]. They are mounted on a home-made mandrel as illustrated in fig 48 of Part 4. On several occasions in this serial I stress the advisability of undercutting shoulders where parts abut. But in the making of this saw mandrel you must be careful. When I made the mandrel shown here some years ago, I found that with the thin saws I couldn't saw straight, the cut kept veering off. The cause was too much undercut on the shoulder of the mandrel and the thin saws were flexed when clamped up tight; the thicker saws resisted this distortion. It is of course important that the corner of the shoulder is absolutely clean and a small undercut may be made at this point, but the main length of the shoulder should be machined straight. Figure 70 shows my saw and the thickness of the blade in this instance is 0.4 mm. The long pointed implement is the scriber of the surface gauge which is set at the centre height of the dividing head. Be careful here, this is not *lathe* centre height, as in this case the dividing head is mounted on the cross slide.

The feed is *not* applied with the carriage feed screw, but with the cross slide feed handle, traversing the wheel through the path of the saw blade so that the latter cuts its way through the rim of the wheel from the inside to the outside. Figure 71 shows the work in progress and you see the saw here after the completion of a cut. Don't forget you index every *second* hole! The speed of the saw can be about 200 r/min. The depth of the cut is $^3/_{16}$ in. In the illustrations that follow, the depth of the teeth are ¼ in but this is unnecessarily deep, $^3/_{16}$ in is more than adequate. Remember, you cannot alter the depth very easily once you have started because of the angle of the saw blade. The carriage must be locked during the work. You will find that the saw goes through the rim of the wheel very easily.

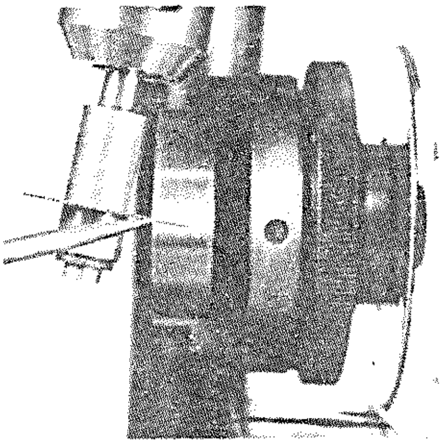


Fig 70 Centring the slitting saw for forming the crown wheel teeth

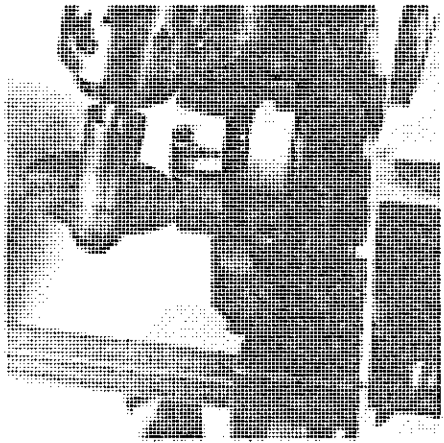


Fig 71 Forming the 20 angled saw cuts in the Unimat

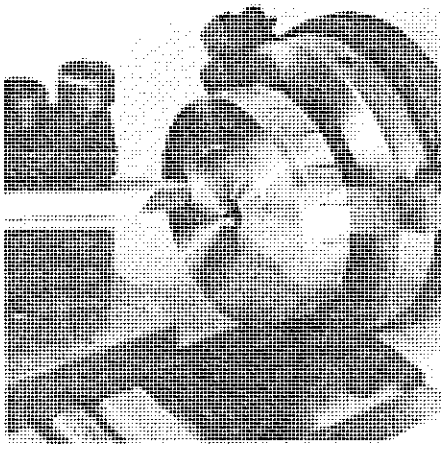


Fig 72 Facing the back of the wheel to size

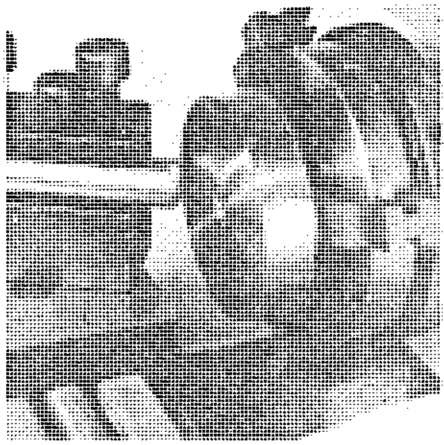


Fig 73 Using a "truing tool" to set the wheel true (see text)

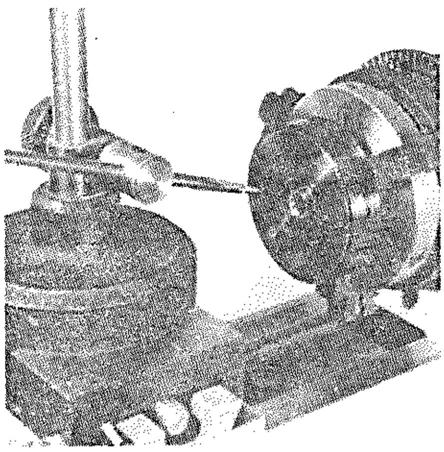


Fig 74 Marking the crown wheel for the crossing template

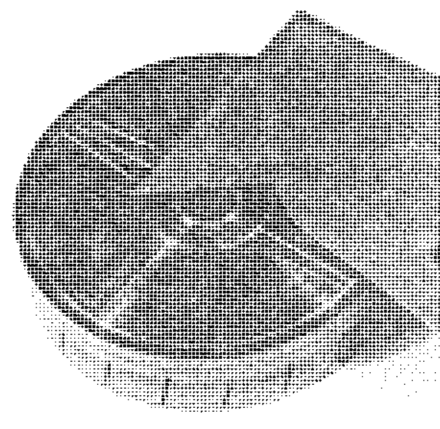


Fig 75 The crossing template in use. The layout blue gives prominence to the lines

The next step is to set the Unimat for turning, and hold the wheel as demonstrated in fig 72. Do not overtighten the jaws in this set-up. The back of the wheel is now reduced in thickness by a series of facing cuts until this realises $^1/_{16}$ in.

It will be desirable to clean up the peripheral surface of the wheel even if you do not actually machine it. In order to obtain complete access to the area, the wheel must be pulled away from the chuck jaws for a short distance, say $^1/_{16}$ in. The problem then is to make it run truly. Figure 73 illustrates a round ended or chamfered steel rod in the tool post. The wheel is held loosely in the chuck (tight enough of course so that it doesn't come out) and the rod is brought up to the edge of the work while it rotates and this will make it run true. Tighten the chuck jaws in moderation again and you can either machine the edge of the wheel or clean it up with emery sticks, 0 grade followed by 00 and 000. Although emery sticks are graded by numbers, this means very

little as it depends how much they have been used. The 00 and 000 are best when they have been well worn.

The crossings are marked out as demonstrated in fig 74 and with the template in fig 75 (*see previous page*).

I mentioned before that the curve to the back of the teeth is not critical, it is simply a clearance curve. In fig 76 you can see how I used a two pence coin as a template in order to draw these. Make sure you draw them in the correct direction.

The waste metal is removed with the piercing saw and a 2/0 blade will be found about right. Note how the wheel is held in the vice using a short length of a wine bottle cork in order not to damage the points of the teeth. Figure 77 depicts this, and the saw must be used at a slight angle in order not to touch the lower half of the wheel.

Filing of the tooth backs is done either with a small crossing file or half round needle file. The tips of the teeth are not brought to a sharp point but a slight witness of the original surface should just be visible. Figure 78 shows how I held my wheel on the sawing board. It is secured with a screw through the board and wheel centre. You can slacken off the screw and rotate the wheel as the work proceeds. In order to form a sharp clean root to the tooth you will require a half round needle file with the flat face made safe. This latter surface can be run along the undercut front face of the tooth without risk of cutting it and this will enable you to form a clean root.

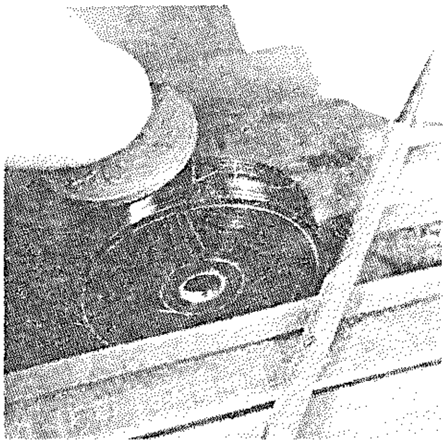


Fig 76 Using a 2p piece as a template for marking out the curved backs to the teeth

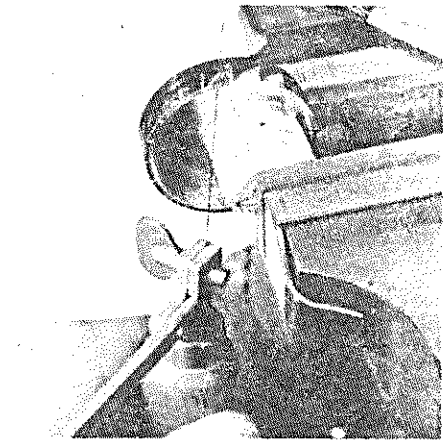


Fig 77 Method of holding for cutting out the waste metal with the piercing saw

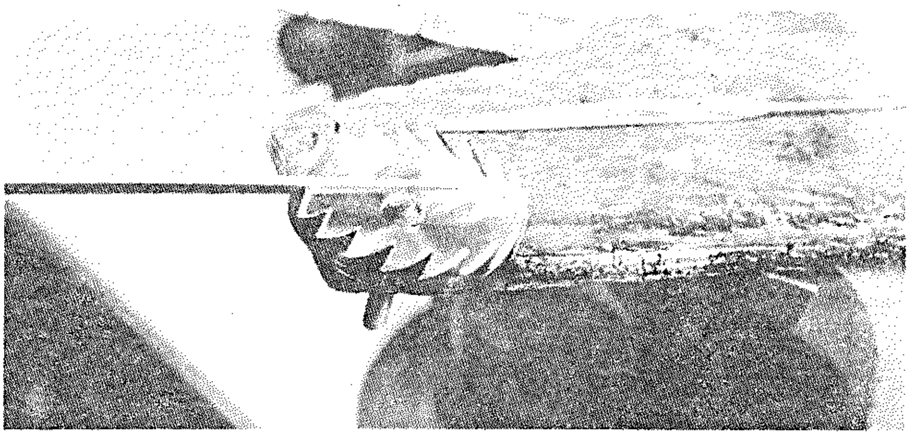


Fig 78 Method of securing the crown wheel while filing the backs of the teeth

Crossing out

Crossing out, along with wheelcutting is another part of clockmaking over which many people have difficulty. It is largely a matter of practice. An experienced operator will cut out and file up a wheel in less than 15 minutes, but the beginner may take two hours. Don't let this worry you, it is largely a matter of confidence in the use of the piercing saw and being able to saw close to the line leaving the minimum of metal to remove by filing.

Figures 79 and 80 show the piercing saw in use on the main and second wheels respectively. The thicker of the two suggested blades is used on the main wheel. The segments which have been removed in the process are also shown. A brush should be used for brushing away the swarf which obliterates the line if allowed to build up. The thinner wheel is perhaps the easiest to start on. If you find that there is a distinct tendency for the cut to veer off to one side, examine the blade carefully and check that the axis of the teeth is in the same plain as that of the clamping sections at the end. This is sometimes a fault in manufacture.

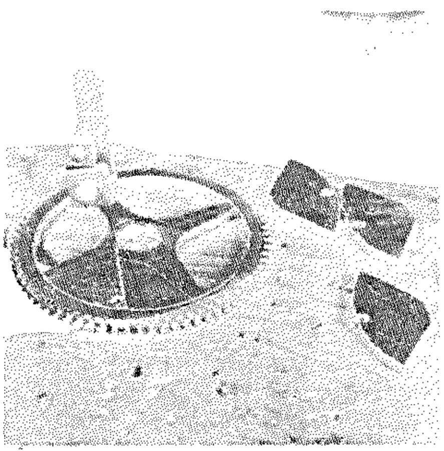


Fig 79 Crossing out the main wheel with the piercing saw

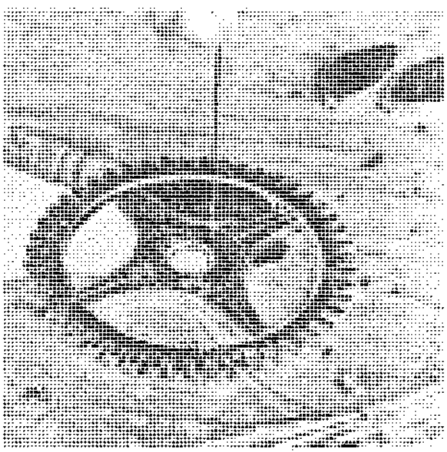


Fig 80 One of the 48 toothed wheels being crossed out

Filing the crossings

Figure 81 illustrates a selection of crossing files [9]. They are all equipped with a different radius of curve on each side. Ideally, one requires the four sizes shown here and in two different cuts, say, No 2 and No 4. Reading from the left, the sizes are 6 in, 4 in, 3 in, and needle. In the size of wheels we are making here the 6 in file is essential. The ordinary half round engineering file has too small a radius to the curve for use in crossing out.

I find that it is best to place the wheel flat on the sawing board over the vee notch and use the file vertically in the manner demonstrated in fig 82, only of course the wheel would be held with the other hand. In this way the peripheral curve and that of

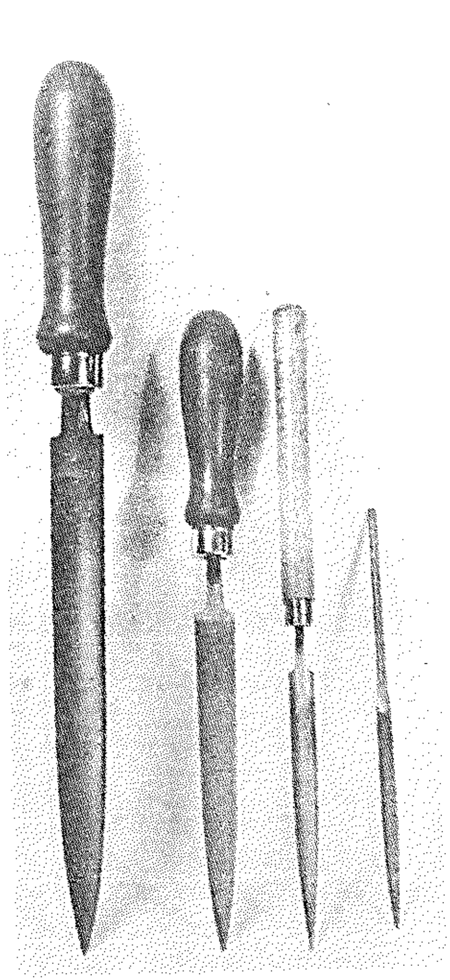
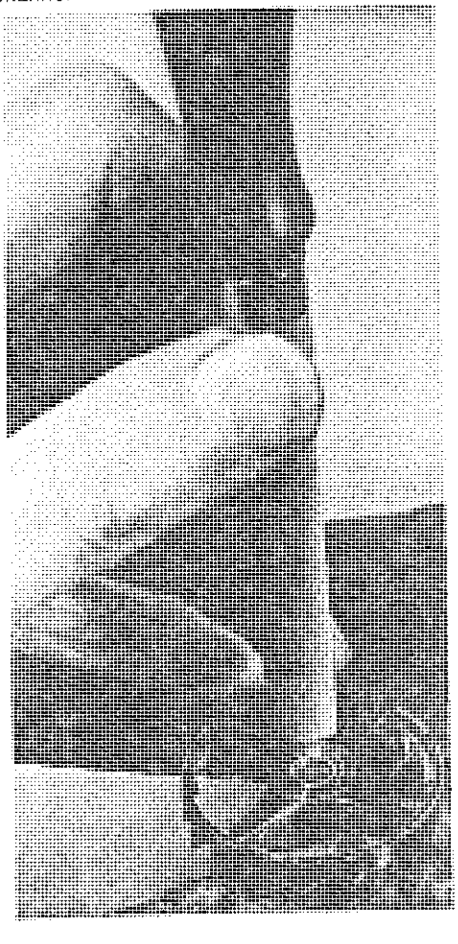


Fig 81 A selection of crossing files

Fig 82 Using the crossing file in a vertical manner



the inside of the crossings can be filed to the line and that will leave the straight tapered parts of the arms. It will probably be found convenient to file these with the flat face of a half round needle file and with the wheel on edge in a small vice as shown in fig 83. (Note the use of a cork to prevent damage to the wheel teeth).

Neither of these files will produce a sharp corner at the junction of the arms with the rim. To do this a file with a safe edge is required, and my favourite for this work is a half round needle file with the flat surface made safe. It is shown in use in fig 83. In this particular illustration it will be moved forward with side pressure towards the rim and at the end of the stroke it is lifted upwards still in contact with the rim. It is difficult to describe the action verbally but I think you will appreciate the method with a little experimentation.

Finally, I show three wheels in fig 84, to illustrate the result of crossing out and the clean sharp corners. The centre wheel is not finished. The peripheral curves and the inside radii of the crossings have been treated with the crossing file but the arms have yet to be done.

Burnishing the crossings

There comes a time during filing the crossings when it is best to clean the layout blue from the surface of the wheels, obliterate all the marking lines and finish the work by eye. It is almost certain that you will find for instance that you may have a good corner on the front face of the wheel but the opposite side is not so good.

Figure 85 illustrates the basic materials I use for cleaning and polishing flat surfaces. In this picture you can see a 2 in x 2 in balsa block, cork blocks and various grades of emery papers which can be wrapped around these. The advantage of using soft materials in this role is that they yield

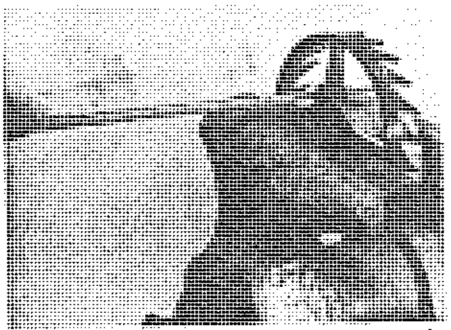


Fig 83 Forming a sharp corner with a safe edged half round needle file

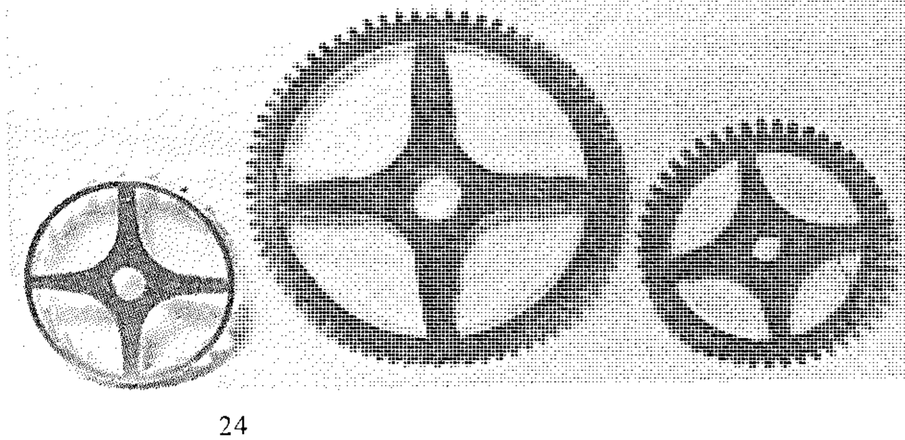
sufficiently to account for the small inaccuracies in flatness which are usually present with flat brass plate.

Initially, the surface blemishes, scriber marks, etc, can be erased using wet and dry paper of 220 grit used wet. This will leave a grained appearance. The wheels should be critically examined and minor corrections in the corners or to the shape of the curves will almost certainly be required. When satisfied that the shape "looks right" all the internal surfaces of the crossings should be drawfiled using a No 4 cut file. Start the file right in the corners and pull it out. The action of drawfiling will give a grain which is lengthwise instead of across the wheel as before.

We are now ready to burnish the crossings. Oval burnishers are available[10] especially for this work but a steel knitting needle works quite well, although the area of surface contact is a little small. A steel sewing needle cemented into a piece of dowelling is useful for getting into the corners. In practice the wheel is held in the vice and the burnishers are applied as in drawfiling with fairly heavy pressure. This should bring up the edges of the crossings to a mirror polish. It is much easier to burnish brass than steel.

The effect of burnishing will upset the metal forming a burr on the faces of the wheel. This is removed with grade 0 emery paper and the cork block. Once the crossings have been

Fig 84 The two outer wheels are finished but the arms of the centre wheel have yet to be filed



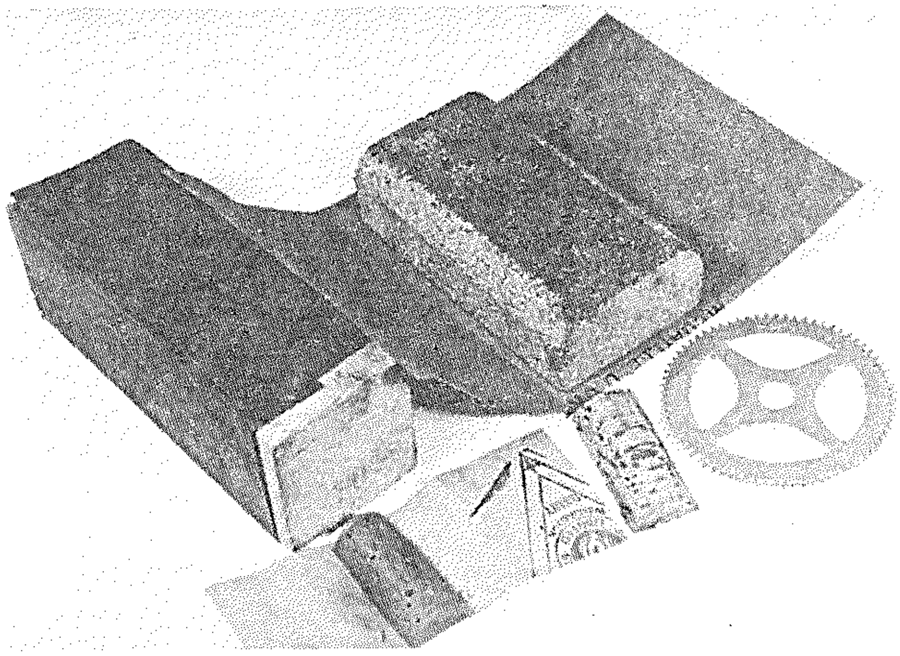


Fig 85 Materials for polishing flat brass surfaces

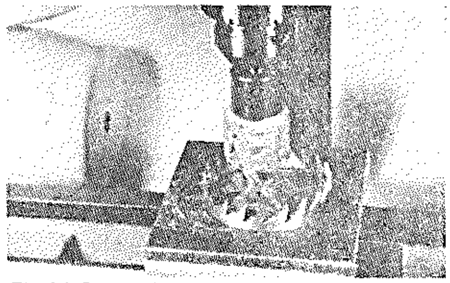


Fig 86 Set-up in the Unimat for polishing the inner face of a crown wheel

burnished satisfactorily the polishing of the wheels can continue with grade 00 emery paper and finally crocus paper [11]. It is important to critically examine the surface after the use of each grade of paper as the more polished the wheel becomes the more the surface scratches will show up.

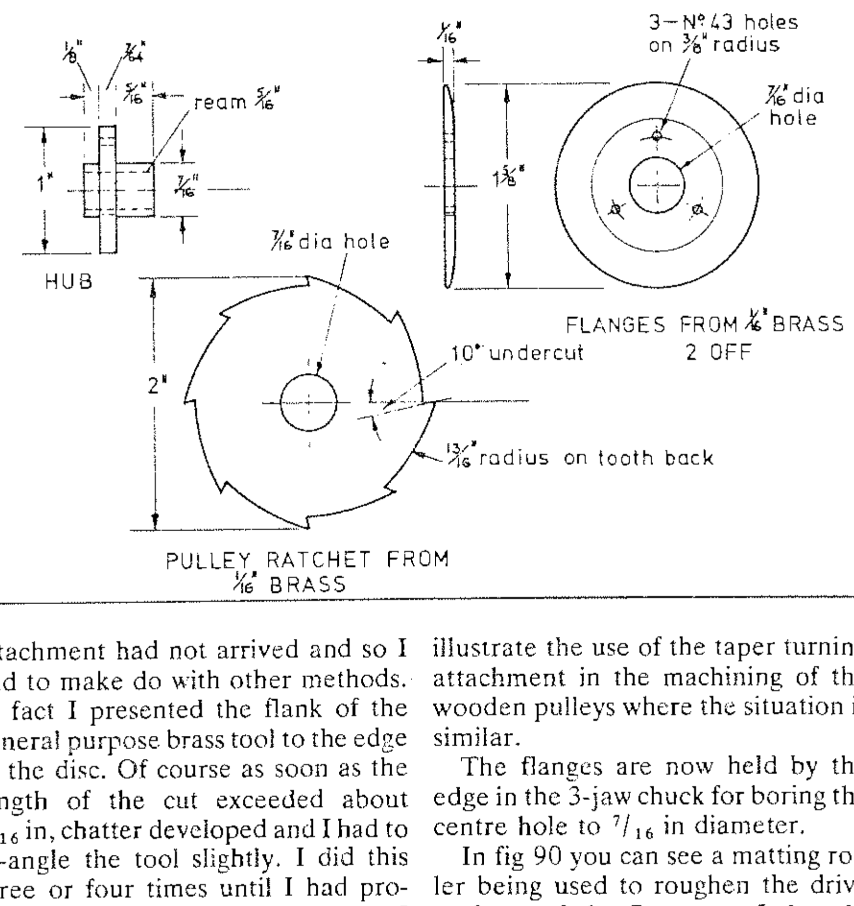
One area which is difficult to polish is the inside face of the crown wheel. Figure 86 demonstrates a procedure which is helpful in this situation. Here a section of cork is cemented to a suitable steel or brass holder and on the under face, emery paper is cemented in position. You can observe that the chuck board is placed on the lathe cross slide and the Unimat is set up as a drilling machine. The wheel is held firmly in the fingers and the lap brought down gently in contact with the wheel. The latter is moved in a circular motion until the turning marks are removed. The process is repeated with finer abrasive papers.

It will be apparent that the polishing of the wheels in the way described could not be carried out when they are colleted, so this is, in effect, the last opportunity to do this work.

The hub, Pulley flanges, Ratchet wheel, Main wheel collet, Lantern pinions, The pins or trundles, Methods of fitting in clockmaking

Chapter 7

FIG 87 DRIVE PULLEY COMPONENTS IN BRASS



The hub

THE hub is machined from a ¾ in length of 1 in diameter brass. It is held in the 3-jaw chuck using the jaws set for small diameter work. The $^5/_{16}$ in step is turned to $^7/_{16}$ in diameter, and the work reversed in the chuck holding it by the part just machined. The second side of the hub can now be turned to conform with the dimensions on drawing (fig 87). The pulley flanges will fit against the 1 in diameter part of the hub and it is important that there is a slight undercut on these faces. The centre hole is drilled from the tailstock in preparation for reaming $^5/_{16}$ in . The finishing drill should be either 7.9 or 7.8 mm. If the letter N drill is used this will leave too much metal for the reamer to remove. Figure 88 demonstrates the use of the reamer in the lathe. A slow speed is used and the lathe carrier provides a hand hold although a tap wrench would do equally well. The tailstock centre is located in the centre hole at the back end of the reamer and the two are held to make close contact with the left hand while the right hand advances the tailstock barrel with the feed screw.

Pulley flanges

These are formed from $^1/_{16}$ in blanks 1¾ in diameter. The jaws of the 3-jaw chuck must be reversed so that each blank can be held in turn for drilling a centre hole ¼ in diameter.

We now use the same wooden faceplate previously used for supporting the 48 toothed wheels in wheelcutting. The flanges are secured through their centre holes with a ¼ in BSF screw and nut. In this way the edges are free for machining the chamfer. Figure 89 shows the arrangement.

At this stage, my taper turning attachment had not arrived and so I had to make do with other methods. In fact I presented the flank of the general purpose brass tool to the edge of the disc. Of course as soon as the length of the cut exceeded about $^1/_{16}$ in, chatter developed and I had to re-angle the tool slightly. I did this three or four times until I had produced some sort of chamfer then I finished the work with the aid of a file.

Towards the end of this series, I illustrate the use of the taper turning attachment in the machining of the wooden pulleys where the situation is similar.

The flanges are now held by the edge in the 3-jaw chuck for boring the centre hole to $^7/_{16}$ in diameter.

In fig 90 you can see a matting roller being used to roughen the drive surfaces of the flanges as I thought this might be necessary to provide a grip for the line. In fact I am quite sure

Fig 88 Using a $^5/_{16}$ in reamer in the Unimat

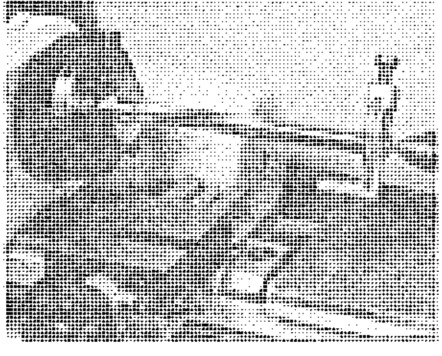
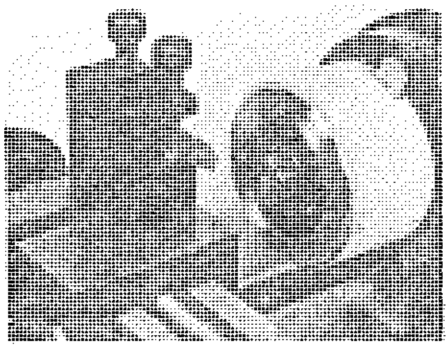


Fig 89 Method of holding the flanges for machining the chamfered edge



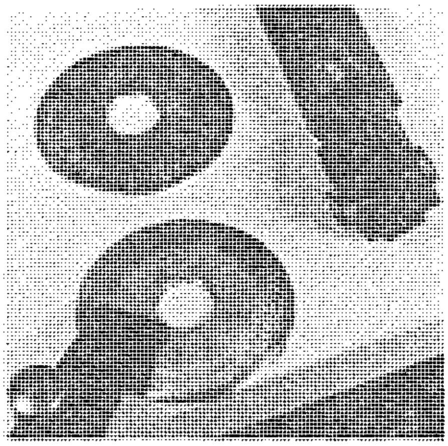


Fig 90 A matting roller can be used to roughen the drive surfaces of the pulley flanges; but this proved unnecessary

this procedure is not necessary as sufficient grip is provided by the wedging action.

Ratchet wheel

This is the last item which together with the two flanges and the hub make up the pulley assembly. The $2^{1}/_{8}$ in diameter blank is provided with a ¼ in diameter centre hole so that it can be mounted on the wooden face plate as in fig 89. Coat the surface with layout blue and it is easy to do this with the work rotating. A good applicator is a woolly pipecleaner; just dip it in the liquid and touch the rotating disc. With a hand held scriber, mark a circle $^{3}/_{32}$ in in from the edge. Remove the disc from the wooden faceplate and bore out the centre hole to $^{7}/_{16}$ in in the same manner as the flanges.

The teeth are cut by hand; they are in no way critical. Set a pair of dividers to 0.78 in and step round the edge, this will give you eight positions. With a rule, scribe a line from each of these positions tangential with the edge of the $^{7}/_{16}$ in centre hole. This will give you the faces of the 10° undercut teeth. The backs of the teeth are formed by placing one of the flanges on the ratchet wheel in the manner shown in fig 91 and using its edge as a template to draw the curvature.

The piercing saw is used to remove the bulk of the metal in the tooth space and then needle files are used to complete the work. Again, in order to obtain a sharp root to each tooth, a three square (triangular) needle file with a safe edge will be needed.

The assembly is held together either by three rivets or three 8 BA screws. I used the latter in case I had to alter the design. If screws are used, they pass through clearance holes in the flanges and hub, and are secured in tapped holes provided in the ratchet wheel.

In order to simulate rivet heads, I have used round head screws through-out the construction.

Although it is not vital that the three holes should be equidistant in this part of the work, it is easy to make them so on the Unimat and I suggest the following procedure.

Set the Unimat up as a drilling machine and put the dividing head on the cross slide facing upwards, fit the 3-jaw chuck on it with the 24 hole plate and hold one of the flanges as demonstrated in fig 92. Hold a small centre punch in the drill chuck and adjust the cross slide so that the centre punch contacts the flange at $^{3}/_{8}$ in radius. You can see how the measurement is achieved in this illustration. *Lightly* mark the flange using the feed lever of the drilling attachment, move the chuck round eight divisions on the 24 hole plate and repeat the operation twice. Now remove the flange from the lathe, enlarge the centre punch marks and assemble the pulley components holding them

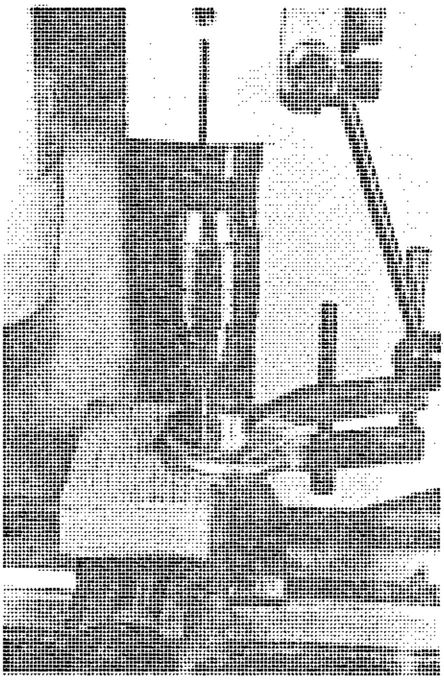


Fig 93 Drilling in the Unimat

together with the toolmakers clamps, as shown in fig 93, which also illustrates the drilling of the first hole. For 8 BA size, drill right through with the No 50 drill. Separate the components and enlarge the holes in the flanges and hub to No 43 size. Tap the hole in the ratchet 8BA and re-assemble the components with one 8BA screw. The other two hole positions may now be drilled with the No 50 drill right through all four components and after dismantling again, the clearance holes are formed with the No 43 drill as before, and the two holes in the ratchet tapped 8 BA.

Whenever mating parts are secured with screws the holes should be lightly chamfered, especially the tapped holes as in this process a burr will be thrown up by the tap. Two types of chamfering tools are depicted in fig 94.

Fig 91 How a pulley flange may be used as a template to mark out the back curve on the ratchet teeth

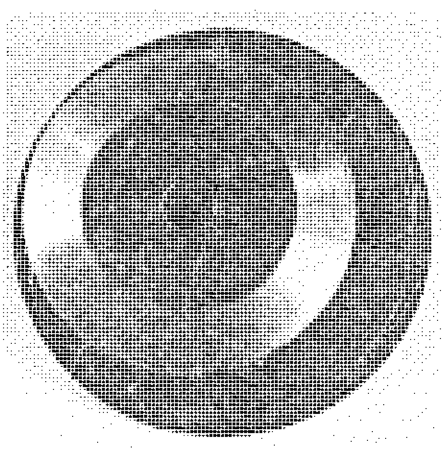


Fig 92 Setting the radius for three equidistant holes required in the components forming the pulley assembly

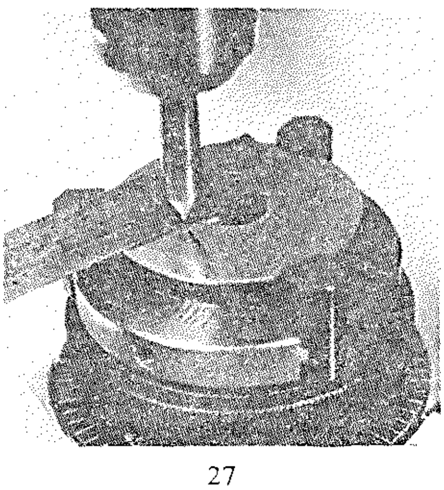
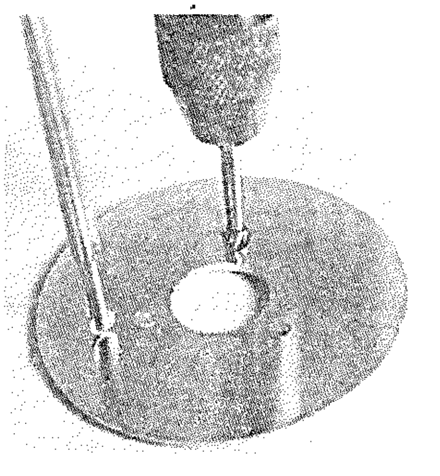


Fig 94 Two types of chamfering tools used primarily in horological work for forming oil sinks



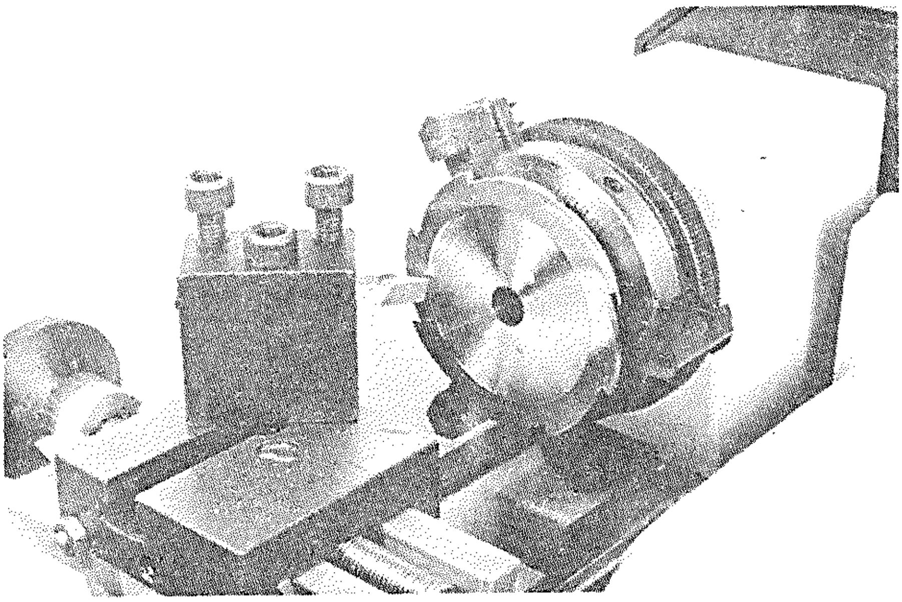


Fig 95 Machining the relief in the centre of the ratchet

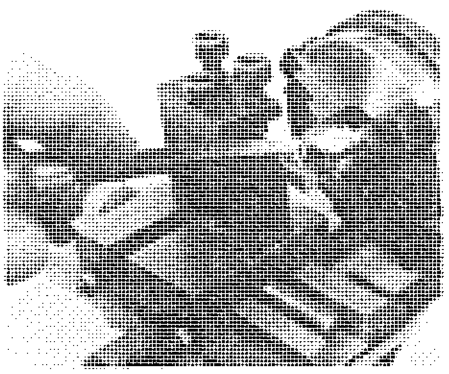


Fig 96a Using the side of the graver for turning a convex shape

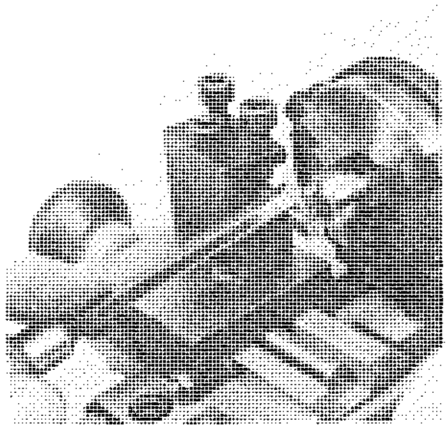


Fig 96b Using the oblique face of the graver for the same operation

If the shoulders of the pulley flanges were undercut and the holes all chamfered, the four components should fit snugly together. *Steel* screws are always used in clockmaking and these can now be tightened up for the final machining operation which is illustrated in fig 95 where the assembly is held by the pulley flanges for forming a shallow recess in the face of the ratchet in order to provide a relief at the centre. The depth of this recess need only be 0.005 in. The machining will at the same time face off the ends of the screws.

Main wheel collet

The main wheel collet is shown on drawing fig 96, and is turned from 5/8 in diameter brass rod. Cut off a length of about 5/8 in, grip it in the 3-jaw chuck and turn the 7/16 in diameter for a distance of at least ¼ in. The collet which is a permanent fixture in the wheel can either be secured with Loctite or made a press fit assisted by light riveting if required. In the latter case it will help in the fitting if a slight taper is formed with a fine file on the wheel seating of the collet. The centre hole is now drilled and reamed 5/16 in and the work reversed in the chuck for facing the back of the collet and forming the curved shoulder with the graver.

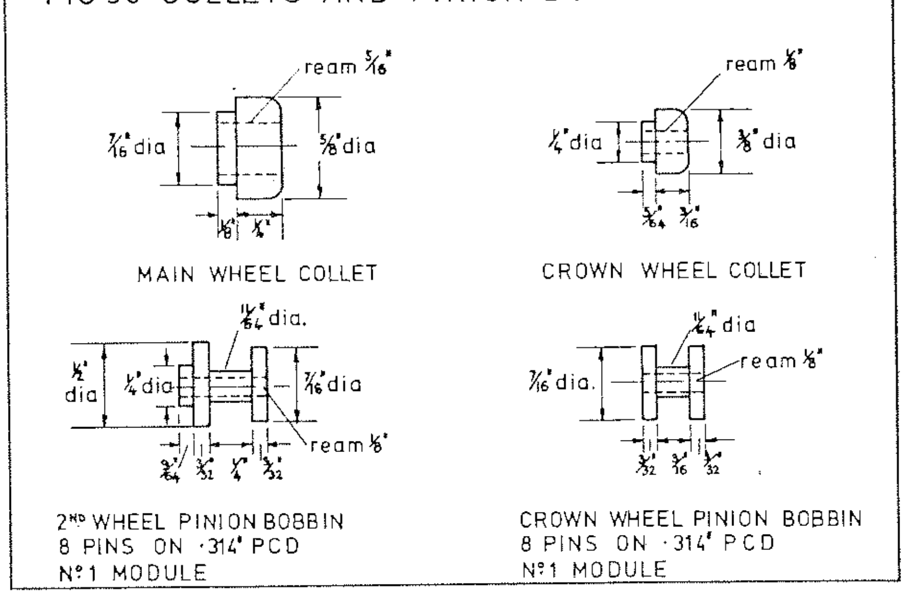
The graver for this kind of work requires to be 3/16 in square and the end is ground obliquely. Like the brass turning tool, it is not enough just to grind the shape, it must be honed on the oblique face and the two side faces. The finish on the work will depend on the polish that is present on the cutting faces of the graver.

The hand turning rest I used is simply a short length of 3/16 in square mild steel held in the tool post, the upper corners are rounded off with a file and it is positioned close to the work. The height of the rest is not so important as might be thought as it is the angle at which the upper surface of the graver makes with the work which matters. This should be a zero or negative rake angle. I think you will see what I mean in figures 96(a) and (b). It does not matter which edge of the graver is presented to the work. Don't be frightened of the graver; in use it can be "clamped" to the rest with the finger and thumb of one hand and the handle manipulated with the other. To form the curve it is swung round on the rest in a sort of pivoting action and you will be amazed how easy it is to do and how satisfying as well.

You will notice that the two important machining operations are carried out at the same setting, ie the machining of the step on which the wheel will be mounted and the boring of the centre hole.

Figure 97 demonstrates the arrangement for pressing the collet in

FIG 96 COLLETS AND PINION BOBBINS IN BRASS



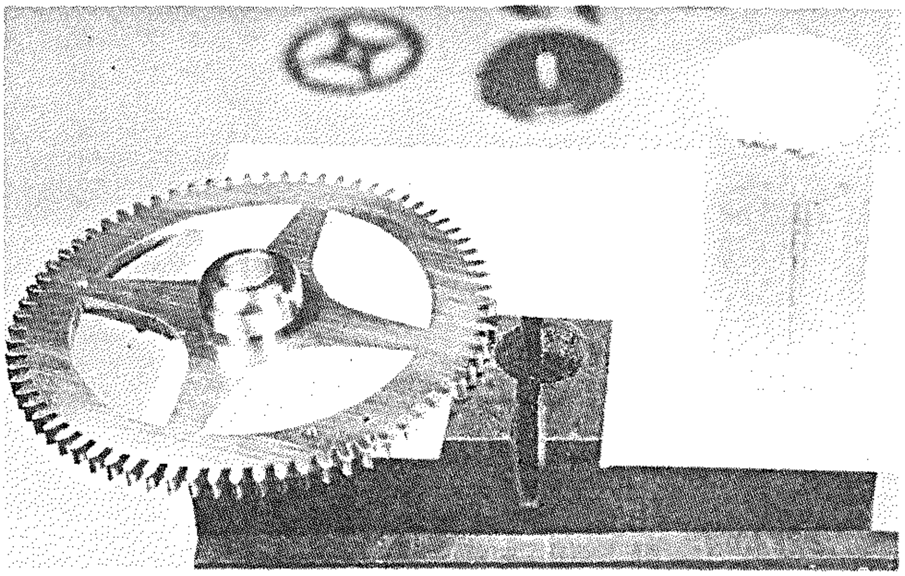


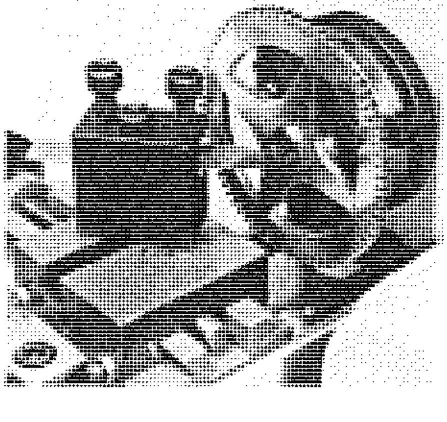
Fig 97 Set-up for pressing or driving the collet into the main wheel

the wheel centre. A steel block with a suitable hole is gripped in the vice and a piece of card is used to prevent marking the surface of the wheel. A wooden dolly is used to prevent damage to the collet from the hammer. The success of this sort of operation lies in the ability of the machinist to turn the seating of the collet about half a thou' larger than the size of the hole. If it turns out to be too loose, the fit must be tightened by riveting. For the beginner Loctite is perhaps the easiest method, but again, the fit must be close as the setting of this liquid depends on the total exclusion of air.

Finally, the wheel is held by the collet in the 3-jaw chuck as shown in fig 98 for turning away the surplus part flush with the wheel. Stiff paper should be wrapped round the body of the collet to prevent damage from the chuck jaws.

The collet for the crown wheel is machined in a similar manner. It is particularly important in the case of this wheel that the collet shoulder is undercut so that a good seating is made. If the wheel is not truly mounted and has a wobble when rotated, it will be impossible to obtain a good action in the escapement.

Fig 98 Facing off the surplus collet material



Lantern pinions

The lantern pinions are also shown on drawing fig 96. The Unimat lathe is ideal for the making of these components. The construction of the two pinions is similar, although the lower one in the clock is a combined pinion and mounting collet for the second wheel.

The work is started as a turning operation with the ½ in round brass held in the 3-jaw chuck for forming the bobbin shape. This is carried out with the parting tool illustrated in Part 2. A succession of plunge cuts is made and it is important to ensure that there is a good finish to the inside flanks of the bobbin. Any turning ridges may deflect the drill in the next stage of the operation. At the same setting the centre hole is drilled No 31.

At this stage the chuck is removed from the nose of the headstock mandrel and transferred to the dividing attachment with the 24 hole plate, the whole assembly being secured to the cross slide. The Unimat is arranged as a drilling machine and the set-up is shown in fig 99. The embryo pinion must be accurately positioned under the drill chuck and you can see in this illustration I am using a centre for this purpose. The one shown here was made from ¼ in silver steel machined to a 60° point after being accurately centred in the 4-jaw chuck or held in a collet chuck. The carriage and cross slide feed screws are adjusted until the centre is properly located.

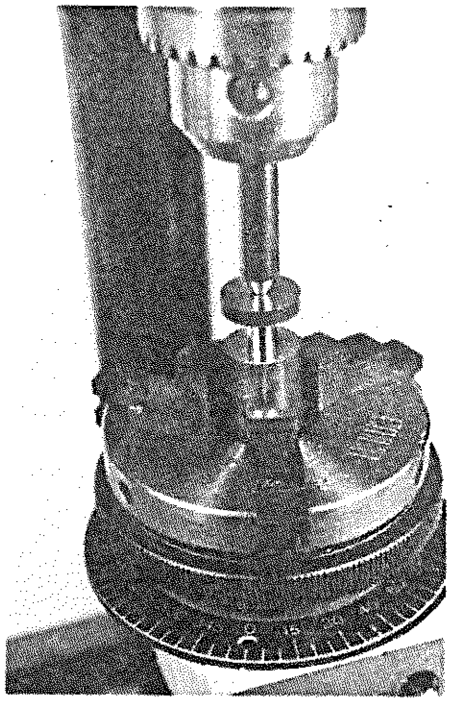


Fig 99 Method of centring the embryo pinion under the drill chuck

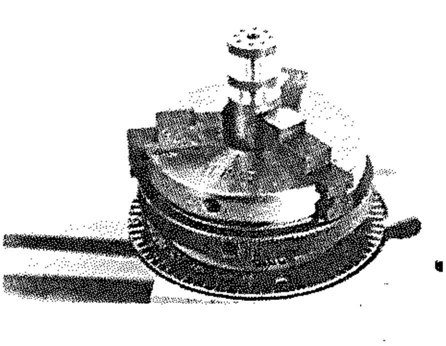
The pins or trundles

I am specifying $^{3}/_{64}$ in silver steel or blued pivot steel (12) No 56 gauge for these. There is a choice of drills for forming the holes in the bobbins. No 57, 1.1 mm, 1.15 mm or 56. The hole wants to be just too small. The best thing to do is to experiment on a piece of scrap brass. There is often a variation in the actual diameter of blued pivot steel.

When the size of drill is decided upon, it is held in the drill chuck with not more than $^{3}/_{16}$ in projecting. The lathe cross slide must now be either advanced or retracted half the pitch diameter of the pinion which is 0.314 in, so we have to move the slide 0.157 in.

As the calibrations on the feed screw are metric it is convenient to convert this figure to 3.99 mm. A drill of this size needs to be run fairly fast. I

Fig 100 The situation after drilling the eight holes in the first flange of the pinion bobbin



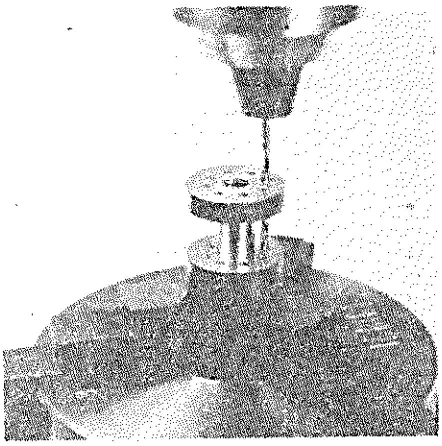


Fig 101 Drilling the second set of holes in the bottom flange after extending the drill from the chuck

used the 1500 speed range. The drilling is taken through the top flange only of course and the dividing head moved three divisions each time.

This stage is illustrated in fig 100 and the drill is now pulled out from the chuck a little further about ½ in this time, depending on which bobbin is being drilled. The operation is repeated taking the drill into the second flange for a distance of about $^1/_{16}$ in and this operation is depicted in fig 101.

This will be the last opportunity to polish the inside surfaces of the bobbin, as once the pins are fitted, they are virtually inaccessible. A fine file will remove burrs produced by the drilling and in the large pinion there is room to use an emery stick with the work rotating in the lathe.

To assist in the fitting of the pins a broach may be used to slightly ease the holes in the outer flange. Figure 102 shows this. Broaches are best purchased in assorted sizes. Hopefully, you will find one that is the right size at its tip as shown here. If not then break one. They should be regarded as expendable items.

If the blued pivot steel is being used, the first step is to remove the bluing with grade 0 emery paper. This hardened and tempered steel cannot be cut with the hacksaw or cutting pliers; it is severed by offering it up to the corner of the grinding wheel. It should be formed into ½ in lengths by this method. Each length is then held in a pin vice and one end is again offered up to the wheel to nicely round the end. Dip the end of the pin in Loctite 601 and with a flat ended punch drive the pin through the first flange and into the second flange until it bottoms in the bole. You can tell immediately by the feel and sound when this occurs. Each pin is treated

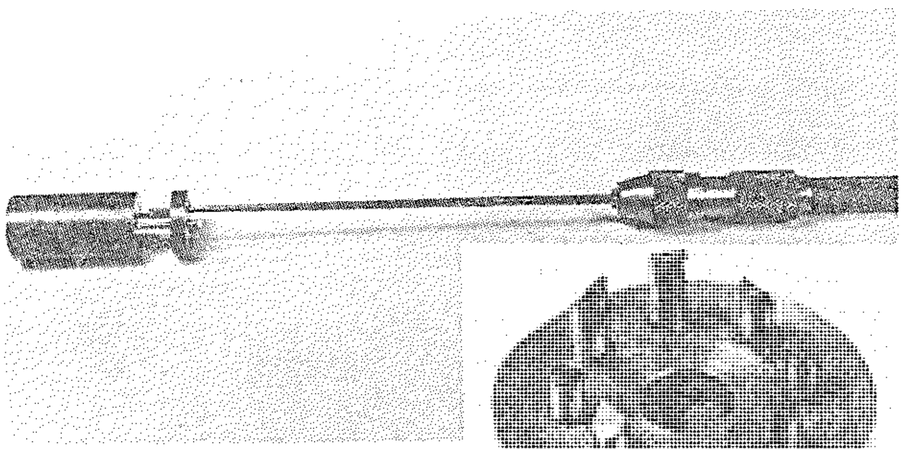


Fig 102 Using a broach to ease the holes in the first flange

similarly and the result should appear as in fig 103. Wash all the Loctite off in paraffin and offer the embryo pinion up to the periphery of the grinding wheel as demonstrated in fig 104 to remove the bulk of the surplus pins. Finally, hold the work in the 3-jaw chuck and with a well oiled carborundum slip stone, stone away the end of the pins until they are flush with the brass of the bobbin. This is illustrated in fig 105.

At this same chucking, the stock can be reduced to $^7/_{16}$ in diameter in the case of the crown wheel pinion and then parted off: fig 106 shows this.

The second wheel pinion can also be parted off leaving a sufficient length for the wheel seating. This pinion is now located by its bore and supported with the tail stock centre for turning the wheel seating to ¼ in

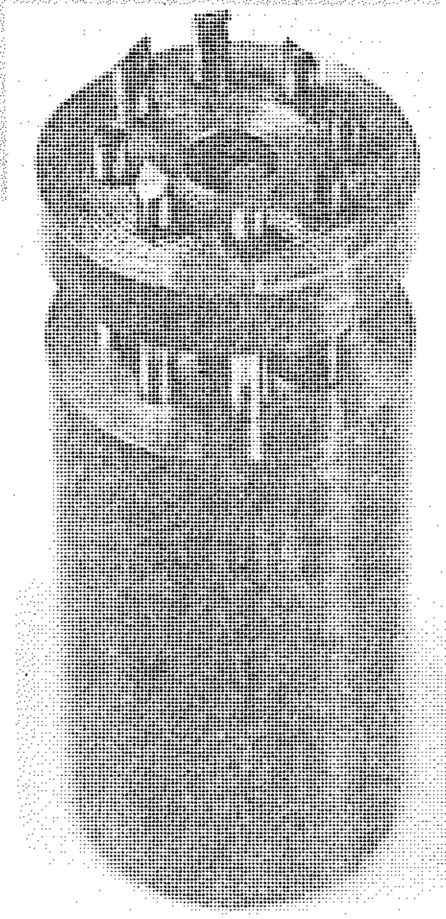
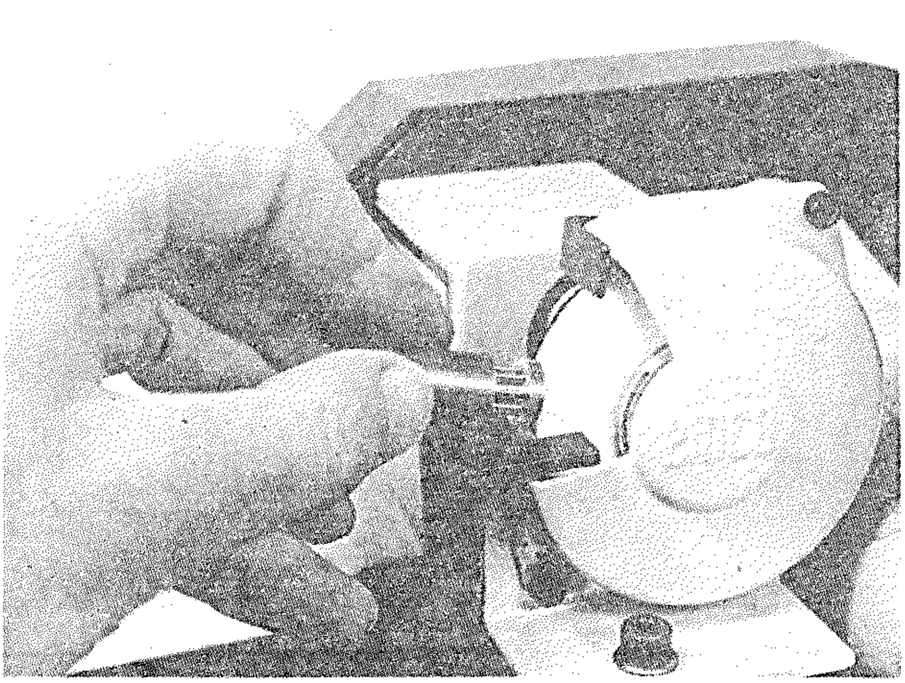


Fig 103 Appearance of pinion after fitting the pins

Fig 104 Cleaning up the surplus ends on the grinding wheel



diameter. You can see the set-up in fig 107. A short length of $^1/_8$ in brass rod is held in the chuck and a slight taper machined or filed. The wheel seating is made longer than required in order to be able to use a micrometer for measuring the diameter. I coated the shoulder with layout blue before machining and you can see quite clearly here how the angle of the tool gives the requisite undercut required for a good mating contact with the face of the wheel.

Methods of fitting in clock-making

In horological engineering, it frequently occurs that parts have to be fitted together as a tight and possibly permanent fit. I am thinking of such components as plate pillars, dial pillars and collets in wheels, etc. In antique clockwork, this was always carried out by riveting and the necessary close fit required prior to making the rivet was carried out by drilling the hole slightly smaller than the spigot it was about to accommodate. The hole was then enlarged with the tapered cutting broach until the mating component would enter about two thirds of the way, when it was then pressed or driven in and the metal expanded in the hole by hammering. In modern times we make use of screw threading equipment for many of these applications. Pillars in clock plates are usually screwed in or held in place by screws, and this is more convenient especially when it comes to cleaning and repairing the clock.

Wheels are not screwed on to collets because of the narrowness of the wheel and the consequent ultra fine thread which would be needed. But in good quality work wheels are secured to their collets with three 10 or 12 BA screws. In cheaper work the wheel is fitted to the collet by riveting, and the method outlined above in which the broach is used to give the closeness of fit prior to riveting is excellent.

Those with engineering training may find the use of the broach difficult to accept and regard it as an outmoded tool superseded by the tapered reamer. This is not so; the broach is designed for use on brass, and the negative rake on the cutting edges makes it most sensitive in use and capable of removing small controlled amounts of brass from a hole. Furthermore it is capable of greater accuracy in enlarging a hole than a twist drill.

In the case of the main wheel and its collet in this clock, there is a sufficient area of surface contact to use Loctite if this is preferred, but in the second and crown wheels, the riveting procedure should be used and whether it is done with the use of the broach as outlined above or whether the hole is sized with the reamer and the collet

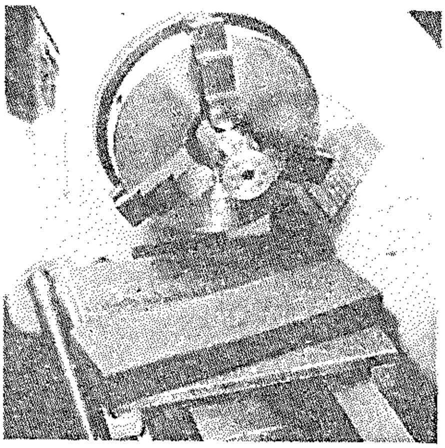


Fig 105 Using a carborundum slip stone to stone the end of the pinion head

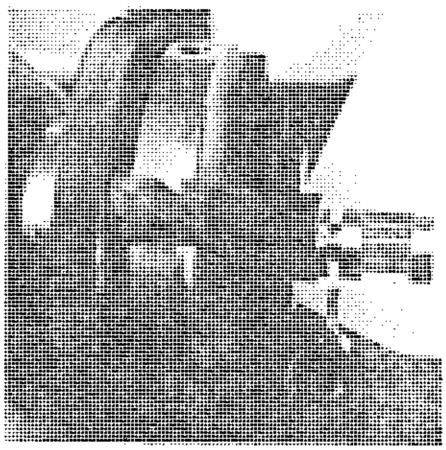


Fig 106 Parting off the pinion

Fig 107 Locating the second wheel pinion by its bore and supported by the tailstock centre for turning the wheel seating to size

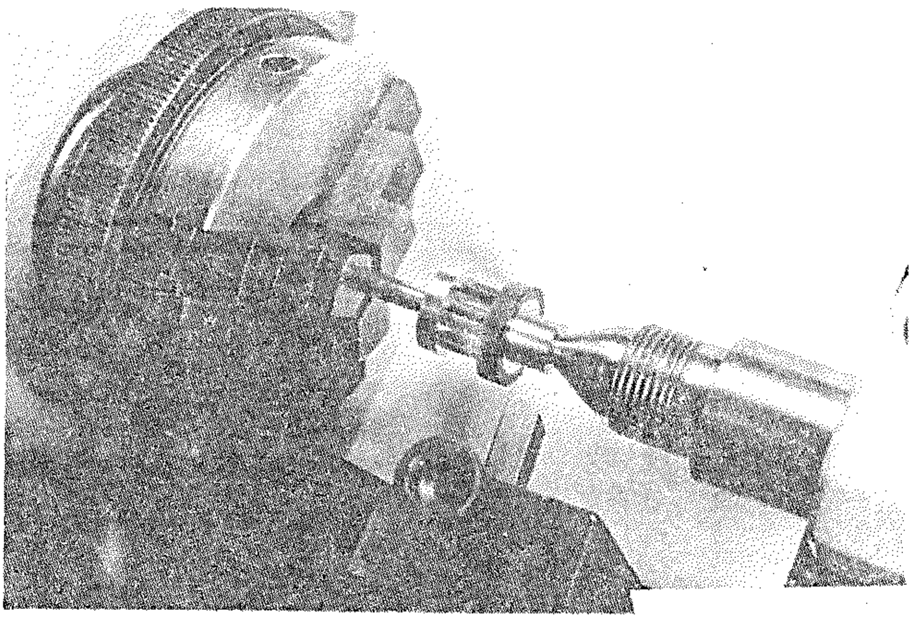


Fig 108 Cleaning up the rivet of the crown wheel collet

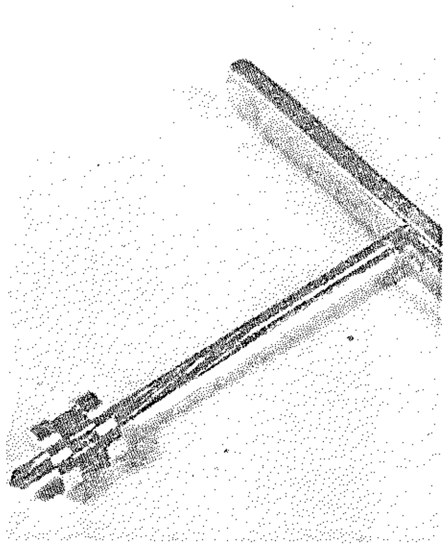


Fig 109 Reaming the centre hole of the pinion in preparation for fitting to the arbor

turned to size is up to the preference of the constructor.

After the rivet has been made by light hammering, the face of the rivet can be tidied up as illustrated in fig 108.

Note the extension of the tool here in order to clear the teeth of the crown wheel. Under normal circumstances this would be bad practice, as at all times in lathework the extension of the tool in the tool post and the work in the chuck should be at a minimum.

In the last illustration in this chapter you can see the centre hole in a pinion being reamed in preparation for fitting to the arbor (fig 109).

The click, Click spring, The arbors, Main arbor, Cutting oil, Measuring the arbor, Registering the plates

Chapter 8

The click

THE click is the horological term for what engineers would call a pawl. It is dimensioned together with the click spring on drawing fig 110, and can be marked out on a length of $^3/_8$ in x $^1/_{16}$ in mild steel strip.

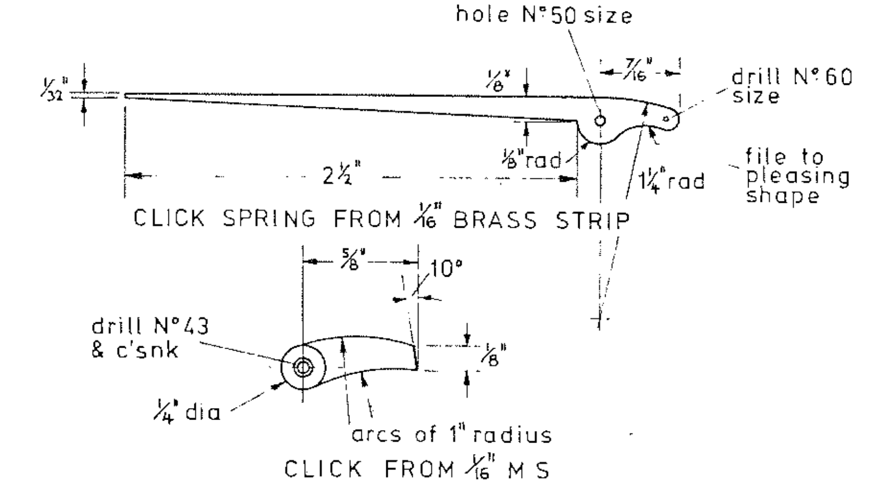
Before cutting it out, it is convenient to position it as demonstrated in fig 111 where you can see I have assembled the main wheel and pulley on a temporary $^5/_{16}$ in arbor and sandwiched the click between the two. Its position is adjusted to ensure that there is clearance on its underside for the ratchet teeth to pass and to ensure that it is not too near the edge of the wheel where it might be fouled by the shrouds of the lantern bobbin. At the same time the engaging angle of the end of the click is checked with the ratchet teeth.

When the most suitable position is found, the click is clamped to the great wheel and a No 50 hole is drilled right through both components. The click hole is then opened out to No 43 size and the countersink formed. The chamfering tools illustrated in the previous chapters are not satisfactory in this instance and a 90° tool should be used which will produce a countersink to match that of the screw head.

Figure 112 shows how the component is left attached to the parent stock until the last possible moment. It is much easier to carry out the filing and shaping while there is some sort of "handle". In this picture the piece is shown clamped to the sawing board for the final parting off with a piercing saw.

The click is pivoted on a countersunk 8 BA screw. It must of course be free to move and the pivot screw in this case is locked at the back of the wheel with an 8 BA nut to prevent it turning. The conventional 8 BA nut will be too thick in this role and it should be run on to a piece of threaded rod prior to reducing its thickness in the lathe to about $^1/_{16}$ in.

FIG 110 CLICK SPRING AND CLICK



Finally, the click is brought to a nice polish by rubbing it on diminishing grades of emery paper.

Click spring

The click spring can be cut from $^1/_{16}$ in brass strip of the extruded type BS 2874. If soft brass is used it will be necessary to harden it by hammering, but with the type specified this is not necessary.

These components are made straight and then curved. After marking out the shape, the waste metal is removed with the piercing saw and the component can be held in an instrument vice as demonstrated in fig 113 for filing the long tapered portion. Figure 114 shows the spring after filing to shape and with the 10 BA No 50 clearance hole drilled.

The curve is started at the spoon end, as shown in fig 115, using the fingers; the remainder of the curve can be accomplished by the use of a suitable diameter former and the tip is most easily dealt with in the manner illustrated in fig 116. Round nose pliers may be helpful but the fingers in

Fig 111 Checking the shape and positioning of the click

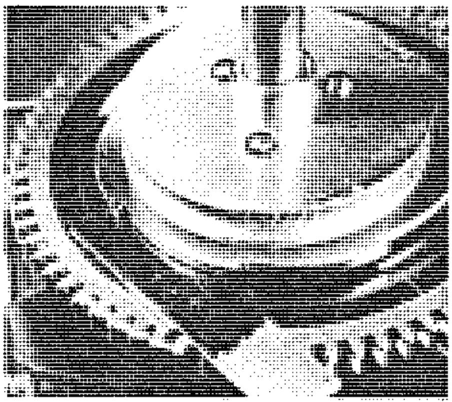
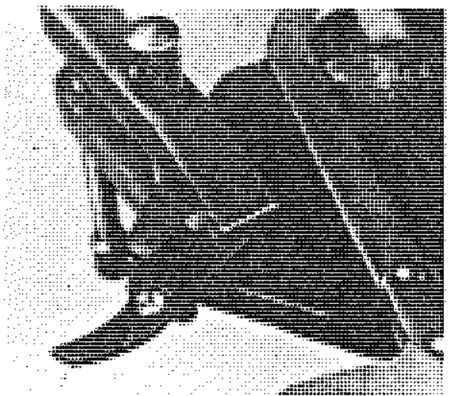


Fig 112 Separating the click from the parent stock



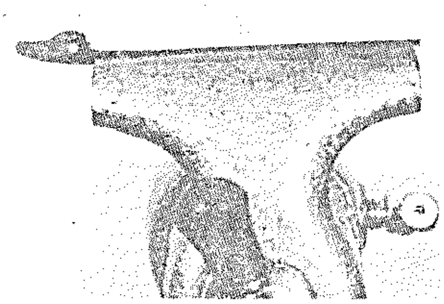
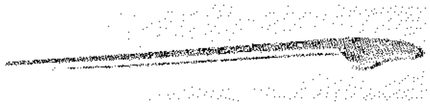


Fig 113 Holding the clickspring for filing long tapered portion

Fig 114 Spring ready for bending



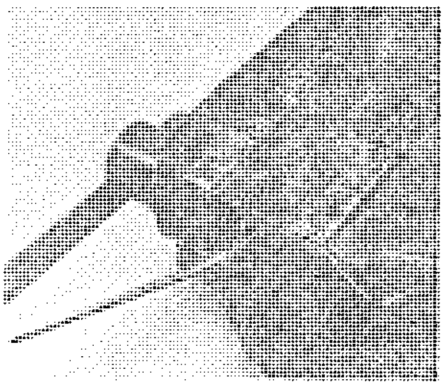
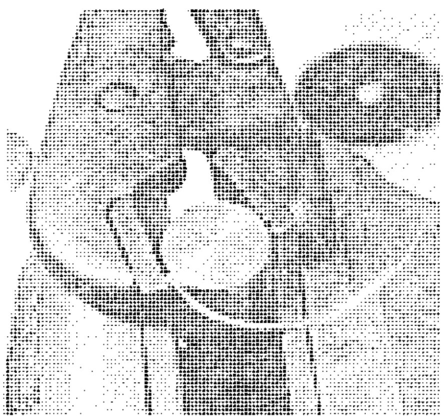


Fig 115 Starting the bend near the spoon

Fig 116 Completing the bend at the tip



conjunction with suitable formers will give the best results.

The click spring is tried in position on the wheel with the click and it is important that the tip of the spring contacts the click as close to the pivot point as possible where the movement is least. Again care must be taken to see that there is clearance for the shrouds of the lantern bobbin. Figure 117 shows the method of clamping the spring to the wheel and the hole position can be marked through the spoon of the click on the wheel. After drilling and tapping the 10 BA hole in

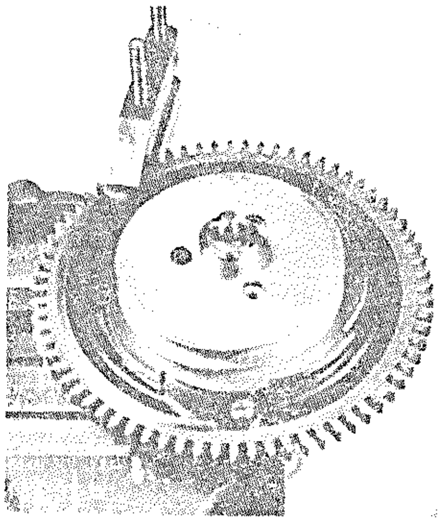
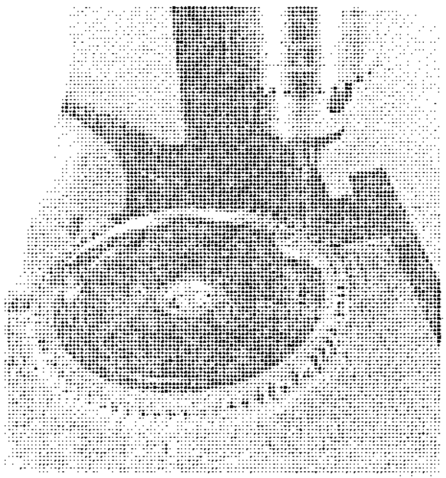


Fig 117 Clamping the click to the wheel for checking position of the spoon

Fig 118 Drilling the No 60 for the steady pin



the wheel No 55 size, the spring is fitted with its 10 BA screw as shown in fig 118 for drilling the No 60 steady pin hole right through the tail of the spoon and the wheel.

The broach is now used through both parts together to form a taper (fig 119) and the holes on the mating sides are chamfered. This is shown in fig 120.

A steel clock pin[13] is used for the steady pin. It is tapped in tightly, using a vice stake as demonstrated in fig 121[14]. It will be appreciated that if the chamfering had not been carried out the metal round the pin hole would have bulged, preventing close fitting of the two parts.

The surplus pin on the top side is cut off and filed flush, the underside is cut to length, filed square and chamfered. There is no difficulty in rounding pins where they can be rotated in the lathe, but in this instance you will require a little hand tool to do this.

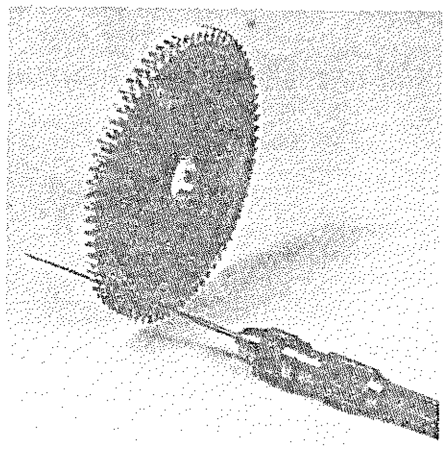
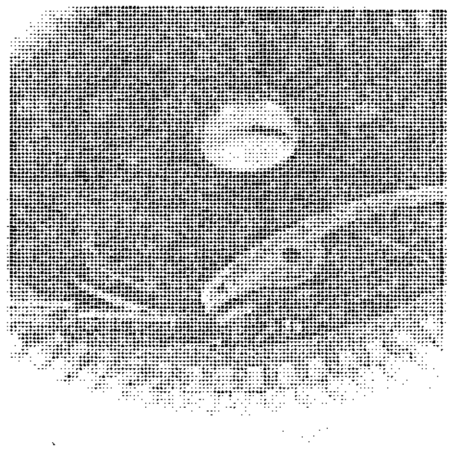


Fig 119 Broaching the steady pin holes

Fig 120 Chamfers on steady pin holes and tool with which they were made



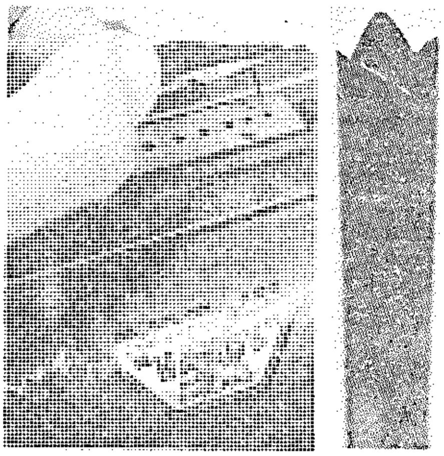


Fig 121 (left) Steady pin about to be hammered in on a vice stake

It is made from a short length of $^1/_8$ in silver steel with two 60° notches filed at 90°. This can be done with a three square needle file. The tool is hardened and tempered to dark straw and fitted into a suitable handle. It is extremely useful for rounding the ends of steady pins and those in suspended lantern

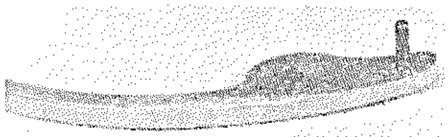


Fig 123 Properly fitted and finished steady pin

pinions as I shall show later on. Figure 123 shows the completed steady pin.

The receiving hole in the wheel will almost certainly need a small amount of broaching so that the steady pin enters for the full length but of course without undue play. Excessive freedom here will be magnified at the operating end of the click spring.

Figure 124 shows a group of wheelwork at this stage.

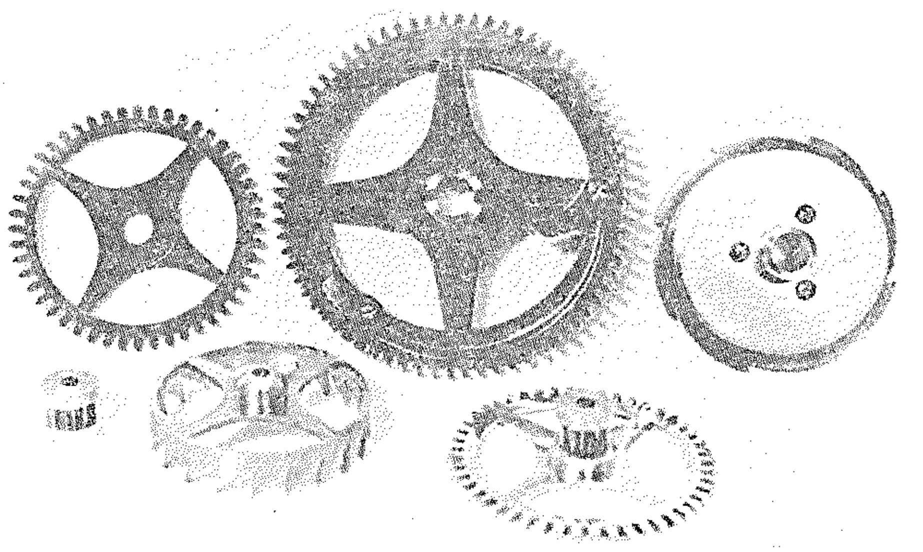


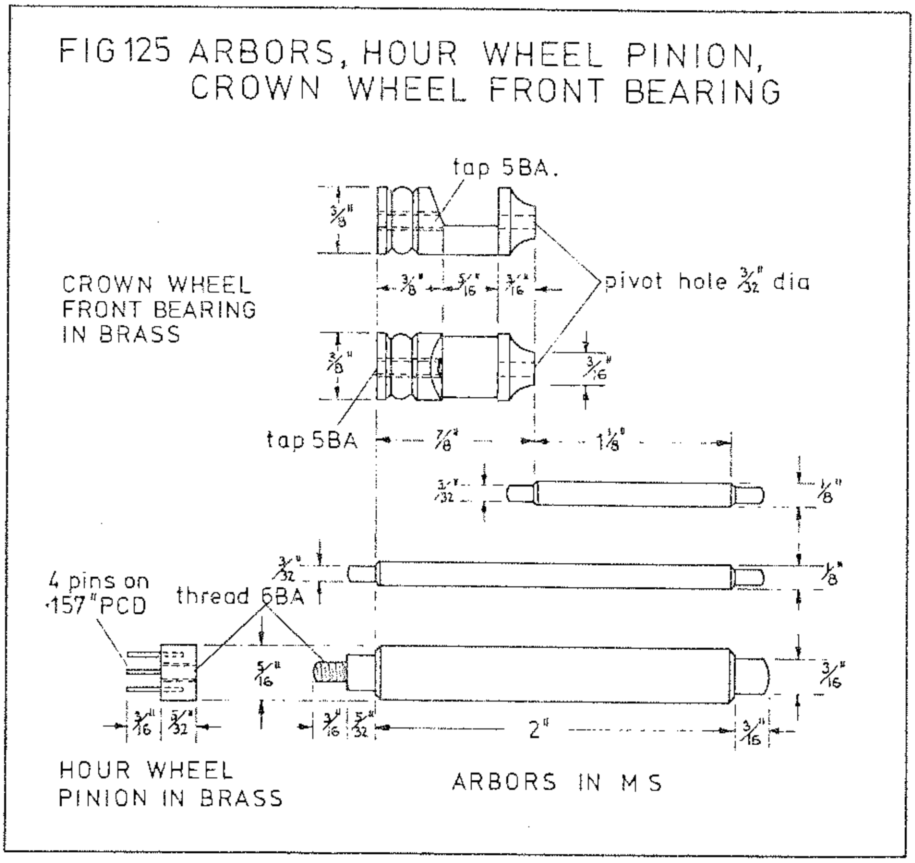
Fig 124 A group of wheelwork at this stage

The arbors

The arbors are shown on drawing fig 125. In clockmaking, the large arbors are usually machined from silver steel as this material, being harder than mild steel, is more able to resist the heavy pressures on the pivots. Also the winding square stands up to the wear from winding better in this material.

In this clock, however, the weight is very light and there is no winding square and mild steel is perfectly satisfactory in this role. I have also used mild steel for the other arbors. There is of course nothing to prevent the reader using silver steel throughout if he chooses.

You can see from drawing fig 125 that there are three arbors and the top one which carries the crown wheel is shorter than the others because its front pivot runs in an extended bearing. This is specially designed and cut away in the centre to enable the verge to take up its position on the centre line of the clock.



Main arbor

We can start with the main arbor, which you can see has a threaded end on which the hour wheel pinion is screwed. This pinion has to be detachable as it is outside the front plate, and screwing it on is an effective method. The direction of rotation is such as to tighten the fixing rather than the reverse. Although this thread could be made part of the arbor, it is I think easier to form it by tapping a hole in the end of the arbor and screwing in a short length of 6 BA studding secured permanently with Loctite. The difficulty in the former method is in producing a thread which runs right up to a shoulder. The matter is one of preference and both methods properly carried out are acceptable.

The general procedure is to chuck the $^5/_{16}$ in steel truly in the lathe. A collet chuck can be used if available or the stock can be set up in the 4-jaw chuck and made to run true using the dial indicator in combination with individual adjustments of the chuck jaws. In my case the 3-jaw chuck was so accurate that I was able to use it for this purpose. The reader must bear in mind that the lathe and equipment which I was loaned was all new.

For those readers whose 3-jaw chuck does not hold true then the alternative is to start with a piece of oversize steel, say $^3/_8$ in diameter, machine centres, male or female, at each end and then turn the arbor between centres reducing the main body to $^5/_{16}$ in and the pivots to $^3/_{16}$ in.

Cutting oil

I haven't mentioned cutting oil yet. Whereas brass is machined dry, a better finish results on steel if a cutting oil is used. Where heavy cuts are being taken it is usual to arrange for a continuous supply of oil to be directed on to the cutting tool, but in the sort of turning we do, it is quite satisfactory to keep the cutting fluid in a jar beside the lathe and apply it with a small brush. Cutting oils are available from suppliers of engineering tools.

The pivot is turned with the right hand knife tool to $^{3}/_{16}$ in diameter and the chamfer formed so that the appearance is as shown in fig 126. A turned finish is not good enough in clockwork and it is usual practice to finish the pivot surface with the pivot file and finally the burnisher[15]. In fig 127 the same pivot is shown after treatment with the pivot file and in fig 128 after burnishing. It is possible these stages will not reproduce very well. However, the difference between fig 126 and 128 should be quite noticeable.

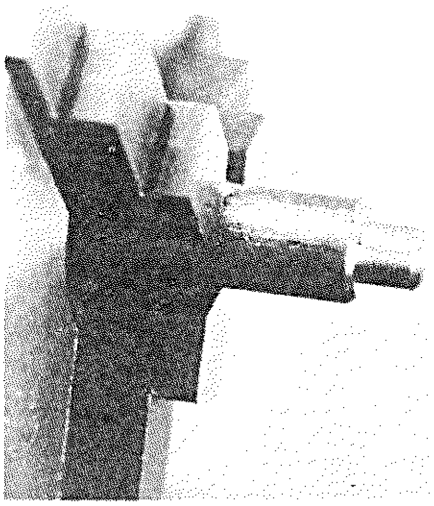
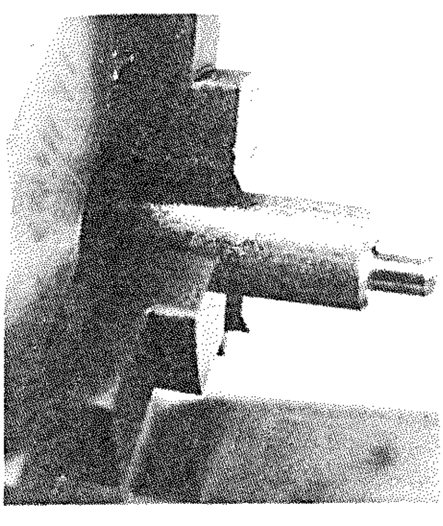


Fig 126 A turned pivot

Fig 127 The same pivot after treatment with the pivot file



The combined pivot file and burnisher shown in fig 129 is ¼ in wide. Its use as a file is straightforward and those readers who doubt their ability to file the pivot parallel can make the little roller rest which I describe later in this series.

With all the turning marks removed, the opposite end of the tool is used to burnish the surface and before doing this it will be necessary

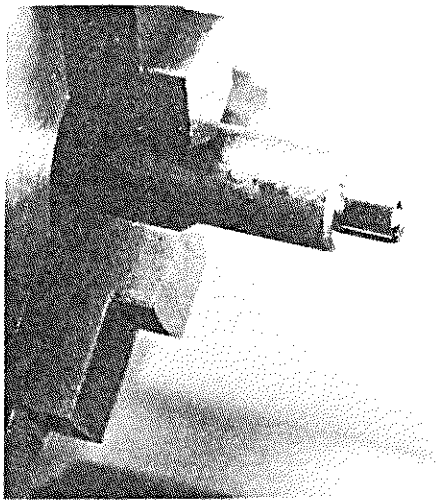
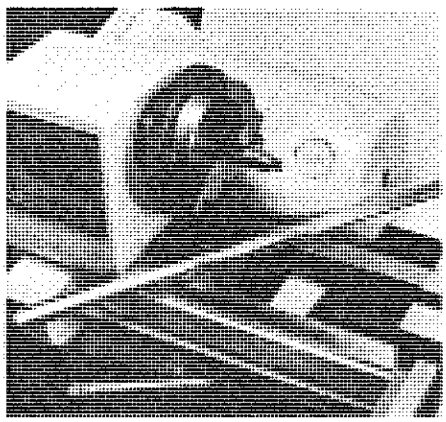


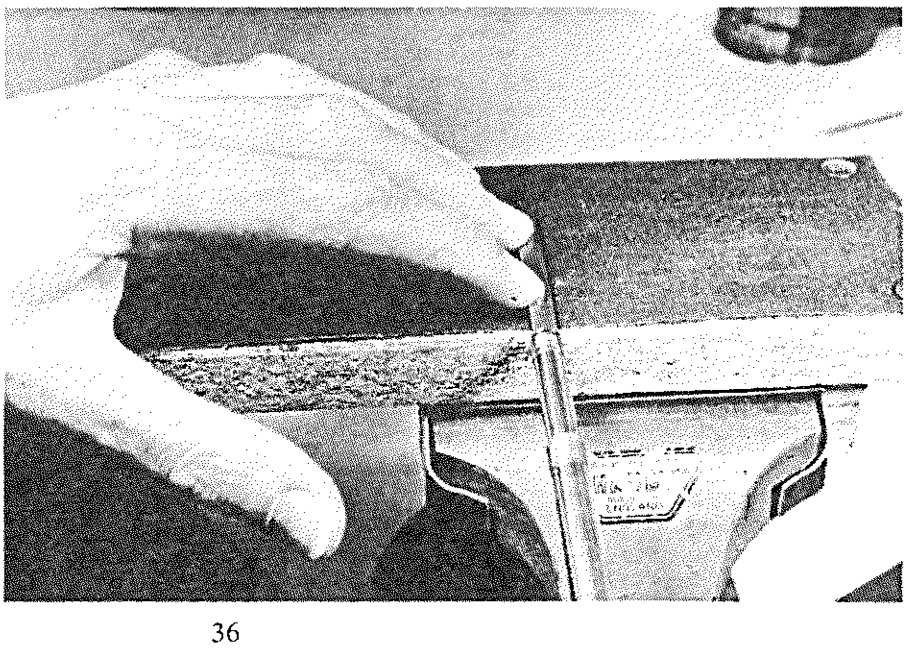
Fig 128 The pivot after burnishing

Fig 129 Combined pivot file and burnisher



to "make" the burnisher as clockmakers say. In fig 130 you can see this being done. The burnisher is being pushed along the surface of a fairly coarse grade of emery cloth. Two hands are used of course, but my other hand was operating the camera shutter release. Ideally, the piece of

Fig 130 Making the burnisher



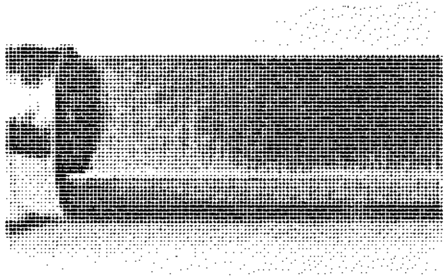


Fig 131 Enlarged portion of burnisher showing cross grain imparted by the emery cloth

wood backing supporting the emery cloth should be curved slightly in its length to assist in keeping the surface of the burnisher flat and not convex. The appearance of the surface is shown in fig 131 and the cross grain imparted is, I hope, clearly visible. Some operators use both the file and burnisher with oil. I prefer to use them dry, but in the final stages of burnishing it sometimes helps to moisten it with saliva. A fair amount of pressure is used in the operation and the tool is taken round the end of the pivot to polish that as well. You should achieve a mirror polish.

If for some reason you are not successful, then the pivot can be finished with emery sticks in diminishing grades, but this does not give quite the same effect as a burnished surface. Don't worry about the finished diameter of the pivot, this is not important as the hole will be broached to fit. This is the usual technique in pivot fitting.

Measuring the arbor

With one pivot formed, the arbor is laid across the frame as demonstrated

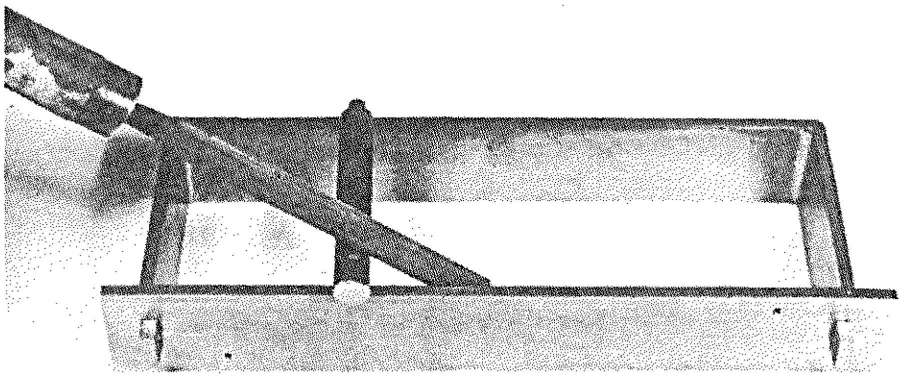


Fig 132 Marking shoulder position of pivot

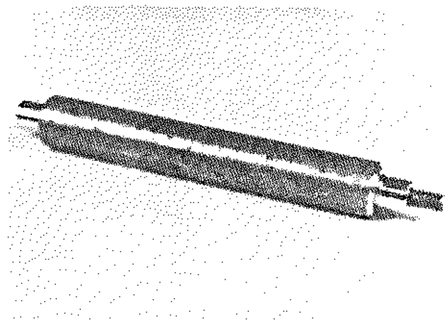


Fig 135 The completed arbor

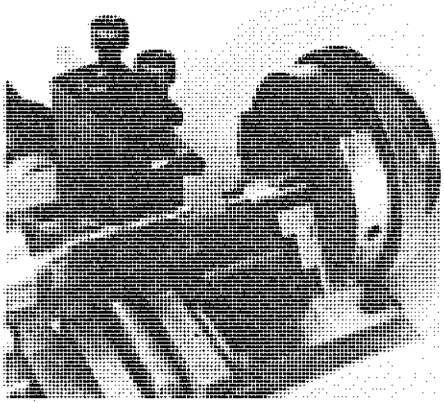


Fig 133 Turning the second pivot and drilling the end

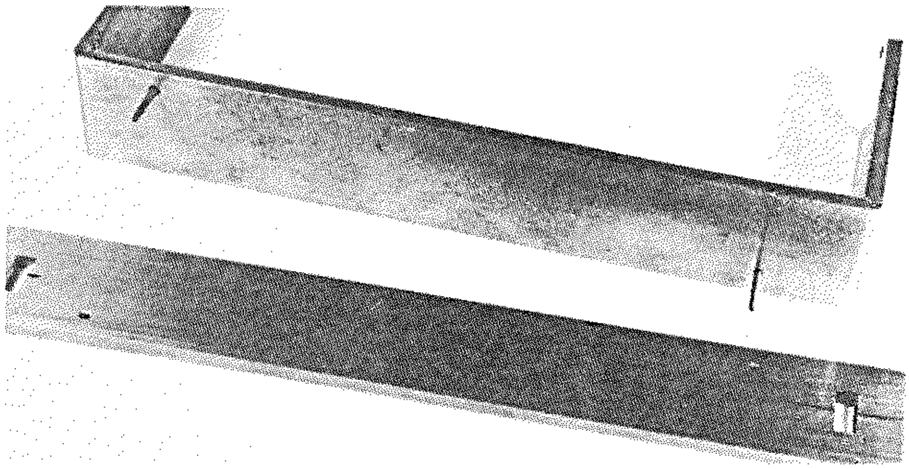


Fig 137 The plates registered for drilling the pivot holes

Fig 134 Tapping the end hole 6BA

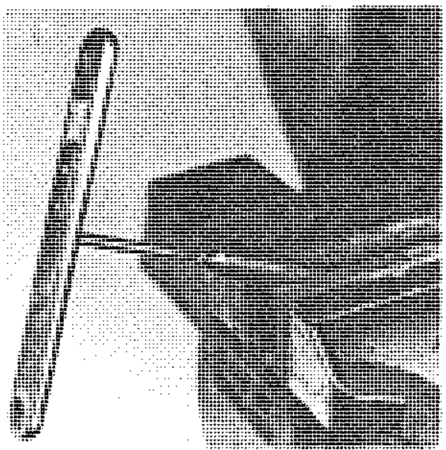
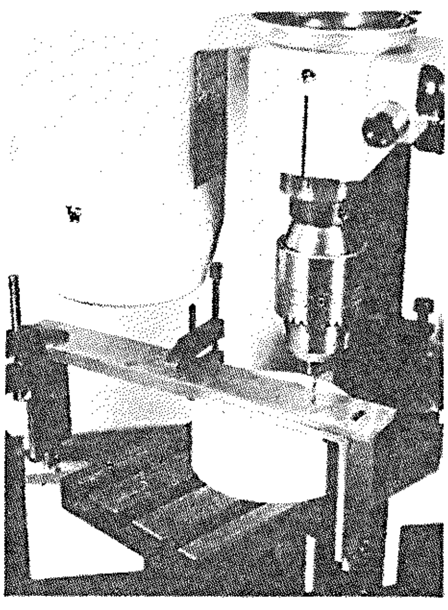


Fig 136 Drilling machine set up for forming the holes for the register pins



in fig 132 for marking the shoulder of the other pivot. Unfortunately, in the posing of this photograph I omitted to pin up the front plate which is a serious omission. The assembly must be pinned up tight. The shoulder of the pivot is marked with a needle file, or as in this case, a screw slotting file and the second pivot turned and burnished in the same manner. At this same setting the end is centre drilled, followed by the No 43 or 2.3 mm drill in preparation for tapping 6 BA. This is illustrated in fig 133, and the tapping in fig 134. The arbor, with the 6 BA studding (which can be a short length of a 6 BA screw) is shown in fig 135.

The second wheel arbor and the crown wheel arbor are treated in the same way; the length of the latter is made according to the drawing and the front bearing will be machined to suit it.

Registering the plates

Before pivot holes are drilled the two plates must be registered by fitting them together with register pins. The position of these pins is shown on the drawing fig 29 at A and B. Because of the design of this clock the front plate is placed behind the back plate but still facing in the normal direction and the marking out for the pivot holes will take place on the back of it. So the first step is to clamp the front plate to the back plate sighting through the holes of the tenons and secure the two firmly with toolmakers clamps. After marking out the position of the register pin holes, drill through both plates with a No 55 drill as illustrated in fig 136. The fitting of the register pins is exactly the same as previously described and the result is shown in fig 137.

Depthing, Laying out the train, Checking the freedom, The crown wheel front bearing, Decorative turning, The verge, Filing the flats on the verge arbor, Soldering the pallets

Chapter 9

Depthing

IT is of course true that there is a theoretical distance for the wheel centres with two meshing gears and it is quite easy to calculate. You simply add the total numbers of teeth on the wheel and pinion, halve the sum and divide the quotient by the diametral pitch. As an example we can take the hour wheel and its mating pinion. Here 48 + 4 = 52 and this halved becomes 26 and divided by 25.4 =1.02 in.

If the wheels and pinions were cut with mathematical accuracy this theoretical distance could be accepted. However, in hand made clocks it is safer to carry out a practical meshing test of the gearing and clockmakers do this on a special jig which has adjustable centres and on which wheels and pinions can be tried at different engagements until the optimum position is found. The tool is then taken to the clock plate and this distance transferred by scribing an arc.

The conventional depthing tool is designed to test wheels and pinions which are mounted on their arbors. It is a controversial tool and suffers from the disadvantage that the centres which are used to scribe the distance on the clock plate can be as much as 4 in or 5 in from the meshing position of the two gears. This is illustrated in fig 138. Many clockmakers doubt whether the design of the tool is capable of giving the requisite accuracy under these conditions.

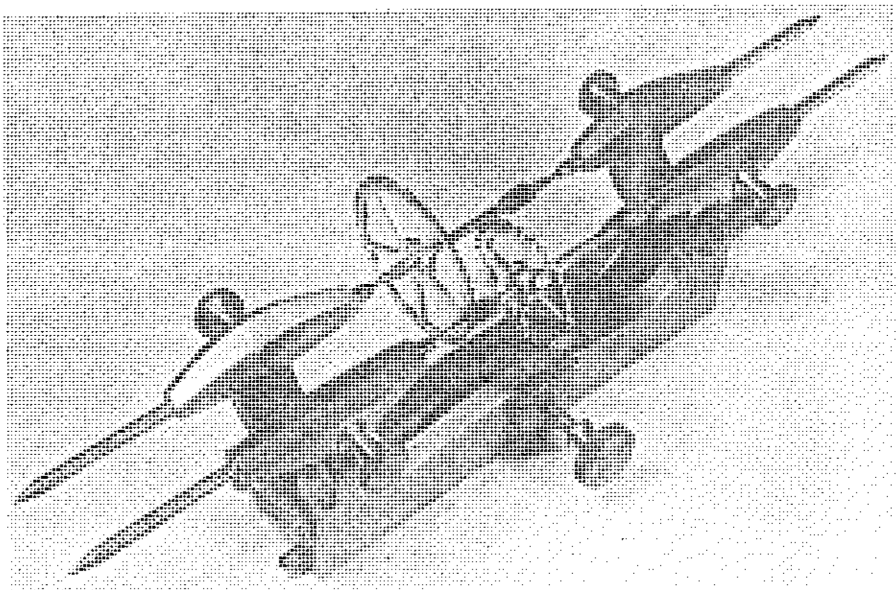


Fig 138 Conventional depthing tool

The little tool which I designed some years ago and which I show in fig 139 and 140, has the advantage that the distance between the scribing centres and the two wheels in mesh is less than 1 in. Furthermore, the tool is easily made and can be used for other purposes such as the construction of pallets. It is true that wheels and pinions which are already mounted on their collets cannot be depthed on this tool, but in the making of a clock it is just as convenient to carry out the depthing before this is done.

A drawing of the tool is given in fig 141. Unfortunately, I have no illustrations of the actual making of this tool as it was built some years ago. However, there is nothing very difficult in its construction.

The most important consideration is to obtain a piece of 1 in x $^1/_8$ in brass strip which is flat. The long slot is not critical and can be formed by drilling two ¼ in holes, one at each end, and joining them up with the piercing saw and filing. The fixed bush should be undercut so that it seats truly in the base plate, where it is made a light press fit. The runners or scribing points are carefully turned from silver steel and the tips hardened and tempered to blue. In addition to the two plain points you will need a "trumpet" runner for locating the tool in an actual pivot hole. In addition you will

Fig 139 Simple home-made depthing tool

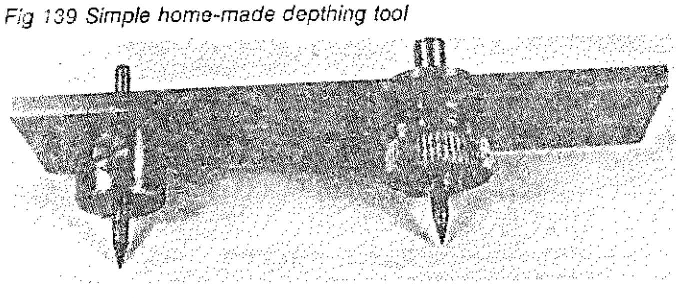
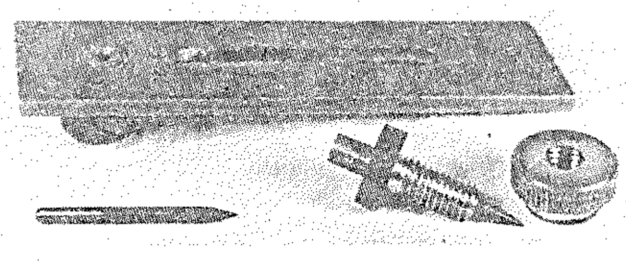


Fig 140 The depthing tool dismantled



need to make several bushes or tubes to fit on the upper extensions to accommodate various diameters of wheel centres.

It should be noticed that the pointed runner in the fixed bush is both removeable and adjustable so that the main plate can be kept parallel with the clock plate. The other runner can be fixed permanently with Loctite.

Laying out the train

Remember we shall be marking out the pivot hole positions on the *back* of the front plate. Firstly apply layout blue and scribe a centre line using the oddleg calipers as described in the second chapter. Mark out the centre position and make a *shallow* centre punch mark just deep enough to locate the point of the dividers. Set your dividers to 1.02 in and scribe an arc below the centre position as demonstrated in fig 142. This marks the position of the main wheel pivot hole. By this method we have established that the hour hand will be central on the front plate, as 1.02 in is the theoretical distance between the hour wheel and its mating pinion.

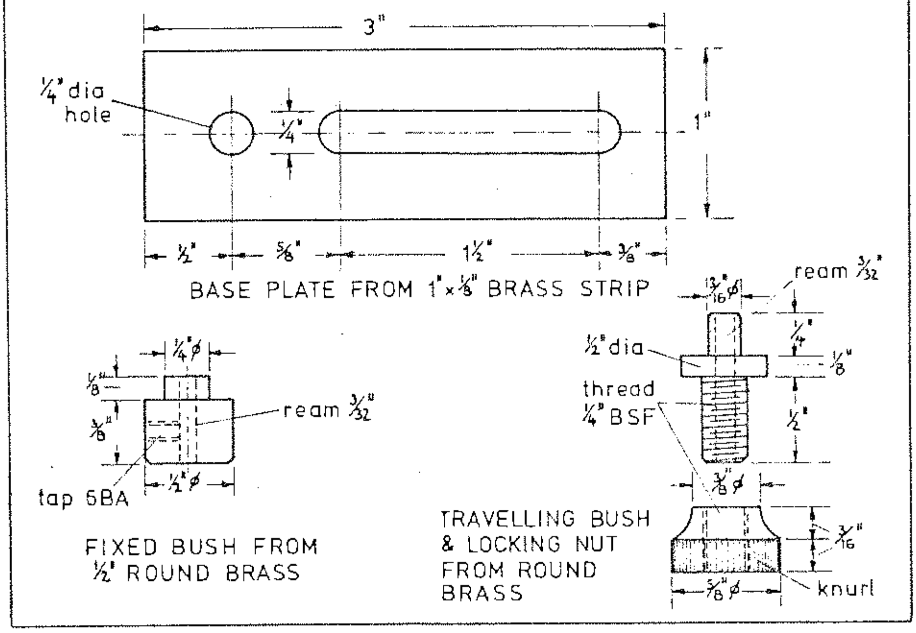
There are two options in the pivoting with this clock. We can either run the pivots in the steel plates, or we can bush these with brass bushings which is the better method and that which I shall describe here.

A suitable diameter of brass bush to accommodate a 3/16 in pivot is 5/16 in. When drilling a hole of this size it is quite possible that the finished hole will not be concentric with the original centre punch mark. It is advisable therefore to scribe a series of circles with the dividers, the largest being slightly bigger than 5/16 in diameter, before starting the drilling. This will give a visual guide as to whether the drilling is proceeding accurately. If not, correction can be made with a round file before carrying on with the next size of drill. With the Unimat the increments in drill size should be kept to 1/32 in the larger sizes. The plates should be clamped together firmly and the drilling taken through both together if possible.

The brass bushes are turned in the 3-jaw chuck from $^3/_8$ in brass rod and the centres drilled $^1/_8$ in diameter. A slight taper is formed on the outer surface with a file and they may be parted off to ¼ in in length. When located in the plates (from the inside) they should not pass right through the hole but only enter part of the way. Now place the plate on a steel stake, as shown in fig 143, and hammer the bush right home and continue with a few more blows of the hammer to expand the bush in its hole. The surplus bushing is removed by filing, or, a useful tool is the counterbore shown in fig 144. Be careful not to damage the surface of the plate in either method.

The holes are now broached to fit the pivot as demonstrated in fig 145. When using a broach, keep turning the work through 90° backwards and forwards to check the uprightness of the tool. A *slight* chamfer is formed on both sides. The freedom of the arbor can be checked with the plates pinned

FIG 141 A DEPTHING TOOL



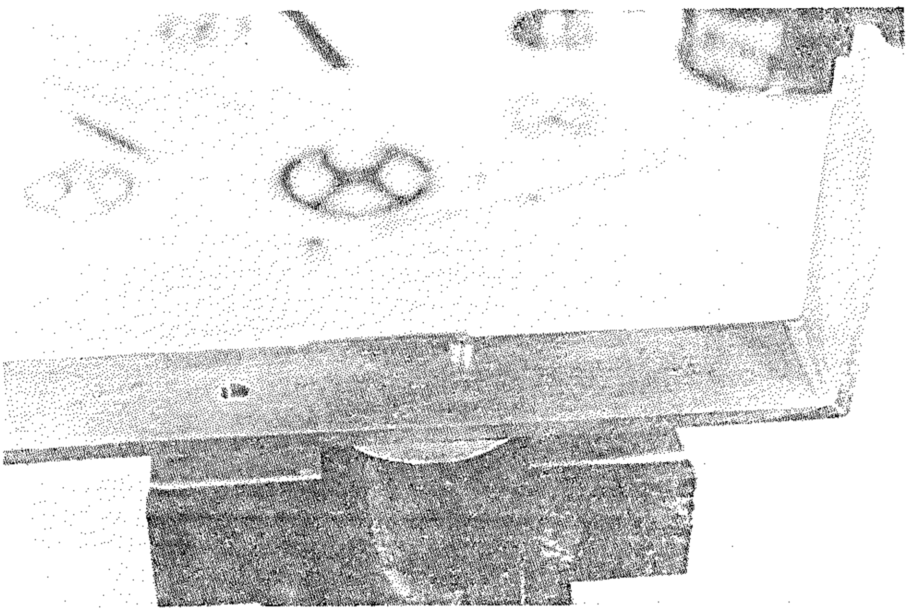
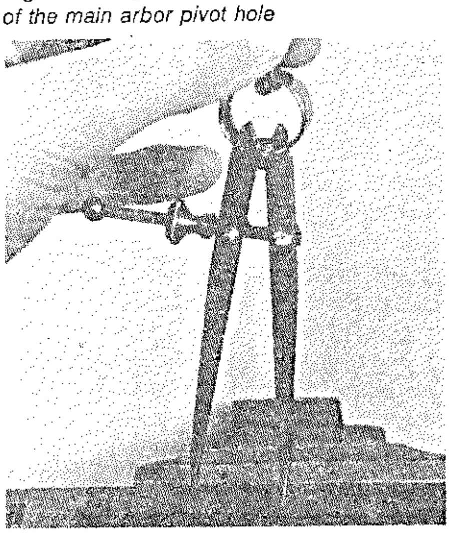


Fig 143 Set-up for hammering in a brass bush

Fig 142 Using dividers to mark the positions of the main arbor pivot hole



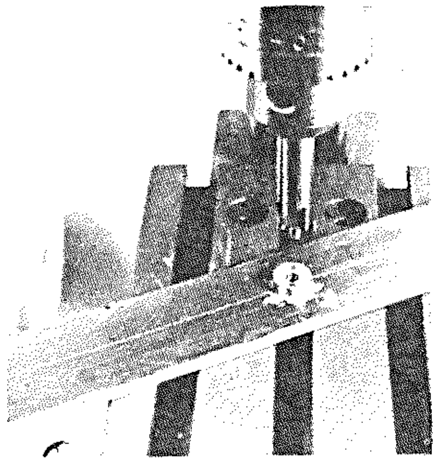


Fig 144 Using a counterbore to remove bulk of surplus bush

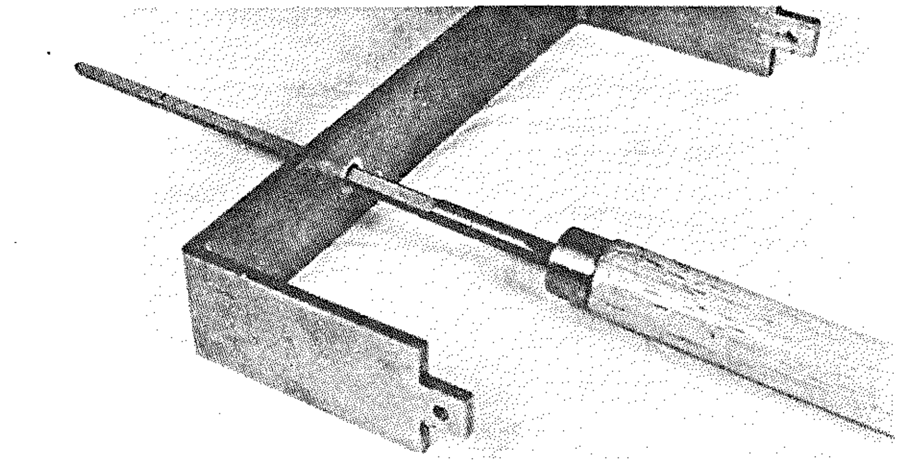


Fig 145 Broaching the bush to fit the pivot

up. There must be end shake. The amount is not critical, but it *must* be present. Aim for about 1/64 in to 1/32 in. It will not be possible to check the fit of the hole properly until the main wheel has been permanently secured to the arbor.

The next step is to depth the main wheel with its mating pinion (fig 146). Although the latter is shown fitted to the second wheel it is really easier to do the depthing before this is done. There is better visibility without the wheel there. As mentioned earlier it will be necessary to turn up different sizes of tubes to fit the wheel centres and one soon accumulates an assortment of these. In this picture a bush having a centre hole of 3/16 in and an outside diameter of 5/16 in is required for the main wheel and a bush with an outside diameter of $^1/_8$ in and a centre hole of 3/32 in is also required.

The best test for the optimum engagement is that of feel. Apply resistance to the pinion with pressure of the finger and turn the wheel. If there is a gritty feel then the depthing is either too tight or loose.

When the optimum position is found the setting is transferred to the clock plate. In this case as the main pivot holes have been drilled, the trumpet runner is used as demonstrated in fig 147.

Remember that as we are marking out on the back of the front plate the second arbor pivot hole will be on the opposite side to that shown on the drawing. This time the hole size may be 5/32 in and a brass bush made from 3/16 in brass rod in a similar manner as before. The centre hole should be drilled to 1/16 in. It is hammered in on a steel stake as illustrated in fig 143. It will be found that the largest size of bouchon as supplied by Progress in their English clock selection is exactly

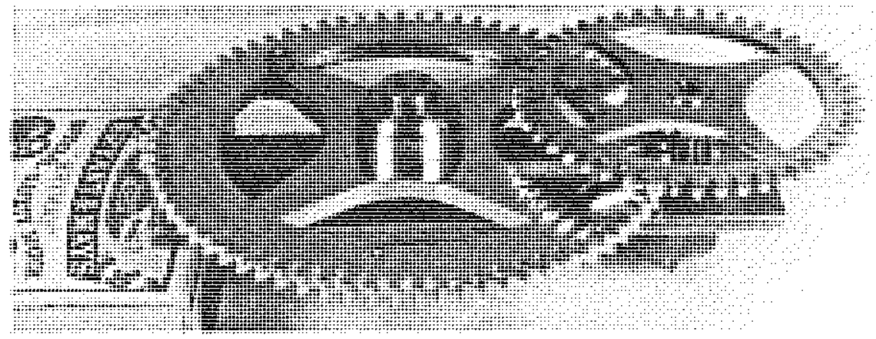


Fig 146 Depthing the main wheel and second pinion

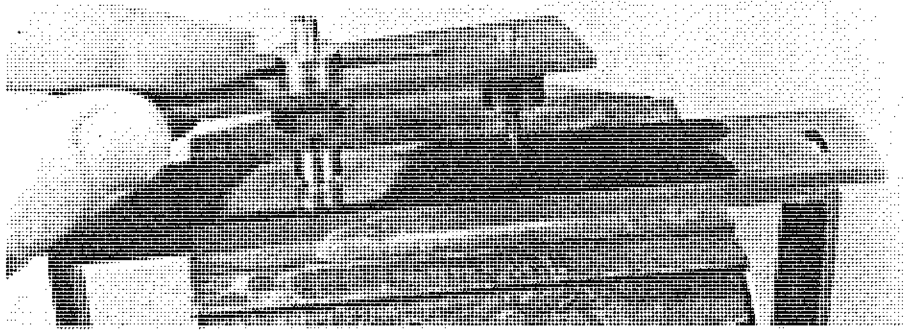
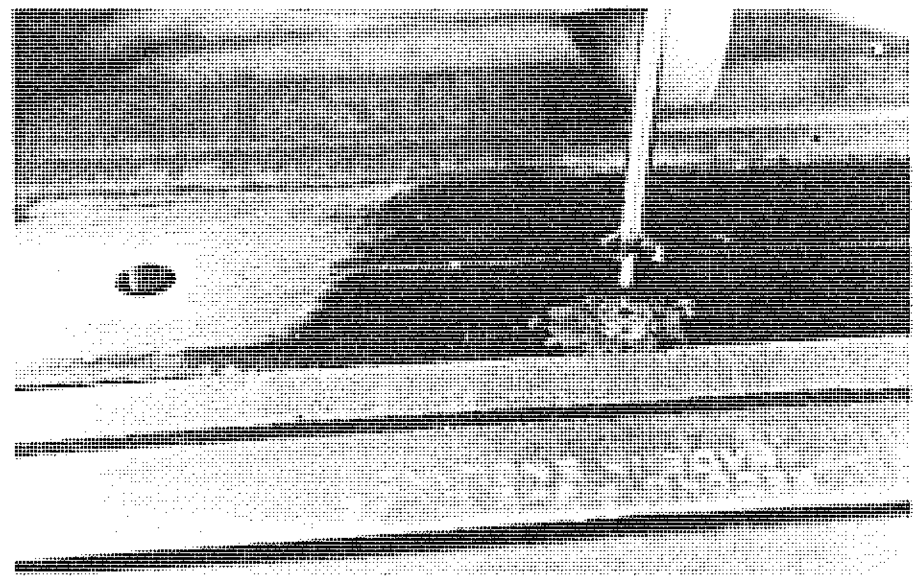


Fig 147 Transferring the distance to the clock plate

Fig 148 Using a miniature counterbore to remove surplus bushing



the right size[16]. The surplus material is removed as before and you can see the little counterbore which I use in fig 148. Again the hole is broached to fit the pivot always from the inside.

In the last depthing operation the second wheel and crown wheel pinion are meshed and the distance set out on the plate as illustrated in fig 149. Remember that the top arbor is set out 1/16 in off centre.

Although we still have to make the front bearing for the crown wheel arbor, the fixing of the main wheel and the second wheel to their arbors can be carried out now. Figure 150 shows how the position of the main wheel is marked on the arbor and the location can be judged from the general arrangement drawing fig 3. You can also see in fig 150 the bottle of Loctite 601 in the background. Both mating surfaces should be degreased. If the fits are as close as they should be, the Loctite will stiffen up in seconds and the parts become immoveable with the fingers in a matter of minutes so make sure you have the final position clearly marked.

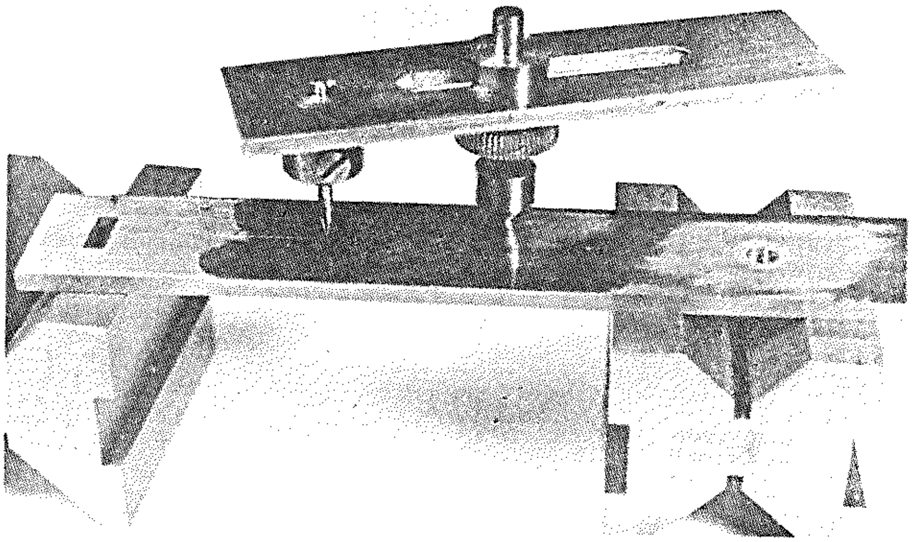
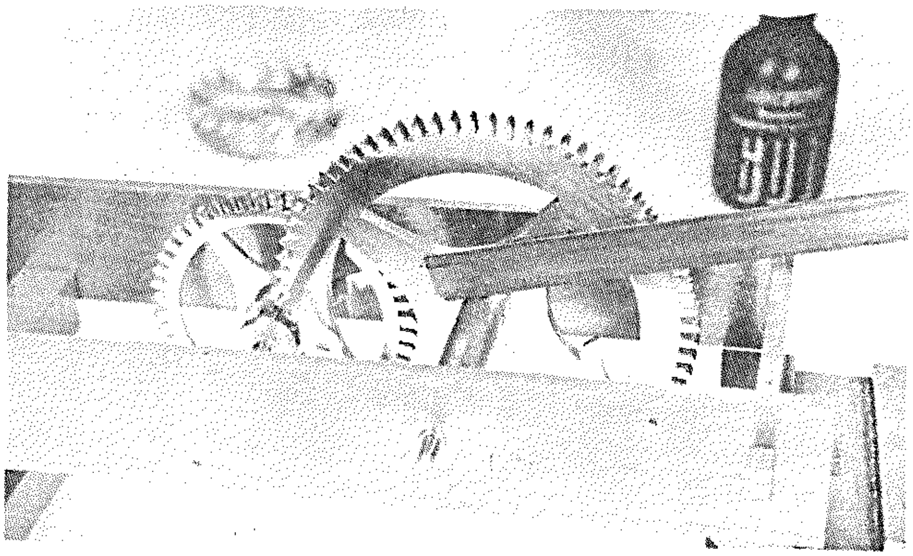


Fig 149 Using the trumpet runner in the depthing tool located in second arbor pivot hole and scribing the arc for crown wheel pivot

Fig 150 Marking position of main wheel on its arbor before fixing with Loctite



Checking the freedom

It is vital to check the freedom in clockwork. Put each arbor in position separately and spin it. It must rotate absolutely freely gradually coasting to a halt. There must be endshake, and as the frame is tilted over from one side to the other, the arbor should drop down with an audible click. If the endshake is satisfactory then tightness will be due to a tight pivot hole which must be broached out very gently from the inside.

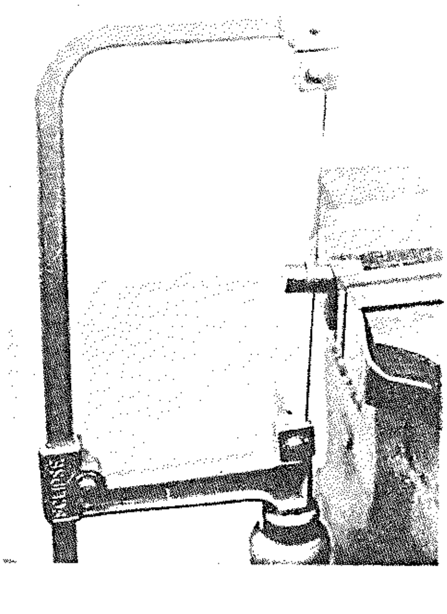
There is no question of letting it go, if a bit on the tight side, assuming that it will run itself in. This doesn't work with clocks. *You must have complete freedom in the train.*

The crown wheel front bearing

The crown wheel front bearing was dimensioned in drawing fig 125 and the first step in its construction is to hold the stock in the 3-jaw chuck for facing each end and drilling and tapping the 5 BA hole. Suitable size drills for this are No 37 or 38. The work is reversed in the chuck for drilling the pivot hole which can be 1/16 in initially.

The centre part of this component is cut away with the piercing saw in the manner demonstrated in fig 151. I see that I have not given a dimension for the thickness of metal remaining here. The saw cut can be on the centre line of the stock and the filing can be taken a further 1/32 in leaving 5/32 in. The matter is not critical providing there is clearance for the verge arbor. The best way to file this surface is to lay the stock on the partially opened vice jaws as shown in fig 152. In this manner the work will find its own level.

Fig 151 Removing centre part of crown wheel front bearing



Decorative turning

Decorative turning is, of course, optional but adds interest to the design.

The work is held as shown in fig 153, and it is important that there is a proper bearing for the tailstock centre. If, when drilling for the 5 BA thread, the 3/16 in centre drill was used, this will have formed a sufficient bearing for the lathe centre. This centre is of course fixed and when used should be lubricated with a drop of oil.

Diagram fig 154 illustrates the steps in forming the decorative

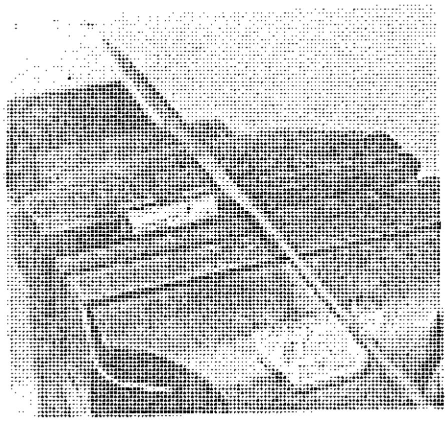


Fig 152 Filing the flat

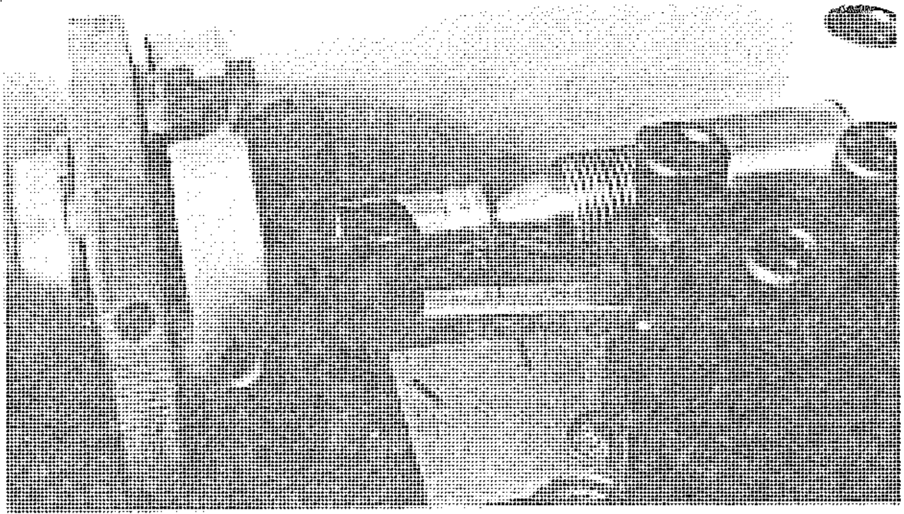


Fig 153 Set-up for decorative turning

grooves. The graver is presented on its side, first one way then the other as shown in 1 and 2, and in 3 you can see how the point of the graver was located in the apex of the left hand recess and then swung round to the right to make the curve. The same procedure would be followed on the right hand side swinging the tool tip round from right to left, so forming the shape illustrated. The hand turning rest is a 3/16 in square piece of mild steel held in the tool post with the upper corners rounded off.

It should not be necessary to use needle files, and anyway they will not produce the surface finish that a well honed graver will, and furthermore they will not produce the sharp corners at the bottom of the vees in the way that the graver can.

The stock is now reversed in the chuck for taper turning the other end. The taper attachment is set over 20° and the work is illustrated in fig 155. The concave surface is formed with a hand tool as demonstrated in fig 156. As you may be able to see, this tool was made from an old file with the serrations removed by gentle grinding and the tip radiused as shown. As usual the cutting surfaces are honed and thus a fine finish will be imparted to the work.

The bearing is secured to the inside of the front plate with a 5 BA screw, and the pivot hole is broached out to fit the crown wheel front pivot. It may be necessary to face off one or other of the ends to give the end shake.

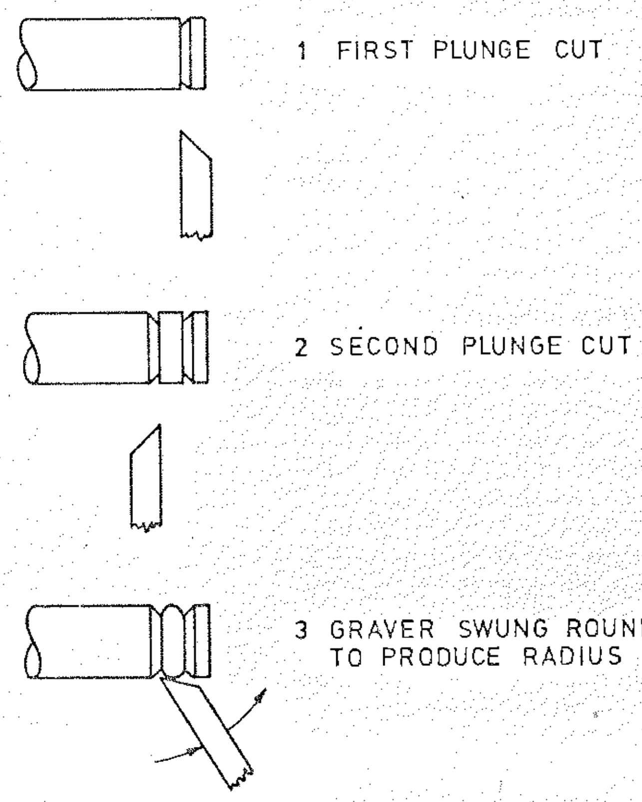
The verge

As I mentioned in Chapter 1, a source of heat is necessary in the small workshop for such jobs as soldering – both soft and hard, and for hardening and tempering tools. The Ronson blowtorch is adequate for these applications and will give ample heat for the silver soldering required in the construction of the verge.

The design of this component which is shown on drawing fig 157 requires the pallets to be silver soldered to the arbor of the verge and to form an included angle of 40°. Flats are filed on the verge arbor to accommodate the pallets and of course these must also be formed to include this angle.

Here is an example of the usefulness and versatility of the Unimat. We shall use the dividing attachment in conjunction with a simple home made filing rest in order to file these two flats in a precise manner.

FIG 154 DIAGRAMMATIC REPRESENTATION OF THE SEQUENCE OF CUTS WITH THE GRAVER



Filing rest

A filing rest is a valuable piece of equipment for any lathe. The best type is the "two roller" rest where the rollers are mounted on a bracket, which in turn is adjustable for height. The rollers straddle the work which is held in the chuck and in this way precise and accurate filing can be carried out.

In drawing fig 158 I show a very simple roller rest which is primarily designed for use in repairing pivots where it ensures that the pivot file is parallel with the lathe bed. It does not give the control and accuracy of the two roller rest, nevertheless, it is an assistance in producing flats and squares, which are so often required in clockmaking. The filing rest disassembled is illustrated in fig 159, and you can see that the pivot pin on the end of the $^3/_8$ in square arm is formed eccentrically. By mounting the square shank in the tool post in one of three positions, a crude form of height adjustment is obtained, sufficient to enable the file to be used in a horizontal plane with varying diameters of work.

After marking out the centre of the pivot pin on the end of the square stock and forming a centre punch mark, the work is held in the 4-jaw chuck and set to run true with the aid of a centre wobbler.

Here again we find the need for a simple gadget which I am sure is available from tool shops but which the keen machinist will like to make for himself. I show the wobbler in fig 160 and in use in fig 161. You can see that its operation lies in magnifying the error and the longer the tail is made the more sensitive the tool is. Normally the tip of the tail would be lined up with the tailstock centre to give a datum from which to compare the movement. However, in a small lathe there is not sufficient length in the bed and as you can see in the illustration I have used the scriber in the surface gauge for this role.

With the centre punch mark running true, the work can be machined according to the drawing. It is advisable to make the roller first, as then the 7/32 in reamed centre hole may be used as a gauge for machining the pivot pin. You can see the right hand knife tool being used in this part of the work in fig 162.

Filing the flats on the verge arbor

Figure 163 shows the set-up in the Unimat for carrying out this work

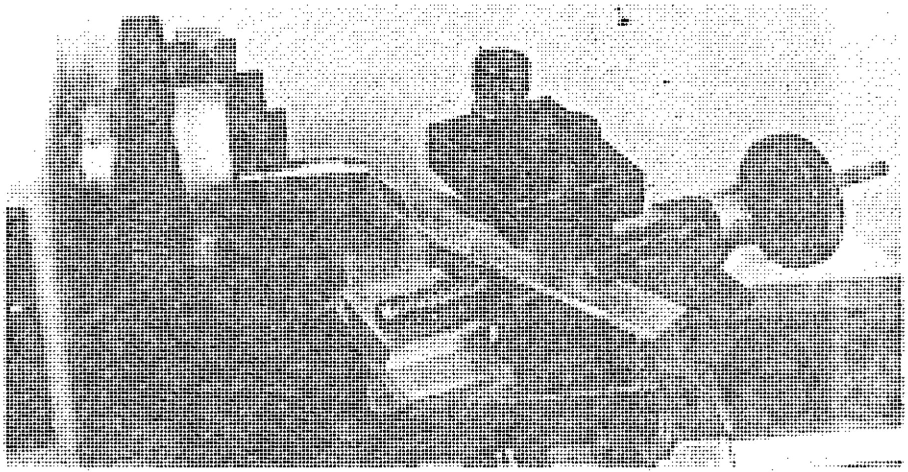


Fig 155 Machining the taper on the front bearing for the crown wheel

Fig 156 Forming the concave shape to the end of the crown bearing with a hand tool

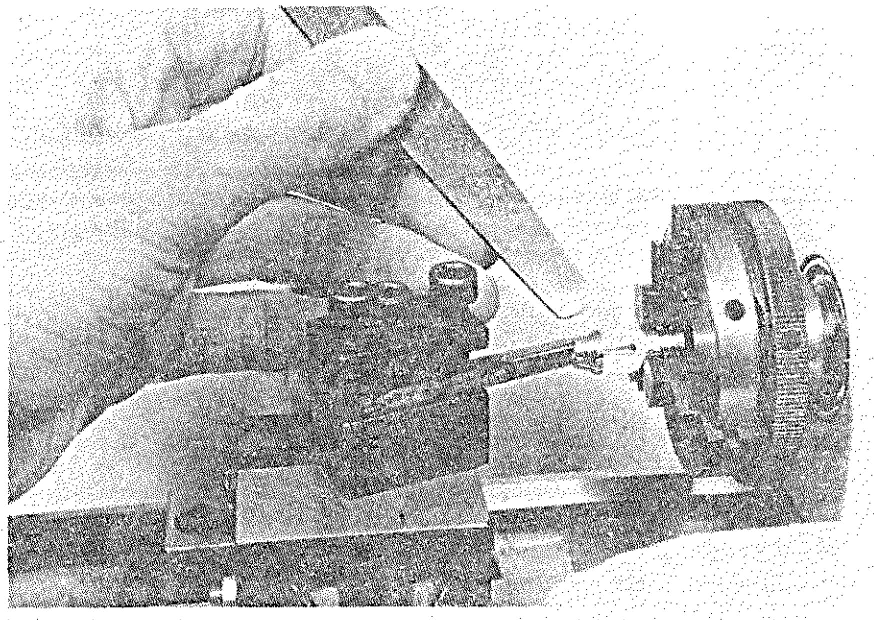
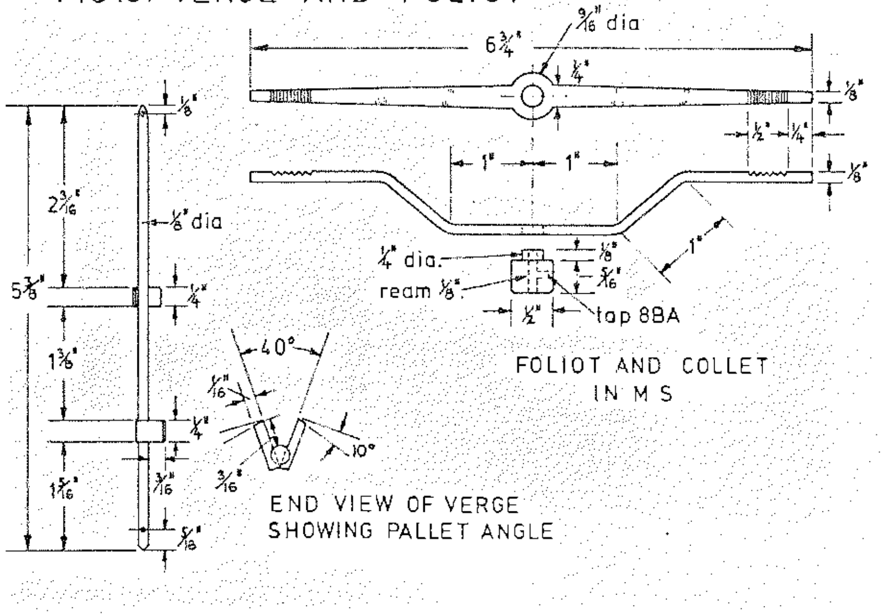


FIG157 VERGE AND FOLIOT



using the roller rest just described. The dividing attachment is fitted to the lathe bed with the 36 hole plate in position and indexed at zero degrees.

The verge arbor, which should be cut a little longer than required, should have the locations of the pallets marked, and held at each end by the two chucks as illustrated. The flats are not filed to the centre of the arbor as I found that this weakened it too much. They are taken to about a third of the diameter.

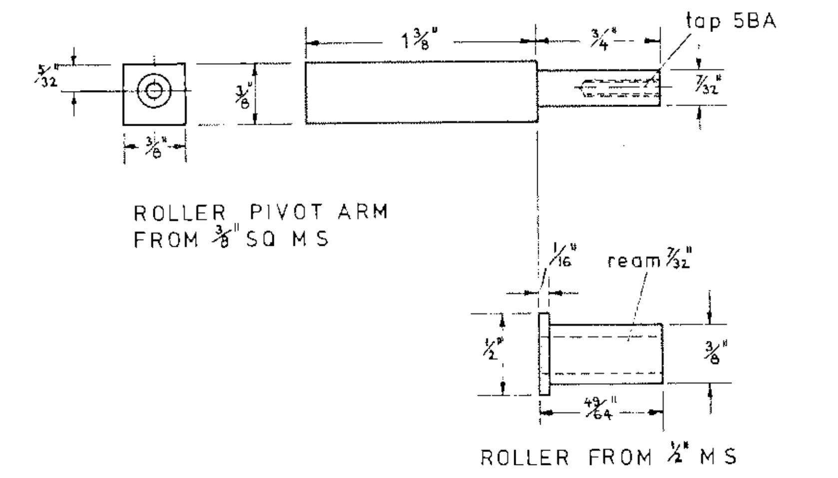
After the first flat is formed, the arbor must be rotated through 180° plus a further 40°, in other words 220° in all and the direction should be away from you. Don't forget to loosen the jaws of the tailstock chuck! With this second position indexed and the lathe carriage moved up the bed, the other flat is filed. By holding the safe edge of the file against the shoulder on the roller of the rest you should obtain neat ends to the flats. I used a file $^3/_8$ in in width.

Soldering the pallets

I always recommend the use of silver solder paste [17] for small jobs such as this. The flux is already incorporated in the paste. It is easier to handle the work if the pallets are still part of the parent stock as demonstrated in fig 164. Here you can see the arbor positioned on a fire brick and the ¼ in x 1/16 in mild steel strip placed with one end on the flat and the silver solder paste applied to the joint; bring the area to red heat.

Figure 165 shows the verge after the second pallet had been soldered but before the surplus material had been cut off with the hacksaw. The flux residue can be removed with a wire brush and the verge generally cleaned up. The length of the pallets should be left a little overlength for the moment.

FIG158 A ROLLER FILING REST FOR THE "UNIMAT" 3



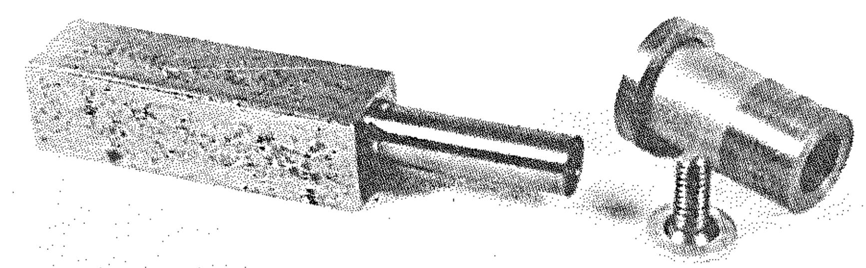


Fig 159 Parts for a simple design of filing rest for Unimat

Fig 160 The two components of a home made centre wobbler

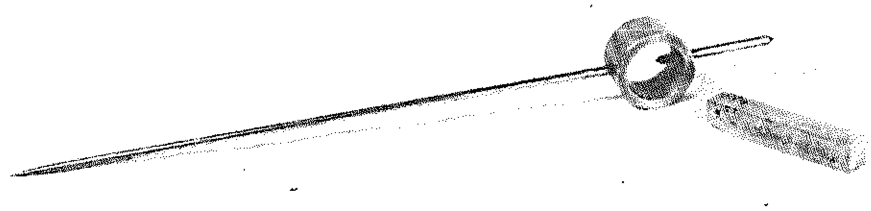


Fig 161 The centre wobbler in use in conjunction with the 4-jaw chuck

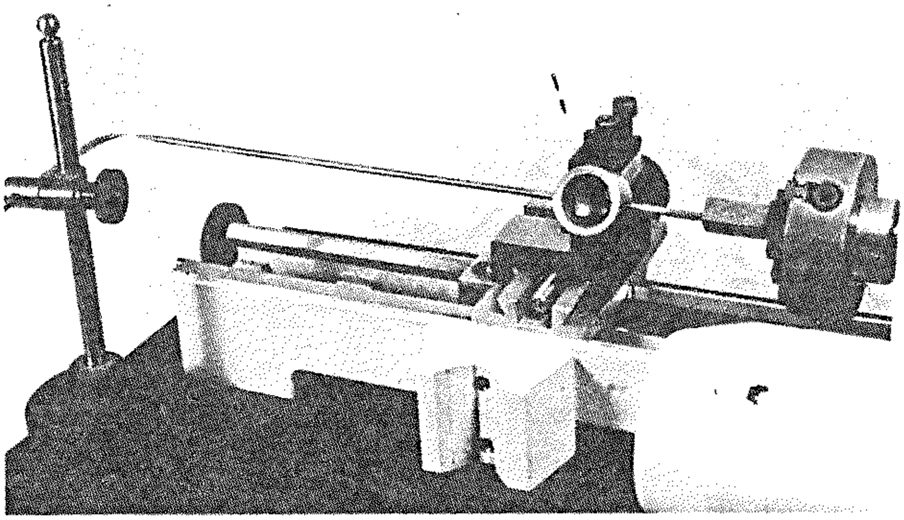
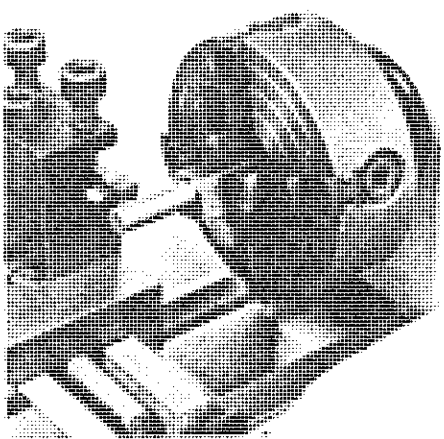


Fig 162 Turning the eccentric pin for the roller of the filing rest



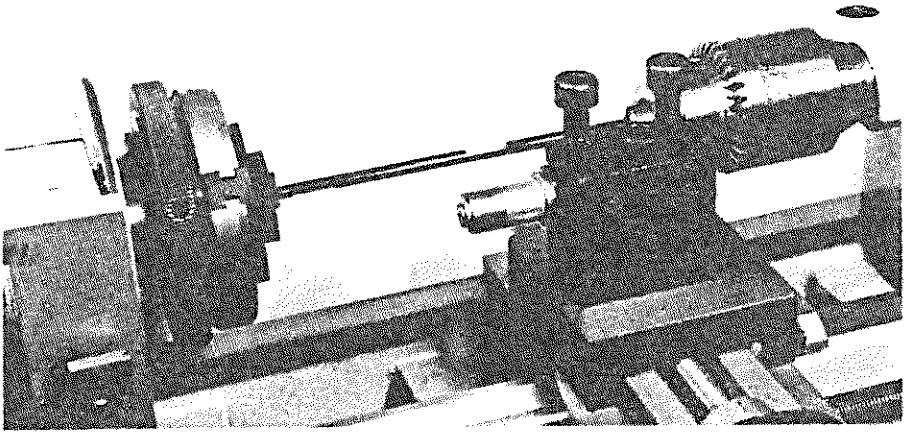


Fig 163 The home made filing rest being used to assist in filing flats on verge arbor

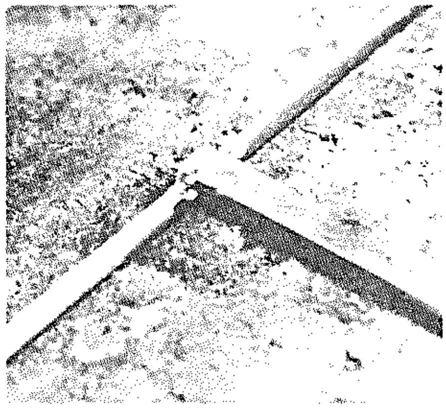


Fig 164 Pallet ready for silver soldering — note solder paste on joint

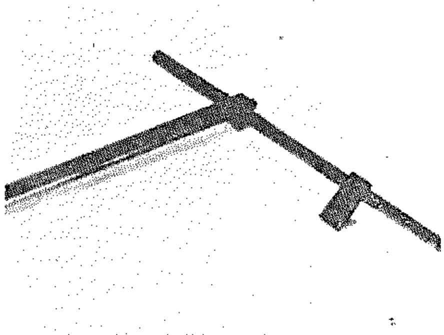


Fig 165 Verge after the second pallet has been soldered on

The included angle embraced by the pallets can be checked by sighting down the verge and holding the workshop protractor set at 40° on the same axis. If an error has been made the fault can be corrected by twisting the verge arbor between the pallets. To do this, that part of the arbor should be brought to red heat, and holding one end in the vice and the other with pliers, an adjustment is made. Almost certainly this will put the verge out of truth and this may be checked by spinning it between centres in the lathe, removing it and applying light blows with the hammer on the convex side.

In chapter 10 we continue by making the foliot suspension bracket and the two verge bearings. Then we can assemble the parts and check the action using a temporary foliot. We shall also complete the remainder of the steelwork.

Foliot suspension bracket, Lower frame support, The hanging ring, The verge lower bearing, The verge upper bearing, Cross drilling, Adjusting the escapement, The line

Chapter 10

Foliot suspension bracket

IN this part we complete the remainder of the steelwork in the clock. Those with a sense of organisation might wonder why all the construction in steel could not have been carried out together when the main frame was made. It could, and really should have been. However, I am bound to present the construction in the order that I built the clock otherwise the photographs would be out of sequence.

Drawing fig 166 gives the dimensions of the foliot suspension bracket, hanging ring and lower frame support.

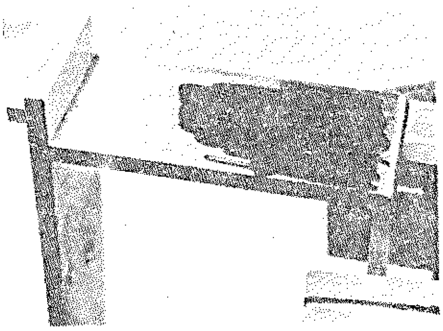


Fig 167 Marking out the position for the mortice to accommodate the tenon of the foliot bracket

In fig 167 you can see how the mortice is marked out on the top of the main frame and it is formed in exactly

Fig 168 Method of drilling the foliot bracket

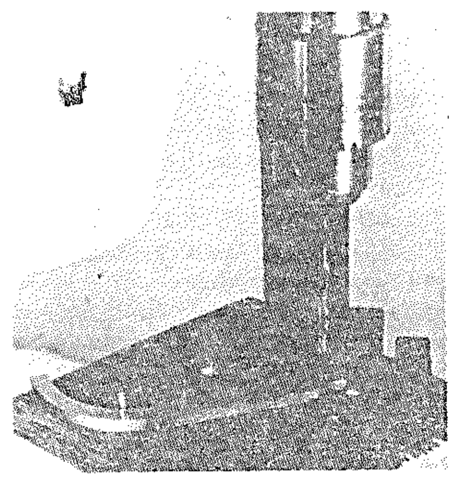
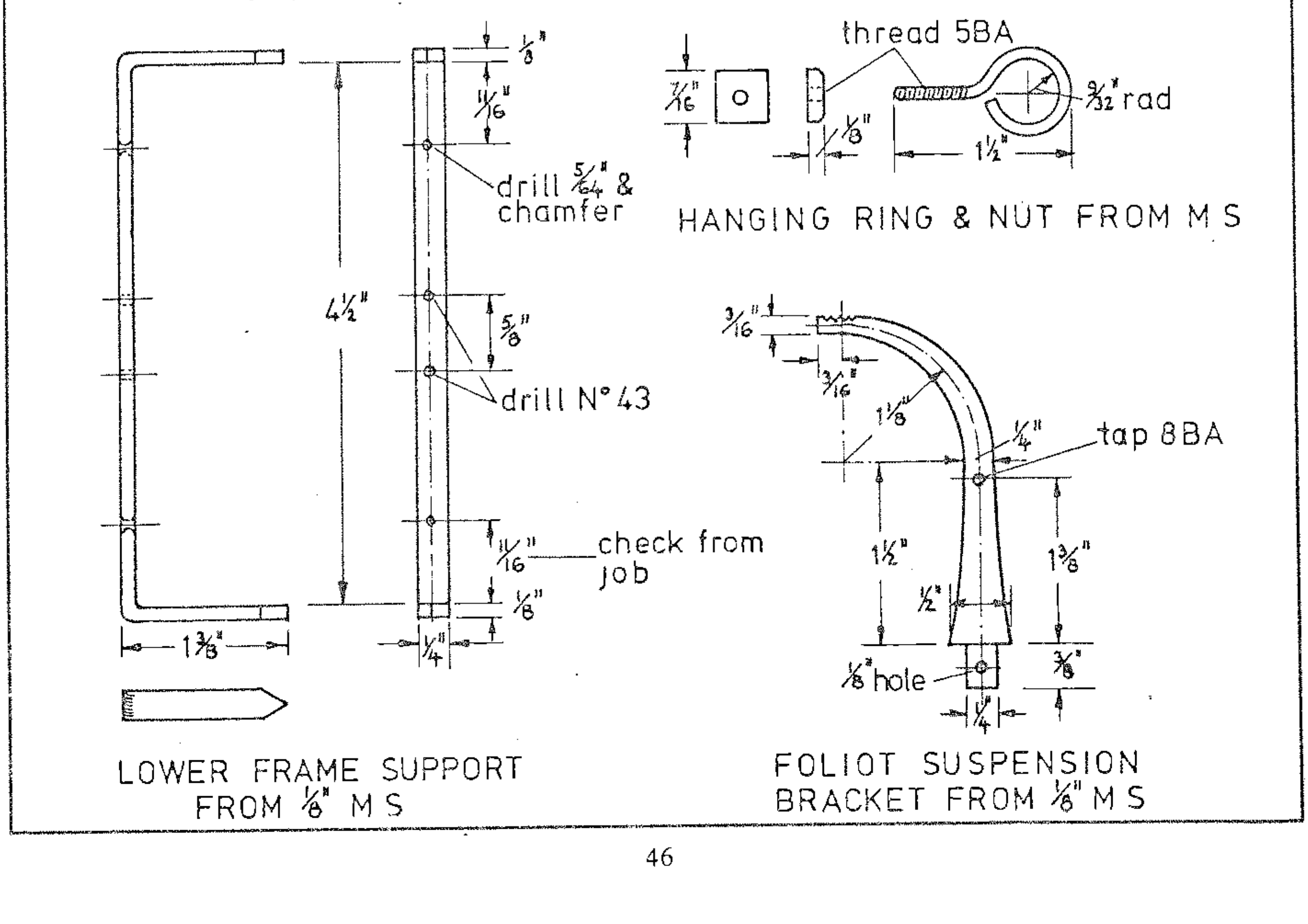


FIG166 LOWER FRAME SUPPORT, HANGING RING, & FOLIOT SUSPENSION BRACKET



the same way as those in the front plate.

After marking out the foliot suspension bracket, this can be cut out, either using a piercing saw, or by a series of straight cuts with a hacksaw. Again the drilling of the $^1/_8$ in hole is carried out so that a portion of it is occluded by the underside of the main frame. When drilling this component it is difficult to hold it in a machine vice, but the method shown in fig 168 where the arm is supported against a clock pin hammered into a piece of wood will give adequate support against the rotation of the drill. A series of vees are filed at the top of the bracket to provide alternative positions for the suspension thread.

Lower frame support

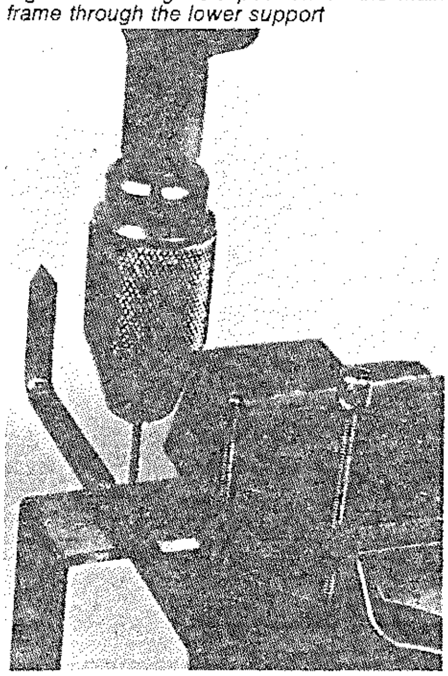
With this thin section of steel strip, the bending can be carried out by simply holding the main length in the vice and hammering the feet round the end of the vice jaws.

Although I have specified 8 BA screws to fix this component, rivets could be used. One of the register pin holes (B on fig 29) is used as a fixing hole and after fitting the two components together with one screw. They can be aligned with the engineers square then clamped together as illustrated in fig 169 for drilling through both together.

The hanging ring

In order to form the hanging ring neatly and without having to use force, it is advisable to heat the work.

Fig 169 Marking hole position on the main frame through the lower support



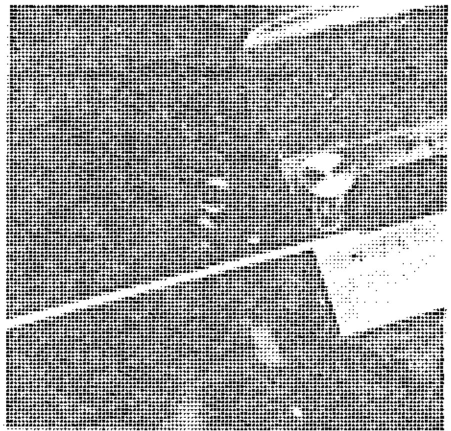
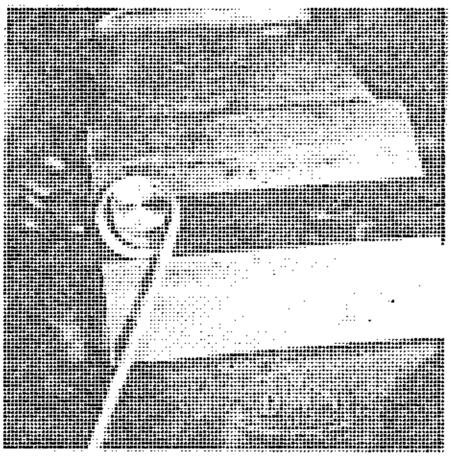


Fig 170 Forming hanging ring, first stage

Fig 171 Completion of the second stage in the forming of the ring



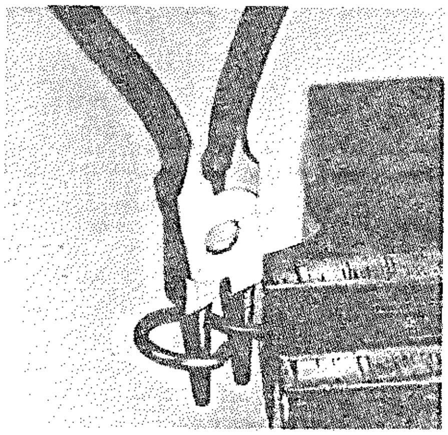


Fig 172 Putting in the bend at the neck with round nose pliers

Fig 170 shows the first step in forming the bend. A ½ in mandrel is gripped in the vice together with the end of the $^1/_8$ in rod. This is then pulled right round hugging the mandrel tightly as shown in fig 171. Another heat is taken and the work held in the vice as shown in fig 172. The round nose pliers are used to form a bend of the opposite hand at the neck. Finally, the work is held in the vice for threading 5 BA as demonstrated in fig173. The nut can be cut from $^1/_8$ in steel strip and filed to shape, the centre hole

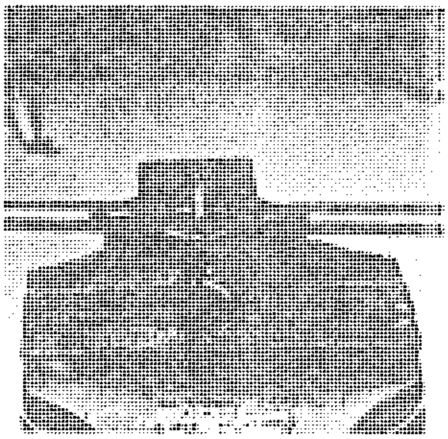


Fig 173 Threading the shank of the hanging ring

being drilled No 37 prior to tapping 5 BA.

The verge lower bearing

The lower verge bearing is formed from a short length of ¾ in x ¾ in x $^1/_{16}$ in brass angle but it could just as well be bent up from $^3/_8$ in strip.

If being made from angle, it is marked out according to drawing fig 174 and the work can be held in the Unimat machine vice in the manner demonstrated in fig 175. Note the soft packing between the brass and the surface of the machine vice. After all the holes have been drilled the work is separated from the parent stock with the hacksaw and the best way to file the sides, is to place a large file in the vice and push the work along it. This method will be illustrated in a later part. Finally, the weakening curves are filed, as illustrated in fig 176. These give a small measure of adjustment by means of bending, should this be necessary when adjusting the escapement.

The verge upper bearing

The verge upper bearing is made from ¼ in square brass which has a slot formed at one end to give some adjustment if required. Initially, the stock is cut overlength and set up in the 4-jaw chuck for facing both ends square and to form a centre at one end with the centre drill. The work is then pulled out from the chuck and supported from the tailstock, for turning the centre part.

At the time of making this component, my taper turning attachment had not arrived and I simply turned the centre to $^1/_8$ in diameter and then formed the taper with a file.

I then drilled the $^1/_8$ in hole and formed the slot with the piercing saw and needle files. The work was then taken to the Unimat for a milling operation.

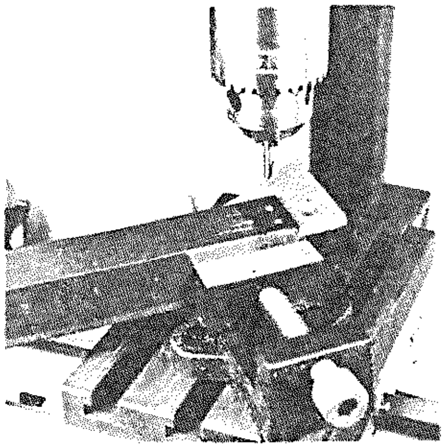


Fig 175 Method of holding brass angle for drilling on the Unimat

Fig 176 Filing the weakening curves in the lower verge bearing

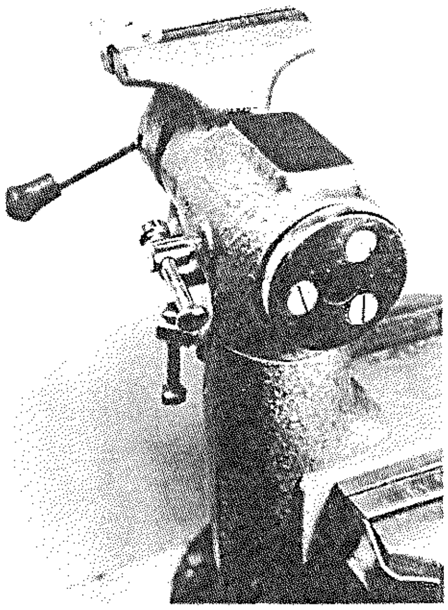
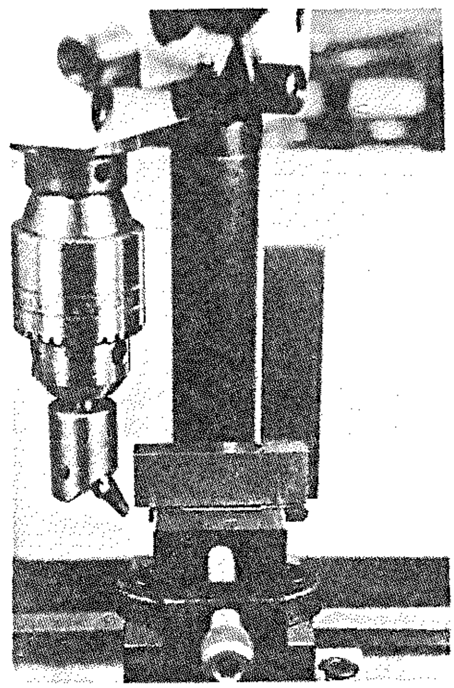


Fig 177 Checking the state of levelness of the upper verge bearing prior to milling with a fly cutter



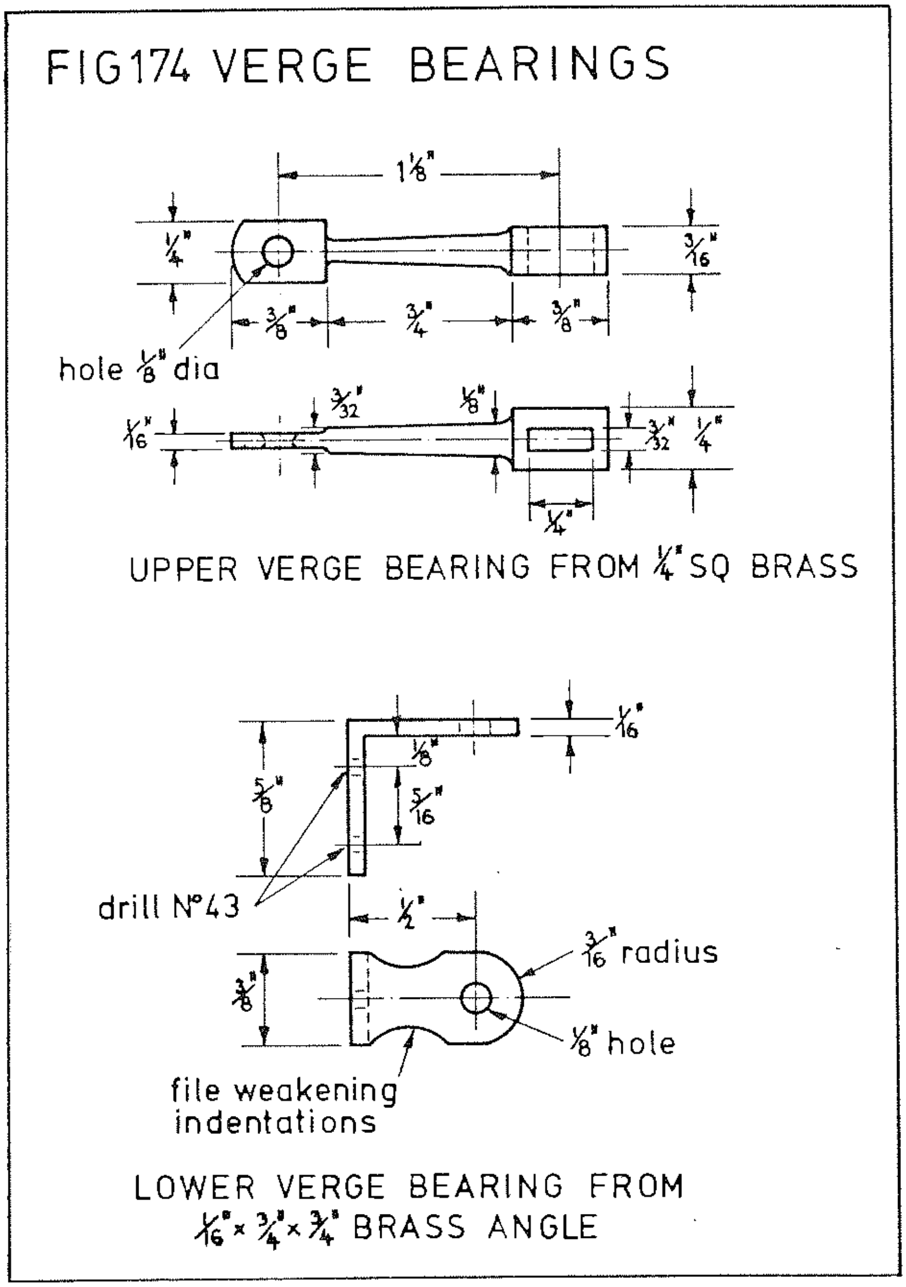
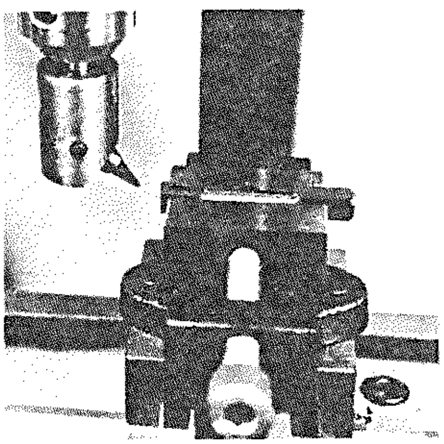


FIG174 VERGE BEARINGS

In fig 177 I show the set-up. The Unimat machine vice was fitted to the cross slide and the work clamped so that the upper surface was above the vice jaws. I then placed a small square as shown and by making a critical

Fig 178 Milling the slotted end of the upper verge bearing



observation of the blade against the Unimat's upright column I adjusted the work in the machine vice so that it was horizontal.

A fly cutter is part of the Unimat accessories but I already had a home made holder which is drilled to accommodate ¼ in silver steel cutters and I show it in this illustration. One thirty-second of an inch is taken off each side, so reducing the total width to $^{3}/_{16}$ in. This work can be seen after milling one side in fig 178.

The end which forms the actual bearing is reduced in thickness to $^{1}/_{16}$ in and I did this by filing.

It will be observed from drawing fig 23 that there is a $^{3}/_{8}$ in hole on the top of the frame. This is a clearance hole for the verge and it should be marked out now but only drilled No 30 size. With the bottom verge bearing in position, locate the verge as shown in fig

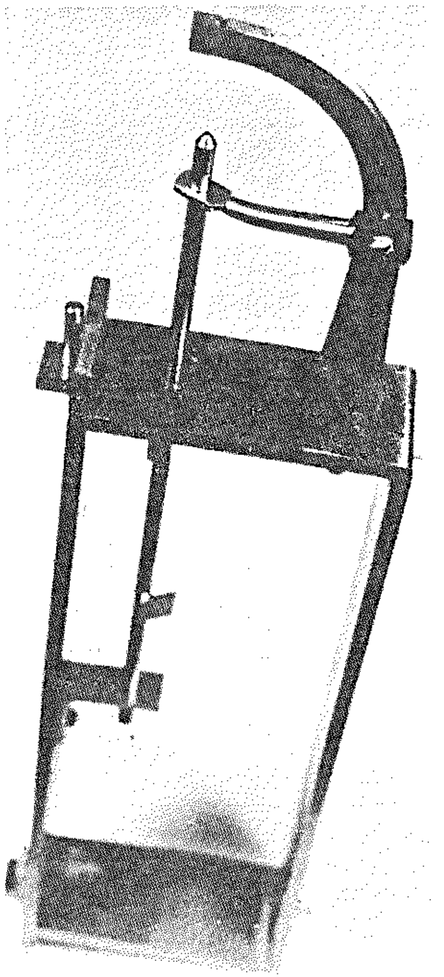
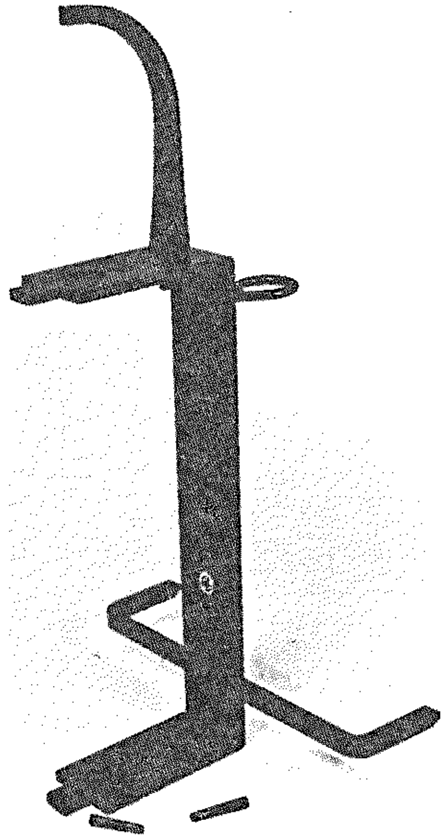


Fig 179 Method of checking the "set" in the upper verge bearing

Fig 180 The steel framework of the clock less the front plate



179, where it is held in its bearing at the bottom and through the hole in the frame. The centre of the verge arbor is positioned ½ in from the front plate as you can see from the drawings. The "set" is now put in on the small diameter of the arm of the top verge bearing. This can be done with round nose pliers and then tried in position on the foliot bracket. The set is adjusted by gentle manipulation until all three holes are in line. Finally, the clearance hole for the verge in the top of the frame is opened up by drilling to $^3/_8$ in.

In fig 180 you can see the steelwork of the clock at this stage. In fact the metal here has been blued.

We are almost ready now to have a trial run and to test the escapement.

You will notice that the verge is suspended on a loop of carpet or button thread which passes through a cross-drilled hole in the top of the verge.

Cross-drilling

Apart from the cross-drilling of the two holes in the verge arbor, there are several other places in the construction where it is necessary to produce a hole diametrically through an arbor or stud.

Well equipped workshops usually have cross-drilling jigs to locate the work accurately, the drill being taken through a guide which ensures that it passes through the diameter of the work.

In clock work we are not very often concerned with the accuracy so long as it *looks* all right, as in most cases the holes are only required to accommodate a tapered clock pin. A very satisfactory way to do the work is to fit a vee pad in the tailstock, the work is located in the vee and the drill is held in the headstock chuck. Unfortunately, this accessory is not included in the Unimat range and I did not have time to make it on this occasion. Instead I took a short length of $^5/_8$ in brass, turned ¾ in to ¼ in diameter and filed a vee on the other end. It is important to try and file the vee symmetrically in relation to the axis of the stock. I set the vee jig up in the Unimat as illustrated in fig 181 and using a length of ¼ in diameter steel in the drill chuck, I adjusted the jig with the carriage feed screw so that it was accurately located under the chuck as shown here. With the carriage locked, I drilled the cross holes in the verge arbor as shown in fig 182. It is of course necessary to form a

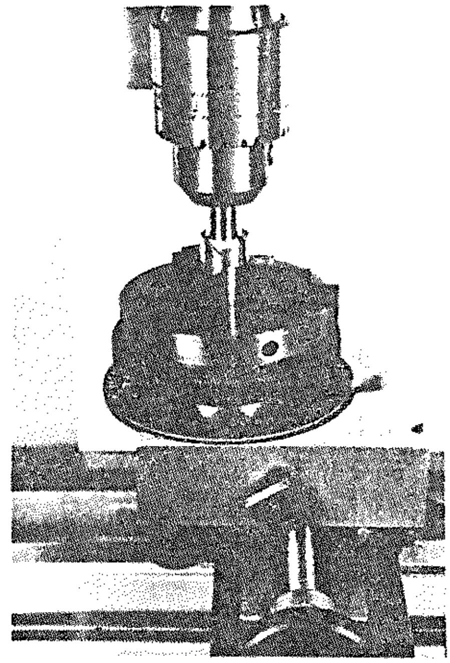
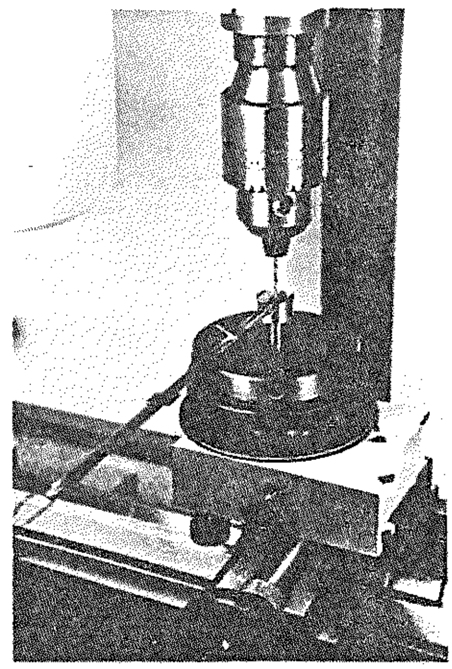


Fig 181 Setting the cross drilling fixture in the Unimat

Fig 182 Cross drilling for the pin holes in the verge arbor



positive marking with the centre punch on the work.

It will be noticed that the top of the verge arbor is tapered and the tapering should include the area where the hole is drilled as otherwise the suspension thread will be sheared off when threading the upper end of the arbor through the bearing hole.

Although the bearing holes in both the top and bottom verge bearings are shown to be $^1/_8$ in, they should initially be drilled No 31 size and a chamfer formed on both sides. The final sizing is done with the broach.

On all occasions when broaching is mentioned, I mean to imply that the

cutting broach is used. That is the one with five sides. Clockmakers use a round or smoothing broach as well and this has the effect of burnishing and work hardening the bearing surface of the hole. It is an excellent practice to use the round broach although it seems that not many clockmakers do in fact use it. The round broach will produce a burr or swelling at the entrance to the hole and this must be removed with the chamfering tool otherwise the end shake will be reduced.

Adjusting the escapement

An important setting in this type of escapement is the location of the crown wheel on its arbor. It should be positioned so that there is $^1/_8$ in between the teeth of the wheel and the verge arbor. This wheel can be secured with Loctite, or if the reader feels happier it can be secured with a small 8 BA grub screw through the collet to provide a means of adjustment. But this of course is not traditional practice. With the wheel correctly positioned on its arbor, the pallets are reduced in length by filing until they allow the teeth of the wheel to escape. It is important that the length of the pallets is not reduced more than necessary for this to occur. If too much is removed, then the drop will be excessive.

The drop is a feature of almost every clock escapement. It is the free movement of the escape wheel as a tooth escapes from one pallet and is arrested by the other. It should be minimal, as it is wasted energy. Not only must the drop be minimal but it should be equal on each pallet.

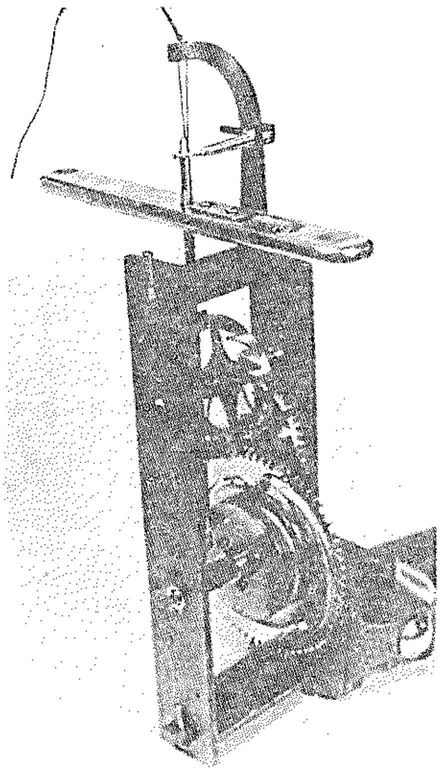


Fig 183 The movement at this stage, and ready for the initial testing and adjustment of the escapement with a temporary foliot

If, for instance, we notice that the wheel makes a larger movement when it is arrested at the top pallet, the upper verge bearing must be bent over to the right to bring the top pallet in that direction. If on the other hand the larger movement occurs when the wheel is arrested by the lower pallet, the bottom bearing must be bent a little to the left. You will find the amount of movement needed extremely small.

The engaging surfaces of the pallet should be given a good finish with diminishing grades of emery stick.

At this stage a temporary foliot can be improvised with an Eclipse tap wrench as shown in fig 183 and as finger pressure is applied to the teeth of the main wheel the escapement should start to function.

Just as it was important to have freedom in the wheel train, so it is with the verge arbor which should be absolutely free in its bearings. There should be a healthy recoil in the action and of course this cannot be if there is tightness.

The clock can in fact be hung up on a wall in this condition and driven with a temporary weight.

The line

I have used a piping cord $^1/_8$ in diameter as sold for edging cushions.

In the finished clock you will require 12 ft.

A weight of some 1½ lb should drive the clock on a single line for this initial testing.

The foliot, The foliot weights, The weights, Hour wheel stud or post, Hour wheel collet, Dial feet and pillars, The dial, The hour hand, The pulley frames, The pulleys, General finishing and polishing the steelwork, Oiling, Conclusion, Modification to the pulley design in the foliot clock

Chapter 11

The foliot

THE foliot was shown on drawing fig 157 and I shall describe its construction now with illustrations. It is cut out of $^5/_8$ in or ¾ in mild steel strip and the first step is to mark out a centre line, find the centre, scribe the $^9/_{16}$ in centre circle and drill the ¼ in hole. The sawing can be carried out with the hack saw in straight cuts and the component should look as in fig 184. The locations of the bends should also be marked with light centre dots. The work should now be filed to the line and it is convenient to clean it up with wet and dry paper before putting in the bends. It is always much easier to finish stock which is in the flat condition.

One way to form the bends neatly and under control is illustrated in fig 185 where you can see that I have utilised an old strap hinge in conjunction with the bench vice. The strap of the hinge providing the lever. The bends are made to an angle of 40° and you can see this angle being checked in fig 186.

The serrations for the foliot weights should not be filed in a haphazard manner. They can be marked out on both arms in a positive way as shown in fig 187 in increments of $^1/_{16}$ in. The piercing saw is then used to form a shallow cut on each mark and finally the three square file is used to form the notches. Figure 188 depicts the piercing saw in use for this operation.

The collet which is also of mild steel is straightforward turning and the foliot arm is riveted in position.

The foliot weights

The foliot weights are also in mild steel and dimensioned on drawing fig 189. You can see that a fairly large chamfer is formed on their upper surfaces and if the taper turning attachment is available then it may be used

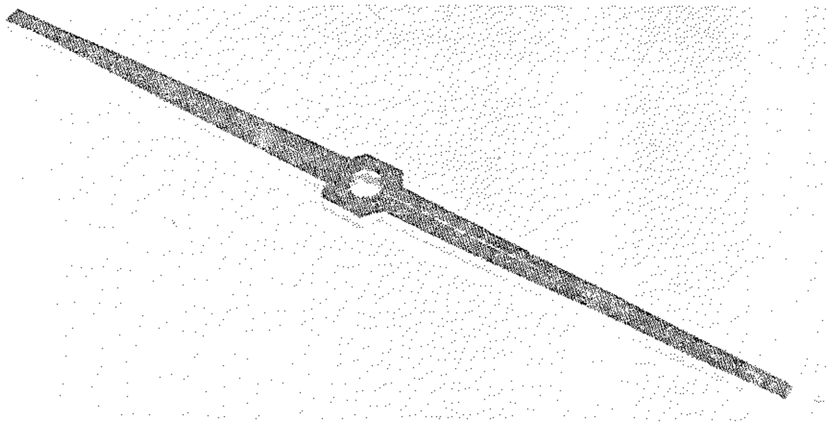


Fig 184 The first stage in the construction of the foliot

Fig 185 Using a strap hinge in the vice to assist in forming the bend

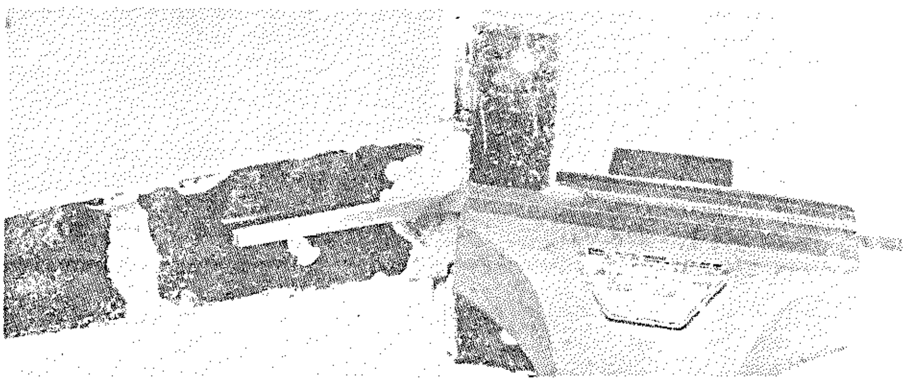
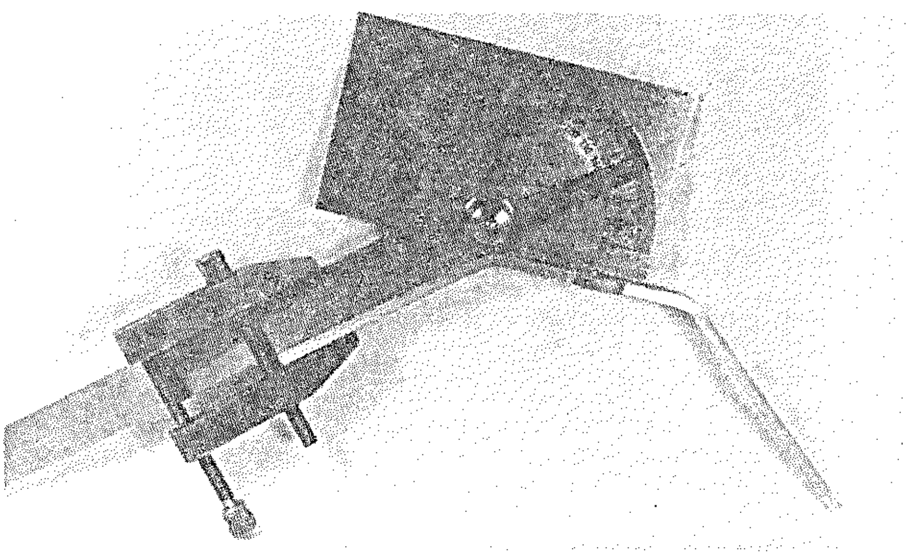


Fig 186 How the angle of the bends can be checked with the workshop protractor



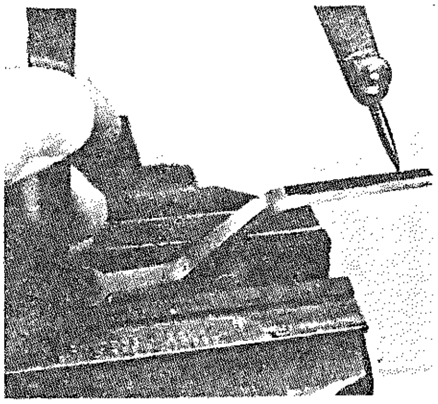


Fig 187 Marking out the positions for the rating notches on the arms of the foliot

Fig 188 Using the piercing saw to start the notches on the foliot

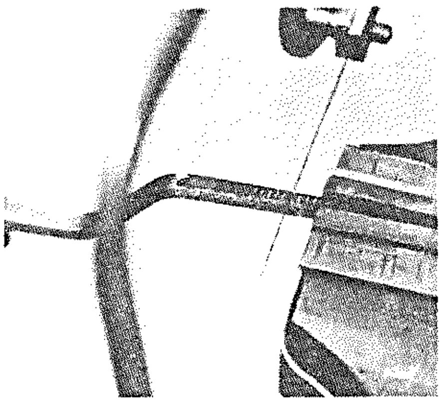
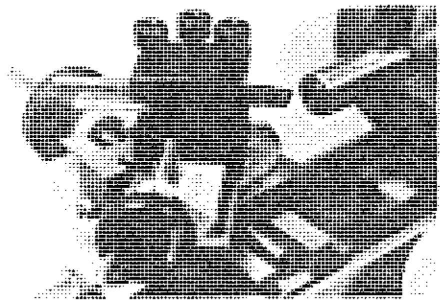


Fig 190 Machining the chamfer on a foliot weight



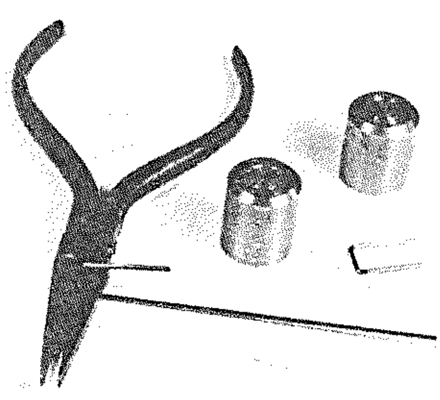
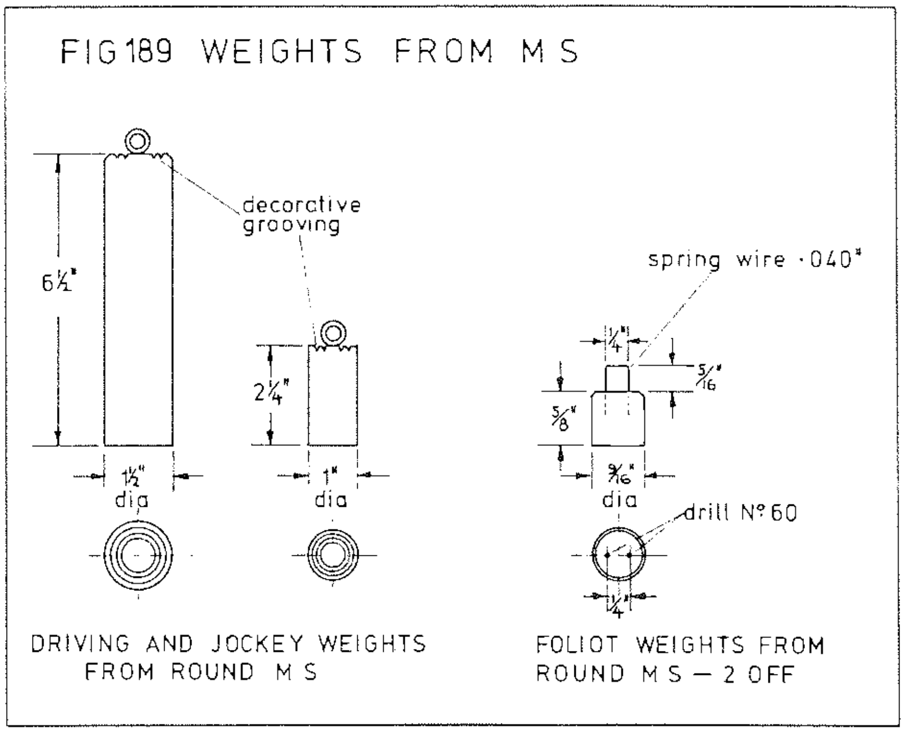


Fig 191 Bending the wire for the foliot weights

in the manner demonstrated in fig 190. You can also machine a shallow circle ¼ in diameter which will be a convenience for drilling the holes for the wire hooks. After cutting off with the hacksaw and facing the bottom, a



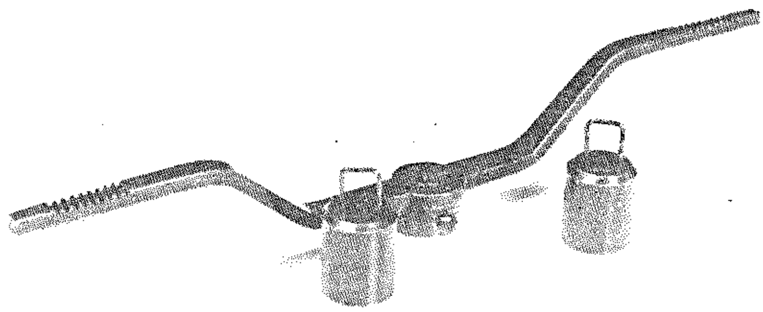


Fig 192 The completed foliot assembly

diametral line may be scribed on the upper surface and the hole positions marked with a centre punch.

I used a stiff wire 0.040 in diameter and the holes in the weights were drilled No 60 size.

The wire is bent into a U shape as illustrated in fig 191 and they are tapped into position with a little smear of Araldite on each leg if necessary.

The complete assembly is shown in fig 192. Here again the steel has been blued and I will be commenting on the finishing of the clock at a later stage.

The weights

As the weights are also on drawing fig 189 I shall deal with them now. It is quite common to use stones in this role and there is no objection to this provided a suitable shape can be found. The driving weight needs to weigh some 2½ lb and the jockey weight 8 oz. The dimensions given in the drawing will fulfil these requirements and 1½ in diameter can be accommodated in the fixed steady of the Unimat lathe which is convenient for facing the end and drilling the hole for the eye or hook. In the absence of the fixed steady, the stock can be filed reasonably flat at the ends and a centre marked out as accurately as possible. After drilling the centre by hand the work can then be held in the 3-jaw chuck at one end, and by the tailstock centre at the other for facing and chamfering the end. Figure 193 shows the two weights.

Hour wheel stud or post

The hour wheel stud or post, is dimensioned on drawing fig 194. It is made from $^5/_{16}$ in mild steel rod. The machining can be carried out with the work held in the 3-jaw chuck, turning the $^5/_{32}$ in diameter first. The pivot file may be used to form a good finish on this part and the work is then reversed in the chuck for forming the 5 BA thread.

The hole in the front plate to accommodate this stud can be marked out with the depthing tool in the manner shown in fig 195. Here you can see that the hour wheel and its mating

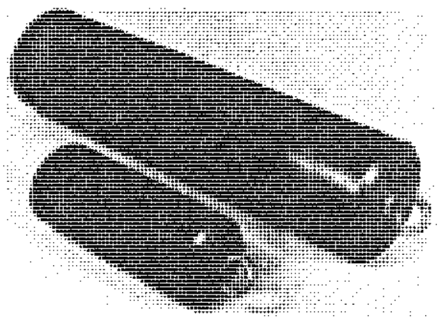
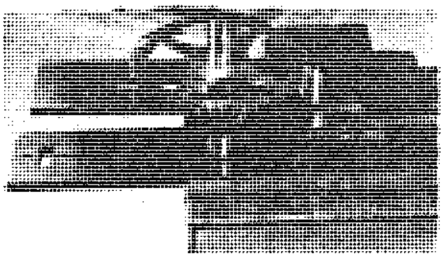


Fig 193 The driving and jockey weight

Fig 195 Depthing the hour wheel and pinion and marking out the radius on the front plate



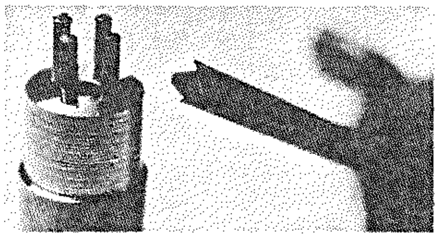
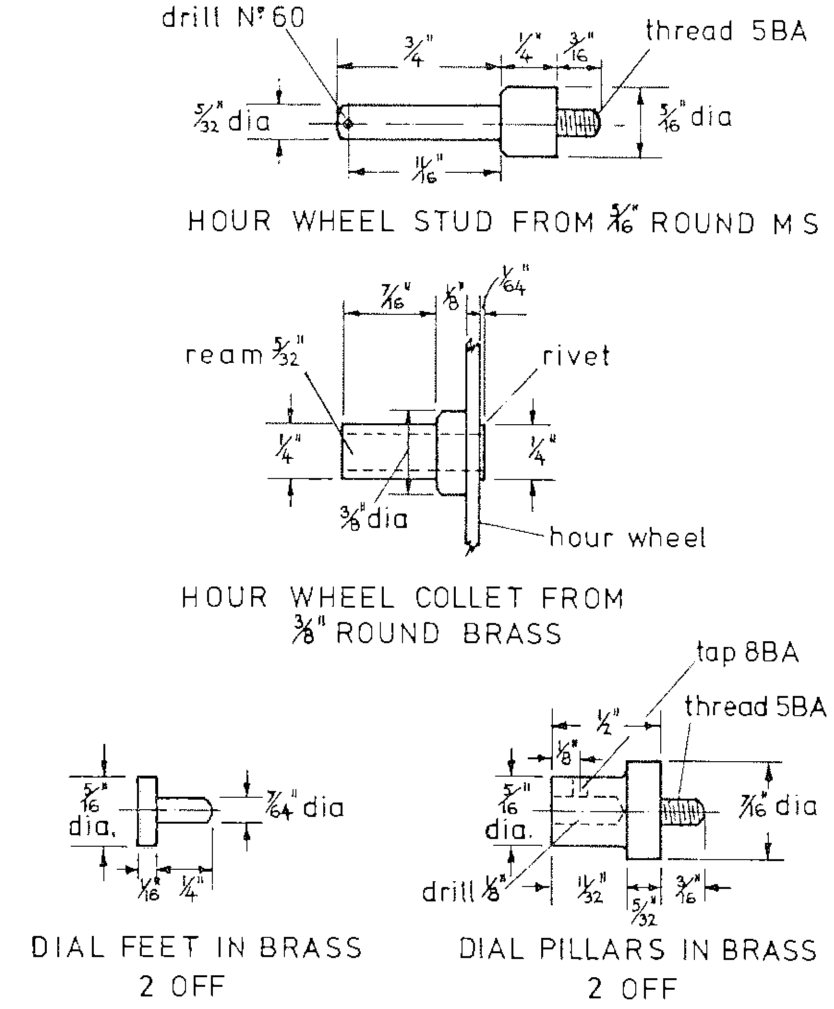


Fig 196 Showing the chamfering tool for use in rounding the ends of pins

FIG194 HOUR WHEEL STUD & COLLET, DIAL PILLARS, DIAL FEET



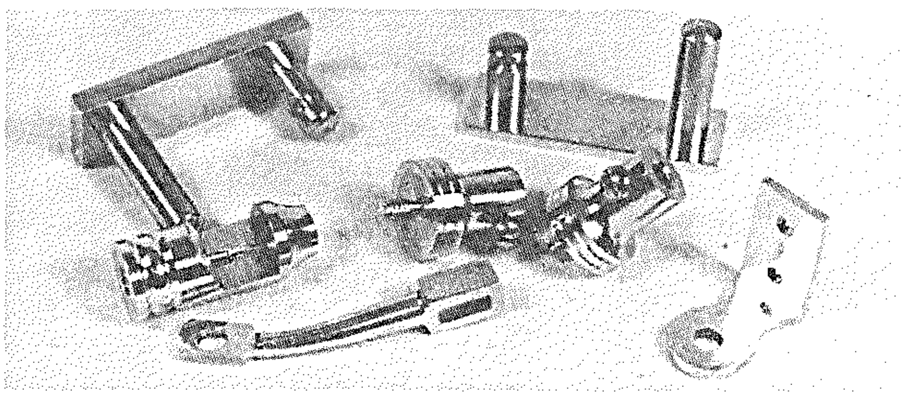


Fig 197 A group of small components

pinion have been mounted in the tool for checking the engagement, and with the trumpet runner engaged in the main arbor pivot hole, the other runner scribes an arc. It will be interesting to see how this arc compares with the theoretical measurement which you marked out in the early stages of the construction of the clock.

I have not shown the making of this pinion as it is carried out in the same way as the others. After tidying up the ends of the pins on the grinding wheel it will be necessary to chamfer them and the little tool shown earlier can be used. Figure 196 depicts a stage in the construction of this pinion and you can see that the two pins on the right have been chamfered with the tool illustrated, whereas the two on the left appear in the state left from grinding.

Hour wheel collet, dial feet and pillars

The hour wheel collet, dial feet and pillars are shown on drawing fig 194 and are straightforward 3-jaw chuck work. In each case the stock is held for the first part of the turning, parted off and reversed in the chuck for machining the other end. A group of brass components is illustrated in fig 197 and a view of the front plate is given in fig 198 where you can observe that the hour wheel stud has not been cut to length. The dial pillars have, however, been screwed into the plate and it is better to do this prior to drilling the cross holes for the 8 BA screws as then these can be located in a convenient position for access with the screwdriver. It will be appreciated that the dial feet will be cemented to the back of the dial and locate in the sockets of the dial pillars where they are retained by the 8 BA screws.

A further group of wheels is shown in fig 199, and in fig 200 you can see the train wheels sitting in their pivot holes on the main frame as they would be in preparation for fitting the front plate.

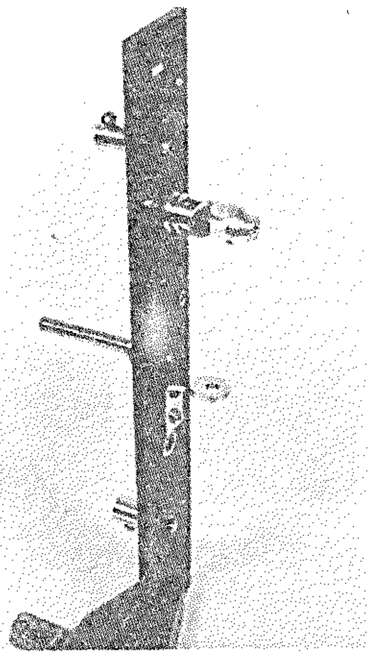


Fig 198 The front plate with its fittings

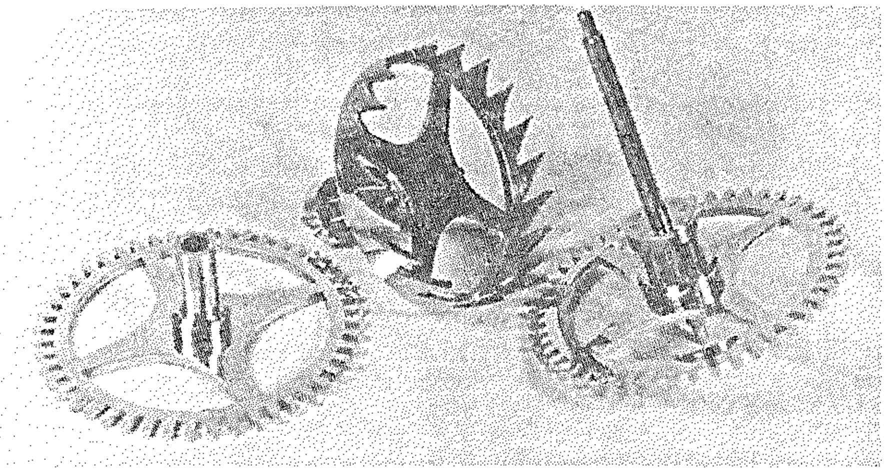


Fig 199 A group of wheels

Fig 200 The train wheels in position in the main frame ready for fitting the top plate

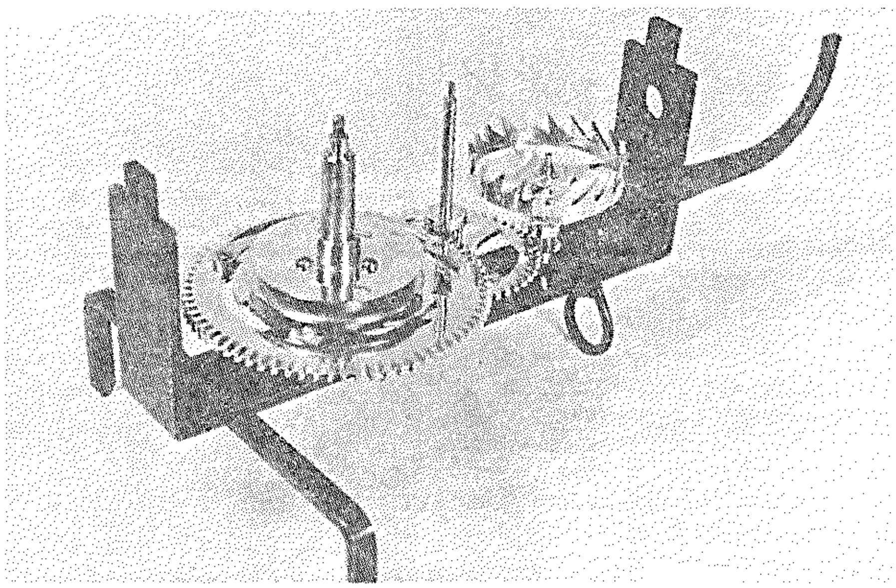
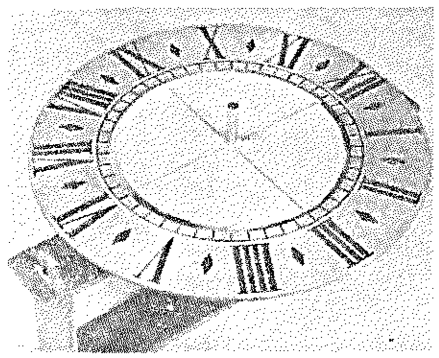


Fig 201 Centralising the dial ring on the front plate

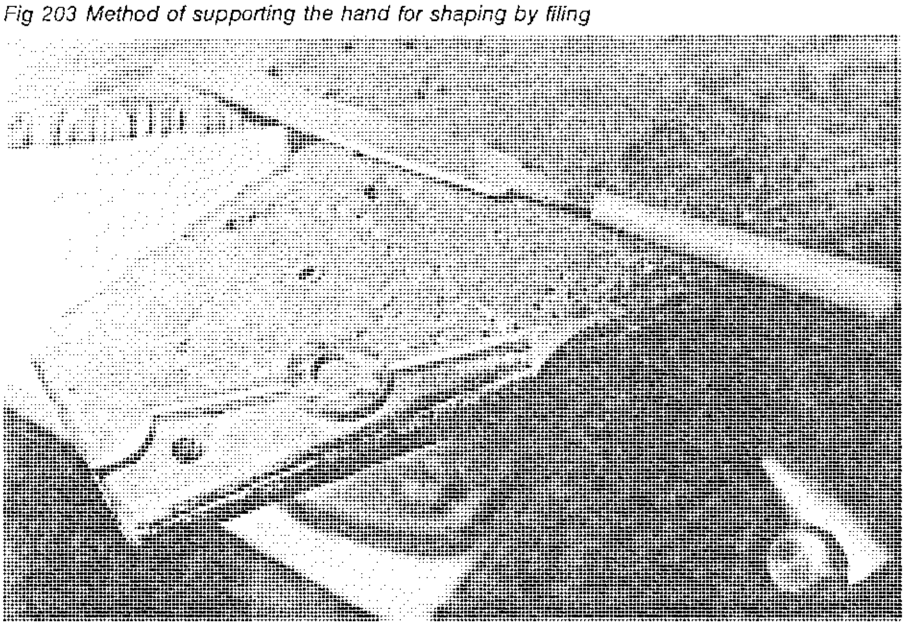


The dial

I am recommending the purchase of the dial as it would be difficult to engrave it on the Unimat in the manner that I have done with the other clocks[18]. For the benefit of those who would like to make some attempt at this, either with Letraset or by painting, etc, the dimensions of the ring are:– od $5\frac{5}{8}$ in and id $3\frac{3}{8}$ in.

A satisfactory way of centralising the dial on the clock is shown in fig 201. In this illustration the dial feet have been placed in their sockets in the dial pillars and a blob of Araldite placed on the upper faces of each. Needless to say the area on the back of the dial where the feet will be secured should be roughened with emery cloth and the faces of the dial feet treated similarly. A circle of thin card is cut out a little smaller than the inside of the dial ring and two cross lines drawn as shown. This is impaled on the hour wheel stud with one of the cross lines parallel with the axis of the front plate. The dial ring can then be dropped in position and manoeuvred until the 90° markings coincide with those on the cardboard circle as shown in this illustration.

Fig 203 Method of supporting the hand for shaping by filing



The hour hand

A drawing of the hour hand is given in fig 202 together with its collet. Of course the constructor is at liberty to indulge his own preference in this matter. The one I show is quite simple

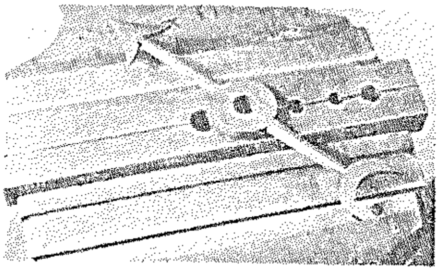


Fig 204 Using a home made split vice stake for riveting the collet in the hand

Fig 205 The back of the dial and the wheelwork

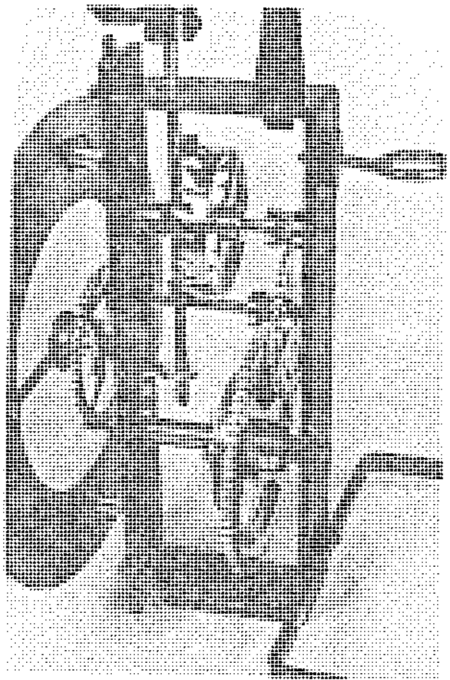


FIG 202 THE HOUR HAND

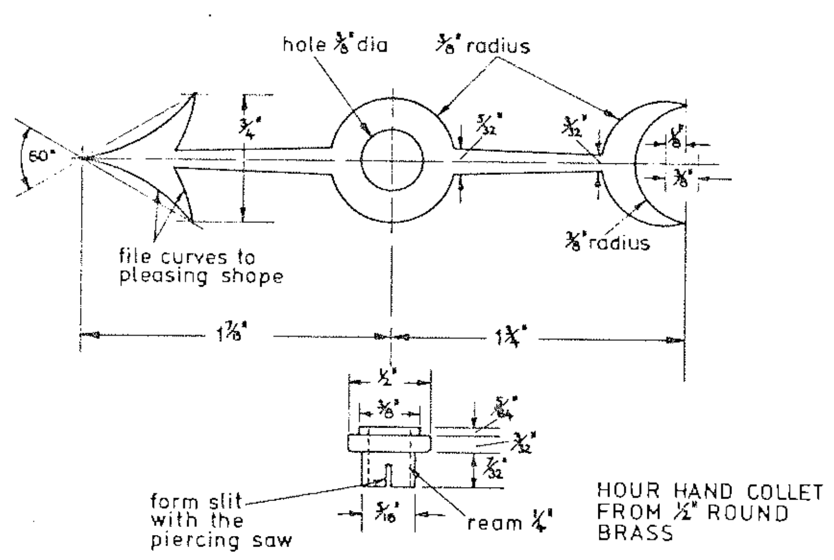
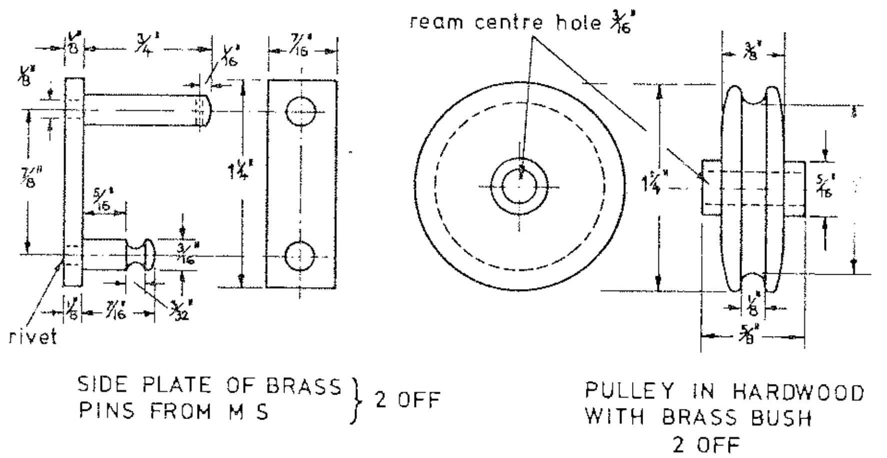


FIG 206 PULLEY AND PULLEY FRAME



to make. It is cut out from a strip of $^1/_{16}$ in mild steel ¾ in wide. After marking out, the $^3/_8$ in hole should be drilled and the shape can then be cut out with the piercing saw. When filing to shape, the edges are not formed at right angles to the face of the work but angled inwards so forming an upwards taper. The hand is also given shape at the tip and tail which are both thinned at their extremities. There is also a tapering towards the sides and the main stem is ribbed. A convenient way to hold the hand for this work is to position it on the edge of the sawing board. A couple of clock pins are knocked in to support it against the thrust of the file. This is illustrated in fig 203.

Another view of the hand is shown in fig 204, where you can see the collet being riveted in the centre. The back of this collet is slit with the piercing saw as depicted on the drawing and the saw cut slightly pinched up in order to make it a friction fit on the hour wheel tube.

Figure 205 illustrates the back of the dial and the method of fitting. It also gives a general view of the wheelwork. It has just occurred to me that I have not explained the reason for the second pin hole at the bottom of the verge arbor. It will be apparent that if for any reason the verge is lifted up, the pallets will be disengaged from the crown wheel and the latter will run away at high speed. It is almost certain that on re-engagement the teeth of the crown wheel will be damaged. This pin is located in such a position that it contacts the underside of the lower verge bearing before the pallets become disengaged. The same will happen if the thread breaks, and this situation can be avoided, either by making the arbor sufficiently long at its lower end so that it bottoms on the main wheel arbor, or by positioning the foliot so that its collet rests on the frame before the pallets become disengaged.

The pulley frames

The pulley frames are the final parts to be made and are dimensioned in drawing fig 206. The pins are riveted in the side plates and in fig 207 you can see again the clockmakers broach being used to enlargen the hole until the pin will enter about halfway. In fig 208 you can see how I use a wooden dolly to protect the polished end of the pin from the hammer. You can also see the vice stake. The tightness of the press fit should be such that hardly any riveting is required. The back of the side plate is tidied up in the manner shown in fig 209. Here the file is held in the vice and the component pushed along it.

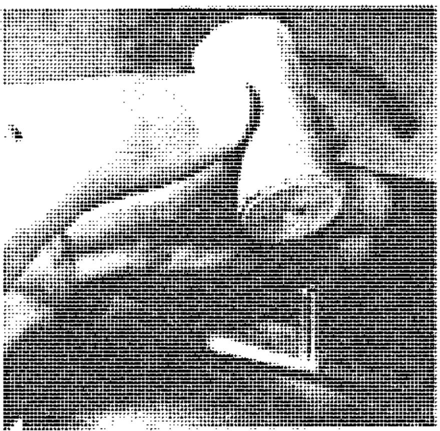


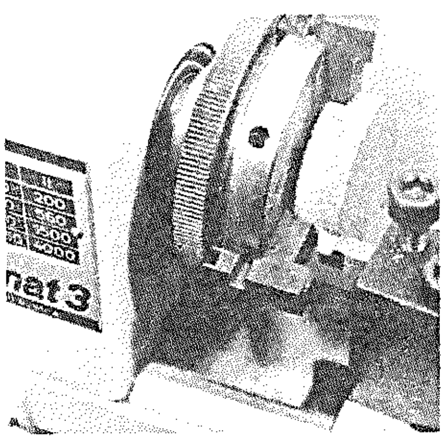
Fig 208 A wooden dolly being used in conjunction with the hammer and vice stake in order to drive the pin home

The pulleys

The machining of the pulleys is such an interesting operation and covers such a range of lathework that I decided to photograph every step and the beginner might like to make these parts first as an introduction to general turning.

The first step is to mark out two 1¼in diameter circles in pencil on a piece of flat hardwood $^3/_8$ in thick. These are then cut out by any convenient means to as nearly circular as possible and held in the 3-jaw chuck as demonstrated in fig 210. You can see one of these pieces positioned on top of the headstock, the other piece has been turned to 1¼ in diameter for as far as the chuck jaws will permit. An ordinary knife tool ground for steel turning is being used. In fig 211 you can see the work has been reversed in the chuck and the other half of the pulley turned to the same diameter. At this same setting the pulleys are drilled from the tailstock to $^5/_{16}$ in diameter. It sometimes happens that when drilling in wood the drill tends to wander out of truth and if this occurs the boring tool should be used.

Fig 211 Stage 2: here the work is reversed in the chuck for machining the other half. Note the setting of the tool



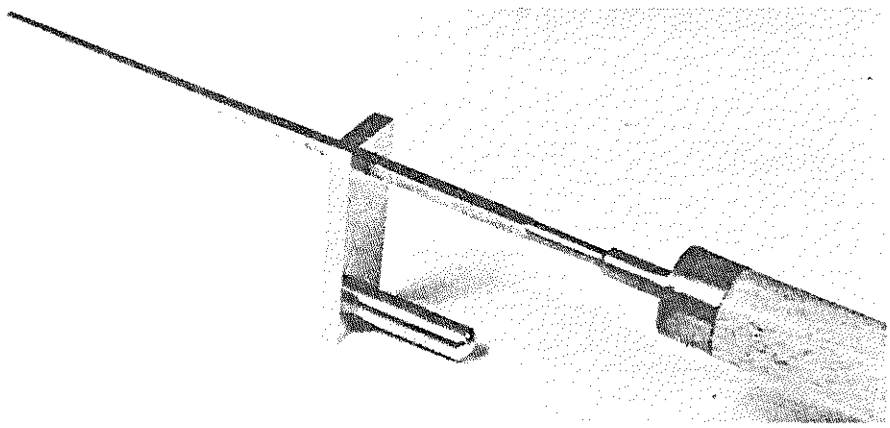
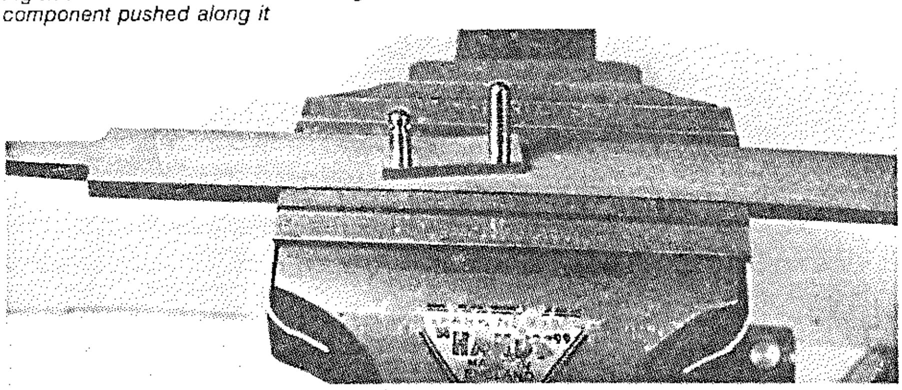


Fig 207 The broach being used to enlarge the hole prior to fitting the steel pin

Fig 209 A convenient method of filing small flat surfaces. The file is held in the vice and the component pushed along it



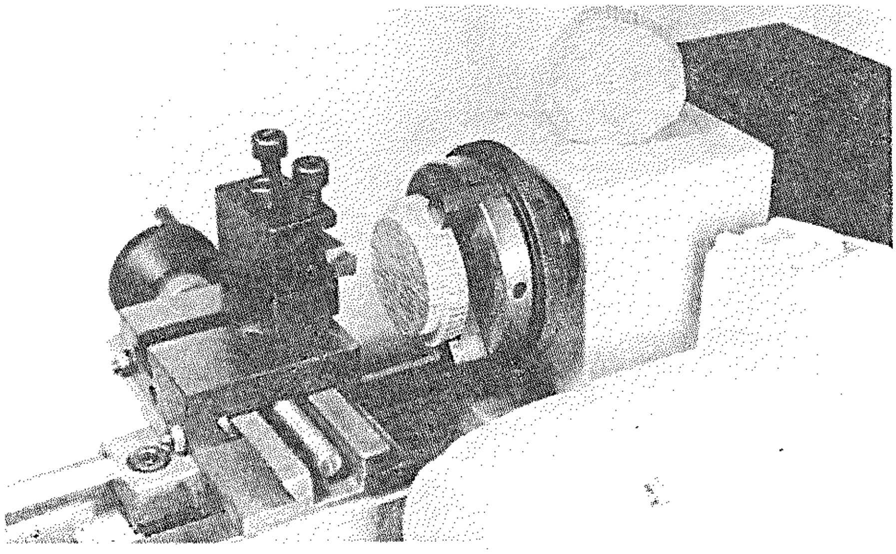


Fig 210 The first step in machining the wooden pulleys

Two 1in lengths of $^5/_{16}$ in brass rod are now cemented in the centres of the pulleys. This stage is illustrated in fig 212. A groove is formed now according to the drawing by feeding in a roundnose tool as shown in fig 213. In a small lathe the work will be facilitated by keeping the round nose for the final shaping and using a parting tool first to remove the bulk of the material. The work is held this time by the brass rod and the chuck jaws have been reversed.

If the taper turning attachment is available then it may be used to form the sloping sides as shown in fig 214. The slide is offset ten degreees and in this position the engraved markings are of no help so the workshop protractor is used as demonstrated here in order to set the slide. In fig 215 you can see the flanks of the pulley being machined. Finally the sharp corners are removed with a fine file and emery paper. In fig 216 you can see the pulleys at this stage, the one on the left still has to have the sharp corners on the flanges rounded off.

In fig 217 you can see the decorative grooves being put in with the graver and following this, which completes the machining on the actual

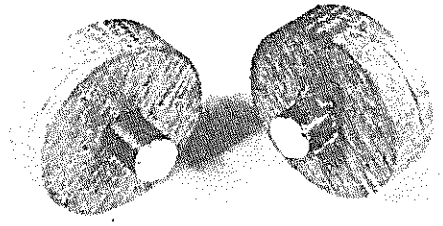
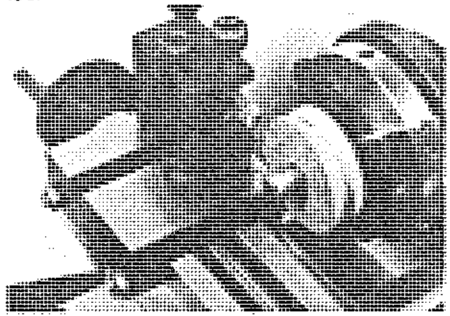


Fig 212 The embryo pulleys drilled for the chucking pieces which have been cemented in position

Fig 213 Holding the pulley by the chucking piece for forming the groove with a round nose tool



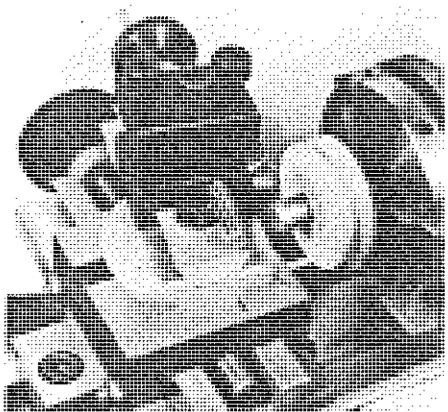


Fig 215 Machining the tapered flanks of the pulley

wooden pulley, we can turn away the chucking pieces as they have now served their purpose. In fig 218 I have reduced the length of the brass to $^1/_8$ in and am using the centre drill prior to drilling through with the No 13 or 14 drill (fig 219). This would then be followed with the $^3/_{16}$ in reamer.

In order to work on the other side of the pulley we have to locate the work by its bore as we have lost the chucking piece on that side. A short piece of scrap brass rod is turned to just over $^3/_{16}$ in and a taper formed with a fine file. The pulley is "wrung on" and we can now shorten the other side as demonstrated in fig 220. The constructor might be wondering why the pulley could not be held by the $^1/_8$ in length of brass rod. In an emergency it could be, but there would not be a secure hold and excessive tightening of the chuck jaws in an attempt to compensate for this would strain the chuck and generally be bad practice.

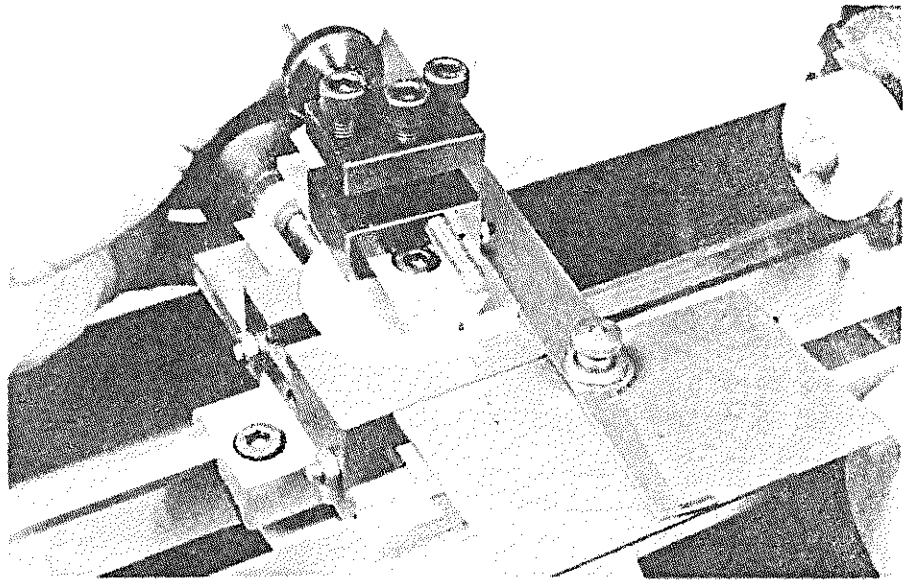
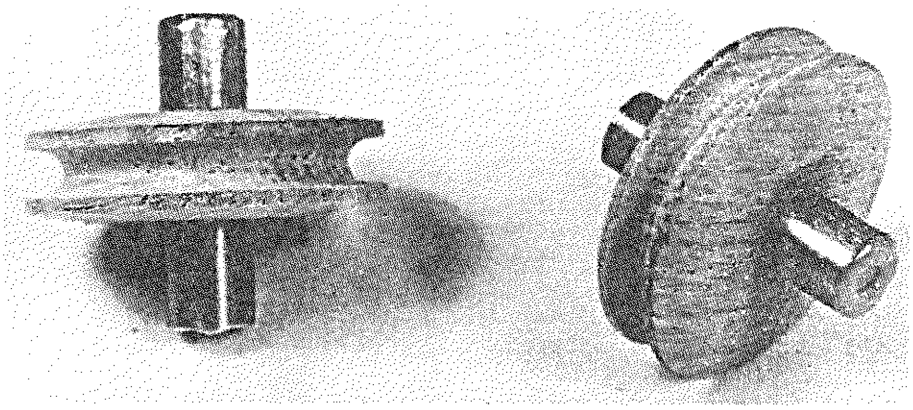


Fig 214 Using the protractor to set the top slide in preparation for turning the 10° taper to the sides of the pulley

Fig 216 A further stage in the making of the pulleys



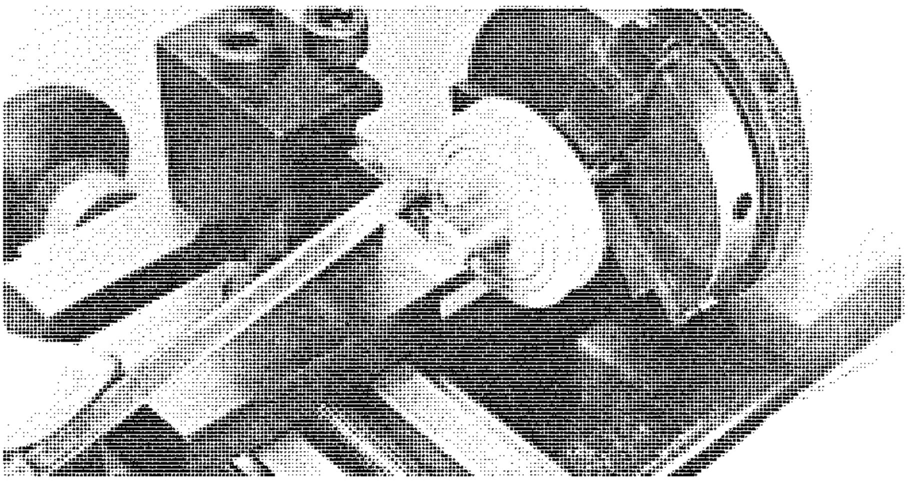
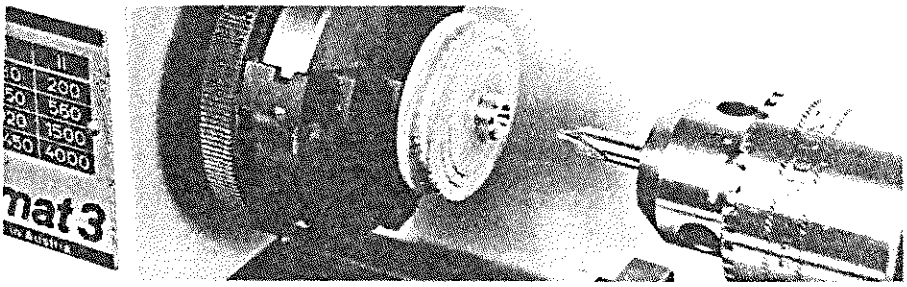


Fig 217 Putting in the decorative grooves with the graver

Fig 218 After turning away part of the chucking piece, the centre drill is used



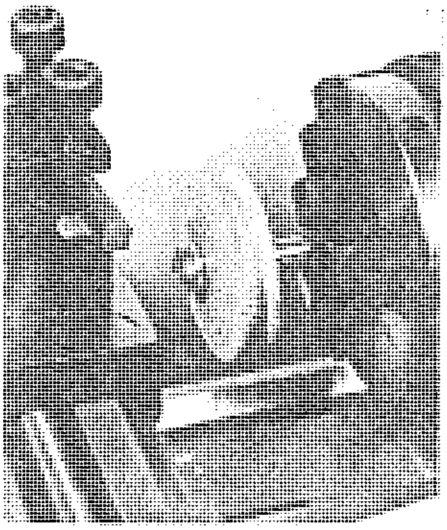


Fig 220 Locating the pulley from its bore for facing and chamfering the second side

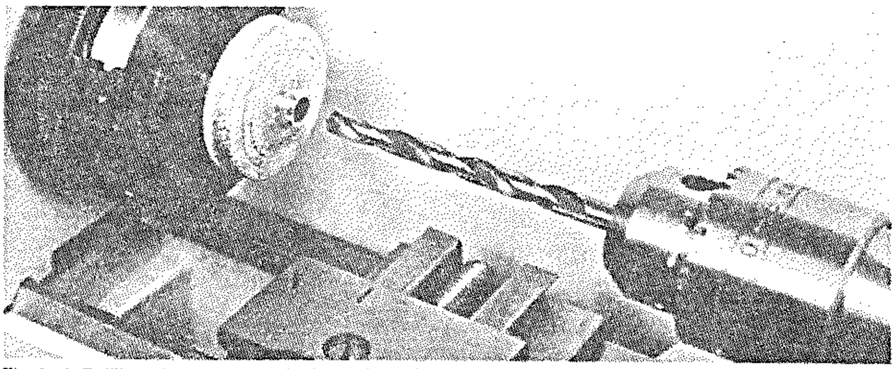
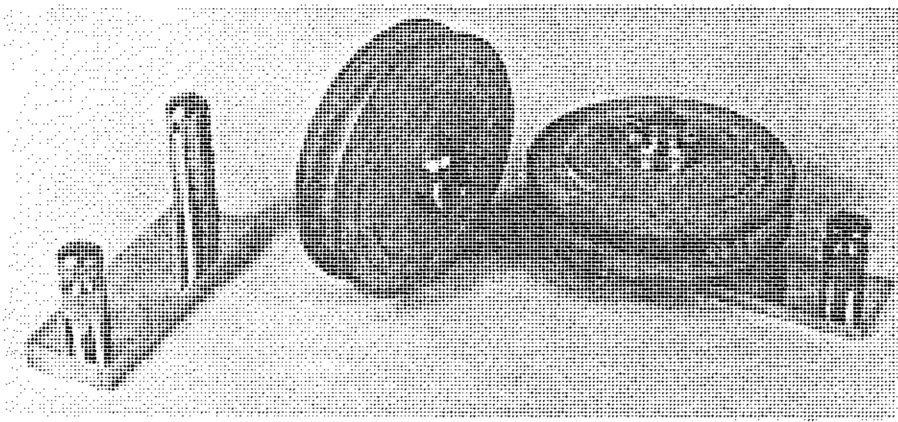


Fig 219 Drilling the centre hole from the tailstock

Fig 221 The completed pulley assemblies



The pulley assemblies are illustrated in fig 221.

General finishing and polishing the steelwork

Although ironwork is usually painted in turret clocks to protect it from moisture, etc, in the case of domestic clocks paint is seldom used at any time except on painted dials. There are really two choices – the steel may be blued or left in its natural state but protected from rusting by a fluid such as Jenolite. I chose to blue my steel and used Perma Blue which is sold for bluing gun barrels, etc,[19]. It is very easy to use and full instructions are supplied with the kit. The depth and colour of the blue depends to a large extent on the finish of the steel. Blemishes and scriber marks should be removed with wet and dry paper and then a fine grained finish obtained with emery paper of grade 0. A burnished finish can be obtained with a fine steel wire wheel as shown in fig 222 where you can see it being used on the foliot. Although this polishing spindle is a Unimat accessory, the overhang here is excessive and the set-up bad. My own feeling is that the lathe should not be used for polishing of this type and wheels or mops can, if required, be used on a portable drill secured in a bench stand where there is a great deal more power available.

A pleasing blue-black will be achieved with Perma Blue and if the work is treated to a gentle application of 000 wire wool this will highlight the corners and edges and make for an attractive finish. I restricted my bluing to the frame components and the foliot. I did not blue the arbors.

Screw heads are burnished using the pivot file initially and then turning

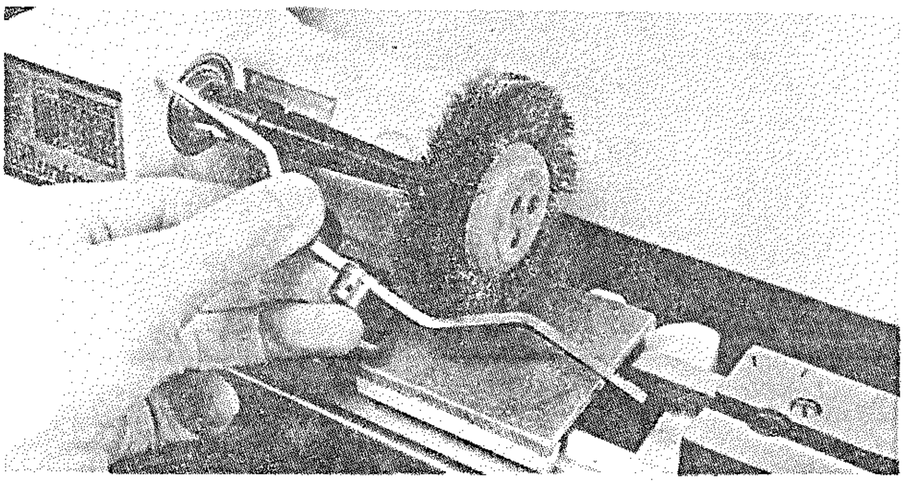
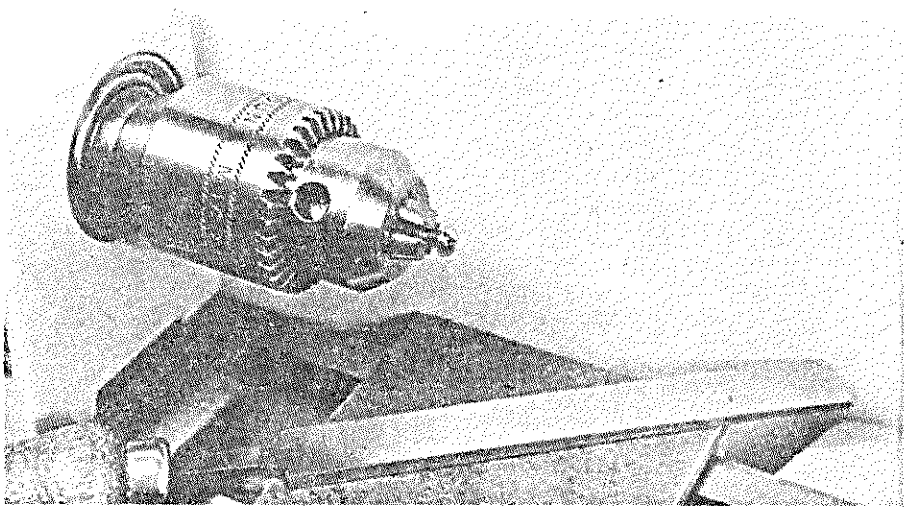


Fig 222 Burnishing the foliot with a soft steel wheel in the Unimat

Fig 223 Burnishing screw heads in the lathe. Note the use of the drill chuck for holding the work which is safer than the 3-jaw chuck



it over for burnishing. This is shown in fig 223, and you will see that the drill chuck is used and not the 3-jaw as there is less likelihood of an accident if the burnisher slips off the work.

Arbors should have been polished with emery sticks in the lathe before the collets and pinions were fitted. The ends of all pivots and pins, etc, should be rounded and burnished.

The round brass work is polished with fine grades of emery sticks in the lathe, although, if the tools have been properly honed there should be very little need for polishing. The flat surfaces are treated again with fine grades of emery paper on the cork or balsa blocks finishing with Crocus paper.

The principle of polishing is the application of abrasive papers in progressively diminishing grades. Metal polish can be used in the final stage and should be applied with a grease brush[20]. This is a stiff bristle brush especially designed and used for clock cleaning. After polishing with a soft clock brush[20] the parts must be washed in paraffin to remove all traces of the metal polish from pivot holes, etc. After shaking the excess paraffin from each part, it may be dropped into a box of sawdust which is then shaken up. The sawdust will absorb the moisture and the parts can then be brushed using a soft clock brush charged with chalk[20]. This should bring up the brasswork to a high polish. These latter processes are the normal methods employed in clock cleaning.

I have not lacquered any part of my clock. If gloves or finger cots are worn when assembling the clock the brass will remain bright for a considerable time.

Oiling

All pivots are oiled, together with the pallets and other points where metals are in rubbing contact, but not the gearing; this always runs dry in clockwork[21].

The two ends of the line are secured through steel hooks which pass through holes drilled in the lower frame support bracket. This can be seen in fig 1.

The weights may be blued like the other steelwork but I used Jenolite on mine to retain the natural steel colour.

The clock is designed to hang from a standard picture hook, and as already stated in Part 1, this should be positioned about 6½ ft above floor level for a full thirty hour run.

Conclusion

That completes the constructional work on this clock.

I hope the reader will agree that expensive lathes and machine tools are not necessary for the making of clocks. There was no operation in the construction of this clock when I felt that the Unimat was inadequate for the work, which is really a most praiseworthy statement to make in view of the fact that horology is a specialised field of engineering.

I am informed by the importers that at least two firms manufacture a division plate to enable the Unimat to cope with the high wheel numbers encountered in clockmaking. With the use of one of these I hope to describe the making of an 8-day clock in the near future. However in this series the object has been to introduce the beginner to the craft of clockmaking using an inexpensive lathe with its standard accessories.

After the construction of this clock my lathe appears as new, the bed is unmarked, nothing has been damaged and no part strained. In other words, the work carried out has been well within the limits of the tool.

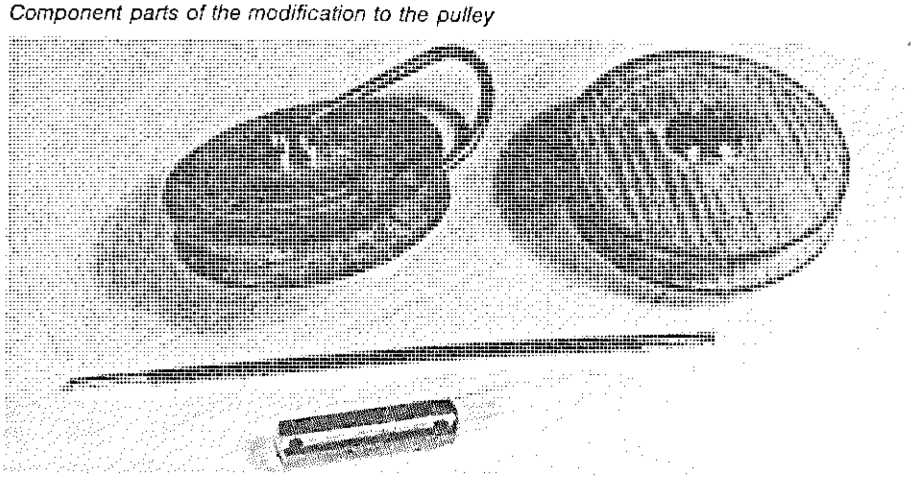
Modification to the pulley design in the foliot clock

SINCE making the original clock which has formed the subject for this series, I have made a second one and in both cases I have found the design of the pulleys to be a little unsatisfactory. There is a tendency for the weight to slip off the horizontal pin, either if it is allowed to bottom on the floor or if wound over vigorously.

An alternative arrangement is shown in the accompanying two illustrations where you can see that a conventional stirrup is used. This can take the form of a length of $^1/_{16}$ in round brass rod about 2½ in long, which is slightly tapered at each end. Holes are drilled in the pulley spindle slightly less than $^1/_{16}$ in say No 55 size and the ends of the brass wire riveted over. The bending can be carried out round a length of $^7/_{16}$ in round rod with the fingers.

This arrangement has proved to be more functional.

Component parts of the modification to the pulley



The completed pulley after modification

References

[1] K R Whiston Ltd. New Mills. Stockport SK12 4PT. can supply all steel requirements. tools. screws. etc; catalogue sent free.

[2] J Smith & Sons (Clerkenwell) Ltd. 42-54 St John Square. London EC1P 1ER. or at any of their branches at West Midlands. Bristol. Bracknell. Nottingham. Biggleswade. and Horsham.

[3] Arkansas slip stones available from Nathan Shestopal.

[4] A set of ready cut wheels and pinions are available from Geoffrey Booth. Tower House. Tower Hill. Bere Regis. Wareham. Dorset.

[5] Pivot files available from Nathan Shestopal.

[6] Emery sticks from Nathan Shetopal.

[7] Barrette file from Nathan Shestopal.

[8] Circular slitting saws available from Nathan Shestopal.

[9] Crossing files available from Nathan Shestopal.

[10] and [11] Oval burnishers and polishing papers available from Nathan Shestopal.

[12] Blued pivot steel. three lengths of No 56 gauge required and these are available from Nathan Shestopal.

[13] Assorted steel clock pins from Nathan Shestopal.

[14] A vice stake available from Nathan Shestopal.

[15] Pivot files and burnishers available from Nathan Shestopal. Two are really needed. one ¼ in wide and another ½ in wide.

[16] Bouchons for English clocks by Progress. available from Nathan Shestopal.

[17] Silver solder paste available from K R Whiston.

[18] A finished dial ean be obtained from "Timepiece". 15 Pudsey Hall Lane. Canewdon. Rochford. Essex SS4 3RY.

[19] Perma Blue from any gunsmith.

[20] and [21] Clock cleaning brushes. chalk and clock oil from Nathan Shestopal.

Appendix 1

Mounting a division plate on the Unimat 3

AT the time I wrote the first of the clock constructional serials in the HJ – The Watch & Clock Journal, many of the special items of equipment required in the construction of a clock were difficult to obtain. As the series gained in popularity, manufacturers came to the rescue and such items as milling spindles, cutter frames and division plates are now readily available.

High quality division plates, very suitable for clockmakers and repairers, are now produced by Chronos Designs Ltd[1].

I describe here the fittings and indexing arrangement necessary to mount these plates on the Unimat 3.

In the current serial on the construction of a foliot clock the dividing can be carried out with the standard facilities available from the range of Unimat accessories, it is, however, a little easier to use a division plate containing the exact tooth numbers required and those who wish to make the more advanced of my clocks will of course need a plate giving the higher tooth numbers.

In fig 1 you can see the DD62 pattern plate, 6 in in diameter and manufactured by Chronos Designs Ltd. It is illustrated attached to the rear end of the lathe mandrel. The indexing arrangement can also be seen.

The plate can be fitted or removed in less than ten seconds, and when taken off, the detent arm is folded down out of the way as demonstrated in fig 2. You can also see in this illustration that the lathe wheel guard can be closed in the normal manner.

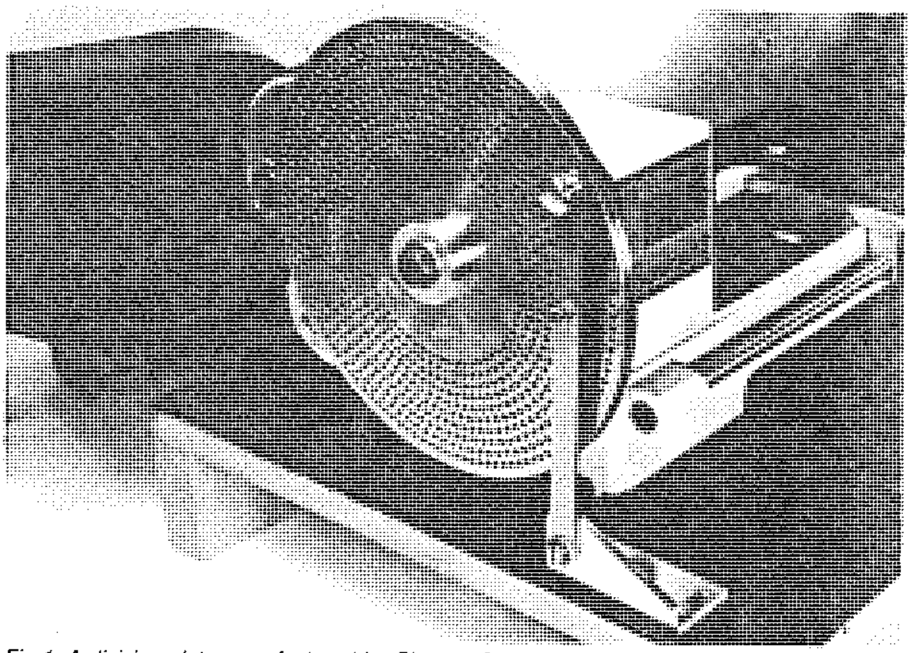


Fig 1 A division plate manufactured by Chronos Designs Ltd fitted to the Unimat 3

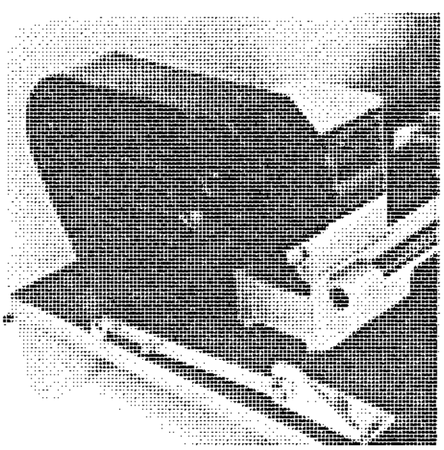


Fig 2 Illustrating how the detent arm folds down out of the way when the division plate is not in use

The fittings necessary for attaching the plate to the lathe are quite simple and can be made on the lathe itself. Use is made of the cross drilled hole in the lathe mandrel provided for the insertion of a tommy bar to hold the mandrel when fitting and removing the chucks. The division plate is clamped between two brass flanges, one of which has a locating spigot which fits snugly in the bore of the lathe mandrel. A drawbolt passes through the flanges and locates in a brass nut which is also cross drilled. A fulcrum rod passes through the nut and the lathe mandrel. When the drawbolt is tightened the whole assembly is rigidly secured to the lathe mandrel.

The Chronos division plates are supplied with $\frac{1}{2}$ in or $^5/_8$ in centre holes and both are equally suitable for use on the Unimat 3.

FIG 3 PLATE HOLDING FLANGES AND FULCRUM NUT IN BRASS

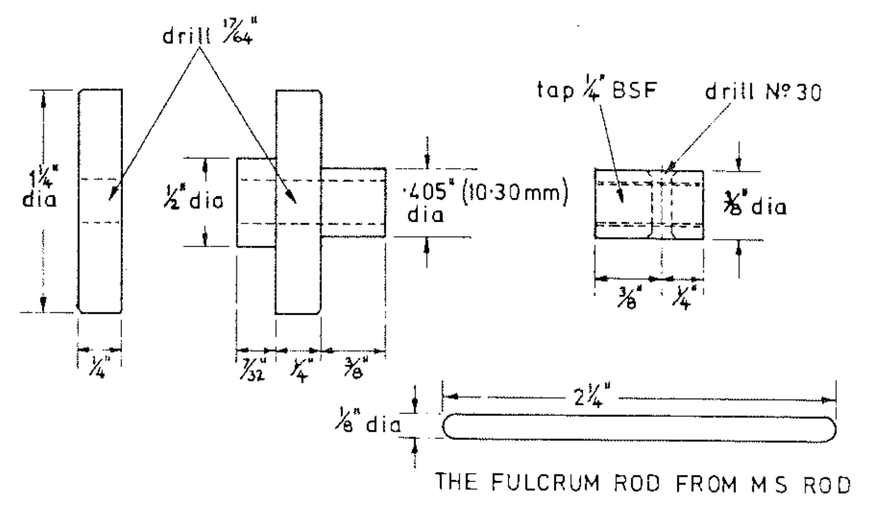


Figure 3 is a drawing of the plate holding flanges, the fulcrum nut and the fulcrum rod, and these items can be seen in fig 4.

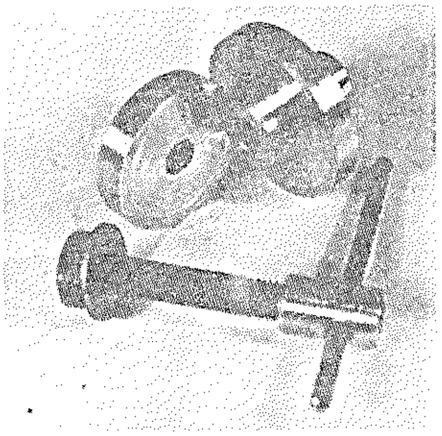
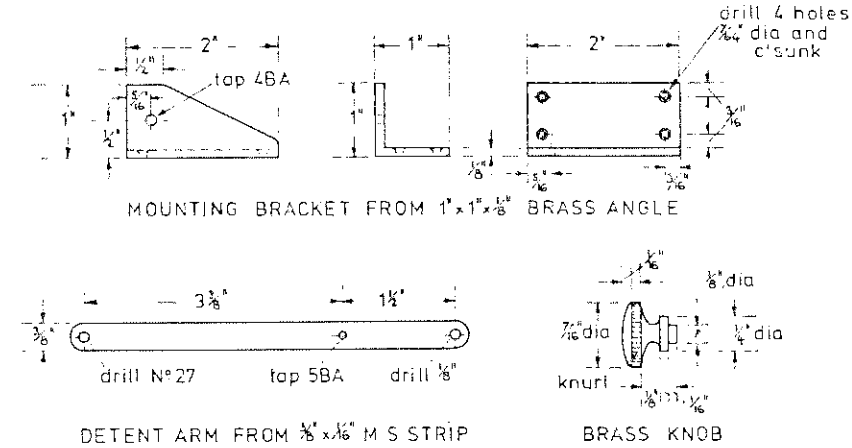


Fig 4 Showing the two flanges, the drawbolt and nut, and the fulcrum rod

FIG 5 MOUNTING BRACKET, DETENT ARM, AND BRASS KNOB



A 1½ in length of brass or light alloy having a diameter of not less than 1¼ in is required. The two flanges can be obtained from this length but it is asking a bit much of the Unimat to part off in this diameter, so a section of the stock some $^3/_8$ in in length should be sawn off with the hacksaw. This smaller flange should be held in the 3-jaw chuck with its jaws in the position for holding large diameters. After carrying out a facing cut, the work is reversed in the chuck for facing the second side and reducing the thickness to ¼ in. At the same setting, a clearance hole for the ¼ in drawbolt is drilled from the tailstock and a shallow relief or recess is formed to ensure that the clamping action takes place at the maximum diameter. This recess although not shown on the drawing is visible in fig 4. A chamfer is also formed on the outer shoulder.

The flange that locates in the bore of the lathe mandrel is held in the 3-jaw chuck and the position of the chuck jaws will be dictated by the diameter of the stock. Normally, any diameter in excess of 1in should be held with the jaws set as previously described and in this case I suggest that a centre is formed in the work so that support can be given from the tailstock centre. A step $^3/_8$ in in length and 0.405 in diameter is machined. It will be found that this diameter will be a close fit in the bore of the lathe mandrel, and the chuck complete with the embryo flange can be unscrewed to check this fit. After this, the work is reversed in the chuck and the jaw positions altered so that the component is held by the spigot just machined. The flange is now reduced to ¼ in thickness and the centre machined to fit the centre hole of the division plate. At this same setting the shallow recess is formed as before and a clearance hole of $^{17}/_{64}$ in diameter drilled right through the centre.

The brass nut is machined from a short length of $^3/_8$ in diameter brass rod which again is held in the 3-jaw chuck for drilling No 3 size. This is a convenient size of drill to precede the ¼ in BSF tap. The work is then removed from the chuck and held in the vice for tapping part of the length and cross drilling the No 30 hole. It will be clear that the length of the ¼ in drawbolt must be such that the threaded end does not reach the hole in the nut for the fulcrum rod, therefore the tapping need only be carried out as far as this point. However it is easier if the taper tap at least is taken past the cross drilled hole.

The fulcrum rod is simply a length of $^1/_8$ in diameter round mild steel rod.

The plate together with the holding flanges, ¼ in drawbolt and nut can now be fitted in the bore of the lathe mandrel. The fulcrum rod is threaded through the cross drilled holes in the mandrel and the nut, and the drawbolt tightened. If the flanges have been relieved as suggested, the plates should be rigidly held.

I tried several materials for the detent arm and various shapes for the actual point of the detent. However a mild steel strip stiffly pivoted in a simple bracket proved to be rigid in operation and to have sufficient spring when moving from one hole to another.

The shape of the detent tip that proved to be most satisfactory was a 60° cone formed on the end of a 5 BA screw.

Figure 5 gives the measurements of the components. The mounting bracket is made from brass angle and is straightforward sawing, filing and drilling. The detent arm is marked out, drilled and filed according to the drawing and a knob is provided for convenience in operating the detent arm. This latter component is secured at its base in the tapped hole in the mounting bracket with a 4 BA screw tightened up to the requisite amount and then secured with a lock nut. The knob at the top end of the detent arm is riveted in position and the 5 BA detent screw is also secured with a lock nut.

The tip of the detent can be machined in the lathe using the set over top slide. The screw can be held in the 'screw head holding tool' described in my book on the construction of a Congreve clock. After the 60° cone has been formed, the extreme tip is rounded and burnished to avoid scoring the division plate.

The mounting bracket is screwed to the Unimat base with four No 6 wood screws and the pivot point is located centrally under the ten rows of holes. It is also positioned so that the detent is biased against the plate.

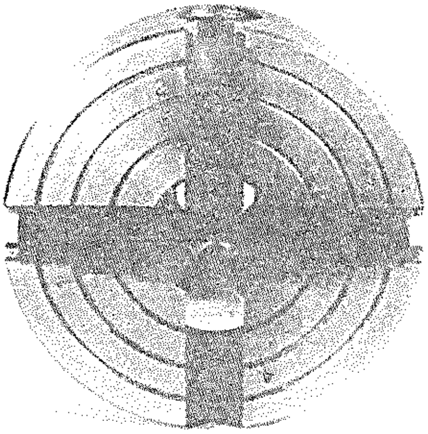
When using the plate, always try and use a hole circle of large diameter. For example, if a 30 toothed wheel is to be cut, the 120 row of holes would be selected and indexing carried out on every fourth hole. It is advisable to mark the holes with a felt tip pen in these cases in order to lessen the chance of a mistake over the counting.

References

[1]The Chronos division plates can be obtained from the manufacturer, Chronos Designs Ltd, Woods Lane, Potterspury, Towcester, Northants; or, Nathan Shestopal, 1 Grangeway, London NW6 2BW; or, A Shoot & Sons Ltd, 116-118 St John Street, Clerkenwell.

Modifications to a 4-jaw chuck

by **John Wilding**



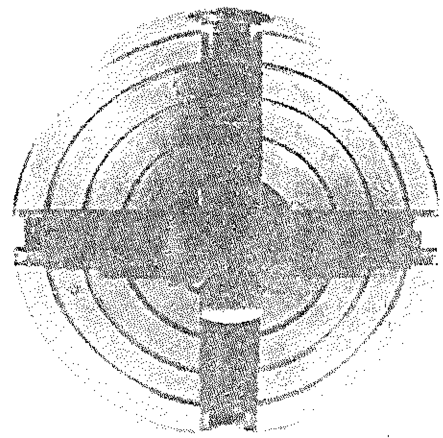


Fig 1 (left) The 4-jaw chuck for the Unimat 3 showing the minimum closing capacity of the jaws
Fig 2 (right) The same chuck after modification to the feed screws

IN lathework, when we require to hold a length of round stock so that it runs true, we have the option of using a collet chuck or the 4-jaw chuck with independently operated jaws. In the latter case a dial indicator is used and the individual jaws are manipulated until the needle of the indicator remains motionless as the stock is rotated.

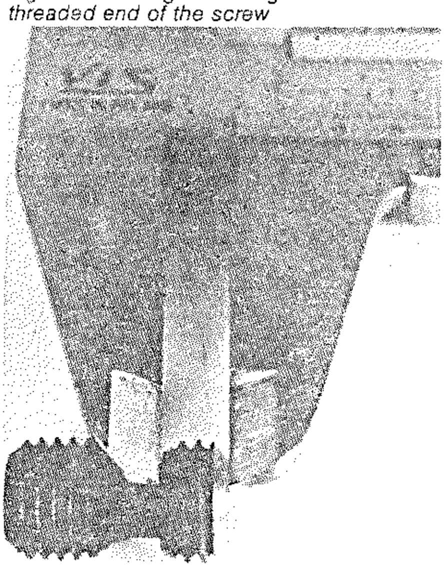
Collets are much quicker in operation, but the disadvantage is their restriction to a particular diameter and they must not be used on either oversize or undersize stock as this will strain them. It will be apparent therefore that a great many collets are required to cover all requirements in turning and this in turn involves an expensive capital outlay.

A 4-jaw chuck on the other hand can cope with an unlimited range of diameters within its physical capacity, the only disadvantage is that the stock must be manually adjusted to run true with the aid of a dial test indicator and this takes time.

When I came to use the 4-jaw chuck supplied with the Unimat 3 for the first time, I was astounded to find that the jaws would not close down to hold a diameter of less than about $\frac{3}{16}$ in and as in horological work our arbors are much smaller than this in most cases the chuck appeared to be useless in this type of work.

I was so amazed at this error in design, that I approached the importers to see if I had been supplied with the wrong chuck or a faulty one. But this was not so. The manufacturers had taken the option of giving the chuck a maximum rather than a minimum holding capacity.

Fig 3 Checking the length of the lower threaded end of the screw



When I examined the chuck I found that the feed screws operating the jaws butted together when the latter were in the closed position thus preventing any further movement. Figure 1 illustrates the chuck as purchased with the jaws in the fully closed position. In fig 2 I show the same chuck after modifying the feed screws and it can be seen that the jaws very nearly meet at the centre and can be made to do so if necessary.

The modification involves the removal of approximately $^1/_{16}$ in from the end of each screw and the forming of a 45° chamfer. The work can be carried out on the bench grinder by locating the feed screw on the chuck key and presenting the end to the periphery of the wheel. After removing the bulk of the metal in this manner the screw can be placed in a vee block and offered up to the side of the wheel in order to form the end flat and true. It will be appreciated that these feed screws are hardened and cannot be turned in the lathe.

The end section of the screw should be ground until it measures ¼ in and fig 3 shows how this measurement can be checked using a caliper gauge.

A 45° chamfer should be formed on the end as this assists in further advancement of the screws. I illustrate a suitable set-up in the lathe in fig 4. Here the toolpost grinder is clamped to the top slide which is then offset to 45° and the spindle driven from the overhead gear. In the absence of this equipment the chamfer can be formed in a freehand manner on the grinder which will be better than not forming it at all.

The modification is well worth carrying out as the usefulness of the chuck is greatly increased by its ability to hold small diameter arbors which it is incapable of doing in its manufactured state.

Finally, I show an illustration of the modified chuck being used to centre an arbor. The anvil of the dial test indicator is located against the arbor and the jaws are adjusted until there is no movement of the needle when the chuck is turned.

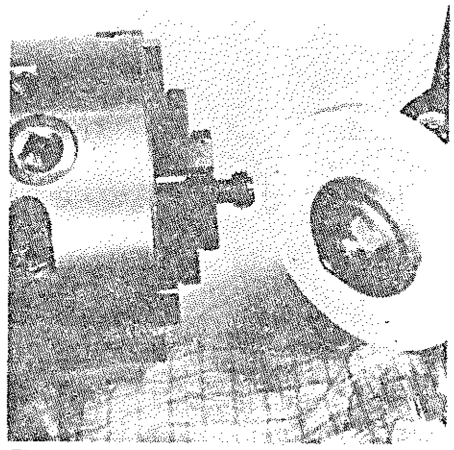
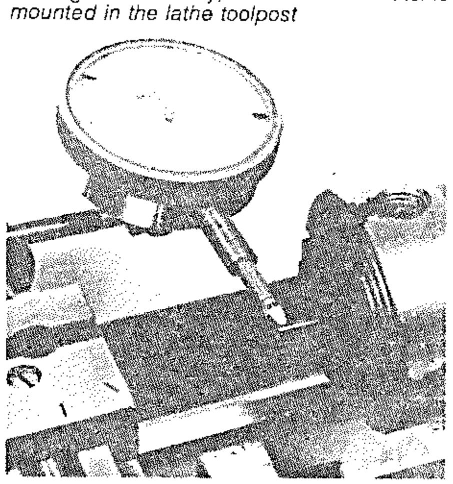


Fig 4 Forming the 45° chamfer on the end of the screw

Fig 5 Showing the modified 4-jaw chuck in use holding an arbor truly; the dial test indicator is mounted in the lathe toolpost



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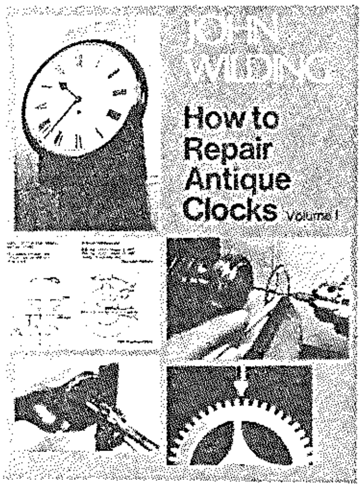

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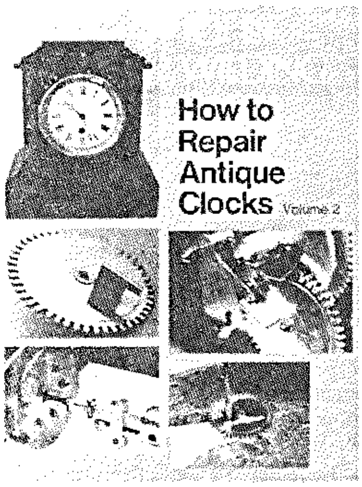

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