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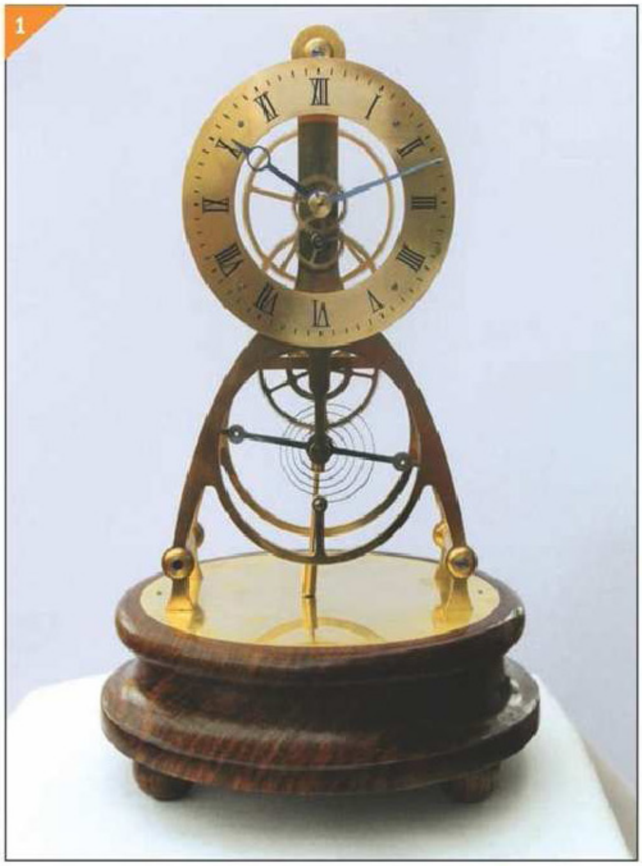
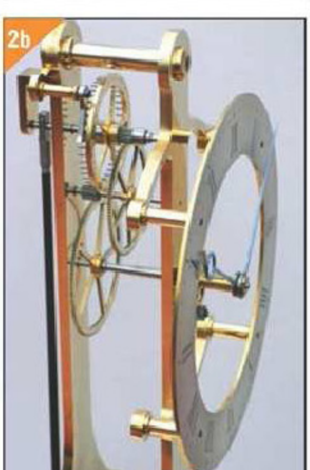
NEW SERIES

PART 1

Richard Stephen describes a most interesting, different, and attractive new clock to challenge readers.





1. Big balance version.

2a. Half second pendulum clock.

2b. Side view of pendulum clock.

Magnetic drive CLOCK

Several months ago I decided to construct a large balance wheel clock. The design of the clock was particularly interesting as it presented a number of interesting challenges. Initially I wanted the clock to be weight-driven with a lever escapement. The clock was eventually constructed. Unfortunately the weight required to run the clock was excessive and the use of weights to drive it had to be abandoned.

I was reluctant to toss the whole thing into the scrap box and so I began thinking of using a magnetic drive for powering the movement. I wanted to use modern electronics for the drive circuit and, in particular, I did not want to have to use any electrical contacts. These contacts, nearly always, eventually give problems.

I was aware of a possible technique using two concentric air cored coils, which might fit the bill. It did!

This drive system works as follows: The inner coil is used as a sensing coil. A magnet attached to the bottom of a pendulum sweeps over the sensing coil and generates an electromotive force (e.m.f.) in the windings of the coil. This e.m.f. is used to generate a delay of duration equal to half the period of the pendulum (balance). As the pendulum passes the centre point of the two coils the delay triggers a pulse in the outer coil, which repels the pendulum and generates the required impulse. **Photo 1** illustrates the big balance version of the design. The arm attached to and extending below the balance arbor carries the drive magnet. The two coils are placed under the base plate, which is recessed to reduce the distance between the magnet and the coils to about 1millimeter.

With all the drive system hidden in the base, the clock appears to have no motive power, an aspect that adds to the interest of the design. A further feature of the design is that unlike traditional movement trains which are 'wheel' driven this train is pinion driven from a pinion attached to the balance or pendulum arbor. The pinion drive used in this movement, as far as I am aware, has not been used before. More of this later.

As the design proved so successful I decided to develop a version using a half second pendulum and a further version with a seconds pendulum instead of the balance wheel. The pendulum is attached directly to the pinion drive arbor and is thus suspended on ball races. This version is illustrated in **Photos 2a and 2b**.

Of the two versions the pendulum one is I think the most successful as it is relatively easy to construct and a clock that should appeal to most amateur makers. The construction is very straightforward as it requires only two wheels and two pinions apart from the drive wheel and the motion work.

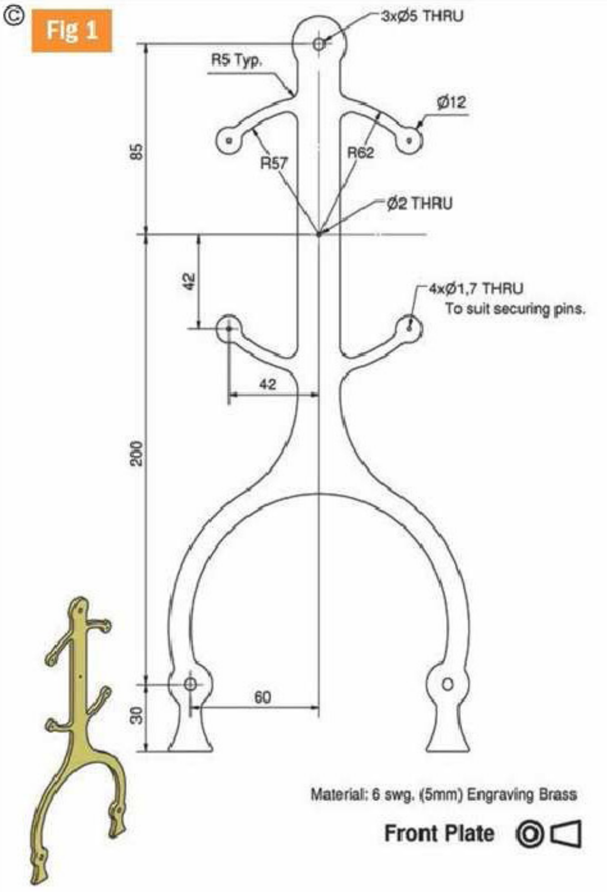
MATERIALS REQUIRED FOR THE HALF SECOND VERSION

Plates:	Two pieces of 6 gauge (3/16in. or 5mm) engraving brass sheet 350 mm x 160 mm.
Base:	10 gauge (1/8in. or 3mm) engraving brass 200mm x 120mm
Feet blocks:	120mm of 30mm diameter brass rod
Pillars:	200mm length of 12mm diameter brass rod
Dial Pillars:	150mm length of 8mm diameter brass rod
Wheels and Dial:	16 gauge (1/16in. or 1.5mm) engraving brass sheet 300mm x 160mm
Drive wheel:	30mm x 50mm engraving brass 6.0 mm thick
Bearings:	For the half second pendulum version
5	1.5mm i.d. shielded stainless steel ball races (681XZZ)
1	3mm i.d. shielded stainless steel ball race (MR63ZZ)
1	3mm i.d. roller clutch (HF0306KF). The roller clutches are only supplied by INA.
Drive magnet	Half second pendulum version: 7 mm diameter 4 mm long samarium-cobalt magnet DCSC01454 These magnets are supplied by Magnet Developments Tel: + 44(0)14793 833200.
Silver steel:	300mm lengths of 2,5mm, 3mm and 4mm diameter rod
Carbon fibre rod:	a 1m length of 4mm diameter tube for the pendulum rod
Pendulum Bob:	30mm of 25mm brass rod
	Pivot steel 4, 1 mm diameter 100mm lengths. 1 length of 1,5mm pivot steel.
Drive PCB	The drive PCB is available from Model Engineers Electronic Workshop Tel:- +44 (0)1586 852122
Drive coil:	50mm length of 50mm diameter Tufnol rod.
Sensing coil:	50mm length of 25mm diameter Tufnol rod
Wire for the coils:	1 500 gram spool of 40 SWG.(~36AWG or 0.125mm) enamelled copper wire. Available from Scientific wire Co. http://www.wires.co.uk/acatalog/List05R2c.pdf

In addition to the above you will need some short lengths of EN1A (Free cutting with sulphur but no lead) mild steel 10 mm, 8 mm and 6 mm diameter and 12 mm, 6 and 4 mm brass rod.
Sphinx micro drills are available from Fenn Tools http://www.fenntool.co.uk/html/products.html. These drills are best for drilling small accurate holes.

The construction series will begin with the half seconds pendulum version. As in my previous series, CNC has been extensively used in the construction of the components of the movements.

©
Fig 1



Material: 6 swg. (5mm) Engraving Brass

Front Plate

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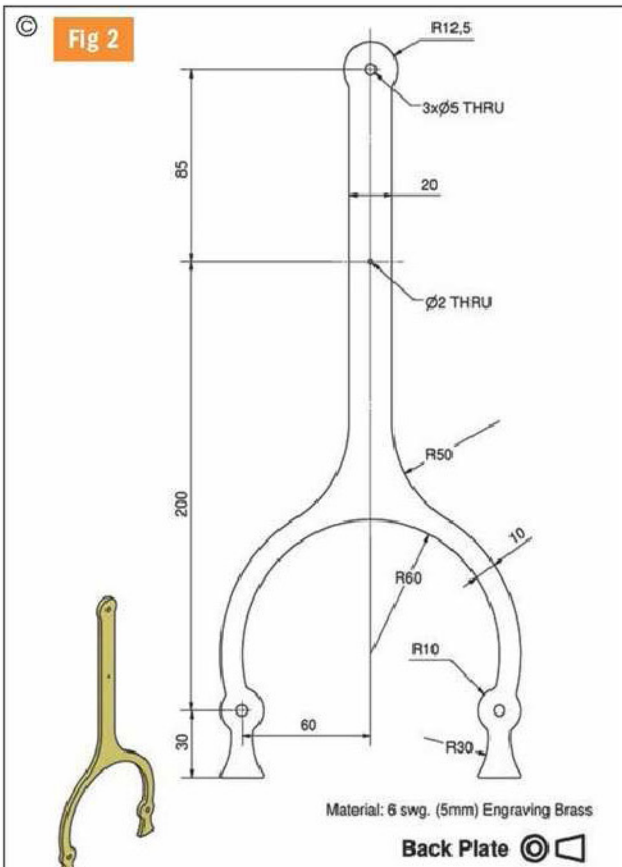
Fig 2



Material: 6 swg. (5mm) Engraving Brass

Back Plate

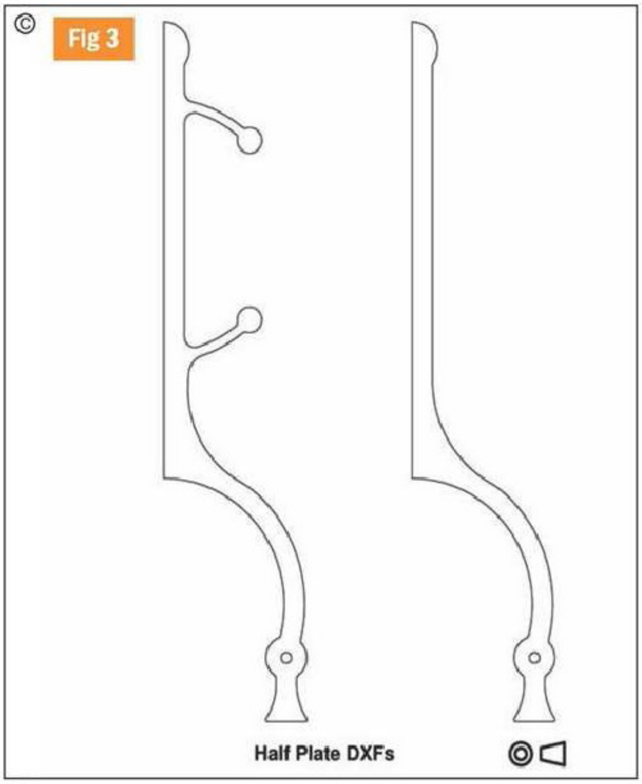
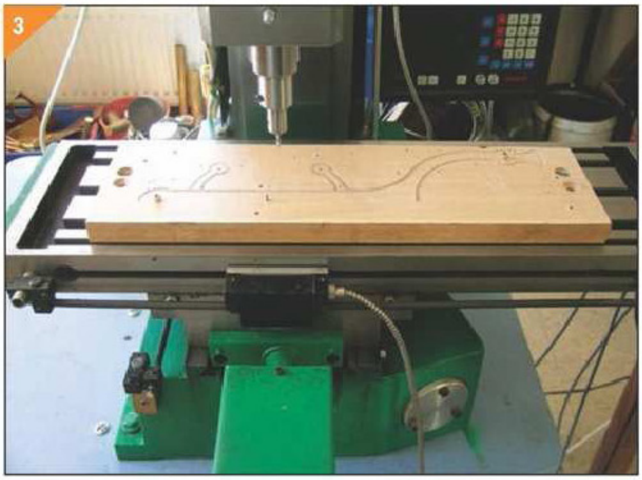


Fig 3

Half Plate DXFs



3

Base for holding the plates.

This clock needs to be carefully constructed in order to reduce the friction in the train to a minimum. Detailed drawings and instructions have been provided for this series along with all measurements.
It must be stressed, that although the dimensions given are precise, these must only be taken as a guide.

As each component of the clock is made its dimensions may need to be tailored to fit with the parts already made. Especially as material sizes may differ from those used in the prototype clocks. Do not attempt to make all the parts, put each aside and when all the parts have been made attempt to assemble the clock. If you do this do not be surprised if nothing fits correctly.

Cutting out the front and back plates

The front and back plates are illustrated in **Figs. 1** and **2**. Full size drawings of the plates will be made available as .dxf or .bmp files. I profiled my plates on my X3 milling machine, which has a maximum travel along the x-axis of 350mm and on the y-axis of 150millimeters. The total length of the plates is 330mm and the width is 140millimeters. The x-axis travel was just adequate provided the work was accurately positioned. The y-axis travel was I felt just a bit marginal to allow the plate to be profiled in a single operation. To overcome this problem the drawings of the plates were halved along the centre line.

The half plates are illustrated in **Fig. 3**. Drawings of the half plates will also be made available. Each plate is then profiled in two operations.

Profiling the plates in two operations

To profile the front and back plates in two operations start by cleaning the surfaces of both plates to remove all grease and dirt. I find household cream cleaner works very well as a degreasing agent. Dry the plates and stick them together with double sided adhesive tape. A piece of tape top and bottom will be adequate.

Lightly scribe lengthwise a line in the centre of one plate. This side of the plate will eventually be used for the outside of the front plate of the clock. The rear of the underside plate will be the back of the back plate. It is worth marking these two sides so that you will not make a mistake later. Mark, on the line, the position of the centre arbor on the plate. Put the two plates to one side. Cut a piece of 18mm thick Melamine covered MDF board the same width as the plates and about 60mm longer. Attach the board to the table of the mill with suitable countersunk screws (see **Photo 3**) Clamp the two plates to the MDF board using hold-downs.

Centre the mill exactly on the marked position of the centre arbor. The best way of doing this is to use a centring microscope fitted in the spindle of the mill. If you don't possess a centring microscope you should get one or make one using the Hemmingway centring microscope kit. It will soon become an indispensable tool. I use mine continuously for accurate setting up, accurately positioning pivot holes, setting lathe tools at the correct centre height, etc etc.

Drill a 2mm hole at the position of the centre arbor through both plates and 10mm into the melamine board. Remove the two plates and insert a piece of 2mm silver steel 20mm long into the hole in the board. Remember to chamfer both ends of the 2mm peg. Replace the plates using the 2mm peg to position them.

The scribed line must now be orientated precisely along the x-axis of the mill. This is most easily done using a centring microscope. Centre the spindle on the 2mm peg and set the digital readout (assuming you have one) on both x and y to zero. Move the table to x = –80 mm and rotate the two plates until the scribed line intersects the cross hairs. The plates will now be precisely lined up along the x-axis.

Clamp the plates in this position. Move the table a further 5mm to x = -85mm, the position of the top pillar. Drill and ream a 5mm hole through both plates and 10 mm into the board. Make a 5mm brass peg 20mm long, chamfer both ends, and insert it into the hole just drilled. Now move the table to the position of the on the lower pillar i.e. at x = 200mm y = 60mm and drill and ream a second 5mm hole 10mm into the board.

Leave the spindle in this position, remove the plates and turn them over and replace the plates using the top 5mm peg and the centre 2mm one to position the plates. Clamp firmly down and drill and ream the 5mm hole for the second pillar. Remove the two plates and separate them. Double sided tape holds very securely, to make it easier to separate the plates warm the plates to soften the adhesive. Clean off any remaining tape and adhesive using solvent.

Two further 5mm pegs drilled and tapped for 2.5mm metric screws need to be made. These pegs should extend 4.5mm above the surface of the board. The pegs are secured in the two holes in the board using superglue. The length of the 2mm centre peg should also be reduced to 4.5mm above the board.

To be continued

MAGNETIC DRIVE CLOCK

PART 2

Continued from page 202 (M.E. 4293, 16 February 2007)

Richard Stephen continues with profiling the plates and moves on to the wheels and pinions.

4. Back plate ready for profiling.

The pegs are secured in the two holes in the board using super glue. The length of the 2mm centre peg should also be reduced to 4.5mm above the board. The back plate can now be profiled. **Photograph 4** illustrates the back plate ready for profiling the second half of the plate. The screws securing the plate to the 5mm pegs can be seen. It is essential that before you start profiling that both the plate and all the waste material are very well secured to the board. I find that 20mm panel pins are the best way to secure the waste material. Make sure that the pins will not foul the slot drill.

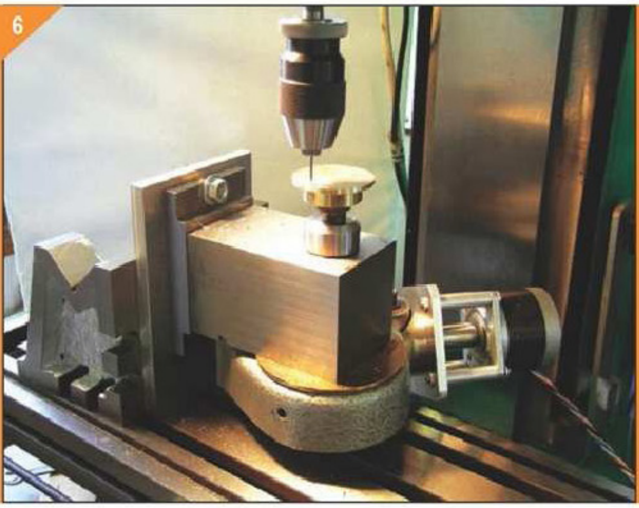
Returning to the front plate, with the plate and all the waste well secured, check that the 2mm centre hole is still precisely at the origin of the co-ordinates (x = 0, y = 0). Now drill a 1.7mm hole at the position of the two dial pillars x = -42mm, y = 42mm and x = 42mm, y = 42mm. Secure the dial pillar arms to the board with 20mm panel pins. The front plate is now ready for profiling. For a good final finish the following points should be observed.

The finished plates are shown in **photo 5**. The profiling of both plates after setting up took a morning to complete. Here is some guidance on cutting them out:

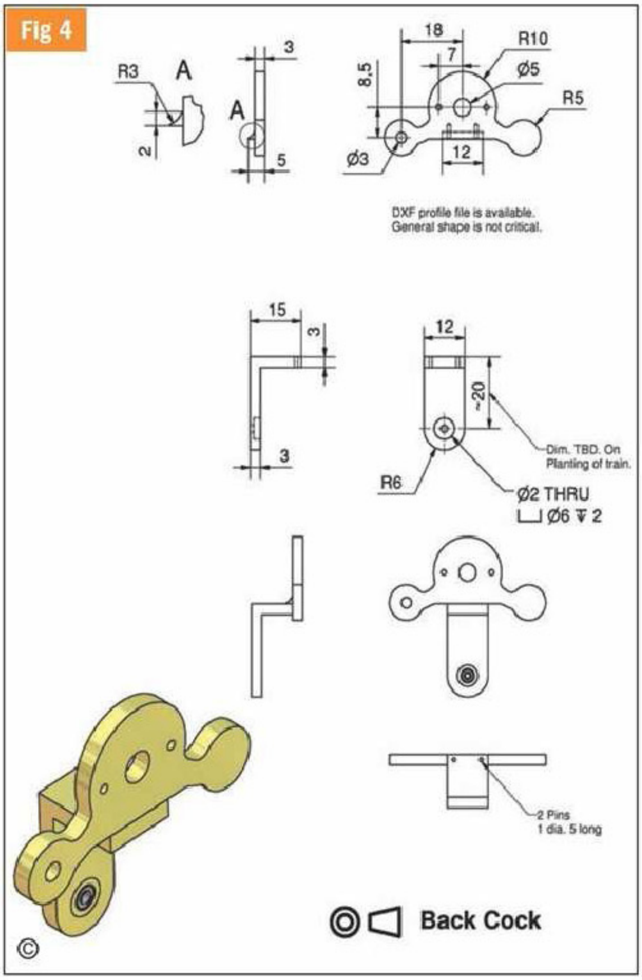
- The plates are designed for profiling with a 3mm slot drill.
- Use a new slot drill.
- It is necessary to continuously remove the chips that are produced using a vacuum cleaner particularly as the cutting depth increases. If the chips are allowed to accumulate in the cut they will get stuck between the side of the slot drill and the work. This will certainly damage the surface finish and, in extreme circumstances, cause the breakage of the slot drill.
- Keep all parts of the work well secured to the baseboard.
- Do not use too high a feed rate 60mm/min is quite fast enough.
- A spindle speed of about 2500rpm is ideal if you are cutting dry. The combination of the recommended feed rate and spindle speed will reduce the chip size and make it a lot easier to vacuum chips out of the cut.

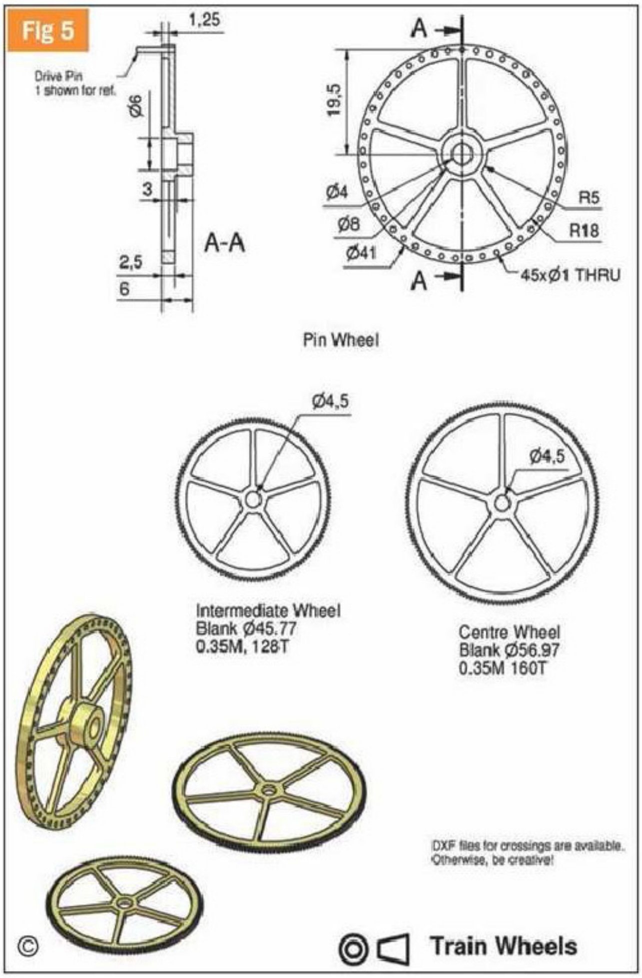
If these points are observed you should have almost no

5. The finished plates.



6. Drilling for the pins.





further work to do on the edges of the plates.

Back cock

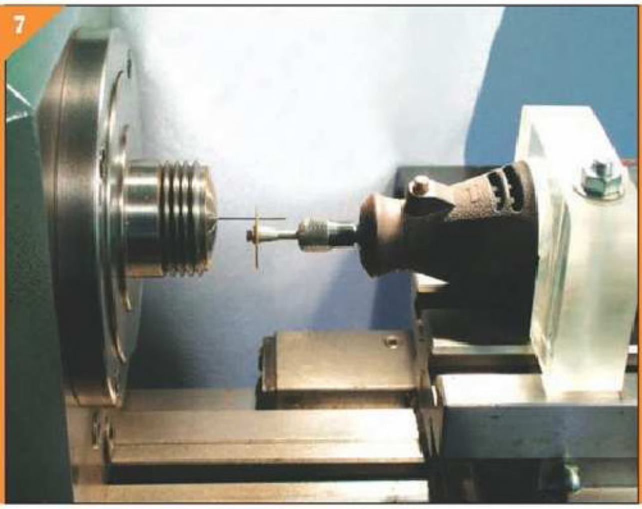
The dimensions and details of the back cock are shown in **fig 4**. The cock is fabricated for ease of construction in two parts. The plate is profiled out of an off-cut of 5mm engraving brass and the L-shaped section cut out of a suitable scrap of 12mm compo brass plate. The plate of the cock is quite small and as a consequence awkward to hold securely for profiling.

I soft-soldered the blank to an off-cut of 3mm brass sheet, which in turn I screwed to a piece of 18mm MDF board which was clamped to the table of the milling machine. The origin of the drawing, and the start point for the profiling is the centre of the 5mm hole that fits on the upper pillar extension. Drill and ream a 5mm hole at the origin. The 3mm hole for attaching the pin wheel non-return ratchet should be drilled and reamed at the co-ordinates shown. Return the spindle to the origin position and profile the back cock plate.

With the profiled plate still in position on the milling machine, reduce the thickness of the >>

7. Grinding down the pins.

8. Polishing the teeth.



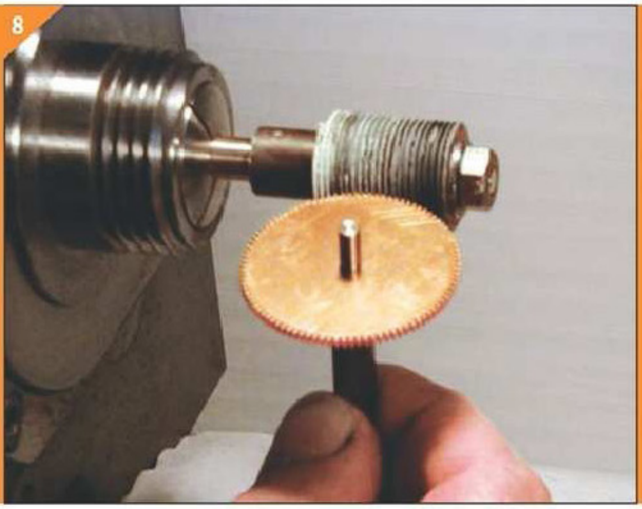


plate to 3mm leaving the section shown the full thickness. Replace the slot drill used for reducing the thickness with a 6mm ball nose cutter and fillet the raised section as shown in fig 4. Remove the plate from its mounting and clean up all the surfaces and edges with wet and dry paper. Now cut the L-shaped section out of a scrap of 12mm thick compo brass plate. Clean up all the edges and surfaces with wet and dry paper. I joined the two sections with Loctite 326 and 1mm brass pins for extra security.

Wheels and pinions

Details of the wheels and pinions are given in **fig 5** and **fig 6**. The pin wheel shown in fig 5 has 45, 1mm pins set on the circumferences of a circle 39mm in diameter. The pin wheel forms part of the drive mechanism of the clock.

The pendulum only drives the train as it swings in a clockwise direction The gravity ratchet engages with the pins in the wheel to prevent the pendulum from driving the train as it swings in an anti-clockwise direction (see details of the pinion drive mechanism). The amplitude of swing of the pendulum is determined by the number of pins in the wheel. The pendulum for this clock is designed to have a total amplitude of swing of 8deg. (±4deg.). With this amplitude the pendulum will have to make 45 complete oscillations (i.e. periods) for the pendulum arbor to make a 360deg. rotation. For a half second beating pendulum (period 1 second) this will take exactly 45 seconds. The centre arbor of the clock takes 60x60 = 3600 seconds to make a complete revolution. Dividing 3600 by 45 gives 80 (8 x 10) as the gear ratio required between the pin wheel and the centre arbor. The train uses 0.35 module 16 leaf pinions through out. Suitable wheel counts for the intermediate wheel and centre wheel, using the above factors, are 128 and 160 teeth respectively.

Pin wheel

The pin wheel is made from a disc of free machining brass 6.0mm thick and 45mm in diameter. I cut my disc off a length of 50mm dia. brass bar. If you use brass bar, begin by facing off the end. Turn down the end to form a boss 3.5mm long and 8mm in diameter. Drill and ream a 4mm hole about 8mm deep in the centre. Now part off the blank, 8mm from the end of the boss. This will leave you plenty of material to true up the parted off end and reduce the thickness of the blank to 2.5mm (6.0mm including the boss). Turn the blank down to 45mm in diameter. The 45 holes for the pins should be drilled next. The holes are drilled on the circumference of a circle 39mm in diameter. The wheel will eventually be reduced to 41mm in diameter. This diameter leaves adequate clearance between the wheel and the arbor of the intermediate wheel.

Photograph 6 illustrates the set-up I used to drill the pin holes. The stepper drive dividing head was mounted vertically on the table of the milling machine using an angle plate. My gear cutting programme was configured to drill the 45 pin holes. I used a Sphinx 1mm micro drill.

Grip the 8mm wheel boss in a collet and reduce the diameter to 41 millimetres. The wheel is then recessed to a depth of 1.25mm leaving a rim of width 3mm and a boss 10mm in diameter. Bore the 4mm hole in the centre to 6mm diameter to a depth of 3mm. The wheel can now be crossed out, the dimensions of the crossings are shown in fig 5. Clean and polish the crossings before you insert the pins.

The 1mm pivot steel pins should be cut next. The blue pivot steel must first be polished with fine wet and dry paper to remove all traces of the blue. Unless this is done the Loctite used to secure the pins in the holes will not cure. Loctite requires both surfaces to be clean metal if the adhesive is to cure and grip.

Photograph 7 illustrates the set-up I uses to cut the pins.

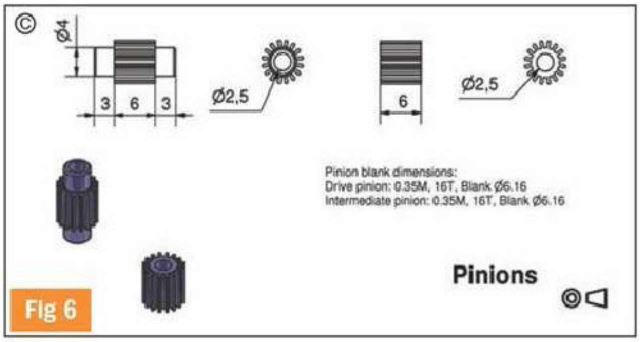


Fig 6

The Dremel, fitted with a 20mm diameter carborundum grinding disc, was clamped to the top slide of the lathe using a home made clamp. Grip a length of pivot steel in the lathe using a collet if you have one. Leave no more than 25mm sticking out. With the lathe turning fast and the Dremel set to maximum speed true off the end of the length of pivot steel. Using a slip stone remove the sharp corner of the end of the pivot steel. Advance the top-slide 9mm and with both the lathe and Dremel running cut off a length of pivot steel. Again remove the sharp corner and cut off a second length. Continue cutting until you have cut off 45 pins and a couple of spares.

The pins can now be inserted in the holes in the wheel rim and secured with Loctite 603. Press the ends of the pins flush with the back of the wheel rim. Carefully remove all excess Loctite from around the pins as you insert them. If any traces of Loctite remain after all the pins have been inserted this can be removed with a little Xylene solvent (if you can get some). To finish the wheel the pins all need to be ground to the same length (approximately 6.5mm proud of the surface) again using the Dremel grinder and the carborundum grinding discs.

The set-up is illustrated in photo 7 is used to grind down the pins. Grip the wheel by the boss in a collet or chuck. With the lathe turning slowly and the Dremel at maximum speed slowly advance the grinding disc until the pins are all ground to the same length, about 6.5mm from the wheel surface. This completes the pin wheel.

The pinions and wheels are made next. The dimensions of the wheels, pinions and the design of the wheel crossings are shown in fig 5 and fig 6. I make my pinions out of EN1A mild steel as this steel cuts very cleanly and preserves the edge of the very expensive Thornton cutters I use. The drive wheel pinion is made with a 4mm diameter by 3mm long boss at each end. The holes in the pinions are drilled 2.5 millimetres.

Case hardening the pinions

Before hardening the pinions true up and smooth the ends. The safest way to do this is to use the side of a carborundum dental cutting disc in a Dremel mini-drill. Hold the pinion in a collet in the lathe and grind the faces true. Now make a mandrel out of a 60mm long scrap of 3mm steel rod. Using a file taper the end so that it fits tightly into the hole in the pinion. Grip the mandrel in the chuck of a cordless or a hand drill (not mains powered). Check the pinion rotates truly. Heat the pinion with a blowtorch while at the same time rotating it. To minimise the formation of scale use the end of the flame not the base. When it is hot (not red) dip it in the case hardening powder and return to the flame. Repeat this process until you have built up a good covering on the pinion. Now heat the pinion up to red heat and maintain it at red for at least two minutes all the time rotating it in the flame. This continuous rotation ensures the pinion is evenly heated. Quench the rotating pinion in cold water. Quenching while rotating will prevent any distortion from occurring. With the wheels cut and the pinions hardened the

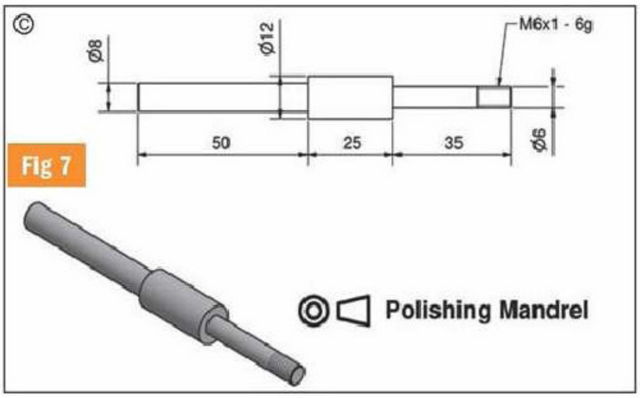


Fig 7

teeth on both the pinions and wheels should be polished. Polishing the teeth significantly reduces the engaging friction.

Polishing the teeth of the wheels and pinions

Readers may wonder why I go to the bother of polishing the wheel teeth. If one examines the teeth of a newly cut wheel under a microscope it is clear that the teeth are not smooth. Cutting the teeth even with the sharpest cutter will leave a slight surface roughness. This surface roughness generates a certain amount of friction as the wheel engages with the pinion. The presence of this friction is highlighted by the sound the wheel makes as it engages with the pinion before and after polishing the teeth. The sound generated reduces significantly after polishing indicating a reduction in friction. If polishing the teeth was a time consuming exercise it would possibly not be worth doing. Fortunately it is not.

Making the polishing hobs

To make the hobs you will need a piece of box wood (the best) or any other hard close grained hardwood 70mm long and 30 x 30mm. Centre the block of wood in a 4-jaw chuck and turn a cylinder approximately 30mm in diameter. Drill a 6mm hole through the cylinder and cut it into two pieces about 30mm long. This gives enough to make two hobs one for brass wheels and one for hardened pinions. Make the mandrel shown in **fig 7** and attach one of the hob blanks. Screw-cutting wood is a problem using conventional screw-cutting methods because the wood being rather brittle tends to break up. The easiest way to cut a clean thread in the hob is to use a milling spindle on a vertical slide fitted with the cutter used to cut the wheel you want to polish. Fix the vertical slide so that the axis of the milling spindle is parallel to the bed of the lathe. Running the cutter as fast as possible, cut the thread in the hob blank in the same way as you would any other thread. The pitch of the thread should be the same as that of the wheel you want to polish. For both versions of the clock you will need four hobs two for the 0.35 module wheels and pinions and two for the 0.40 module wheels and pinions. Suitable pitches for the hob threads are 1.10mm (0.35 mod) and 1.25mm (0.40 mod).

Polishing the teeth

Grip the mandrel in a collet or 3-jaw chuck. The hob first needs to be charged with a polishing compound. If the wheel being polished is made of brass, the polishing compound must be a non-embedding abrasive. The best non-embedding abrasive I have found is Autosol polishing paste for car paint work. This works equally well on hardened pinions. An advantage of non-embedding abrasives is that they will do little damage to the lathe if by chance some gets on the bed. Rather than taking any chances protect the lathe bed and compound slide with paper towel to ensure that the abrasive doesn't go where it shouldn't! To polish the teeth hold the wheel on a hand held arbor. Engage the wheel in the thread of the hob, as shown in **photo 8** with the plane of the wheel inline with the axis of the hob. Run the lathe at about 500rpm. As the hob rotates the wheel is forced to rotate as well engaging with the abrasive loaded hob thread. As the wheel turns one flank of each tooth is polished. To polish the other flank, simply turn the wheel over on the arbor. The advantage of this method of polishing is that it does not damage the tooth form of the wheel. Polishing the teeth before you cross also avoids any possibility of distorting the wheel. Polishing pinions with a hand held arbor is a bit awkward because of their small size. Instead I use a fixed arbor as illustrated in **photo 9.**

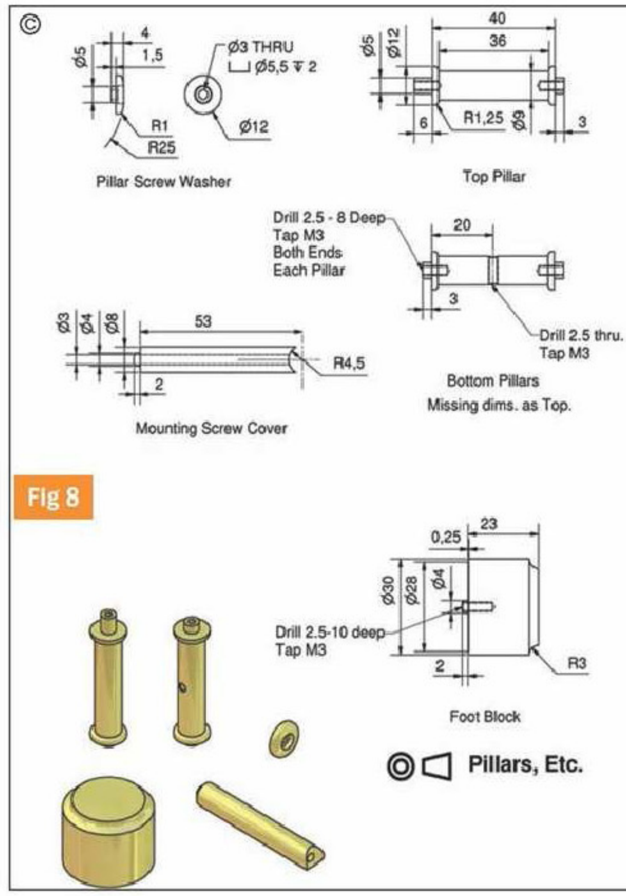


Fig 8

Pillars, feet blocks, screw covers and washers

The details of the pillars, feet blocks and the covers for the mounting screws and washers are illustrated in **fig 8**. The two lower pillars are cross drilled and tapped 3mm precisely in the centre of each pillar.

To be continued.

9. Set-up for polishing pinions.

MAGNETIC DRIVE CLOCK

PART 3

Continued from page 329 (M.E. 4295, 16 March 2007

Richard Stephen continues his instructions with a different type of pinion drive and the various arbors.

The threaded holes in the two lower pillars are for the screws that secure the movement to the feet blocks and the base. Machining these components should present few problems. The two screw covers still need to have the ends fitted to the two lower pillars. This can be done once the base and the feet blocks are made.

Fitting the back cock

The back cock is fitted to the back plate next. To initially position the cock you will need to make a peg to position and secure the cock to the back plate before you can drill the 1.5mm holes for the two register pins. The peg is made from a scrap of 8mm brass rod about 8mm in length. Face off both ends and turn down one end to 5mm for a length of 6.2 millimetres. Drill a 2.6mm hole and tap it 3 millimetres. Mark a centre line on the back surface of the L-section of the cock.

Assemble the cock on the back plate. Align the centre line of the back plate along the x-axis of the mill. Position the back cock so that the centre line you have just marked also coincides with the centre line of the back plate. It is very important to precisely align the back cock as the cock carries the non-return ratchet for the pin wheel.

Figure 9 illustrates the position of the non-return ratchet relative to the pin wheel. The arbor of the ratchet must be precisely at the position indicated if the ratchet is to function correctly. This in turn requires the back cock to be correctly positioned. With the back cock correctly positioned the holes for the 1.5mm register pins can now be drilled at the positions indicated on **fig 10**. The two register pins are secured in the back cock with Loctite 326. The cock is re-assembled on the back plate and the register pins cut off flush with the inner surface of the plate.

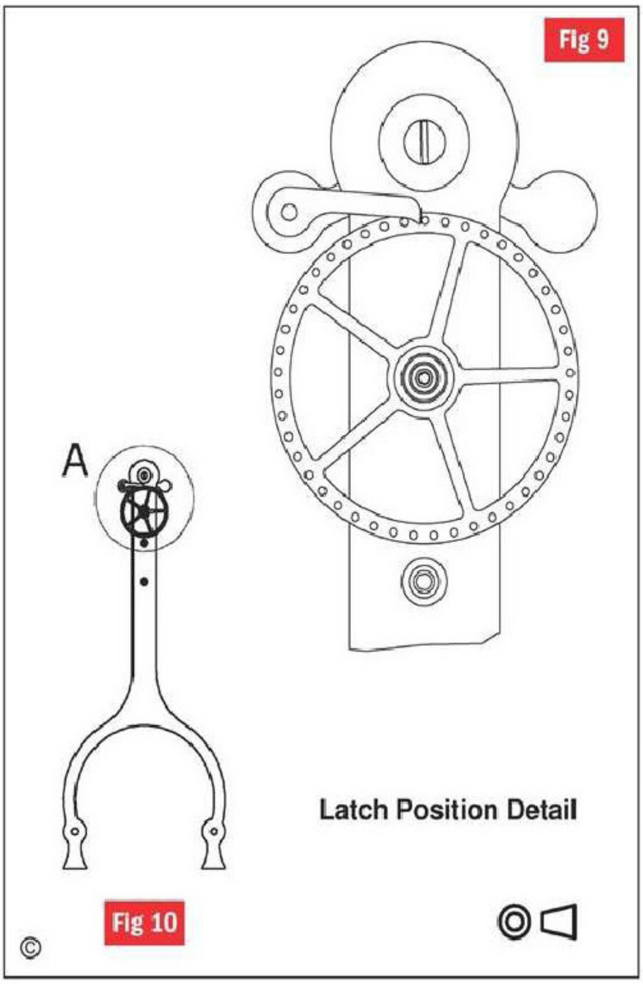


Fig 9

Fig 10

The pinion drive mechanism

The pinion drive mechanism is illustrated in **fig 11a**. As mentioned earlier, the train of this clock is different to the train of all conventional clocks that are wheel driven. Energy to maintain the pendulum motion is derived from a falling weight or tensioned spring and transmitted to the pendulum by a train of wheels and pinions. In the majority of magnetically driven clocks the motion of the pendulum is maintained by applying energy directly from an external source.

A magnet attached to the pendulum is either attracted to or repulsed by a magnetic field induced in a solenoid by an electric current applied to the solenoid as the pendulum swings. A portion of the pendulums energy is used to drive a train to move the hands of the clock. The basic problem with this system is that the swinging pendulum rotates both clockwise and anti-clockwise, where as the train that moves the hands must only rotate in one direction i.e. the centre arbor must rotate clockwise.

A variety of mechanisms have been developed for this purpose in magnetically driven clocks usually involving some form of ratchet and pawl type mechanism. In these movements the pendulum is suspended in the conventional way using a suspension spring. The ratchet and pawl mechanism has to be attached at some point on the pendulum rod. The closer to the point of suspension this mechanism is attached the greater will be the torque the pendulum can apply to the train.

To maximise the available torque the pendulum of this clock is suspended on ball races and attached to an arbor that forms part of the train. As the pendulum swings the pendulum arbor rotates both clockwise and anti-clockwise. A roller clutch incorporated in the drive mechanism and attached to the drive pinion allows the pendulum arbor to rotate freely anti-clockwise but locks to the arbor when the pendulum rotates clockwise and so drives the train. Since the centre wheel rotates 80 times slower than the drive pinion there is more than adequate torque available at the centre wheel, to drive the motion work and the hands without significantly compromising the motion of the pendulum.

The details of the drive mechanism are illustrated in **fig 11a**. Begin by making the housing for the roller clutch. This is made from a 12mm length of 10mm diameter EN1A mild steel. Face both ends of the piece of steel and reduce the length to 9mm and just clean up the outer diameter.

The hole for the roller clutch needs to be made next. The diameter of the roller clutch is 6.5mm, the diameter of the hole in the housing is just slightly less than this as the clutch is a press fit into the housing. The hole in the housing needs to be 6.4985mm exactly. To facilitate boring the hole to this size you will need to make a test bar 6.498mm in diameter. Drill a hole in the housing 6.3mm in diameter. Using a small very sharp boring bar gradually bore the hole until you can just insert the test bar. The diameter of the hole should now be just right.

Check that the roller clutch will just not slip into the hole. Using some fine wet and dry paper wrapped around a length of 5mm dowel rod, taper the front of the hole for about 2mm until you can just insert the end of the clutch. Do not insert the clutch at this time. Cut off a piece of 8mm diameter EN1A about 8mm long. Face both ends; reduce the diameter to 7mm and the length to 5mm. Now turn down one end for 3mm to make an easy fit (not loose) into the end of the housing (not the tapered end). You may need to slightly chamfer the edge of the hole in the housing to get the insert to but snugly.

Attach the piece into the end of the housing using Loctite 326 adhesive. Holding the housing in a collet turn down the insert to 6mm and drill a 4mm hole in the end. Fit the housing and the pinion into the pin wheel and check that they line up accurately. The pinion bearing housing is made next. This is made from a piece of EN1A mild steel 6mm diameter and 5mm long. Face both ends and drill and ream a 4mm hole. I used an aluminium bronze bush for the drive bearing.

Turn a piece of aluminium bronze to 4mm diameter and cut off a 3mm length. Fit the piece into the end of the housing to a depth of 2mm and secure with Loctite 326 adhesive. Turn down the end flush with the end of the housing. Drill and ream a 2mm hole through the aluminium bronze insert. Reverse the housing in the lathe and drill the insert to a depth of 1mm with a 3mm drill to reduce the length of the bearing to just under 1 millimetre. The drive mechanism can now be assembled and fitted to the pin wheel. Do not insert the roller clutch at this time.

The arbors

The details and dimensions of the arbors are shown in **fig 11b**. All the pivots except one on the pendulum arbor and the front of the centre arbor are made from 1.5mm pivot steel rod inserted into the ends of the arbors and secured with Loctite 326 adhesive.

The intermediate and centre arbors

The intermediate and centre arbors are illustrated in fig 11b The intermediate arbor is made from a length of 2.5mm silver steel. Measure the spacing between the plates and make the arbor 0.5mm less than the measured length. Drill a 1.5mm hole in each end to a depth of 4mm. Loctite lengths of 1.5mm pivot steel (blue removed) into the holes and reduce the length of each pivot to 2.5 millimetres.

The centre arbor is fabricated out of a length of 4mm silver steel and a length of 2mm silver steel for the motion work arbor. Again measure the spacing between the two plates and note this value. Cut off a length of 4mm silver steel 7mm longer than the spacing you have measured. Face off one end and drill and ream a 2mm diameter hole in the end to a depth of 12mm for the 2mm motion work arbor. Turn down the end to 3mm diameter for a length of 6mm to fit the front 3mm ball race.

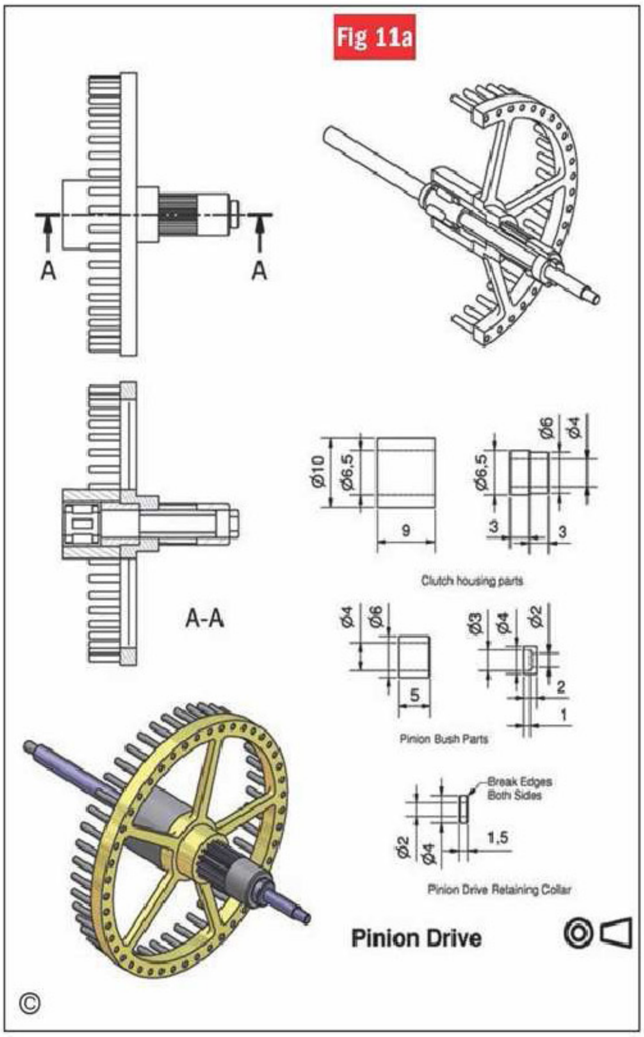


Fig 11a

Square off the shoulder and check the 3mm race is an easy fit right up to the shoulder. Face off the other end and reduce the length from the shoulder to 0.5mm less than the measured spacing. Drill a 1.5mm hole for the pivot to a depth of 4 millimetres. Fit the pivot and reduce the length to 2.5mm. Now turn down the end to 2.5mm for a length of 9 millimetres.

I gently tapered my centre arbor as can be seen in fig 11b. This looks a bit more elegant than leaving it plain. The 2mm front section for the motion work will be made and glued in position later when the dial is in place and the motion work is completed. This will allow the correct arbor length and position of the retaining groove to be determined.

Pendulum arbor

The pendulum arbor is fabricated in two parts from a length of 2.5mm diameter silver steel rod and a length of 4mm diameter silver steel rod. The constructional details of the arbor and the drive assembly are illustrated in figs 11a and 11b. Assemble the plates, pillars and the back cock.

Measure the distance between the inner surface of the back cock and the inner surface of the front plate. The pivot that fits into the front plate bearing is integral with the arbor. Add 2.5mm to the measured length to allow for the pivot. Turn a 1.5mm pivot on the end of the piece of rod. Carefully square off the shoulder of the pivot and check that the pivot is an easy fit in the 1.5mm ball race. Now turn down the arbor for a length of 35mm to 2mm diameter. Drill a 1.5mm hole in the other end of the arbor to a depth of 4mm for the second 1.5mm pivot. Set a piece of 1.5mm pivot steel (remove the blue with fine wet and dry) into the hole with

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Loctite 326. Cut off and reduce the pivot length to 2.5mm and chamfer the end.

Make the hardened sleeve from a length of 4mm silver steel about 12mm long. Face both ends. A 2mm hole is now drilled and reamed through the full length. Check after you have drilled the hole that it is central. Turn down to 3.0mm diameter for a length of 7mm, remove all tool marks and finish the surface with fine wet and dry paper Now reduce the length to 8mm leaving a collar 1mm long. Again remove all tool marks and finish with fine wet and dry leaving a fine polished surface. Now insert the sleeve into the roller clutch. The clutch will grip the sleeve when turned one way and rotate when turned the other way. You will feel a small amount of resistance when the sleeve turns 'freely'. If required, carefully reduce the diameter in small increments until the sleeve turns freely in the clutch one way but still grips when turned the other way.

The sleeve now needs to be hardened. To hold the sleeve taper the end of a 100mm length of 3mm mild steel rod to fit into the end of the sleeve. Grip the rod in a cordless drill and fit the sleeve onto the end. Check that the sleeve runs true. With the drill running heat the sleeve cherry red and with the drill still running, quench the sleeve in cold water.

Return it to the lathe and re-polish the end. Grip it again in the drill and heat to a pale straw and quench in water. Polish the surface again. The 2mm bore will have oxidised as a result of the hardening and will have to be cleaned before it can be fitted with Loctite to the arbor. Loctite will not cure properly if the surfaces are oxidised.

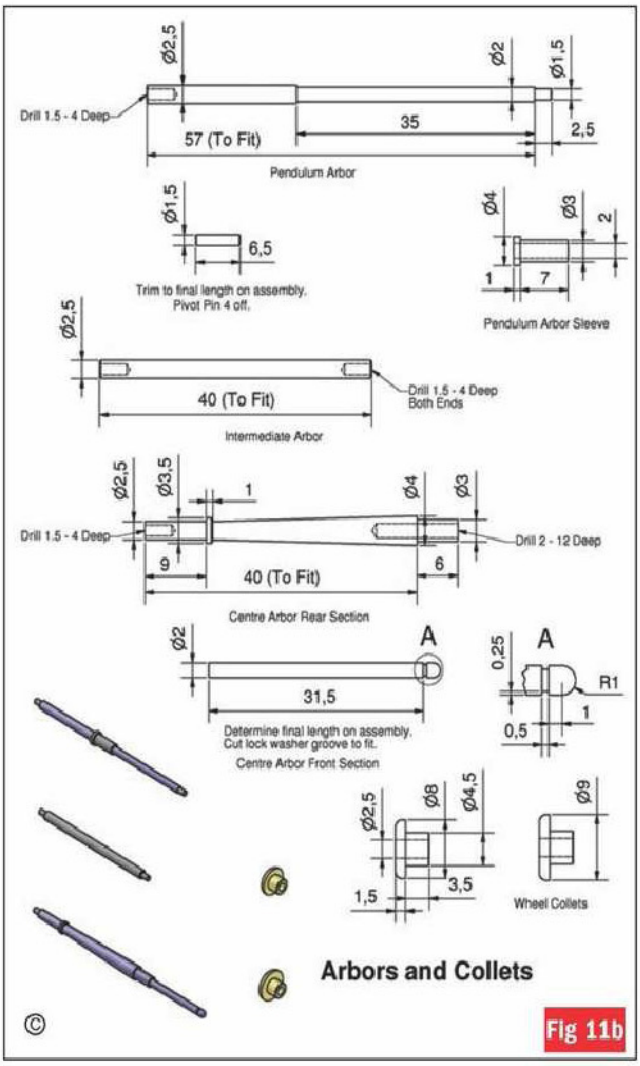
The easiest way to clean the bore is to use a wooden toothpick covered with Autosol paste. Grip the long end in the lathe and with the spindle running quite fast run the toothpick in the bore until all scale is removed. Clean off all traces of the paste. Fit the hardened and tempered sleeve in place on the arbor using Loctite 603.

Inserting the roller clutch into the drive housing

The roller clutch can now be fitted into the housing of the drive mechanism. Before fitting the roller clutch into the housing it is necessary to check that it is being inserted correctly. Once you have pressed the clutch into the housing it will be very difficult to remove it again.

The roller clutch must grip the arbor when it is turned clockwise i.e. the pin wheel must turn clockwise when viewed from the front of the clock and remain stationary when the arbor is rotated in the opposite direction. Once you have determined the correct orientation of the crutch it can be pressed firmly in place in the housing.

To be continued.



Arbors and Collets

Fig 11b

NEXT ISSUE

- **New methods used in making model locomotives**
- **The Imperial measurement debate**
- **Taking digital photos of models**
- **Outstanding milling machines**
- **Centenary Model Engineer Exhibition**
- **Midland 3F locomotive**
- **Savage's *Universal Carrier***
- **Making a ratchet drill**
- **Schools Class locomotive in 5in. gauge**

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Contents subject to change

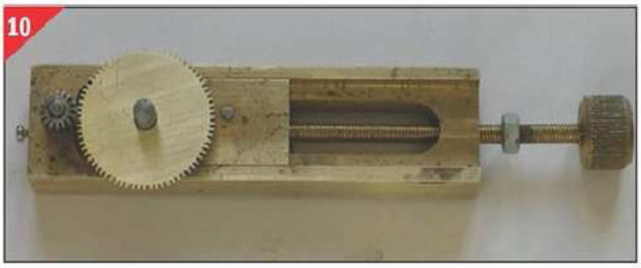
ON SALE 27 APRIL 2007

PART 4

Continued from page 448 (M.E. 4297, 13 April 2007)

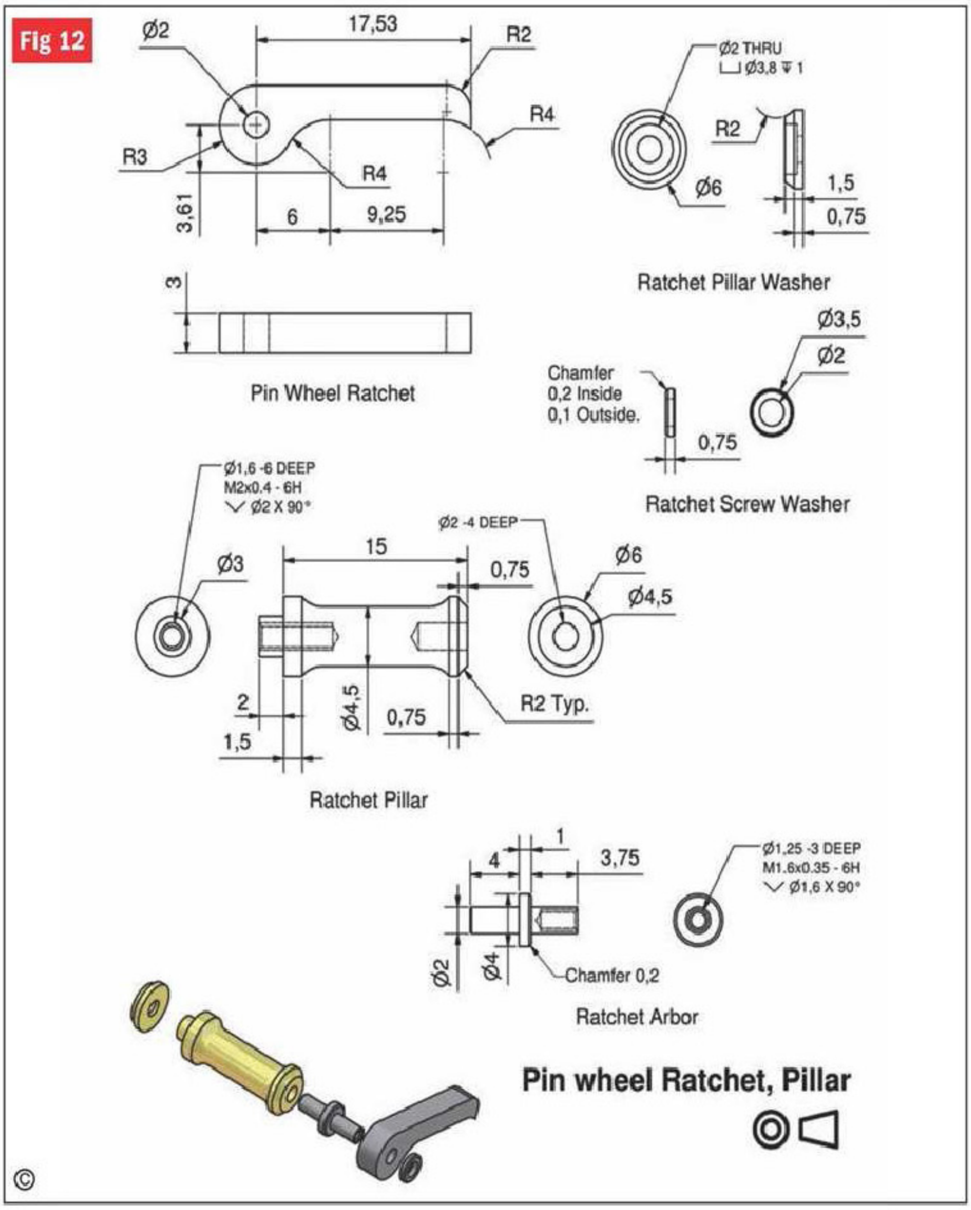
MAGNETIC DRIVE CLOCK

Richard Stephen continues the construction of this fascinating clock by depthing the wheels.



10. Depthing tool.

Fig. 12. Pin wheel ratchet.



I use the depthing tool shown in **photo 10** for depthing my wheels. The advantage of this tool is that it allows very precise adjustment of the arbor spacing, as well as allowing the engaging of the wheel and pinion to be examined either with a hand lens or a binocular microscope.

It is worth taking some trouble with the depthing to minimise the engaging friction between the teeth. A special runner will have to be made to depth the drive pinion and the intermediate wheel because of the roller clutch.

The train can now be planted. All the bearings used in the clock are precision ball races. For minimum friction, the ball races must not be a tight fit in the plates or this will increase the friction in the bearings. The bearings should be a light push fit just tight enough not to fall out.

I have found that it is very difficult to bore blind holes in the plates for the ball races with this precision of fit. Instead I find it a lot easier to counter bore oversize holes and to make sleeves for the ball races.

Most readers will not have suitable counter bores available. A slot drill of a suitable size will work just as well provided the work is securely held in a milling machine.

The plate must be precisely centred and firmly clamped down. To centre the plate you can either use a centring microscope or you can use the method shown in **photo 11**. A 2mm drill rod was held in the drill chuck and passed through the 2mm hole in the brass plate. I have a set of HSS metric drill blanks in 0.1mm increments. I find these invaluable for all sorts of jobs as these blanks are absolutely true as well as being hard. Fit the 2mm rod into the hole in the plate and lower the spindle until the plate can be clamped firmly down. Raise the spindle and remove the rod. Rotate the spindle by hand, and re-insert the 2mm rod. It should enter the hole without any resistance. If it does the plate will be precisely centred.

To counter bore the recess for the 3mm ball race you will need an 8mm slot drill. Centre the spindle of the mill on the hole in the plate. Fit an 8mm slot drill into the spindle and bore a recess 2.5mm deep. Finally drill a 3.2mm hole through the front plate to give adequate clearance for the centre arbor. Repeat the above procedure to counter bore the recess in the back plate for the 1.5mm race. Use a 6mm slot drill and drill the recess which is 1.6mm deep. The existing 2mm hole will give more than adequate clearance for the end of the pivot.

The remaining two wheels can now be planted. Fit the two plates together using the three 5mm register pegs. A peg for centring is made next. Turn down a piece of 6mm brass rod, face off the end and turn down to 3.2mm diameter for a length of 6 millimetres. Drill and ream a 2mm hole to a depth of about 9 millimetres. Part off the peg 8mm from the end. Fit this peg into the hole in the front plate.

Now repeat the procedure using a 2mm dia. rod to centre the spindle on the centre arbor. Check that the rod will pass through both plates without any resistance. Clamp the plates to a piece of 18mm MDF board. Now drill a 2mm hole into the MDF board using the 2mm hole in the plates as a guide. Replace the 2mm drill with the 2mm rod and pass the rod through both plates and into the MDF. Zero the digital readout on the mill.

Remove the drill chuck and fit the centring microscope into the spindle. Move the table about +50mm along the X-axis. Focus the microscope on the front plate and rotate the two plates about the 2mm rod until the crosshairs of the microscope are on the centre line marked on the front plate. The plates will now be precisely orientated along the X-axis. Clamp the plates in this position. Return the digital readout to the zero position.

The remaining two pivot holes can now be drilled. Drill a 2mm hole through both plates for the intermediate wheel and for the pendulum arbor. Separate the two plates and, following the description above, bore the 6mm diameter recesses for the front and back plates for the intermediate arbor and in the front plate for the pendulum arbor.

The pivot hole for the rear pendulum arbor bearing in the back cock must be drilled next. Place the back plate on a suitable piece of MDF board. Centre the mill spindle on the 2mm hole in the back plate for the pendulum arbor as described above. Clamp the plate to the board. Fit the back cock onto the back plate and secure with a 3mm screw and washer as described above. Drill a 2mm hole through the cock.

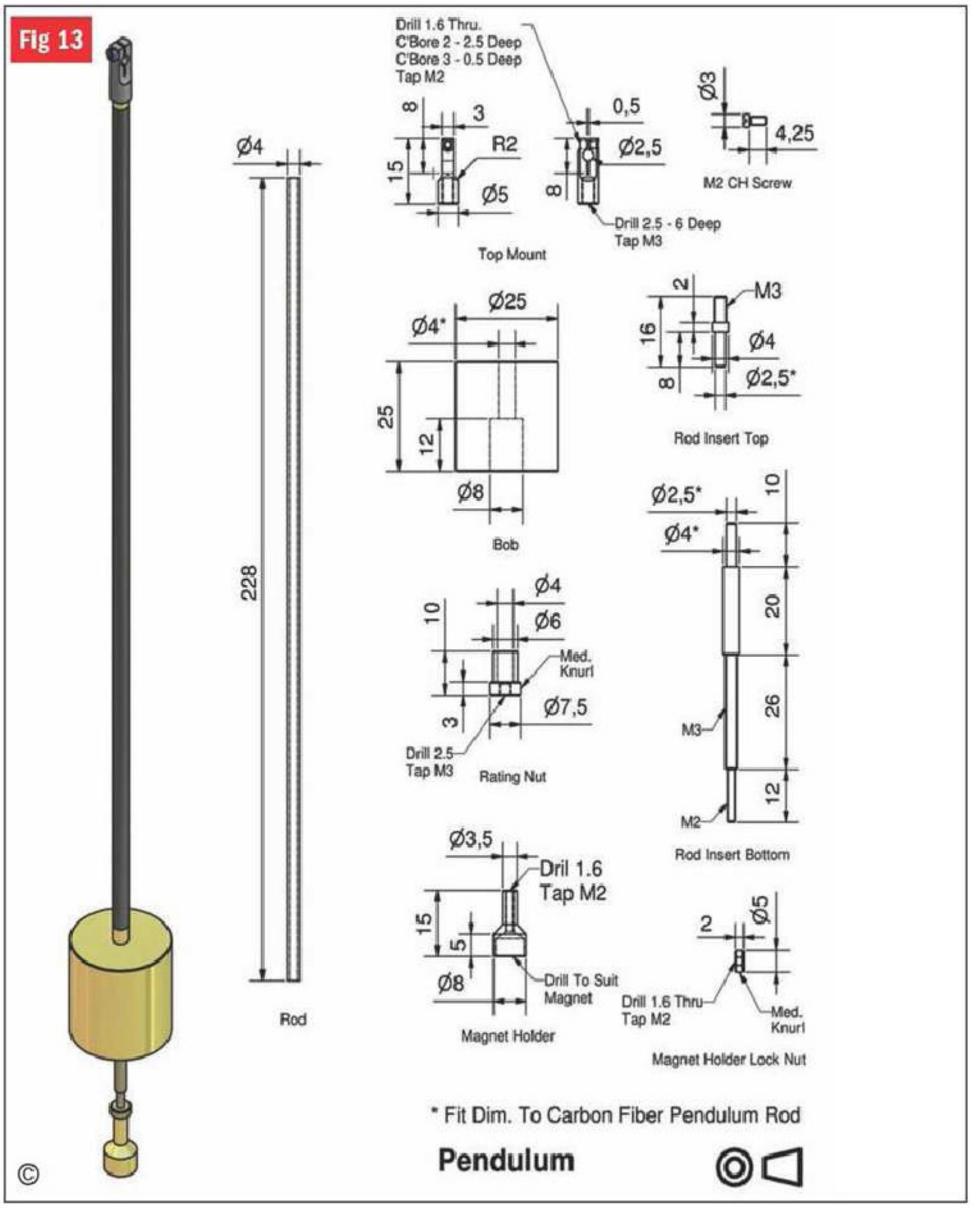
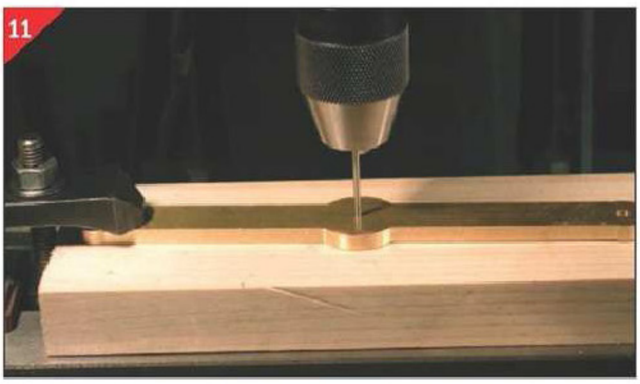


Fig. 13. Pendulum.

11. Centring the plate.



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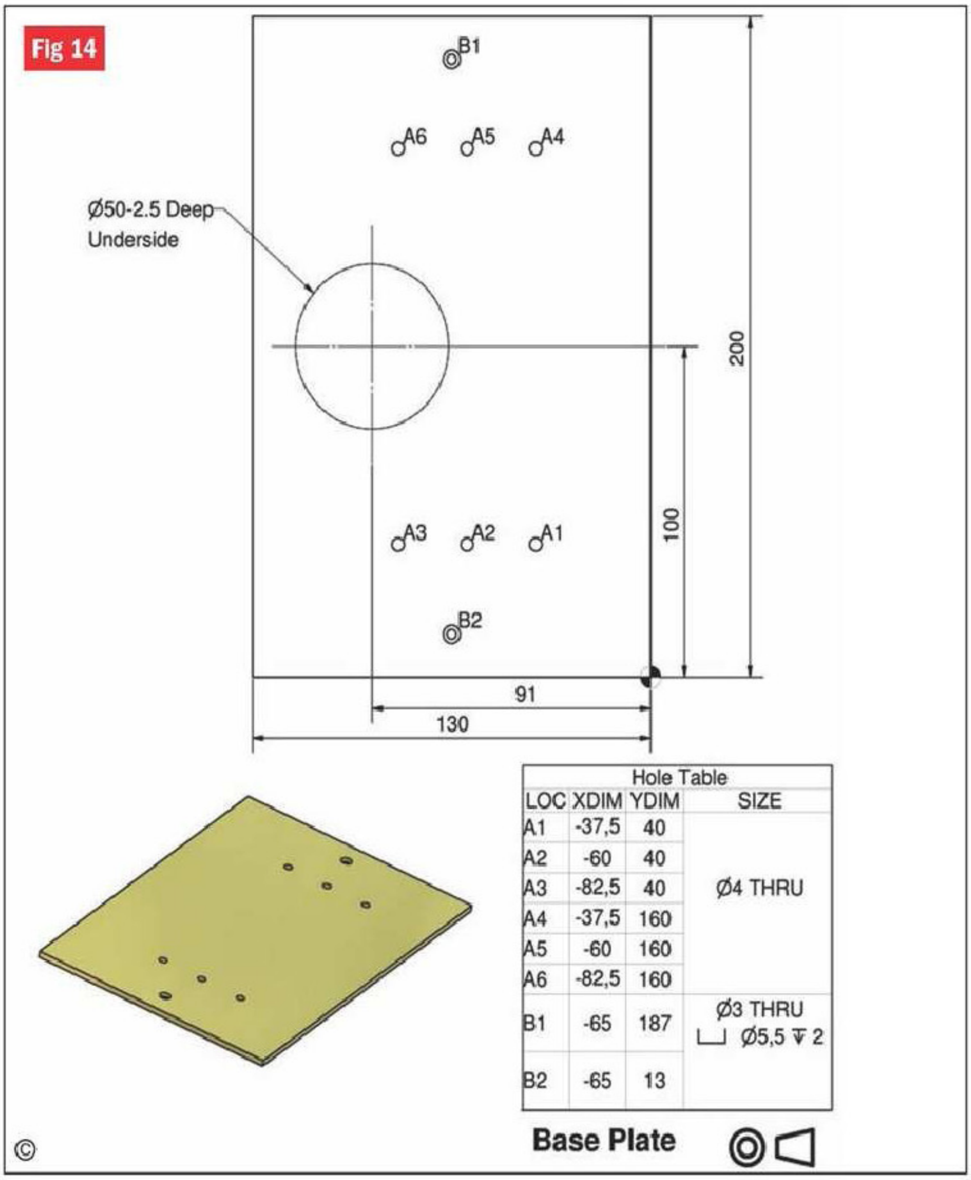

Hole Table			
LOC	XDIM	YDIM	SIZE
A1	-37,5	40	Ø4 THRU
A2	-60	40	
A3	-82,5	40	
A4	-37,5	160	
A5	-60	160	
A6	-82,5	160	
B1	-65	187	Ø3 THRU ⌴ Ø5,5 ↧ 2
B2	-65	13	

Fig. 14. Base plate.

Leave the plate clamped to the board. With the back cock attached to the back plate a 2mm rod should pass easily through the hole in the cock and the hole in the plate. Remove the back cock and then drill a 4mm hole through the back plate centred on the 2mm hole. This will give adequate clearance for the pendulum arbor. Drill the 6mm recess in the back cock for the rear pendulum arbor bearing.

Bearing sleeves

The bearing sleeves are made from scraps of brass rod. For the 3mm bearing sleeve you want about 12mm of 10mm diameter brass rod. Grip the rod in a collet and face off the end. Drill and ream a 6mm hole through the length of rod. Turn down the end of the rod for about 6mm to fit in the recess in the front plate. The fit must not be tight an easy fit is what is required. Before, part off a piece about 2.8mm long and lightly chamfer the end of the sleeve.

The sleeve can now be fitted into the recess and secured with Loctite 326. Carefully clean out any excess adhesive from inside the sleeve. File the sleeve flush with the surface of the plate. Using a hand countersink chamfer the inside of the sleeve. The bearing will be a snug fit and should not fall out easily. Follow the above procedure to make the sleeves for the 1.5mm ball races.

Pin wheel ratchet

The details of the pin wheel ratchet, pillar and arbor are illustrated in **fig 12**. The length of the pillar is given in fig 12. However, the length is best determined with the pendulum arbor and drive wheel in position between the plates. The ratchet wants to rest midway along the length of the pins. The ratchet must be exactly to the dimensions shown in fig 12 for it to operate correctly.

I used CNC to profile my ratchet, which I made from a piece of 3mm thick EN1A mild steel. I always use this grade of steel for small components simply because I get a perfect surface finish. I then case harden the part and polish it. I have used gauge plate but find the work required to produce an acceptable finish is not worth the dubious advantage of having a material that is slightly easier to harden.

Pendulum

The details of the pendulum are shown in **fig 13**, 4mm diameter carbon fibre tube is used for the pendulum rod. There are two reasons for using carbon fibre for the rod, firstly it is non magnetic and secondly it is light as well as being very stiff.

A brass insert threaded 3mm is glued with super glue into the top of the rod. This insert screws into a clamping piece, which attaches the rod to the pendulum arbor. A length of 4mm brass threaded rod is glued into lower end of the rod that carries the rating nut. The lower end of the threaded rod is threaded 3mm for a length of 12mm to attach the brass drive magnet housing shown in Fig 13 to the end of the pendulum. This allows the height of the drive magnet above the coil to be adjusted to regulate the pendulum amplitude. The magnitude of the impulse delivered by the drive coil to the pendulum depends on the distance between the coil and the drive magnet.

The pendulum bob is made out of a length of 25mm brass bar. The bob should be no longer than about 25 millimetres. Do not make the bob too heavy. As will be explained later the accuracy and temporal stability of the clock is not controlled entirely by the pendulum as in a normal mechanical clock. The reason for reducing the mass of the bob is related to the coupling of the pendulum to the electronic drive.

Base plate

The dimensions of the base plate are shown in **fig 14**. The underside of the base is recessed to a depth of 2.7 millimetres. The diameter of the recess is 50mm, slightly greater than the diameter of the drive coil. The reason for recessing the base is to reduce the distance