A FERRIS WHEEL CLOCK

Richard Stephen

begins a new series describing the construction of a fascinating clock powered by steel balls.

●*Part I*

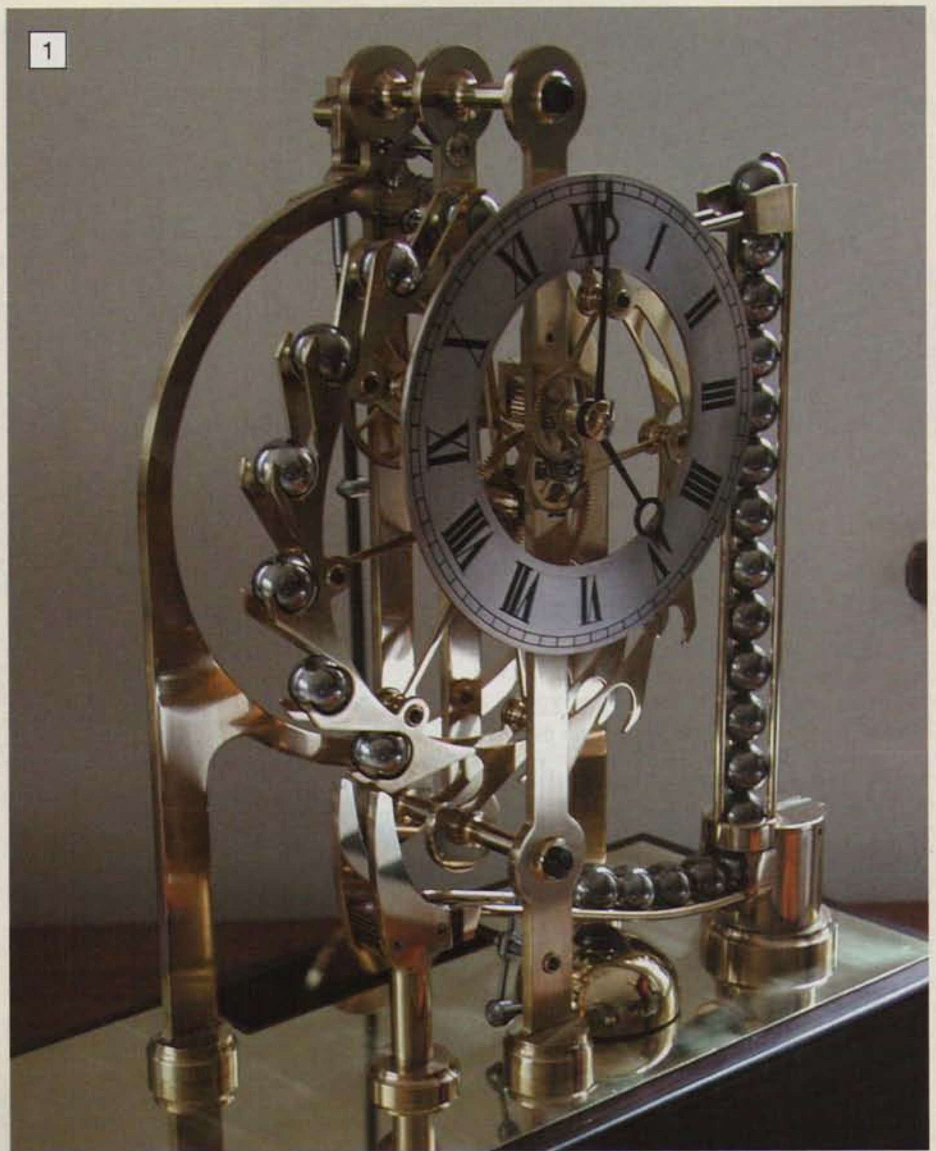
Some time ago our Editor asked me if I would prepare a 'How to Make' clock series for *Model Engineer.* This presented me with quite a problem: what on earth could I make that hadn't been done before? My problem was created by my friend John Wilding, who, over the last 20 or so years, has produced numerous superb 'How to Make' books. John is a very difficult act to follow. At the time of Mike's original request, I was in the process of writing a series for the *Horological Journal* describing the construction of a Vienna Regulator, a clock that had not been done before. Regular readers of *M.E.* may recall a request for suggestions regarding a suitable design; this produced several possibilities. Unfortunately, none of them really appealed to me!

I had been toying with the idea of a clock powered by ball bearings. The clock aspect of the design was no problem; the aspect which stumped me for a while was to devise the most satisfactory method of recycling the balls. All the pictures of this type of clock I had seen involved some dreadfully complicated mechanism for carrying out this task. A further aspect for which I did not care was the frequency of ball recycling, which was generally one ball per minute. The sound of a clock clattering away every minute as it lifted a ball would have challenged my sanity!

After a some considerable cogitation I eventually came up with what I felt was a workable design; the final result is shown in the photographs accompanying this first part of the series.

Modus operandi

The clock is powered by twenty-six 15mm dia. stainless steel balls. The Ferris wheel which holds the balls is furnished with 16 slots or receptacles around its circumference. At any one time 8 balls are held in the Ferris wheel to drive the train. The wheel rotates once every 4 hours; as a result, one ball drops off the wheel every 15 minutes. The ball drops onto a pair of contacts, closing a circuit and energising an electric motor. The motor drives an Archimedean screw which makes a single revolution and lifts one ball through 15mm, the diameter of a ball. In the process a ball is ejected from the top of the stack and rolls into a slot at the top of the wheel. When it drops off the wheel, the ball also actuates a quarter-hour chime. The remaining 18 balls are stored in the recycling mechanism.



With its glass case removed for our photograph and resplendent in gleaming polished brass and stainless steel, this unique Ferris wheel clock will present a challenge to any prospective constructor.

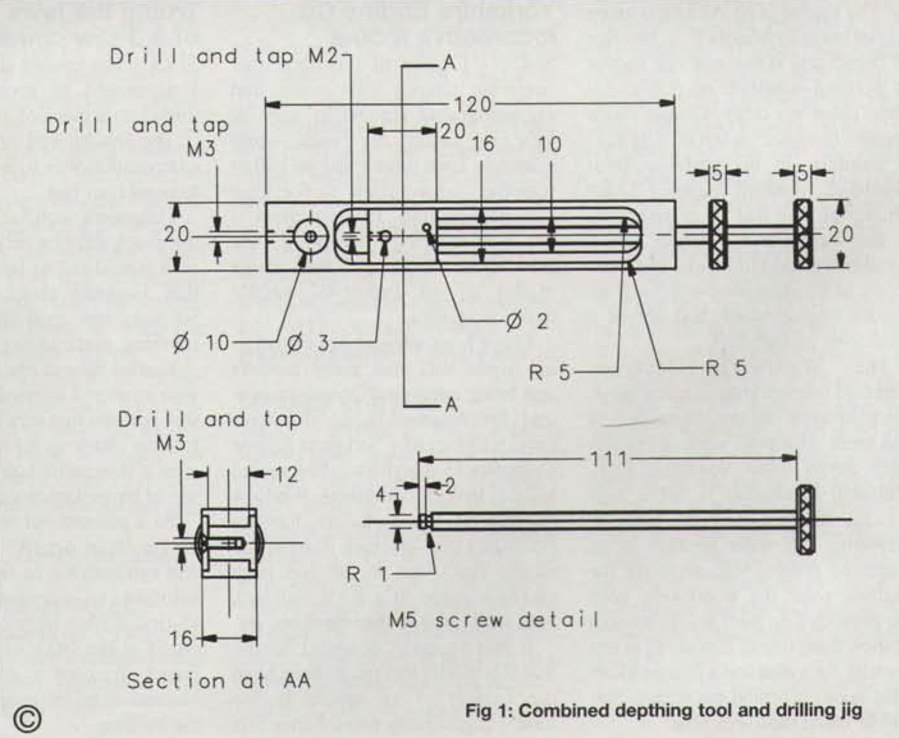
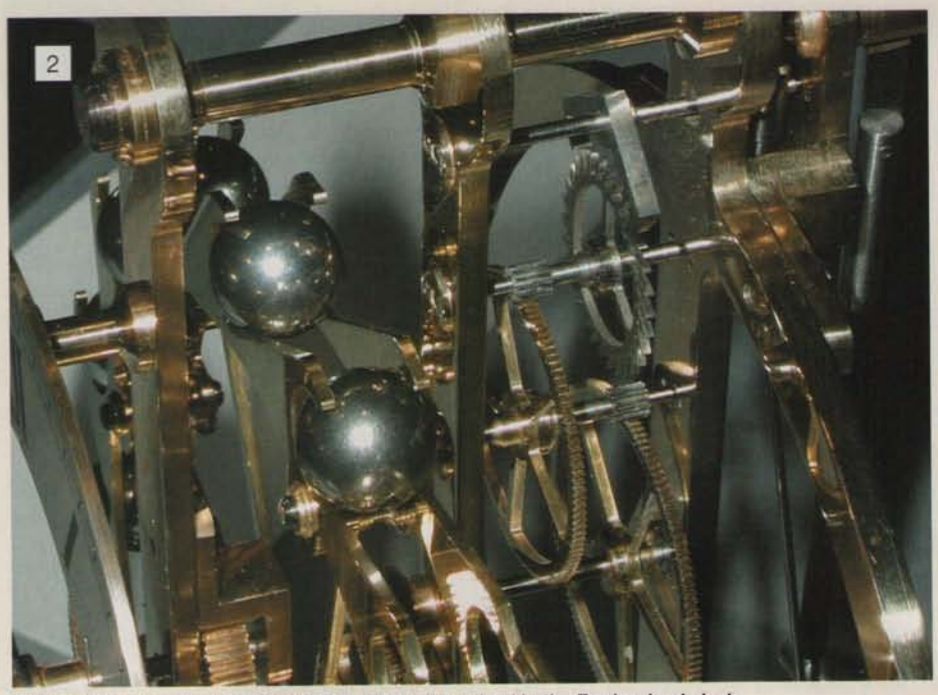


Fig 1: Combined depthing tool and drilling jig



A tantalising glimpse at some of the detail work involved in the Ferris wheel clock.

The clock is mounted on a rectangular wooden base housing the geared motor which powers the ball lift, the electronic circuit board that controls the motor, and a tray containing four D-type cells which provide the power. Initially, I had wanted to power the ball lift mechanically using clockwork. I constructed a suitable drive mechanism using a reasonably powerful spring, only to find that it would only lift a maximum of three balls! The basic difficulty with springs is that, though they can store considerable potential energy, controlled release of this energy over an extended period can lead to problems.

In the case of this clock, to run it for 7 days requires the lifting of 672 balls or the same number of Archimedean screw revolutions. A typical clock spring will require about 10 turns of the barrel for a full wind. As a result, the spring barrel requires to be geared up by a factor of 672:10, or approximately 70 times. Gearing up by such a factor reduces the torque at the top end of the gear train by this amount. To obtain adequate torque at the end of the ball drive gear train to lift 14 balls would have required an immensely powerful spring or, alternatively, a very long constant force (Tensator) spring. Strong springs are difficult to wind and a suitable constant force spring would require about 40 turns every week to wind up the clock.

The advantage of an electric motor is that it runs at a relatively high speed, typically several thousand revolutions per minute. The torque at this speed may be relatively small. To obtain an appropriate rotational speed for the ball lift, i.e. about 1 revolution every 2 to 3 seconds, means that the motor has to be geared down by a factor of several thousand, thus providing a proportional increase in the available torque. Thus, by employing an electric drive means that a relatively small motor can be used which can be conveniently powered by low voltage batteries.

The only down side of this approach, if such it is, is that some electronics are required to control the motor. A somewhat longer-term problem with using electric power is that if the electronics or the motor fail in times to come it is unlikely that replacements will be readily available. Hopefully, this will be someone else's problem!

Clock train

As already mentioned, the Ferris wheel rotates once every 4 hours and drives the centre arbor. The Ferris wheel diameter is 160mm and its arbor also carries two 100 tooth wheels, one on either side of the main wheel. These wheels engage 25 tooth pinion wheels attached to the centre arbor, which is split into two parts. The rear wheel and pinion drive the time train and pendulum while the front pair drive the motion work and the hands. The time train is quite conventional except that the pinions are all 12 leaf. Using larger count pinions allows these to be made as separate items and attached to their respective arbors using Loctite high strength retainer.

The pivots for the centre arbor are made of high-speed steel drill rod fitted into the ends of the mild steel arbors and retained with Loctite. I realise this is probably an anathema to the purist clock-maker; nevertheless I have found it an extremely practical way of creating precision pivots. Inserted pivots allow the shoulders to be made absolutely square. I have found that shoulders with rounded corners can, at times, give rise to excessive pivot friction which can be difficult to locate. High-speed steel is tougher than carbon steel and the drill rod is ground and polished to a very close tolerance. It is also easy to replace a pivot if necessary.

The high-speed steel pivots run in aluminium bronze bushes. I never drill pivot holes directly into the plates of any clock I make. If one makes a mistake with a pivot hole, and we all do at times, it is much easier to replace a bush than to fix an oversize pivot hole made directly into a plate. The wearing properties of aluminium bronze are far superior to those of CZ120 brass. The centre wheel and Ferris wheel arbors run in precision ball races. ▶

Suppliers

Ferrous and non-ferrous metal:

Smiths Metal Centres. This firm has branches at several locations in the UK. I have found Smiths to be most helpful, particularly the branch in Nottingham. The off-cuts bin at Smiths in Nottingham is my principal source of supply of brass sheet and rod.

Columbia Metals Ltd. Wingfield Mews, Wingfield Street, Peckham, London SE15 4LH. Columbia Metals are most helpful.

Small ads: at the back of *Model Engineer* and *Model Engineers' Workshop* are worth looking at.

J&L Industrial Supplies. Free 'phone 0800-663355 for high speed steel drill blanks, ground flat stock, silver-steel and any workshop tooling. Get their catalogue, it's well worth it. The stock range they keep is quite phenomenal. They supply by mail, usually the next day.

Titanium for the escape wheel:

Small offcuts of titanium are difficult to find. If you have a large RAF base near you, a 'phone call to the Engineering Officer is a possible solution. I have managed to obtain some small scraps from my local base and have found the RAF to be most helpful when you explain why you want the titanium. A friend recently got me some from a scrap dealer near Manchester. This dealer takes the scrap from British Aerospace. I may be able to help with pieces if you have real problems getting hold of a supply.

Diamond tooling and abrasives:

Marcon Diamond Products Ltd. Marcon House, 131 High Street, Codicote, Hitchin, Hertfordshire SG4 8UB

Proops Brothers Ltd. 24 Saddington Road, Fleckney, Leicestershire; tel: 0116-240-3400; fax: 0116-240-3300. You should contact them to see what stock is available.

Shesto Ltd. Unit 2, Sapcote Trading Centre, 374 High Street, Willesden, London NW10 2DH; tel: 020-8451-6188.

Gear and pinion cutters:

P. P. Thornton (Successors) Ltd. The Old Bakehouse, Upper Tysoe, Warwickshire CV35 0TR; tel: 01295-680454; fax: 01295-680067.

Precision ball races and 15mm Stainless steel balls:

SMB Bearings Ltd. Unit 8 West Oxon Industrial Park, Brize Norton, Oxon OX13 3YJ; tel: 01993-842555.

Electric motor:

Motors Direct (A.J. Graham), Harvesters Yard, Ditcheat, Shepton Mallet, Somerset, BA4 6RB.

The escapement is a conventional dead-beat type. The nibs are unusual in that they are made of tungsten carbide, a material for dead-beat escapements to which I was introduced by my friend Peter Bradley. Tungsten carbide is without a doubt the ideal material for pallet nibs. It is extremely tough and hard, and takes a very high polish.

The escape wheel is also unconventional in that it is made of titanium rather than the more usual brass. In my opinion, titanium is the ideal material for escape wheels. While very tough it is only half the weight of an equivalent brass wheel. The reduction in the inertia of the escape wheel improves the action of the escapement by at least 25%. The only down side is that titanium is more difficult to work than brass.

The half-second pendulum is approximately 230mm long. You will observe in the photographs that the bob is partially obscured by the base of the clock; this was to minimise the height of the vertical ball column.

Workshop equipment required

To make the clock you will require the following machines:

1: Myford ML7 lathe or equivalent.

2: Milling machine and a good rotary table.

3: Gear cutting equipment either fitted to the lathe or milling machine.

4: Good pillar drill.

5: Dremel (or equivalent) mini-drill.

For myself, I have recently invested in a Wabeco milling machine with CNC capability. The CNC was absolutely invaluable for making many of the parts of the clock, particularly the dial. Dials are a perennial problem. If you have access to CNC equipment, the drawings for some parts of the parts of the clock are available on disc as .dxf files. If you intend to 'get into' clock making, I would advise you to give serious consideration to a CNC machine. The Wabeco software is reasonably user-friendly and makes light work of some of the more complicated parts of the clock.

There is no problem if you don't have CNC, as I will indicate how to make some of the complicated parts without it, using 'conventional' means.

A materials list is included in this first instalment of the series. It may seem somewhat lengthy as I have listed absolutely everything you will need to make the clock. Many of the items will be to hand in most model engineer's workshops. I have also indicated some suppliers to give you a start in obtaining some of the more unusual items.

General comments

Before we make a start on the construction, I would like to make a few further general points. This clock is *not* intended as a beginner's project. A reasonable degree of workshop facility will be assumed. If you have not made a clock before and want to get into 'clocking' you should begin with one of John Wilding's excellent examples. This construction series will extend over a number of instalments. Having prepared 'How to Make' series before I am well aware of the temptation to make each of the parts described in each issue, set them to one side until everything has been made, and then attempt to assemble the clock. It is at this point that we find that some of the parts don't quite fit.

Having made many clocks over the years, I have found that the only satisfactory way to work is to make each part fit those already made. Thus, before making any component, please ensure that the dimensions given for the part to be made will allow it to fit correctly. It may then be necessary for you to make slight modifications to some of the dimensions to achieve this. The consequence of this is that the dimensions given should only be taken as a guide. When I make a clock, I make a rough sketch in a book with the approximate dimensions of each part. In the process of making the part, these dimensions may have to be amended as the part is fitted to those already made.

As far as possible I have used metric units and metric screws throughout the construction. I am fortunate to have a stock of machine cut metric screws down to 1.2mm diameter but admit that it now seems almost impossible to buy machine cut metric screws. Fortunately BA machine cut screws are still available. As nice screws are so difficult to obtain, I now find it easier and quicker to make my own using leaded mild steel: EN1A or equivalent.

● *To be continued*

Further equipment required

Additional to the machines mentioned in the text you will need the following items; the first is not absolutely essential but will be extremely useful.

1: An optical centring microscope. Plans for my microscope were described in *M.E.* 4103, 24 September 1999. If you haven't already made one, I suggest you do so before embarking on the clock. During the construction of my clock, I made extensive use of the one I made. A great many holes need to be drilled which require to be very accurately positioned.
2: A combined depthing tool and drilling jig; a drawing of the one I use is given in **fig 1**.
3: Diamond grinding pastes. You will need a tube each of 10, 6 and 1 micron grit size. Diamond pastes are available from J&L Industrial Supplies.
4: A cylindrical diamond wheel about 6 to 10mm in diameter. Suitable wheels are available from Proops and cost a couple of pounds each. With care they last a long time.
5: A small diamond cutting disc. These are available for a few pounds from J&L or Shesto.
6: A length of 4mm O/D, 2mm I/D carbon fibre rod. Model aircraft and kite makers use this rod which is available at most good model shops.
7: Two pieces of tungsten carbide 2.5 x 2.5 x 6mm for the pallet nibs.
8: A piece of mild steel 50 x 25 x 2.5mm for the arms of the pallets.
9: A piece of mild steel bar 10 x 25 x 70mm.
10: A 1m length of 6mm dia. EN1A mild steel rod.
11: A 1m length of 8mm dia. EN1A mild steel rod.
12: A piece of tempered steel sheet, 100 x 50 x 0.8mm, for the hands (I used an old cross cut saw blade).
13: A piece of annealed titanium sheet, 50 x 50 x 1mm, for the escape wheel.
14: A length of 1.5mm dia. silver-steel rod for the crutch.
15: A piece of CZ120 brass sheet 4 x 200 x 300mm for the back plate.
16: A piece of CZ120 brass sheet 3.5 x 100 x 300mm for the two time bars.
17: A piece of CZ108 brass sheet 1.2 x 200 x 500mm for the Ferris wheel.
18: A piece of CZ120 brass sheet 2.5 x 150 x 300mm for the base.
19: A piece of CZ120 brass sheet 1.5 x 100 x 100mm for wheels.
19: A piece of CZ120 brass sheet 1.2 x 100 x 100mm for wheels.
20: A piece of CZ120 brass sheet 1.5 x 150 x 150mm for the dial.
21: A piece of CZ108 brass sheet 1mm x 50mm x 100mm for the Archimedean screw.
22: A 1m length of 3mm dia. (or 4mm according to taste) brass rod for the ball track.
23: A piece of brass rod 50mm dia. x 150mm long for the pendulum bob and the Archimedean screw housing.
24: A piece of brass rod 30mm dia. x 200mm long.
25: A piece of brass rod 25mm dia. x 200mm long.
26: A piece of brass rod 15mm dia. x 200mm long.
27: A piece of brass rod 8mm dia. x 200mm long.
28: A piece of brass rod 6mm dia. x 200mm long.
29: A brass block 40 x 60 x 12mm for the back cock
30: A piece of aluminium bronze bar 30mm dia. x 50mm long
31: A piece of aluminium bronze rod 6mm (1/4in.) x 150mm long for bushes.
32: Thirty 15mm dia. stainless steel balls.
33: Four, 6mm O/D, 3mm I/D shielded ball races.
34: Two, 6mm O/D, 2mm I/D shielded ball races.
35: A selection of 4mm, 3mm, 2.5mm, 2mm and 1.6mm cheese head and countersunk machine cut steel screws (or 4, 6, 8, 10 and 12 BA similar).
36: A 50mm dia. x 20mm high brass bell.
37: Thornton cutters: 0.40 module wheel and 16 tooth pinion cutter; 0.30 module wheel and 12 tooth pinion cutter.
38: A few 20mm dia. x 0.50mm thick carborundum cutting discs
39: A piece of Tufnol or similar insulating material 15 x 30 x 30mm.
40: Components for the electronic control board (as detailed later).
41: A 12 volt, 60 rpm Buhler geared motor (available from Motors Direct).
42: Quantities of 0.8mm and 2mm dia. drill rod for pivots.
43: Sections of Perspex 100 x 60 x 20mm; 100 x 30 x 20mm; 200 x 100 x 10mm; 100 x 100 x 40mm; 60 x 60 x 10mm for polishing aids.
44: A piece of boxwood approximately 70 x 25 x 25mm for laps.
45: One, 8mm O/D, 5mm I/D shielded ball race.
46: One, 6mm O/D, 2.5mm I/D shielded ball race.
47: Gauge plate or mild steel 30 x 15 x 10mm for the non-return catch