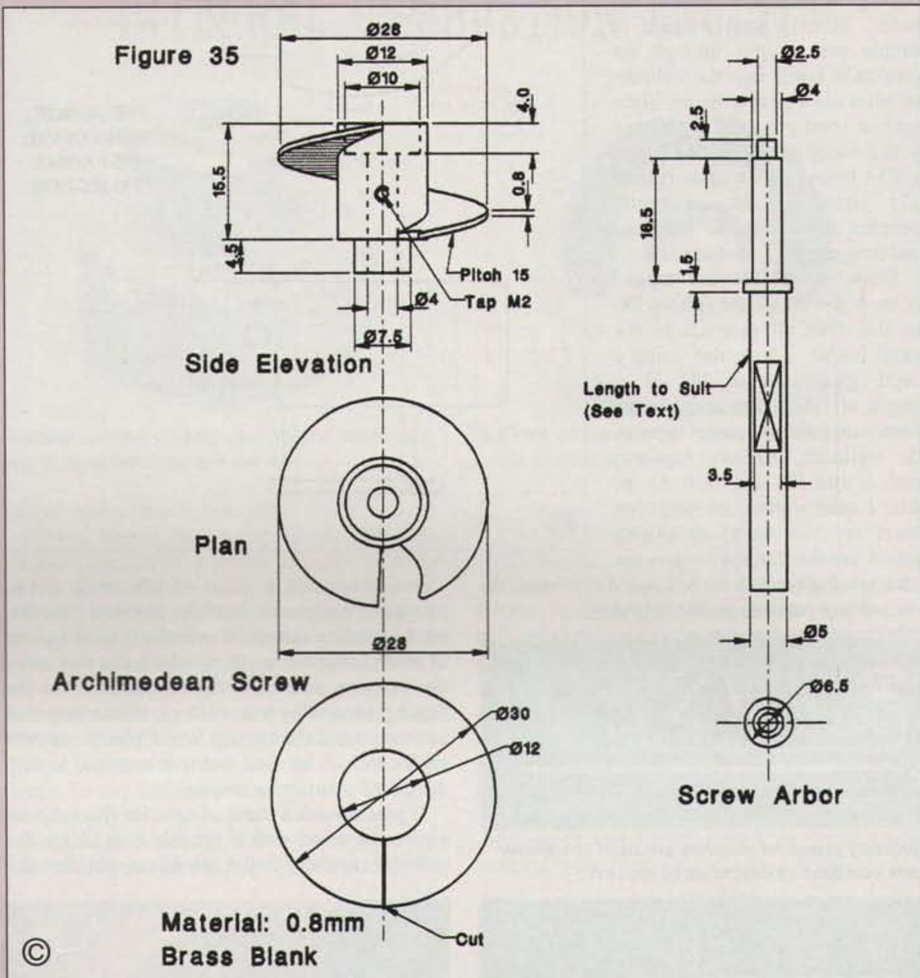
The finished ball lift mechanism showing the lifting tube, cover and entrance bracket. The non-return catch, to be described in a future article in this series, is also shown.

A FERRIS WHEEL CLOCK



Richard Stephen

discusses the evolution of the ball lift mechanism and begins work on its construction.

●*Part IX continued from page 384 (M.E. 4180, 18 October 2002)*

The next phase of the project, the ball lift, was by far and away the most difficult to design and construct. There even were times I thought it would never work!

I had initially wanted the clock to be entirely mechanical, with the ball re-cycling mechanism powered by a spring. To run the clock for a period of seven days, with one ball dropping off the Ferris wheel every 15 minutes, 672 balls were required to be lifted. I planned to use an Archimedes screw to lift the balls. With a screw having a pitch equal to the diameter of a ball this meant that the screw had to rotate 672 times each week. A typical clock spring requires about 10 turns to fully wind it. To obtain 672 ball movements then required the spring to be geared up by a factor of 67.2 with a consequent reduction in the torque of precisely the same factor if friction in the gear train was ignored.

A further negative factor was the fact that the torque of a spring increases almost linearly from zero when the spring is fully unwound to its maximum value when fully wound. This meant that the gearing factor would have to be significantly larger than 67.2. The more I thought about a spring the more impractical it became. To fit a really large spring storing sufficient energy to lift all the balls was really not an option. If any part of the drive mechanism failed at some time in the future with all the stored energy in a large spring being suddenly released I could see bits of clock being scattered over a large area!

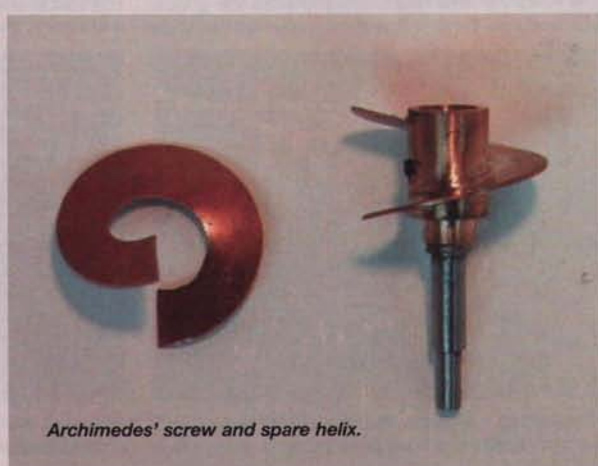
The alternative was to use an electric motor powered by batteries to drive the Archimedes screw. The advantage of electric motors is that they run at high speed and to obtain a rotational speed of about 0.5 rev. per second, the motor has to be geared down. Most suitable battery powered small motors run at several thousand revs per minute. Geared down by a factor of several thousand also results in an increase in the torque by the same factor. This means that even a very modest motor geared down to the required speed would have adequate torque for the job in hand.

The next question was how long would a set of batteries last? I calculated from the characteristics of the recommended motor that four alkaline D cells giving a total of 6 volts, should last about two months. The clock has now run for over four months on one set of batteries. I did toy with the idea of using solar recharging. With over four months on a set of alkaline cells the complexity of fitting solar panels, which do not deliver much power at the light levels found in most front rooms, became a definite non-starter.

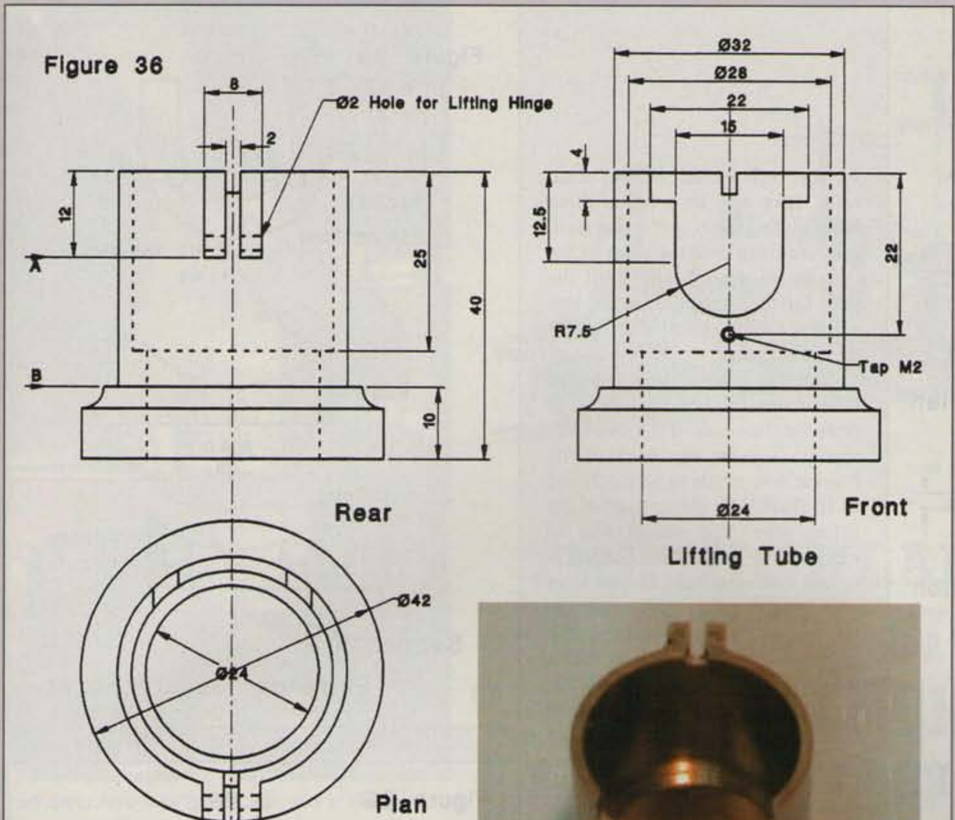
The principal aim in the design of the ball lift was to use the minimum number of parts and to keep everything as simple as possible. As the Ferris wheel rotates, the wheel reaches a point when a ball rolls out of the recess. The ball drops between a pair of contacts, closing a circuit and generating a voltage pulse, which turns on the motor and drives the Archimedes screw. A detent attached to the shaft of the screw operates a micro switch, which cuts off the power to the motor after a single revolution.

Archimedes screw

The components of the Archimedes screw and housing are illustrated in the accompanying photograph. The dimensions and details of the



Archimedes' screw and spare helix.



various components are illustrated in **fig 35**. The simplest way to make the screw is to fabricate the thread. As the screw is used to raise the balls it is not necessary for it to be 'engineering perfect'; it is only necessary for the pitch to be 15mm to match the diameter of the balls. It will not matter if the pitch is slightly greater than 15mm but it must not be less.

Begin by cutting about three brass discs, 30mm dia., out of 0.80mm thick brass sheet. You only need one disc, however it is always useful to have spares. Drill a 12mm dia. hole in each of the discs. Cut along a radius as shown in fig 35. Using your fingers, and where necessary a pair of smooth jawed pliers, pull the two cut edges apart to form the single turn thread as illustrated in the photograph. The effect of pulling the two edges apart will distort the central hole and reduce its diameter. When I made my screw the diameter reduced to just under 11.5mm. Using a fine round file enlarge the hole to fit onto a shaft with a diameter of 12.0mm. Slide the thread onto the 12.0mm shaft, which at this stage should be at least 20mm longer than the finished length shown in fig 35. The sides of the thread should be at right angles to the central shaft and the pitch equal to 15mm. The thread is now silver-soldered to the shaft using as little silver-solder as possible.

Grip the shaft in a collet or true 3-jaw chuck and taking only the very lightest of cuts, true up the thread and reduce its diameter to 28mm. The depth of the thread at this diameter is 0.50mm greater than the radius of the balls. At this thread depth all the force exerted on the balls will be directed vertically. If the thread depth is made less than the ball radius a component of force will be developed which will tend to push the balls out of the entrance to the lifting tube. Finally drill and ream a 4mm dia. hole through the centre of the shaft.

No further work can be done on the screw until the lifting tube is constructed.

The lifting tube is machined from solid brass, including the hinge lugs, evident in this view.

Lifting tube

The dimensions and details of the lifting tube are given in **fig 36**. The body of the tube is best made from a length of 50mm dia. solid brass bar. The hinge for the non-return ball catch is best made as an integral part of the tube and not silver-soldered to the side of the tube. To make it you will need to have a rotary table on which a 3-jaw chuck can be centrally mounted.

Begin by facing both ends and reducing the length to 40mm and the diameter to 42mm. Now turn the rod down to a diameter of 32mm over the section A-B shown in fig 36. Grip the lower end of the tube in the 3-jaw chuck on the rotary table mounted on the milling machine. Using a 3mm dia. slot drill, and only taking very light cuts, remove the excess material. This will leave a radius of 1.5mm in the corners where the hinge joins the tube. The slot for the non-return catch can now be milled out using a 2mm dia. slot drill.

Hold the tube in a vice taking care that the axis of the slot is precisely radial. Again taking only very light cuts, mill out the slot to depth of 5mm i.e. down to the outside of the tube. The 1.5mm radius corners can now be milled away.

The tube can now be bored out. Grip the tube in a 3-jaw chuck and check that it runs true. Start by boring a 24mm dia. hole right through the tube. Now expand the hole to a diameter of 28mm down to a depth of 25mm. The tube can be set aside for the present until the top and the entrance bracket are made.

Lifting tube cover

The cover of the lifting tube is a rather complicated shape and needs to be made carefully if the screw is to work and lift the balls reliably. The cover is made from a 35 x 45mm piece of engraving brass 9.5mm ($^3/_8$in.) thick. If you cannot find a piece of engraving brass a piece of plate will do. If you use a piece of brass plate it would be as well to check that it machines easily before you start.

Begin by facing both sides of the plate and reducing the thickness to 8mm. This is most easily done in the lathe with the plate held in a 4-jaw chuck. Smooth both sides by rubbing on 500 grit, wet and dry abrasive paper placed on a true flat surface. Mark the positions of the two holes A and B, 13.5mm apart as shown in **fig 37**. Using a pair of dividers, scribe the following circles:

centre A of radius 14 and 16mm, and
centre B radius of 11.5mm.

Drill and ream two 3mm holes through the plate at the positions A and B. The positions of these holes must be drilled as accurately as possible.

The cover can really only be machined using a rotary table and a 3-jaw chuck on the milling machine. Before starting work on the cover, you will need to make a brass holder to secure it during machining. The holder is made from a 25mm length of 25mm dia. brass bar. Reduce the end to 3mm dia. for a length of 6mm. The cover is attached to the holder with soft solder, which is easily removed after machining is completed. Solder the plate to the holder with the 3mm peg inserted into hole A.

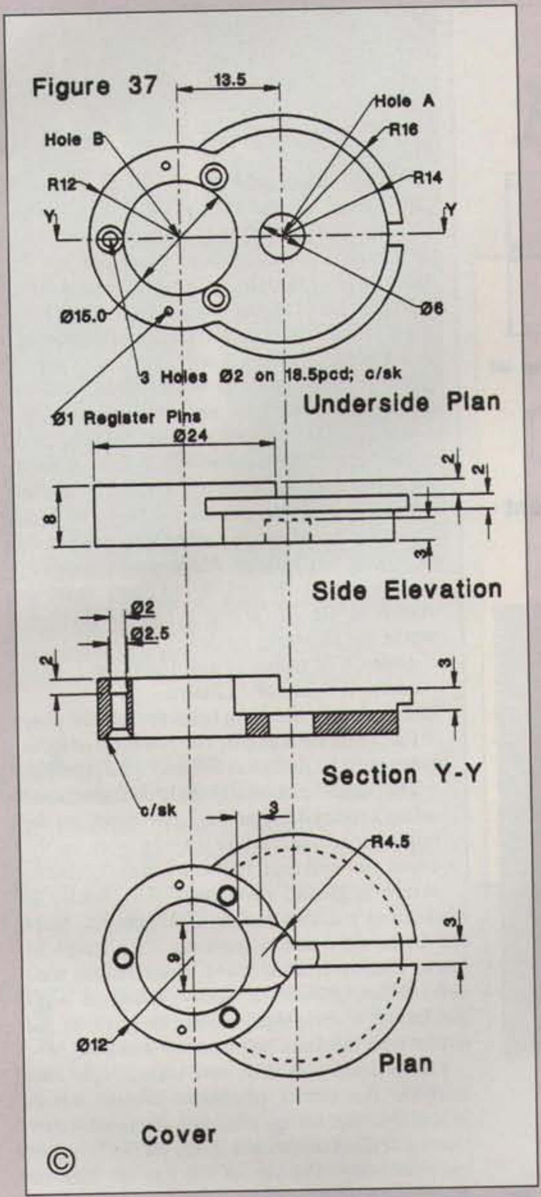
Use a 3mm slot drill and taking light cuts machine the recess (diameter 28mm) which inserts into the lifting tube to a depth of 4mm. Use the scribed circles as a guide for the limits of the machining. The rim of the top can then be machined. Unsolder the top from the holder and re-solder the cover to the holder with the 3mm peg inserted into hole B. Now mill the outside of the delivery tube and the 15mm dia. hole for the balls to pass through. The three 2mm dia. countersunk screw holes and the two 1mm dia. register pin holes should be drilled now. The centres of the screw holes must be positioned exactly 1.75mm from the edge of the 15mm hole. The edges of the vertical 3.5mm ($^9/_{64}$in.) guide rods will then be flush with the edge of the hole through which the balls lift.

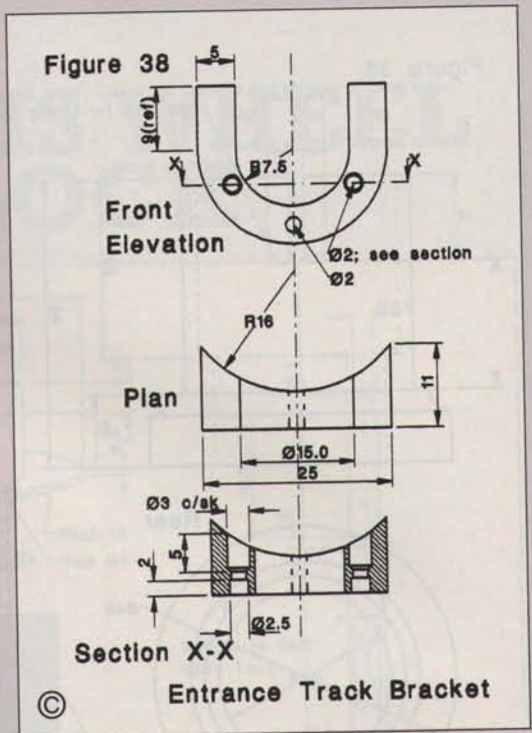
Unsolder the top from the holder. Reduce the holder to 15mm diameter for about 4mm. Insert the holder into the 15mm hole and solder in place. The top of the cover can now be finished in the lathe. Unsolder the cover and clean off all traces of solder.

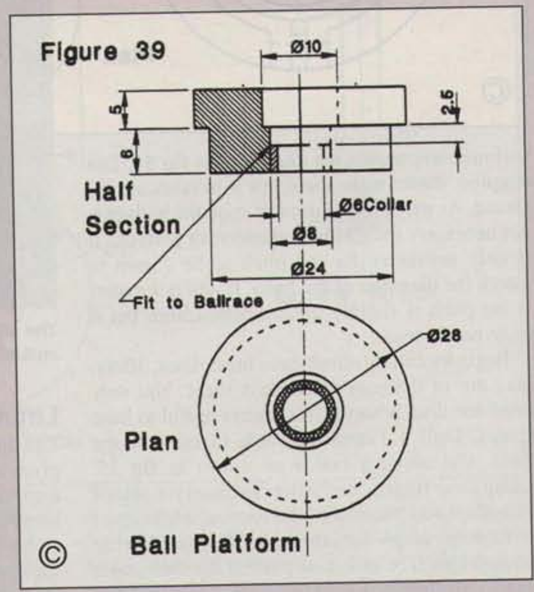
The 2mm dia. holes for the screws that secure the track rods should be enlarged to 2.5mm dia. to a depth of 2mm for the ends of the track rods.

Fitting the cover in place

The cover can now be fitted into the lifting tube. Referring to the previous drawings you will see that the centre of the slot for the non-return catch, the centre of the lifting tube and the centre of the hole through which the balls lift are all aligned. Position the cover on the lifting tube and mark the position of the recess that needs to be cut in the side of the tube. ▶







Using a slot drill mill out the recess down to 4mm. Leave the width of the recess slightly undersize. The cover is best finally fitted with the aid of a file. Drill and tap the two holes for securing the cover to the lifting tube. With the cover fitted in place, the ball entrance in the lifting tube can now be cut out.

Fit the cover in place and use the sides of the 15mm hole to position the sides of the entrance hole for the balls. Using a slot drill, mill out the entrance to a depth of 12.5mm leaving the width slightly undersize. The circular bottom of the entrance will be cut out once the bracket for the entrance track is made and fitted in place.

Track bracket entrance

The dimensions of the entrance track bracket are shown in **fig 38**. The bracket is made from a 25 x 25 x11mm piece of free machining brass plate. Clamp the piece of brass in the vice on the milling machine and square off the sides.

Begin by drilling and reaming a 15mm hole on the centre line 8.5mm from one edge. If you do not have a reamer and cannot borrow one but have a boring head, use this to cut a good clean hole. The sides of the entrance can now be machined using a slot drill. Drill the holes for the two 2mm dia. screws for attaching the track rods right through as shown in fig 38. These holes are then enlarged to 2.5mm dia. to a depth of 2mm for the ends of the 3.5mm track rods. Take care to position these holes so that the edges of the track rods are flush with the sides of the opening in the bracket. Drill the hole for the 2mm dia. screw that secures the bracket to the side of the lifting tube.

Turn the bracket over and drill the countersunk holes to a depth of 5mm for the heads of the 2mm dia. screws. The circular back of the bracket now needs to be machined to fit flush with the outside of the lifting tube. The easiest way to machine the back of the bracket is to use a boring head if you have one. Set the radius of the cutter in the boring head to 16mm, the radius of the outside of the lifting tube. Clamp the bracket vertically in the milling machine vice. Take light cuts and machine the back of the bracket to its final shape. Before taking the final cuts check that the bracket will fit flush with the side of the lifting tube.

If you do not have a boring head the circular back can be machined in the lathe. The bracket will have to be soft-soldered to a suitable piece of brass so that it can be held in a 4-jaw chuck. The chuck will allow you to position the bracket so that its circular back can be turned out with a boring bar.

Fitting the entrance track bracket

The entrance track bracket can now be fixed in position. Fix the top cover in place and secure with the two 1.6mm dia. screws. Now position the bracket against the side of the lifting tube and press firmly against the underside of the cover. The sides of the entrance must be flush with the hole in the cover. You may find that the bracket is just a 'smidgeon' wider than hole. If so, set the bracket symmetrically relative to the hole. Clamp the bracket firmly in place. Using the register pin holes in the cover as a guide, drill the holes in the bracket for the register pins. Release the clamp and fit the register pins into the holes drilled in the bracket.

Re-position the bracket using the register pins and check that the bracket still fits snugly in the correct position. Using a sharp scriber mark the outline of the inside of the bracket on the lifting tube. Remove all the excess metal. The inside edges of the bracket and the lifting tube must be flush and smooth. Remove the bracket and the cover from the lifting tube. The platform, on which the balls rest before being lifted, will be the next thing to be made.

Ball platform

The dimensions of the ball platform are given in **fig 39**. The platform is machined from a length of 30mm dia. brass bar.

Turn the platform to size but leave the 28mm diameter section slightly overlength. The top of the platform has to be flush with the bottom of the entrance track bracket. Slide the platform into the lifting tube and press it firmly down against the shoulder in the tube. Mark with a scriber the bottom of the ball entrance. Remove the platform and face to its final length.

Drill and ream an 8mm dia. hole in the platform for the 5mm I/D ball race. The ball race should be an easy sliding fit. To prevent the race from dropping out of the bottom of the platform, a collar (see fig 39) is fitted into the bottom and secured in place with Loctite high strength retainer. Fit the platform into the lifting tube, screw the cover in place and fit the bracket in position using the register pins.

Clamp the bracket firmly in place and, pressing the platform down, drill a tapping hole for the 2mm dia. screw through the side of the tube and into the platform for a depth of about 6mm. Dis-assemble and tap the hole in the platform for the 2mm dia. screw. Open up the hole in the side of the tube to 2mm diameter.

●*To be continued.*