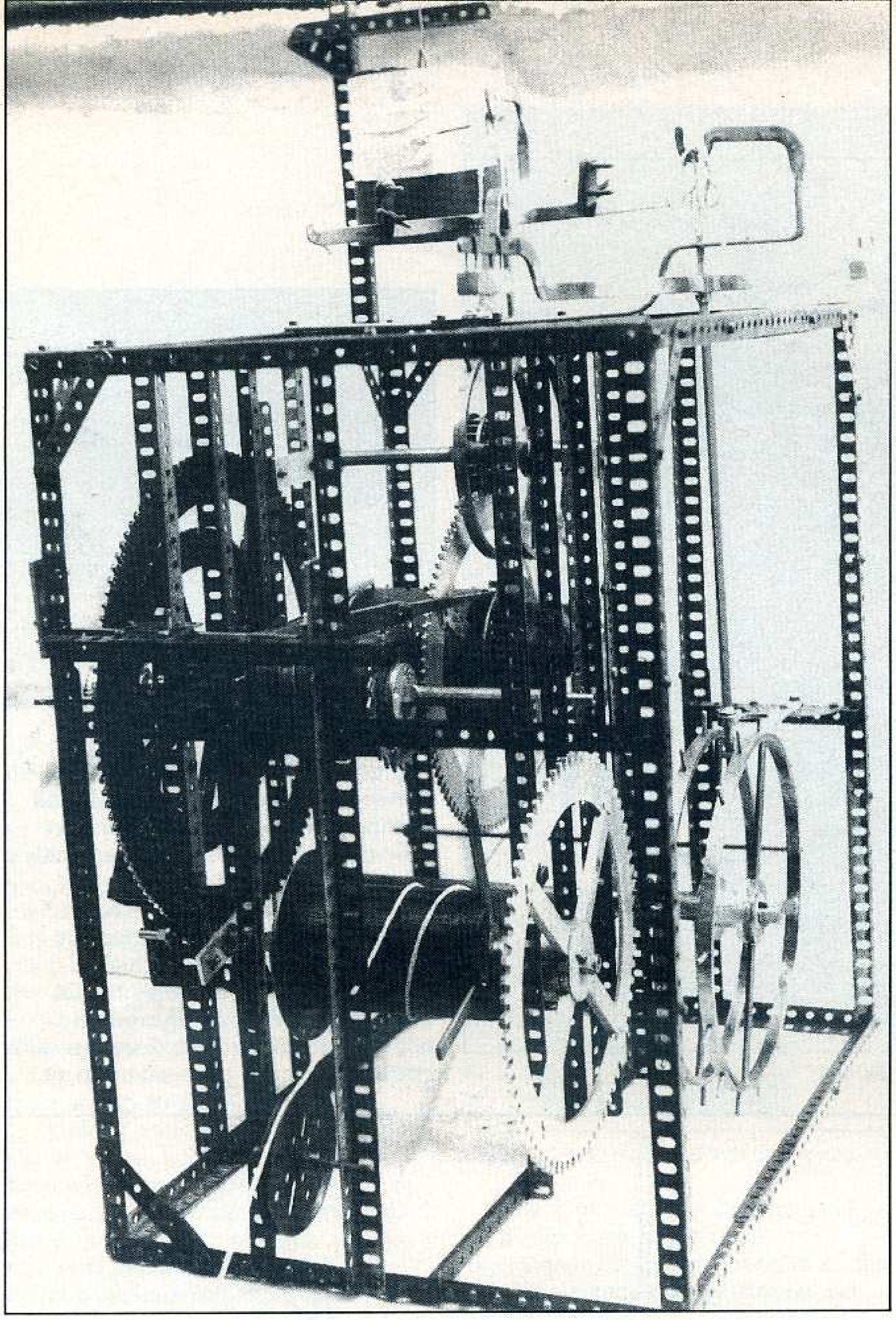

Figure 1: The clock in the temporary Meccano framework.

A brother for De Dondi Part 2

by D J Unwin

To avoid the heavy work making the large gears from steel I used a hard grade of light alloy painted semi matt black when completed.

These wheels were built up of an annular ring, four spokes each with a forked end riveted to it and welded to a hub. I used the same construction except I let the spokes into the hubs and bonded the assembly with epoxy resin. The rings were parted out of a sheet of light alloy held on a chipboard faceplate mounted on my milling machine, being much too large for my lathe.

Making the spokes was a 'mass production' job, 28 being required varying only in length. It was an interesting job which, given a little thought before starting, proved very successful. The outer spoke forks were fixed to the annular ring by rivets, the ends of which were not neatly finished with a snap but left from the hammer as was the medieval practice.

For cutting the teeth and finishing the boards, which in most cases were square, the wheels were mounted on a faceplate secured by clamps across the spokes. Those over 250mm diameter had to be machined on the milling machine, then mounted on the dividing head for tooth cutting. As the medieval tooth was not of involute form I had to make special cutters using the methods I described in *Model Engineer*, 21st August 1970, 1st October 1971, 14th October 1971 and more recently in *The Model Engineers Workshop* in August/September and October/November 1991.

The square holes were cut on the milling machine using my hand slotting attachment which I adapted from an old machine slide.

Small gears were not built up but machined from solid discs with dummy rivets to represent the medieval built-up construction.

Most of the gears mesh with lantern pinions which I made of two discs with trundles of the correct diameter pivot wire secured in position by Loctite. The small square centre holes of these and other wheels were made with a punch using the jig shown in **figure 3.**

All arbors would have been forged iron and to simulate this I turned them from larger rod and machined eight or 12 flats on the surface between the shoulders at each end, examples of which can be seen on a number of figures. On large arbors the medieval clocksmith made his shoulders as split rings forged round the shaft and these I represented by turned and split collars pressed on which can be seen on the left hand end of figure 4 in Part 1. As there were no suitable lathes at that time their journals would have been forged roughly circular between sets then finished off by filing but I'm afraid I turned all mine on the lathe.

Because details of the framework in the manuscript were almost non existent I decided to make all the mechanisms for the astronomical unit and clock first and fit them into temporary frameworks constructed of Meccano, **figure 1**. Both were built as separate units so enabling any changes during construction to be a ▷

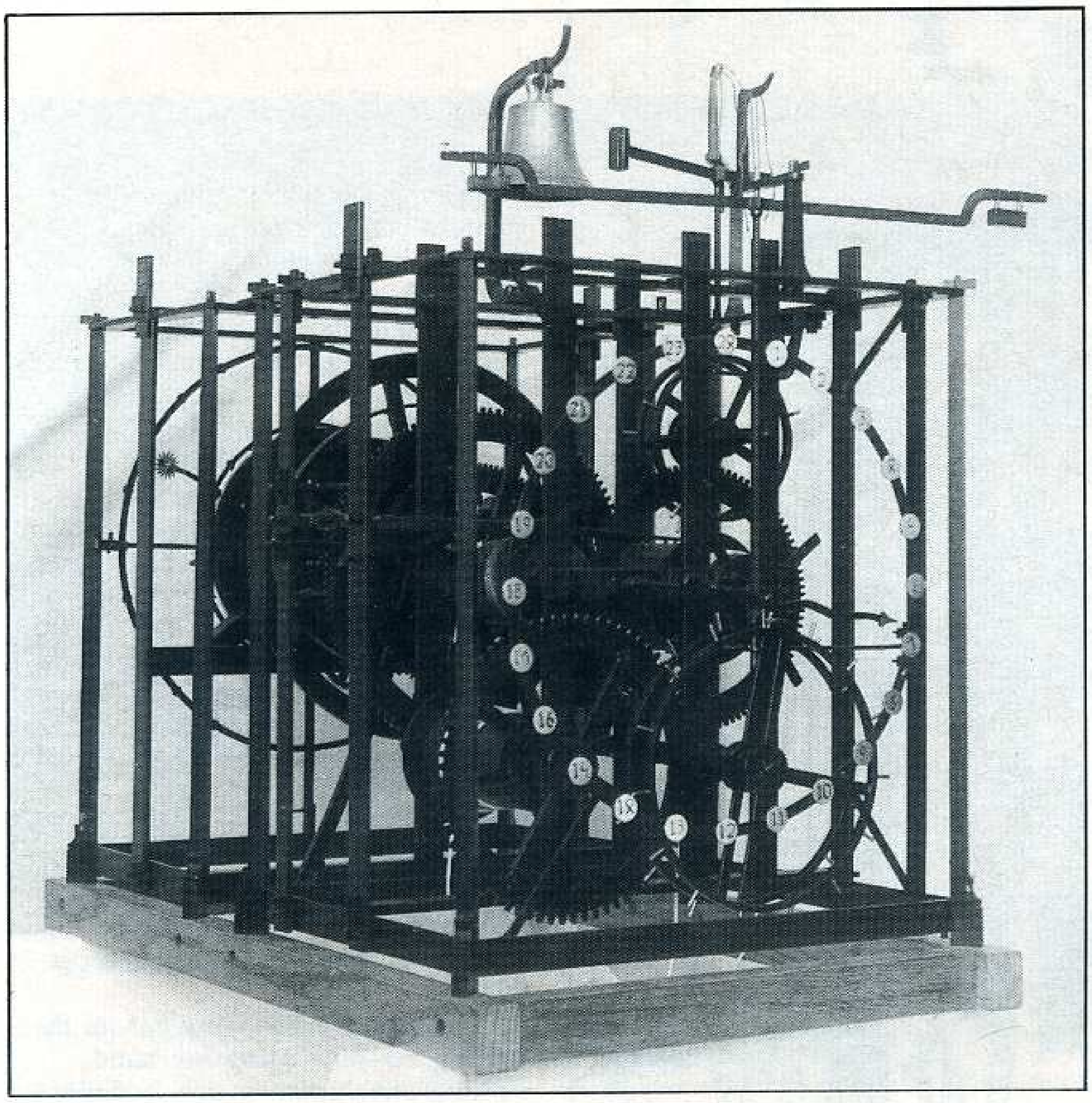

Figure 2: The clock escapement and mean solar time dial end.

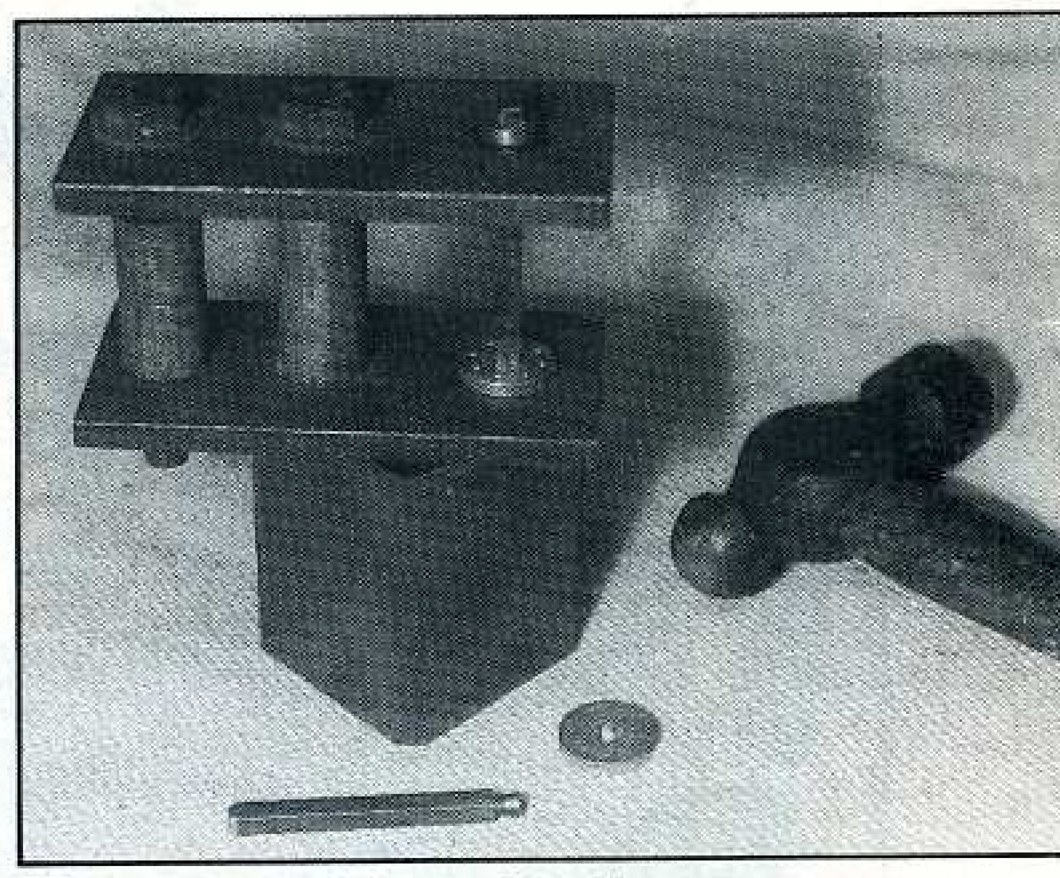

Figure 3: Square hole punching jig.

painless matter, the final fixing of framework details an easy task and putting off the difficult decision of how to connect them together until later!

At the end of the day arbor opposite from the strike selection barrel I fitted a pointer which indicates mean solar time on a 24 hour chapter ring as **figure 2.** It is not clear if Richard fitted such a dial but he concludes the section about

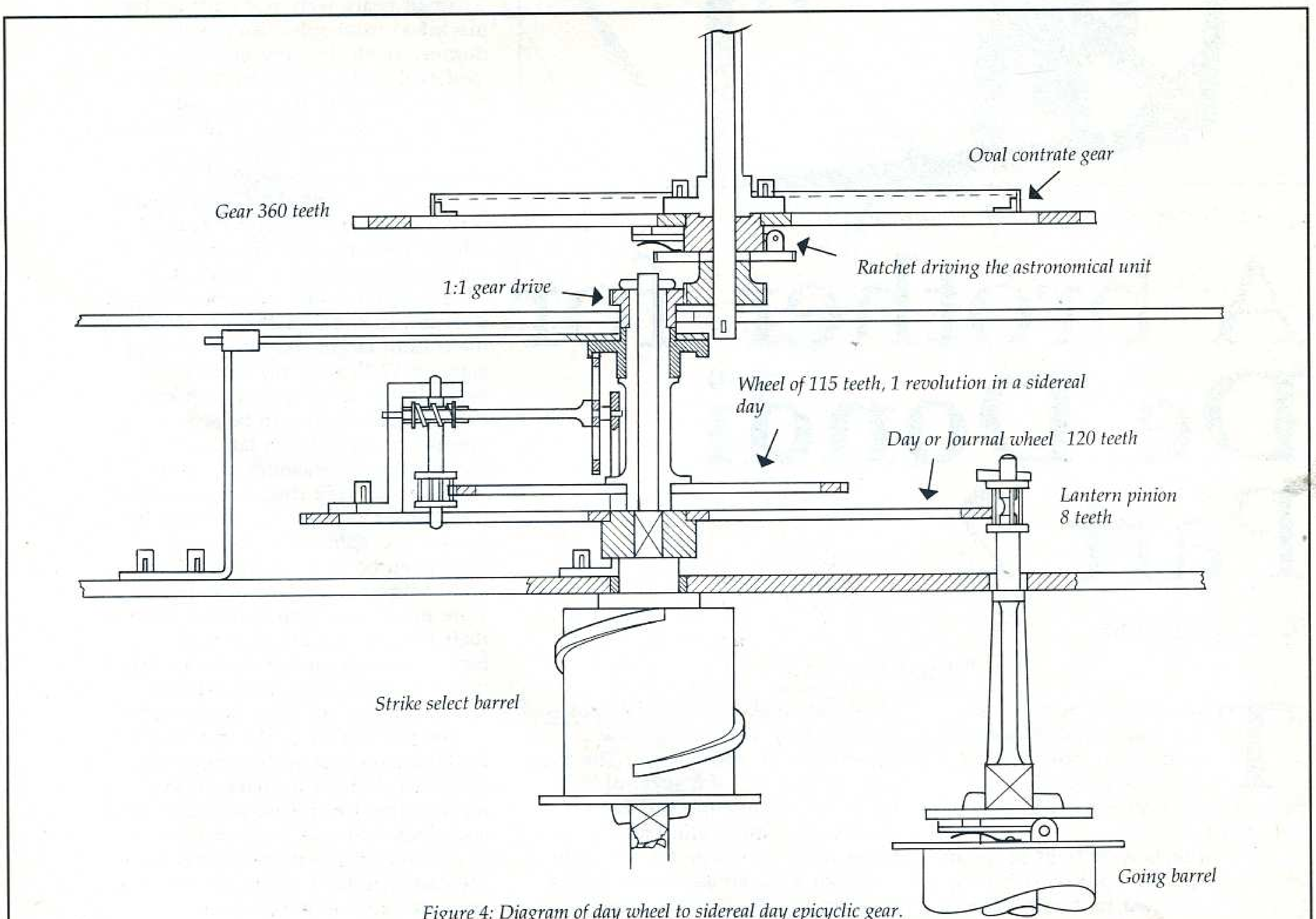

Figure 4: Diagram of day wheel to sidereal day epicyclic gear.

the clock with a sentence 'As for the dial and other parts you may decide for yourself.'

Following the day wheel of 120 teeth rotating once in a mean solar day of 24 hours Richard mentions a '...wheel of 115 teeth for the mean motus of the sun...' that is the mean sidereal day. Dr North deduced that this referred to a clever epicyclic gear train which was connected to the wheel of 120 and increased the rotation of the wheel of 115 to one revolution in a sidereal day of 23 hours 56 minutes and four seconds, an essential requirement for deriving astronomical movements shown diagrammatically in **figure 4**.

Of particular interest is the worm or 'snail' as Richard calls it, seen in **figure 5** and one of several in the astronomical unit. The medieval method of making worms was to forge a rod into a helix of the require pitch round the arbor and fire weld the ends. I reproduced the method by winding a helix of 1.5mm diameter steel wire round the arbor using the lathe with the screwcutting train set up to the required pitch.

A block with a hole in it to guide the wire was held on the tool post then with one end of the wire hooked on the chuck jaws and the arbor in the chuck the lathe was pulled round slowly to wind the helix. Each end was then hard soldered to the arbor at the ends.

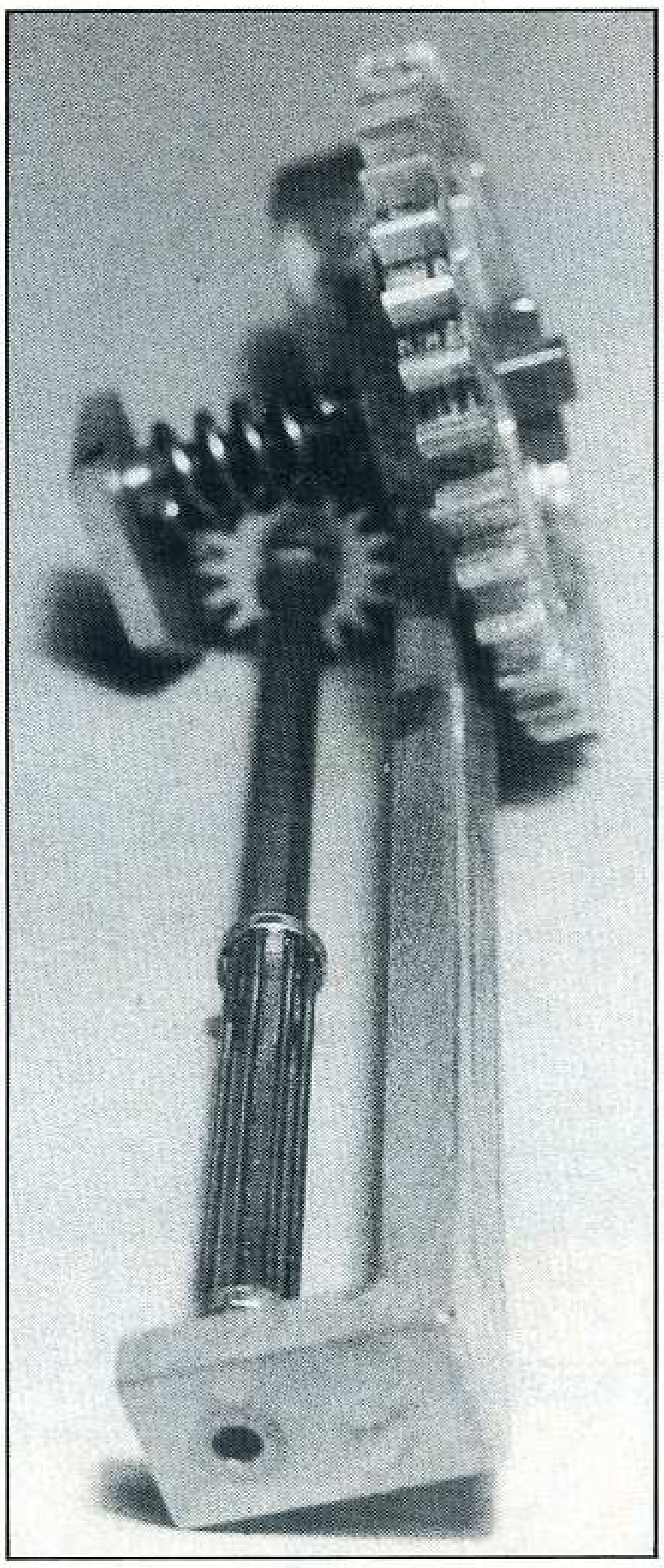

Figure 5: A worm or 'snail' and long pinion.

The next section – Richard says, '...if you want to make an instrument for the true motion of the Sun...' – refers to the astronomical section, a drawing of which is one of the few included in the manuscript. **Figure 6** is a 'tidied up' copy. In addition to indicating true solar or sundial time it has an astrolabe with zodiac ring, date ring, star plate with positions of principle stars, a pierced plate in the front and gives all the other usual information which can be obtained from an astrolabe, that is of course if you know how to read it! (**Figure 7**).

Another feature is indication of the phases of the Moon and the incidence of a lunar eclipse. The phase is shown by the small rotating black sphere representing the moon with half painted white, which can be seen in **figure 7** at about 2 o'clock on the 24-hour dial. The ancients believed that on the occasion of an eclipse the moon was swallowed by the dragon's head near the bottom in the figure, and to represent this Richard causes the moon to move round the outside of the zodiac ring beneath which moves a plate carrying the dragon's head and on the opposite end of the diameter the dragon's tail.

As the moon passes the head or tail it is caused to move outwards and skirt round it. However on the occasion of a lunar eclipse the earth's shadow, at eight o'clock, which is on the opposite end of the sun's regular coincides with the dragon's head or tail and so the moon is obscured when it moves out. ▷

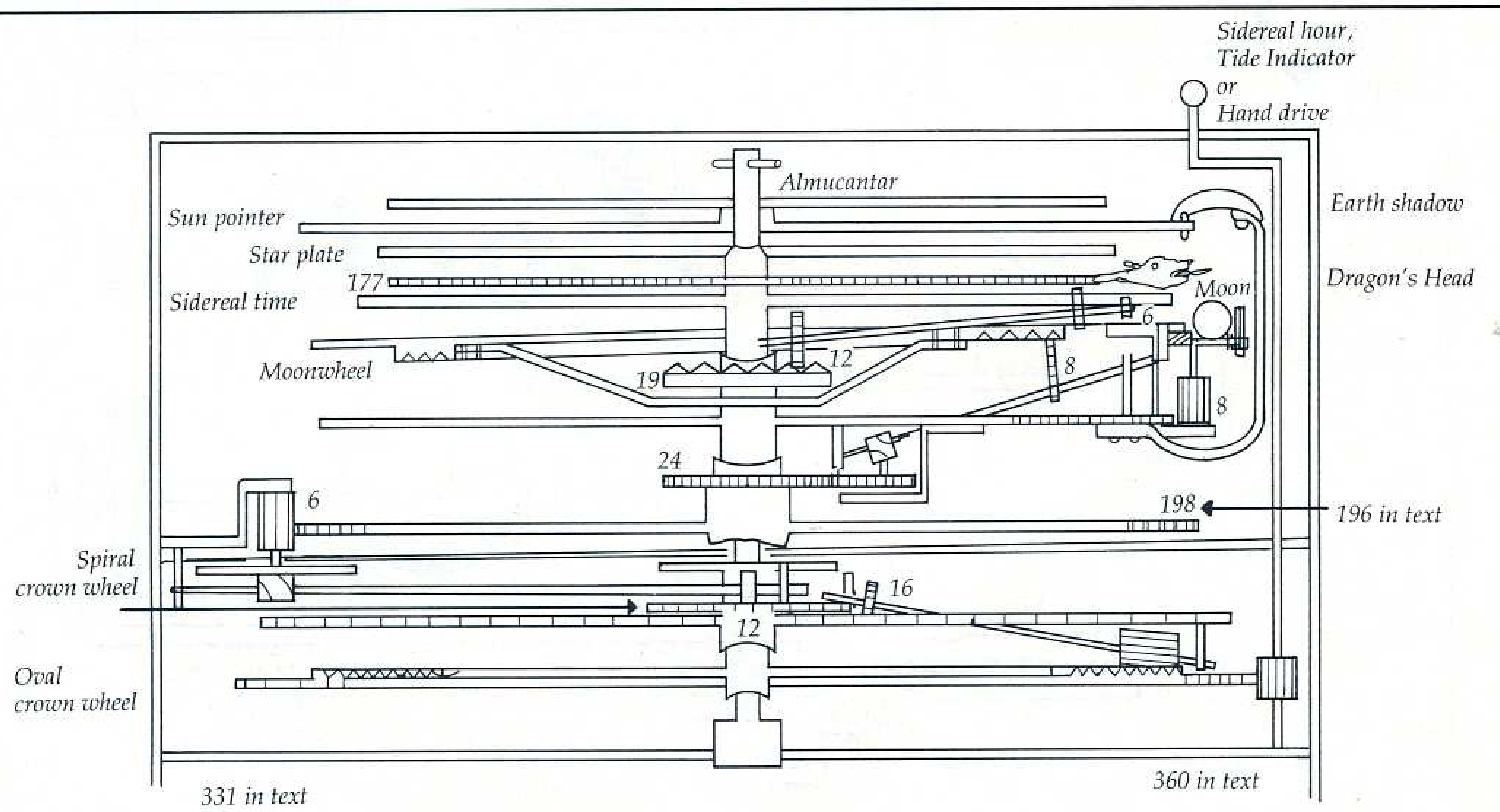

Figure 6: Tidied up copy of Richard's diagram of his astronomical train.

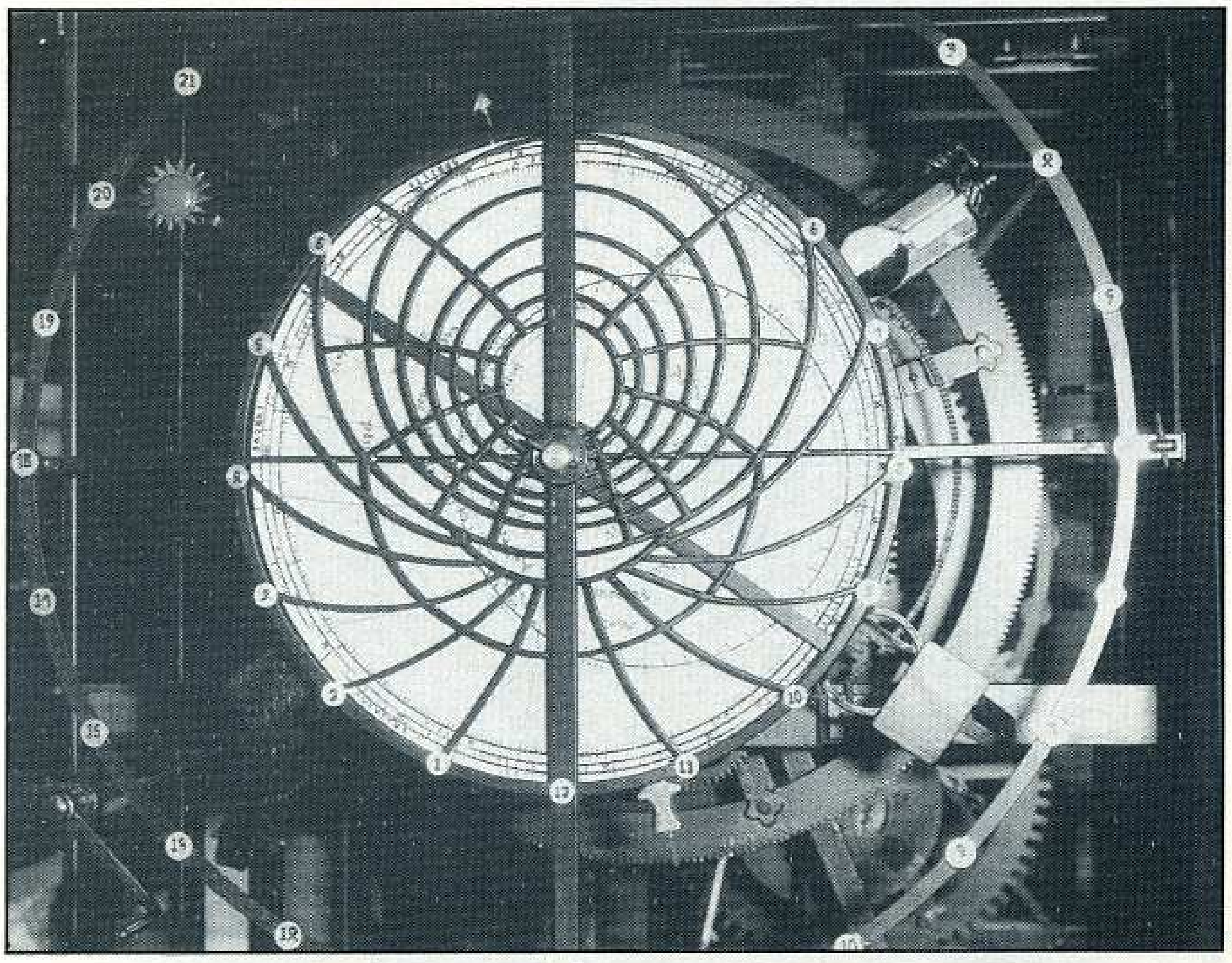

Figure 7: Front of astronomical unit and star plate.

To achieve this is the quite ingenious mechanism shown in the sketch **figure 8**. The moon is mounted on a slide which has a rack driven by a pinion. This pinion is on the lower end of a short arbor, the upper end carrying the 10-tooth pinion which engages with two five-tooth racks on the underside of the disc which carries the dragon's head and tail. One rack is positioned to engage with the inside of the pinion so causing the moon to move outwards then the next rack is positioned on the outside to engage and return the moon back to its original position. **Figure 9** is an eclipse just about to occur.

This figure shows the square shaft on which the moon slides and just above the moon is the arbor which rotates it to show the phases. All this was quite tricky to get to work properly particularly making the two racks which are a series of pins

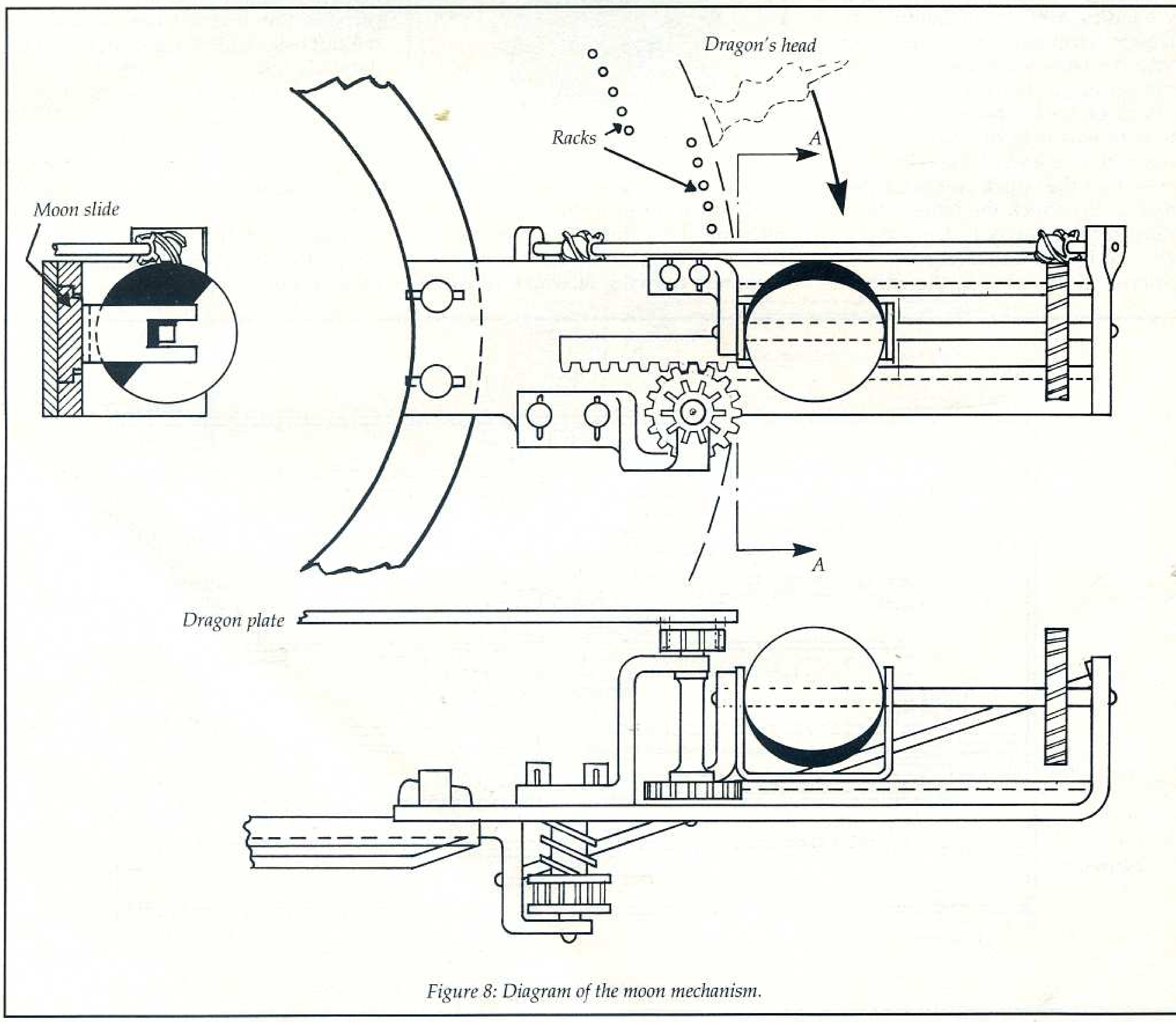

Figure 8: Diagram of the moon mechanism.

radially positioned on a plate and centred at the circular pitch of the pinion. I used my miller as a jig borer using the indexes to position a centre drill held in the vertical head first having calculated the co-ordinates to give the correct pitch and radius.

As the treatise gives no indication of the orientation or method of connecting the astronomical unit to the clock I completed the astronomical mechanism and balanced it so that it would function perfectly with the dial either vertically or horizontal before starting to make the clock so still leaving my options open!

When both were completed and working in their Meccano frameworks I made my final decision which was to mount the dial vertical as Dr North believed, mounting it in line with the clock and coupling it by a pair of 1:1 gears. This decision was largely influenced by the more convenient viewing position for visitors to the Museum. **Figure 10** shows both mechanisms in their Meccano frameworks coupled together.

So that the astronomical section could be demonstrated, a ratchet was introduced in the drive allowing it to be rotated manually as I am sure Richard intended. It can be seen in **figure 7** just outside the chapter ring ▷

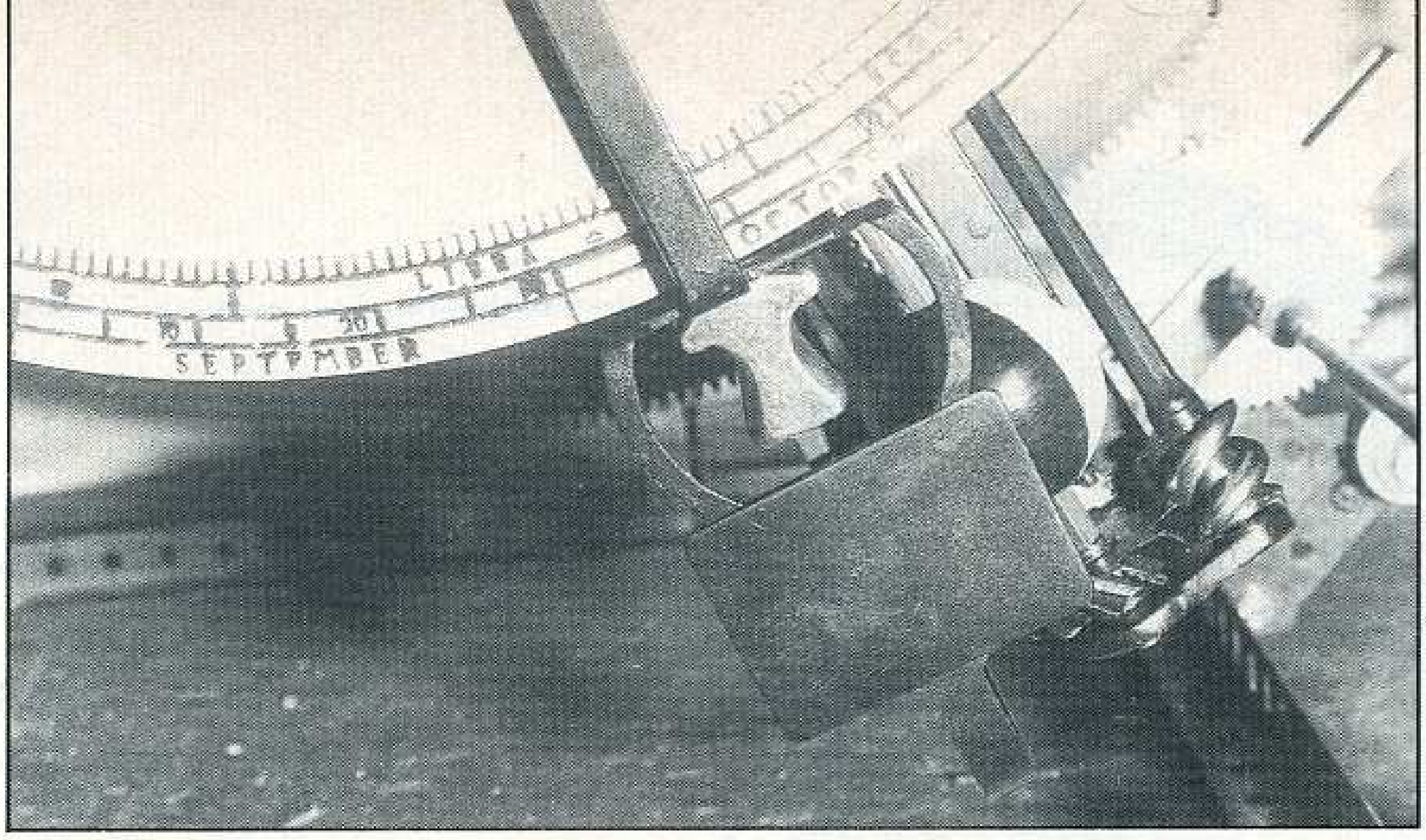

Figure 9: A near lunar eclipse.

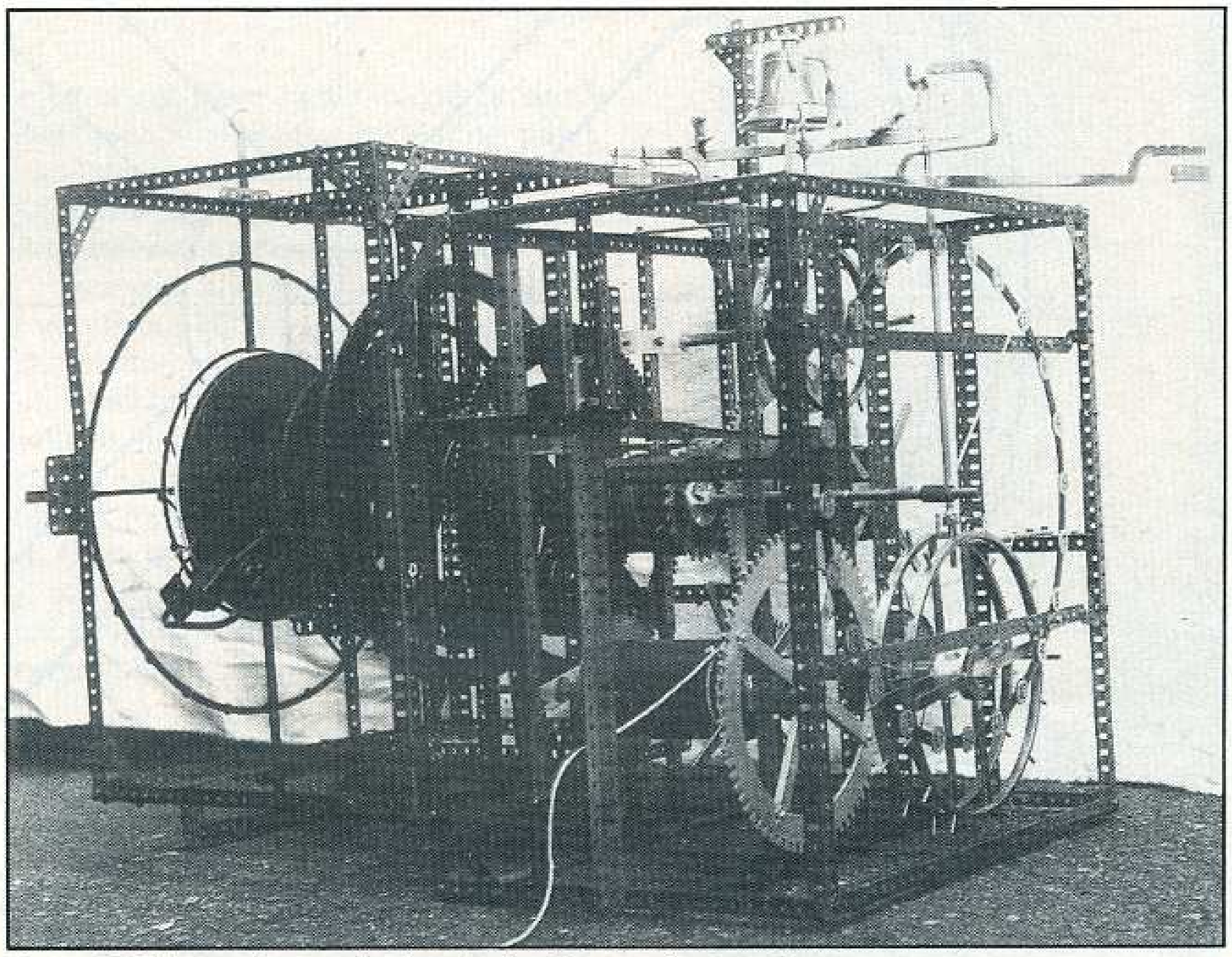

Figure 10: The complete mechanisms in the Meccano frameworks.

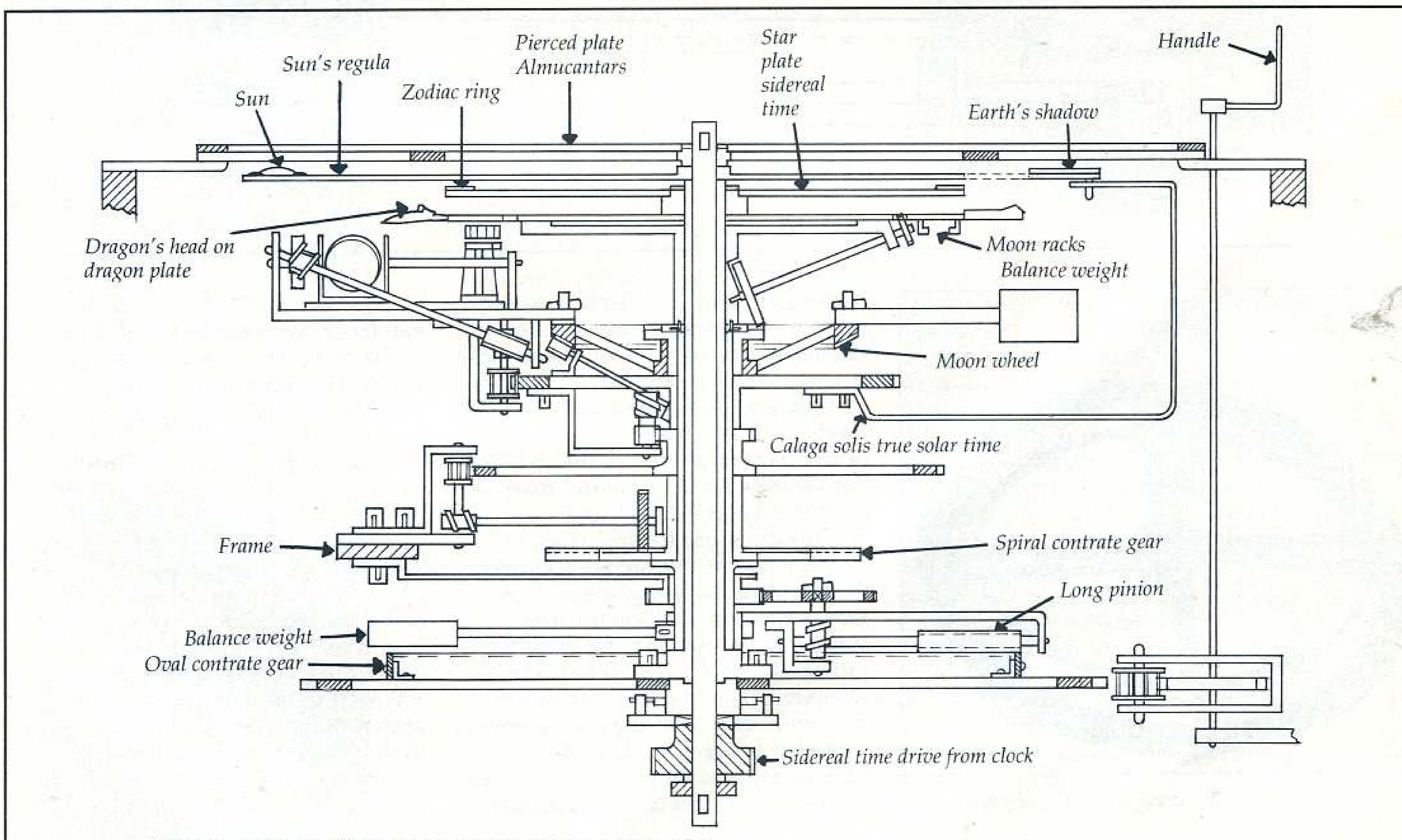

Figure 11: Diagram of the astronomical mechanism of the replica.

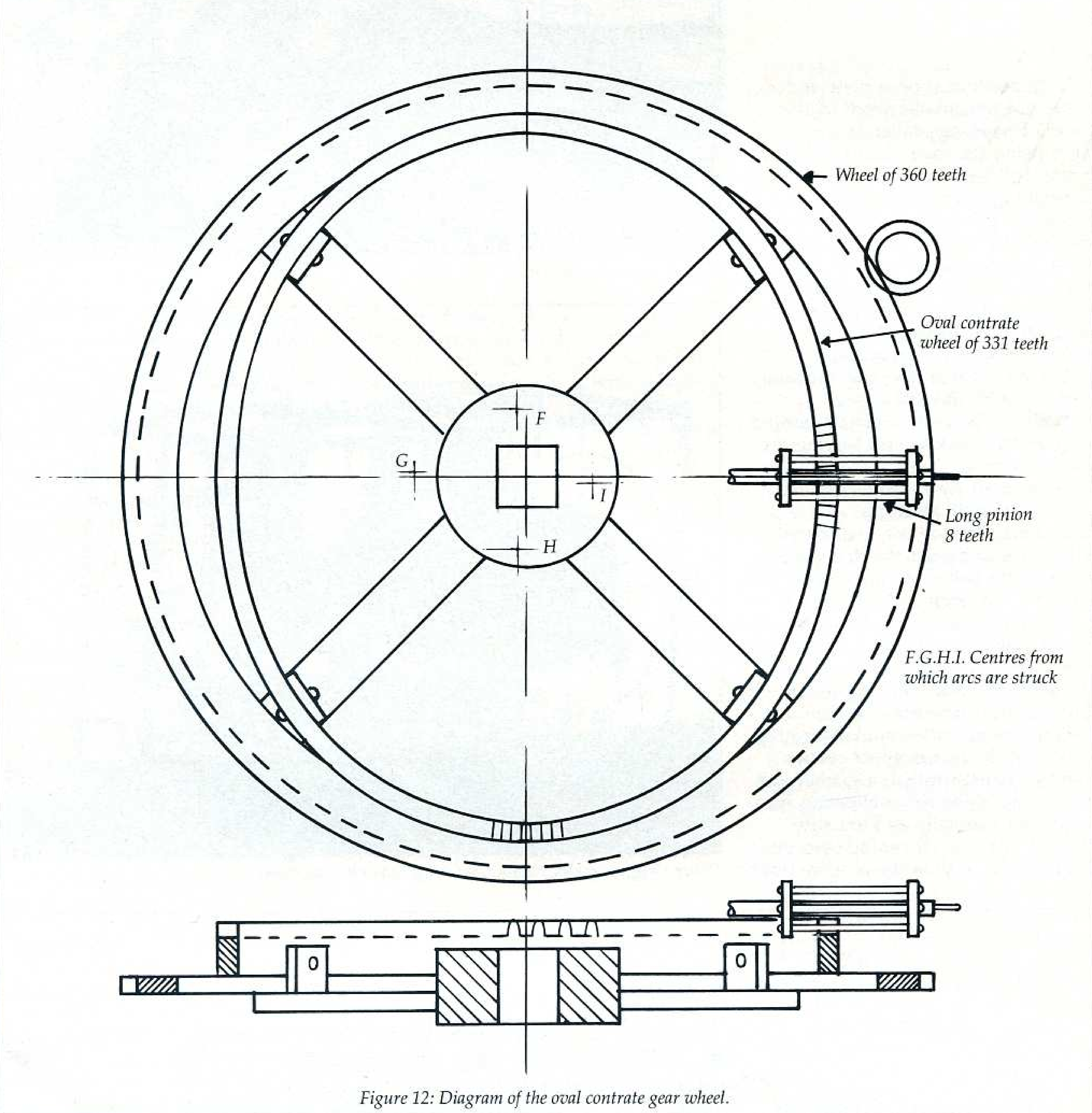

Figure 12: Diagram of the oval contrate gear wheel.

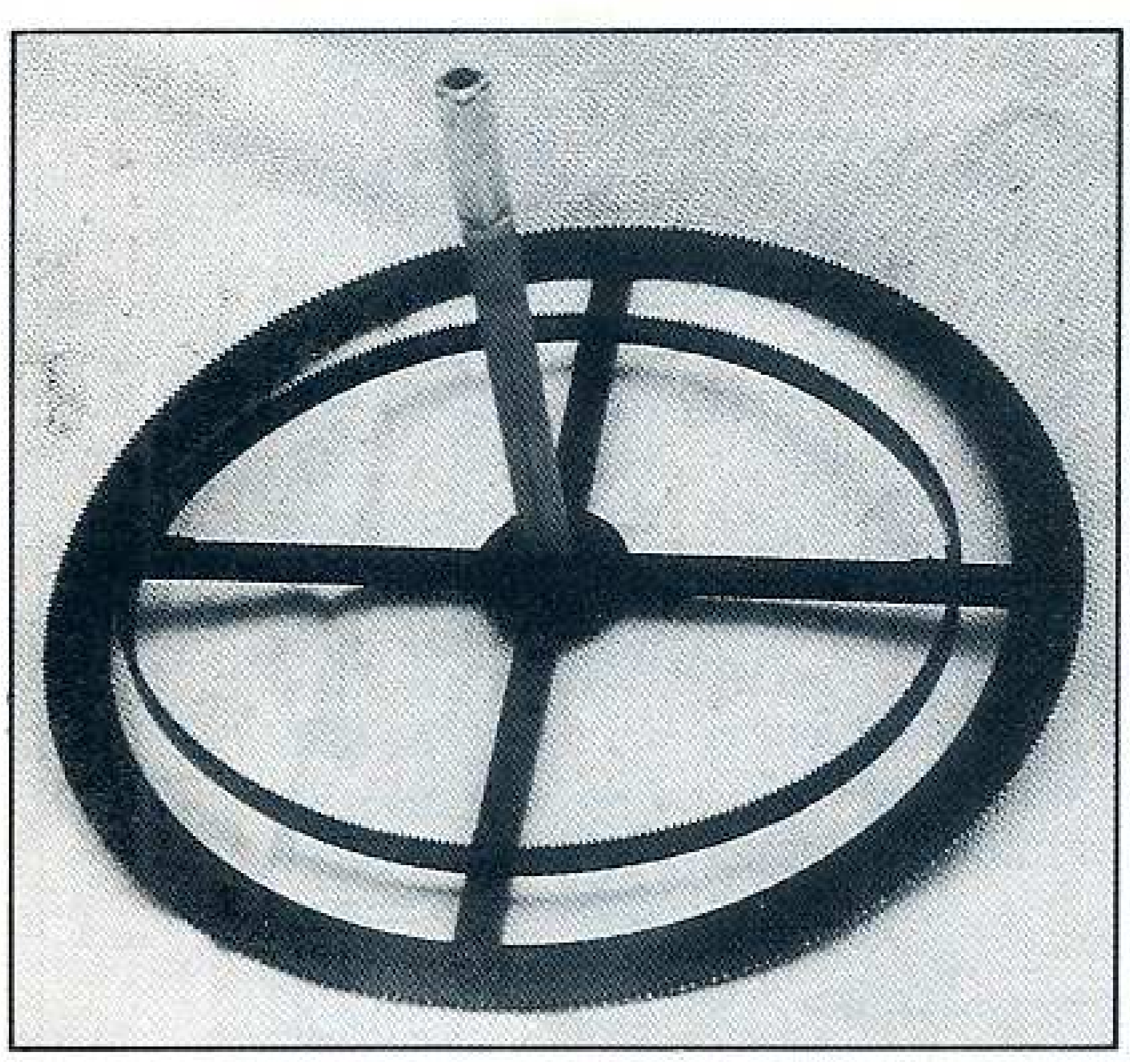

Figure 13: The completed oval gear wheel.

between 15 and 16 o'clock. However, to avoid unnecessary wear, the handle is normally removed and only inserted when needed.

Figure 11 is a diagram of the mechanism as I built it. The first part of the train of interest is that which derives true solar or natural time from the mean sidereal time train described earlier. It consists of an oval 331 tooth contrate with varying radii, **figure 12**. It engages with a long pinion on a concentric arm, **figure 5**, thus varying the velocity ratio between the two depending on whether it was at the minimum or maximum radius of the oval wheel.

Richard gives details of the various radii of the curves that make up the wheel which is mounted on a large wheel of 330 driven by the handle or the mean sidereal train.

To make the wheel, shown in **figure 13**, I set out the outline on a piece of card full size using the various radii Richard gave in his treatise, calculated the circumference using a map distance measurer and by dividing this by the 331 teeth determined the circular pitch needed. This was of course an odd module so I had to make a special module cutter for the purpose. The rim of the oval wheel was made in the flat, cutting the teeth as a rack then rolling it to the correct form, hard soldering the join, finally tweaking it to the correct dimensions and mounting it to the large gear by angle brackets, **figure 13**. □