EARDLEY NORTON'S 1771 PATENT FOR STRIKING CLOCKS & REPEATING WATCHES

by John A. Robey

EARDLEY Norton was a noted London maker of complicated clocks, including astronomical clocks and especially musical clocks playing on bells. A particularly fine example, supplied in 1765, survives in Buckingham Palace. Until recently his origins have been obscure, but it is now known that he was born in Lincolnshire in 1728, and apprenticed as a clockmaker on 25 May 1743 to Robert Dawson of Alford.[1] He was working in St John Street, Clerkenwell, in 1760 and was a member of the Clockmakers' Company from 1770 until he died in 1792. His name was sometimes faked on Swiss watches, and he also used the name 'Yeldrae' (Eardley backwards) on some cheaper watches. He patented a new type of striking mechanism for clocks and watches, but despite this patent often having been referred to, its details have never been published in the horological literature.

Patent number 987, for an invention of:

> 'A Clock which Strikes the Hours and Parts upon a Principle entirely New; and a Watch which Repeats the Hours and Parts, so concisely Contrived and Disposed as to admit of being conveniently Contained not only in a Watch but also in its Appendage, such as a Key, Seal or Trinket',

was applied for on 31 August 1771. The specification (if it warrants that title) is singularly unhelpful, as there is no description, only several diagrams, with some of the parts labelled. The original drawings, stated to be partly coloured, do not survive, only a redrawing made in 1856 when specifications were first printed. The original drawings were probably larger than the redrawn versions.

The lack of a proper description was probably a money-saving dodge to avoid scrivenor's fees for engrossing and copying, and also possibly enrolment fees, which were charged by the folio for a formally written document. At this period there was no official examination of a patent specification, and it was entirely up to the patentee as to what he described, and he took the consequences if the matter was ever disputed.

STRIKING CLOCKS

There are diagrams of three different clock mechanisms, two striking the hours alone, and a further one that also strikes the quarters. The unique feature of all three clocks is that there is no striking train, the power to drive the strike coming from the going train. They could be regarded as complex versions of a passing strike.

As Norton's third clock is easiest to explain, it will be discussed first, and his figure numbers will be retained, even though they are discussed here out of order. The principle of Norton's FIG 3 (here shown as Fig. 1) is a modification of that used by Joseph Knibb in the seventeenth century to repeat the hours on spring timepieces. A large toothed sector,[2] is lifted continuously against the power of a leaf spring by a snail-shaped cam on the reverse minute wheel. As it is lifted a series of pins on the sector pass a pivoted hammer tail, spring loaded so that the hammer is only tripped when the sector falls, not while it is being lifted. At the hour the cam follower

1. D. Moore, *British Clockmakers & Watchmakers Apprentice Records* (2003). The records of Robert Dawson are also confusing. *Britten's Old Clocks & Watches and Their Makers*, 9th edition (1982), lists him as free of the Clockmakers' Company in 1678, but Brian Loomes, *Watchmakers and Clockmakers of the World, Complete 21st Century Edition* (2006), states that this is an error for 1778, and he was not in the Clockmakers' Company.

2. The key to the diagram calls it a rack, the traditional term used in repeating work. The author feels that this word should be reserved for components with saw-shaped teeth gathered by a single-leaved pallet, as used in rack-and-snail striking.

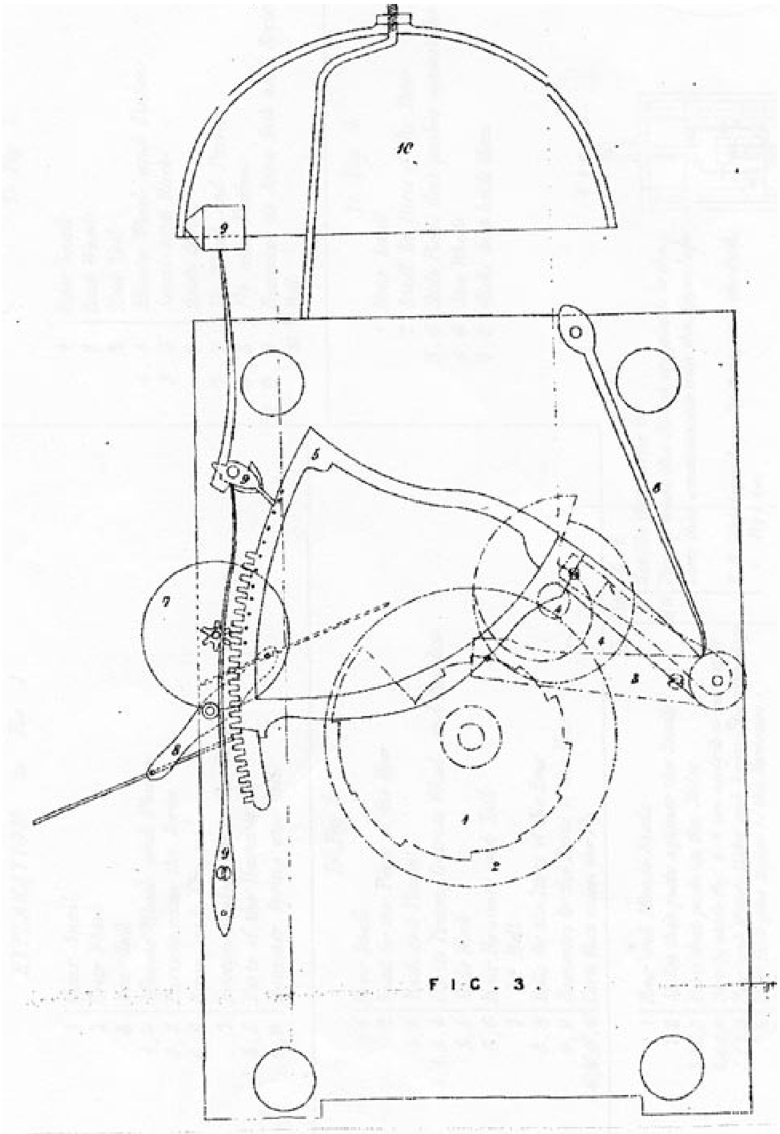

Fig. 1. Norton's patent FIG 3:

1	Hour Snail
2	Hour Wheel
3	Hour Tail
4, 4	Minute Wheel and Pinion
5, 5	Snail and Rack
6	Rack Spring
7, 7	Fly Wheel and Pinion
8, 8	Fly and Pinion
9, 9, 9	Hammer its Joint Tails and Spring
10	Bell.

on the arm of the sector falls off the step of the snail until item 3 the 'Hour Tail' contacts a step on a conventional snail fixed to the hour wheel. The number of hammer strikes depends onto which step the hour tail falls. The teeth of the sector rotate a pinion, wheel and fly, solely to govern the speed of striking.

The contact pin on the hour tail will ride on the snail until it is lifted by the cam follower on the other tail of the sector. Hence the going train has to overcome the friction caused by the spring pressing the tails in turn on to either the snail or the lifting cam. More seriously after 12 o'clock has struck the hour tail will be raised out of its deep step and part way through this lift it will contact the large step of the snail. This is a similar problem to that on rack-striking clocks if 12 o'clock does not strike fully, causing the clock to stop shortly before 1 o'clock. The solution is to have a spring-loaded hour tail and a slope on both the contact stud and the leading edge of the large step, so that the stud rides onto the snail rather than jamming up against the step. On Eardley Norton's clock this would occur after every 12 o'clock and a solid tail with a stud on a light spring passing through a slot (as used on early longcase clocks), would be preferable to a flexible tail (as used later). The effect could be minimised by making the hour tail drop onto each step as close to the beginning of each step as possible, and to cut away part of the large step, leaving just a narrow rim at the 1 o'clock step for the tail to ride over. Eardley Norton makes no provision for this in his diagrams, and one would have thought that a clockmaker of his experience would have appreciated the potential problem. In any event there needs to be pre-tension in the spring to get the fly into motion before the first blow occurs.

Knibb's silent-pull repeat mechanism is powered by a coiled spring, with a pinion rotating the sector, while the hammer pins are fixed to a wheel on the same arbor. On Eardley Norton's striking system the tripping of the hammers comes from the movement of the sector, rather than rotation of a pinwheel, otherwise the two methods are quite similar, although Norton's clock could not be made to repeat.

Norton's FIG 1 (here shown as Fig. 2) is also of a mechanism that only strikes the hours, but is of a more complex construction. The continuous lift by a snail-shaped cam on the reverse minute wheel, with a drop off at the hour and an hour tail that drops onto a conventional stepped snail, are similar to the previous method (with its inherent disadvantage). However, the toothed sector is replaced by a lever that lifts a vertical shaft with a twin-bladed horizontal fly at its upper end. The top support for the shaft also acts as the bell stand, and the shaft passes through the centre of the bell, but this is only for convenience of construction and is not vital to the operation of the system.

The centre section of the shaft has a buttress thread of relatively large diameter. This type of thread has an asymmetrical profile, steep on one side and shallow on the other, so that it can move easily past a click or pawl in one direction only, and is used on quick-action vices for instance. During lift the threads of the screw pass a roller, while during descent the steep side of the buttress threads engage with the roller so that the shaft and fly rotate. The roller would produce less friction than just a spring-loaded click during the rotational descent of the screw.

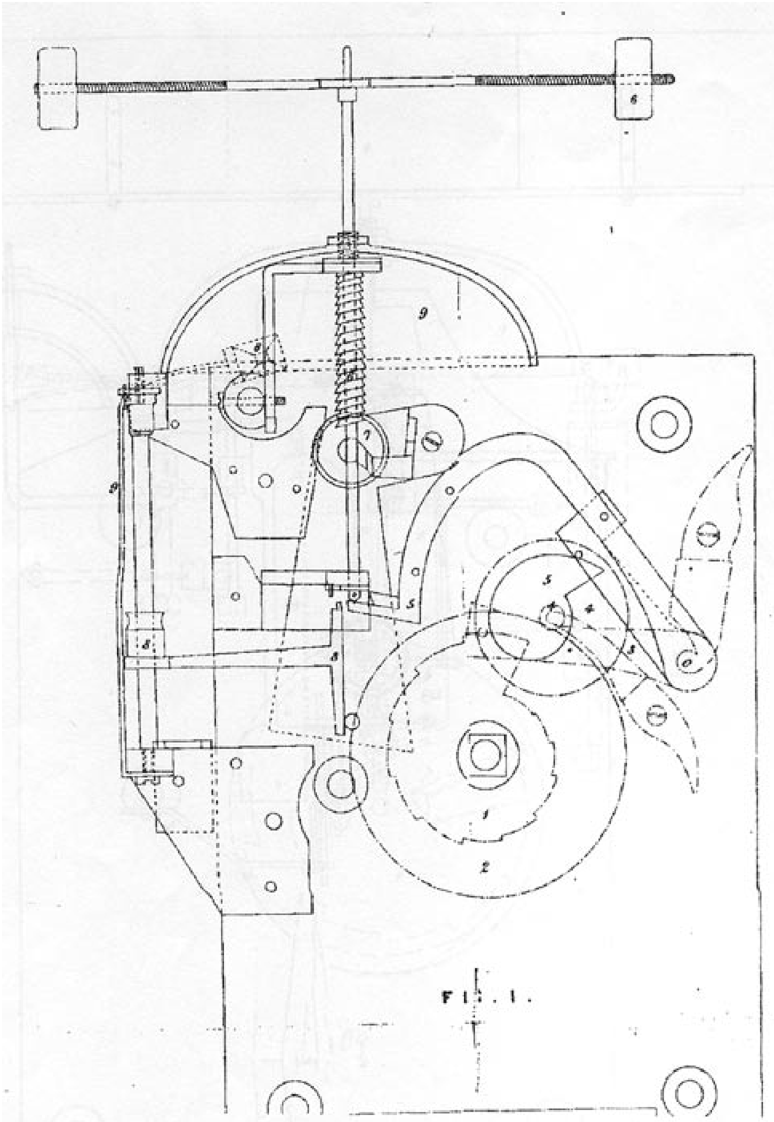

Fig. 2. Norton's patent FIG 1:

1	Hour Snail
2	Hour Wheel
3	Hour Tail
4, 4	Minute Wheel and Pinion
5, 5	Parts to raise the Screw
6, 6	Screw and Fly
7	Friction Rowler [sic] acts on the Screw
8, 8, 8	Parts of the Hammer
9, 9, 9	Hammer Spring and Bell

Each rotation of the shaft correspond to one hammer blow, and their number is determined by how far the hour snail allows the shaft to fall. There must be some spring-loading of the roller to allow the screw to slip past in one

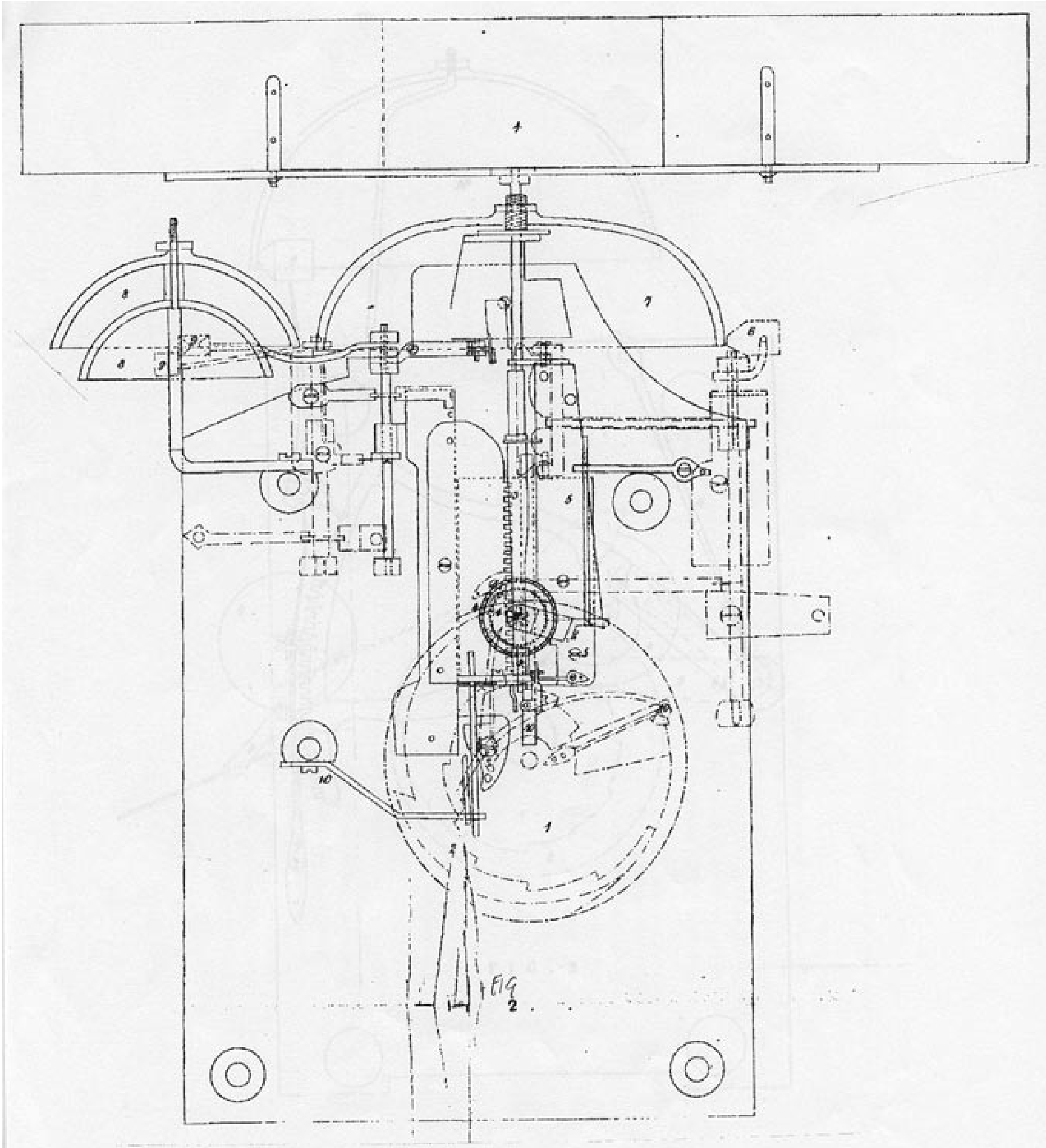

Fig. 3. Norton's patent FIG 2:

1	Hour Snail
2	Snail for Parts of the Hour
3, 3	Rack and Pinion
4, 4, 4, 4	Fly, its Pinion, Contrate Wheel, and Ratchet
5, 5	Slide Work
6, 6	Hour hammer and Tail
7	Do. Bell
8, 8	Bells for Part of the Hour
9, 9	Hammers for the Parts of the Hour
10, 10, 10, 10	Parts that raise the Fly

direction, but to engage in the other, but this is not apparent.

A horizontal arm and pin at the lower end of the shaft (shown in the stop position against the underside of the shaft's lower support bracket), trips the vertical T-section of the hammer tail at each rotation. This part of the hammer tail is shaped so that it can make contact with the arm and pin for the whole of the shaft's descent. The large triangular piece hanging below the friction roller appears to be an unnecessarily large bracket, rather than part of the mechanism. The hammer is powered by the weight of the descending shaft, screw and fly, there being no blade spring as in the first clock. Hence the shaft needs to get up to speed before making the first blow, and this is achieved by the fly having weights rather than thin flat blades, to give it stored inertial energy, and by ensuring that the shaft makes at least one full turn before the arm contacts the hammer tail.

Eardley Norton's FIG 2 (here shown as Fig. 3) shows a much more complex clock, striking the hours on a large bell and also the quarters on two small bells, using some of the principles of his Fig 1. Unfortunately its exact mode of operation is much less clear than the hour-only clocks, and like them, the explanation of the diagrams mainly names those parts which are obvious to a clockmaker, not the special components. This mechanism also uses a horizontal twin-bladed fly (air-resistance this time, not inertial) that is lifted and allowed to fall during the strike. Lifting is not by a cam on the reverse minute wheel (which is not listed in the key), as in the previous clocks, but a curved lever, possibly fixed to the hour snail, is involved. If it was fixed it would lower the shaft, not raise it, so it may have been pivoted at its outer end, and a spring is shown, maybe to return it after each quarter strike. How it is lifted at each quarter is not clear, possibly by four pins fixed to the plate.

The lower end of the fly shaft falls directly onto the snail to determine the number of strikes, without the use of an intermediate lever. There is a quarter snail, apparently also on the hour wheel. Only one step is shown and its curve is continuous (like the snail of a round French movement), so perhaps it has four sets of quarters round its periphery, but these are not shown. The hour snail is possibly free to move round the hour pipe, so that after the quarters have sounded the fly shaft can fall further onto the lower hour steps, in a manner similar to a 'surprise piece'. Two positions of the large step are shown, but how this would operate is not obvious.

Instead of a buttress thread on the fly shaft there is a straight rack with square teeth, a pinion, contrate wheel and click, all part of the assembly marked 5 'Slide Work', which can rotate. The click allows the pinion, and hence the contrate wheel to rotate only during fall, not lift. The rotation of the contrate wheel presumably causes the whole of the slide assembly, including the pinion and contrate wheel, to revolve about a vertical axis. This could occur if the teeth shown on the contrate wheel engaged with pinion leaves cut along the length of the vertical shaft. There are various small levers and a spring shown below the wheel, but their exact function is uncertain. The narrower and taller side of the rotating slide trips the tail of the hour hammer on the right, while the wider but shorter side trips the ting-tang quarters on the left. The release of one quarter hammer triggers the release of the other. As before the hammer arbors are vertical with the hammer heads swinging horizontally, while the fly assembly falls under gravity to power the strikes, as in Norton's FIG 1 (here shown as Fig. 2).

The main areas of uncertainty are: a how is the vertical shaft lifted and allowed to fall at each quarter, b exactly how does the contrate wheel drive the vertical shaft, c how are the quarters and hours selected, and c how is the quarter snail moved out of the way to allow a further fall onto the hour snail at the hour? Presumably the small bells only sound during the first three quarters, with the large bell alone at the hour.

No clocks are known with any of these three mechanisms, but the drawings give the impression that they were of actual clocks, not just theoretical ideas. For instance, Norton's FIG 2 (here shown as Fig. 3) shows a bracket screwed to one of the plates which does not appear to be a vital part of the mechanism. While the hour-striking clocks are feasible and would need far fewer components than a conventional two-train striking clock, the quarter striking clock is so complex that there is unlikely to have been much practical advantage in it, despite not having hour or quarter striking trains. The load on the going train to also power striking for both the hours and quarters must have been considerable, as well as the effort to surmount the large step on the snail. The author would be interested to hear of any clock with a striking system even remotely related to these designs, or indeed any other method of striking without a separate train. Clocks 1 and 3 would make an interesting project for producing a replica to test the principles.

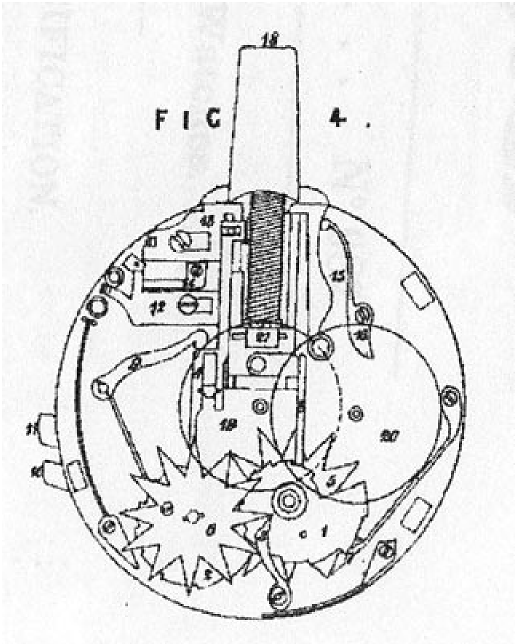

Fig. 4. Norton's patent FIG 4:

1	Hour Snail
2	Snail for Parts of the Hour
3, 4	Slide Pieces that pushes against the Snails
5, 6	Star Wheels
7, 8	Clicks that holds them
9	Spring to hold down the Slide Piece
10, 11	Hammers
12, 13	Tails of the Hammers
14	A Piece that holds the Parts of the Hour back while the hours are struck
15	Click to hold the Screw
16	Spring of the Click
17, 17	Parts that give Motion to the Hammers
18	handle that turns it
19, 20	Motion Wheels
21	Slide the End of the Screw is fix'd in

REPEATING WATCHES

Eardley Norton's patent specification also includes drawings of three repeating watch mechanisms. The drawings are small, with two of the watches having part of the mechanism shown separately. Also one diagram is split between two pages and part is lost in the spine. All three watches are operated manually by depressing the pendant and then turning a knurled knob on either the pendant or at the lower end of the watch to sound the bells. Presumably there is provision to limit rotation to one direction only, but this is not shown on any of the diagrams. There are hour and minute snails, the latter shown with twelve steps, so as drawn they are five-minute repeaters. Starwheels are used to move the snails on the first watch and are likely to have been employed on the other two as well, but these are not shown.

In Fig. 4 a screw follower, shown at the top left, is fixed to the top of the minute 'Slide Piece that pushes against the Snail', as well as item 15 'Click to hold the Screw'. As the pendant is depressed the screw, and hence the minute slide, descends until the tail or 'touch piece' contacts the minute snail. The screw probably has a buttress thread with the follower spring-loaded so that the touch piece remains in contact with the snail, assisted by 9 'Spring to hold down the Slide Piece' as the screw is pushed to its limit. By rotating a knurled knob on the pendant, the screw picks up the slide by means of the one-way follower, and is retracted by the distance required to give the correct number of minute strikes until the top of the slide meets a stop. Clearly if the touch piece contacts a high step on the snail it will be retracted by a short distance until it meets the stop, but a low step gives a larger retraction and hence more strikes. After the repeat the touch piece remains in the up position, and only contacts the snail during operation of the repeat, so there is no danger of it jamming on the high step.

The total distance the screw is pushed needs to correspond to the number of minutes strikes plus the number of hours. The hour slide on the right has a longer tail or touch piece, and must be linked to the bottom of the minute slide, on the left, possibly by a similar one-way click arrangement, but the drawing is too small to show any detail. How the return of the pendant is determined by both minute and hour snails is not apparent. It may be that the hours and minutes have to be repeated by separate operations of the pendant, as is the case with the watch in Fig. 5.

At the lower end of the screw are two pins. The description of this, item 21 'Slide the End of the Screw is fix'd in', does not appear to refer to this, rather to item 17 'Parts that gives Motion to the Hammers', as there is no 17 in the drawing. The hammer tails, items 12 and 13, slide horizontally, the movement of each confined by a screw in a slot, and have their

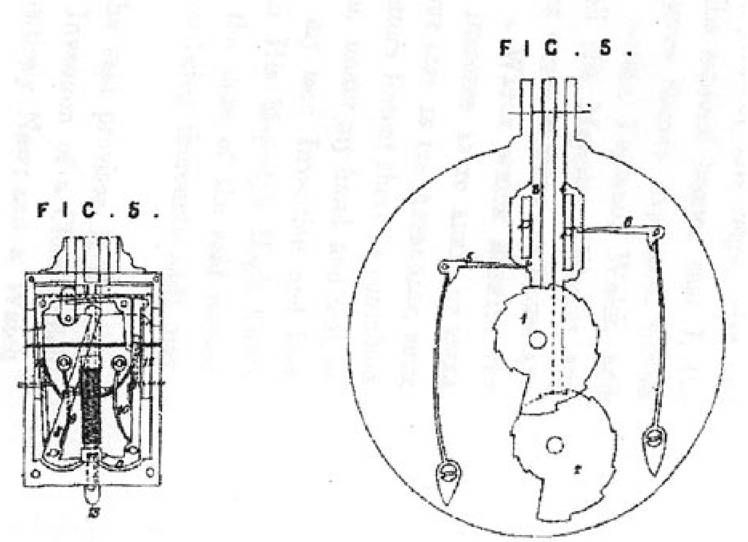

Fig. 5. Norton's patent FIGS 5, 5:

1	Hour Snail
2	Snail for Parts of the Hour
3, 4	Slides that pushes against the Snails
5, 6	Springs that pushes up the Slides
7, 8	Hammers
9, 10	Hammer Springs
11	The Part that gives Motion to the Hammers
12, 12	Slides
13	Handle that turns it

right-hand edges chamfered at approximately 45 degrees. As the pendant is turned to screw it out the long pin will push against the chamfered edge of the lower tail, moving it to the left to sound the hours. Repeating watches normally strike the hours first followed by the minutes, but on this watch the lower hammer tail appears to be for the minutes. Once the pin reaches the top of the hammer tail it will cease to sound the hours, but then must activate item 14 'A Piece that holds the Parts of the Hour back whilst the hours are struck', situated between the two tails, although its exact mode of operation is not apparent. The pin will then operate the upper hammer tail. As shown, with two pins of different lengths, it might be thought that the longer one would operate a shorter hammer tail and the shorter pin push a longer tail, but since they are at the same horizontal level the longer one is always going to make contact first.

The watch in Fig. 5 has the hour snail vertically above the minute snail with separate touch pieces called 'Slides that pushes up against the Snails' that are held off the snails by two levers and springs. It is stated in the description of the next watch that this one requires two pushes to operate, presumably with a split pendant to depress the hour and minute slides independently. The rest of the mechanism is shown in a separate small diagram. As before there is a screw, although item 13 the 'Handle that turns it' is at the bottom, so maybe it was accessed at the lower end of the watch, particularly if there were separate parts of the pendant that had to be pushed. To operate the repeat the user would have to push and rotate to sound the hours, followed by a further sequence for the minutes. Unlike the watch in Fig. 4, the screw does not move vertically. There are also slides in the appendage that presumably connect with the touch pieces.

There are two hammers, a vertical one on the right and another at an angle on the left, each with a spring. Each is pivoted near the bottom and has a curved tail that is shown contacting 'The Part that gives Motion to the Hammers', at the bottom of the screw. In reality there is probably a pin at the end of the screw that pushes against chamfered edges on the hammer tails. Presumably there is a screw follower as in the previous watch, to pick up the position of the slides once the push piece has been depressed. Although something is shown contacting the screw, how it operates is uncertain. Also how the slides determine the number of turns of the screw and hence the number of hammer blows is not clear, although there are two pivoted cranked levers of uncertain function in the top corners. Since there is no provision for any of the mechanism in the appendage to slide when the screw is turned, the whole of the appendage might move vertically during operation.

The watch in Fig. 6 appears to be the simplest construction of three and certainly the easiest to understand, although some uncertainties still remain. Perhaps difficulties with the previous designs resulted in this final arrangement. The hour and minute snails are now on the left and right with levers and springs to push the slides

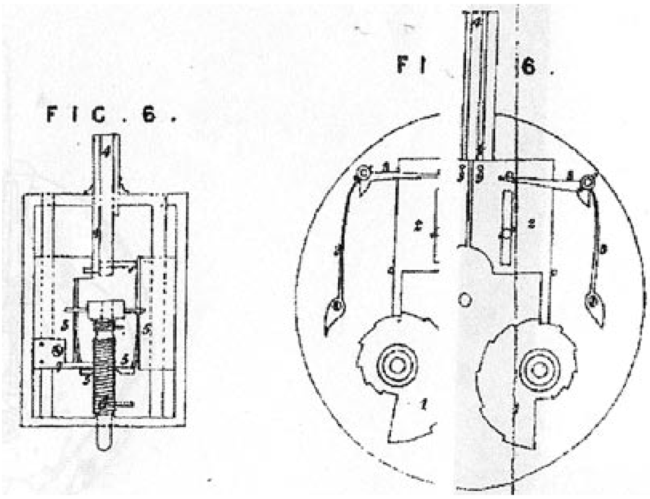

Fig. 6. Norton's patent FIGS 6, 6:

1	Hour and Minute Snails
2, 2	Slides that push against the Snails
3, 3, 3, 3	Parts that push up the Slides
4, 4, 4, 4	Parts by which Figs. 6, 6 are apply'd to each other
5, 5, 5, 5	Hour and Minute Slides and Springs in the appendage
6	Part that gives Motion to the Hammers
7	The Stop

N.B. This Appendage Fig 6 requires one Push, Fig 5 two.

off them. This mechanism requires only one push, presumably with a click arrangement to ensure that once one touch piece has contacted a snail the other can continue to the other snail. Like the previous watch the screw does not move vertically, and only rotates, presumably by the small unlabelled protruberence at the lower end of the watch which is likely to have been item 8 'Handle that turns it'.

The slides in the appendage move on guide bars (shown dotted) and are pushed down with clicks riding over the thread of the screw. As the screw is rotated the clicks engage, raising the slides off the snails. There is no separate thread follower, as this was no doubt found to be an unnecessary complication. There are two pins to trip the hammer tails, a long one at the lower end of the screw and a short one near the top. Although the hammer tails are not shown, they would be similar to Fig. 4, with the long pin tripping a short tail and the short pin tripping a long tail at a higher level.

These mechanisms show some of the features used by Joseph Anthony Berrollas of Denmark Street, London, in his patent 3174 for 'Making infallible repeating watches', dated 31 October 1808. This uses a pendant that is rotated to screw it out and repeat the hours, and then screwed back in to repeat the quarters, but the similarity ends there, for Berrollas uses racks and snails to sound the hours and minutes.[3] Repeating watches by Berrollas are known, but none with the Eardley Norton design of repeating work.

ACKNOWLEDGEMENTS

The author would like to acknowledge the assistance given by the late Philip Spuce, for obtaining a copy of the patent, and for explaining how the English patent system operated in the eighteenth century. This article has benefited greatly by discussions with James Arnfield, not only with respect to the clocks, but especially the watches.

3. *Rees's Clocks Watches and Chronometers 1819-20*, extracts from Abraham Rees, *Cyclopaedia* (reprinted 1970), pp.277, 287.