# John A. Robey

# ‘Leonardo da Vinci and the Earliest Known Clock with Warned Striking’

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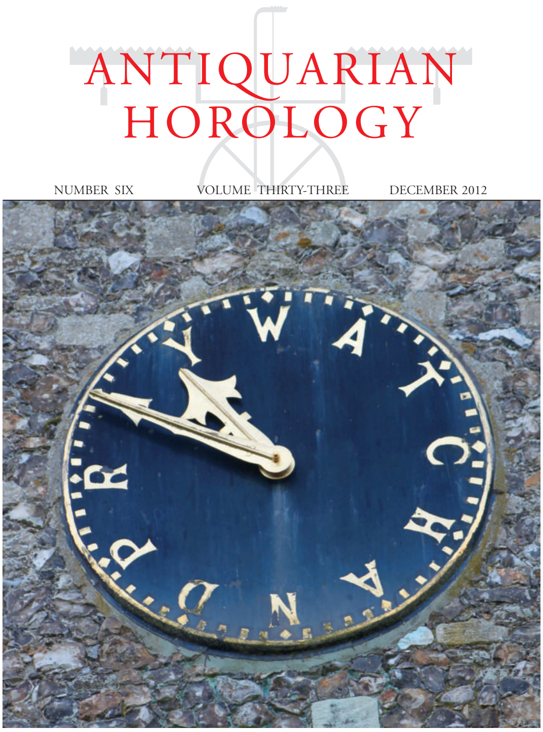


Volume 33 No. 6 (December 2012) has 144 pages. It contains the articles and notes listed below, as well the regular sections Horological News, Book Reviews, AHS News, Letters to the Editor and For Your Further Reading.

# LEONARDO DA VINCI AND THE EARLIEST KNOWN CLOCKS WITH WARNED STRIKING

John A. Robey*

*An important drawing by Leonardo da Vinci of the striking-work of a weight-driven domestic clock is discussed in detail, especially its depiction of warned striking. An iron Gothic clock with a similar arrangement is illustrated. Comparisons are made with other known early clocks with warned striking, as well as the uniquely English method of flail locking used on some turret clocks. Although in use at about the same time, flail locking had limited application and did not develop into the system that became almost universal.*

When and where warning was first used for the let-off of striking has been the subject of discussion and speculation by horologists for many years. It has been suggested that warning may have been invented in England about 1390, as the Salisbury Cathedral clock, supposedly of 1386, does not possess it, while the clock said to date from 1392 in Wells Cathedral has warning on the chime. However, this is improbable as not only is there dispute over the dating of these clocks — they are most likely to have been made in the early sixteenth century[1] — but the chiming train on the Wells clock is a later addition. In fact there is no evidence that warned striking existed much before the 1490s when it first appears in a drawing by Leonardo da Vinci.[2] However, a form of warning, known as 'flail locking' was used on some English turret clocks from about this time (see later). A domestic clock is known with an early example of warned striking with some remarkable similarities to the Leonardo drawing, but the connection has not previously been suggested. Since the Leonardo drawing has not been widely illustrated or described in the horological literature,[3] and only in very general terms in studies of his scientific and engineering work, it is discussed here in detail.

Most of Leonardo's sketches concerning horology only show details, such as escapements, gears, a fusee, spring drive, etc, and scholars have simply regarded this drawing as the only example of an almost complete clock. Its special significance has not been appreciated by non-horologists, as typified by the comment:

> An exception to the illustration of separate horological elements in Codex I Madrid is folio 27 verso, which shows a weight-driven clockwork complete with striking mechanism.

Also:

> The only exception [to just showing the various elements of a clock] is found on one page where the general setup of a weight-driven clockwork provided with striking mechanism is presented. But even here many important parts are missing.[4]

**Dr John A. Robey (john@mayfieldbooks.co.uk) is a publisher of horological books and a clock restorer. He is the author of* The Longcase Clock Reference Book *(Mayfield Books, 2001), which is currently being extensively revised. Current research topics range from early iron clocks and lantern clocks to the makers of painted longcase dials.*

1. C. N. Ponsford & J. M. G. Scott, 'A New Look at the Dating of Early English Clocks' *Antiquarian Horology* 12/1 (Spring 1980), 52-69; 'Wells and Salisbury', *Antiquarian Horology* 12/5 (Spring 1981), 528-9.
2. J. H. Leopold, 'Almanus Re-Examined', *Antiquarian Horology* 27/6 (Dec 2003), 665.
3. G. Brusa, *L' Arte Dell'Orologeria in Europa* (1978, Bramante), plate 45, shows the drawing but without a detailed discussion.
4. L. Reti, (editor), *The Unknown Leonardo* (1974), chapter on 'Horology' by S. Bedini and L. Reti, pp. 249, 250. This is a good overview of Leonardo's contribution to clockwork, but it is written by Leonardo scholars, not horologists, for a general readership. Some statements are not totally accurate or are misleading.

What has not been generally appreciated is that it shows a special striking mechanism, and in order to focus attention on this aspect Leonardo has deliberately omitted those parts of the going train which were commonplace at that time.

## THE STRIKING SEQUENCE

Since a striking train is unlocked by a pin that moves very slowly to lift a lever (the lifting piece), as soon as striking commences it will continue until the lever can fall again. To avoid this continuous striking the train must relock after the first strike and the lifting piece must fall onto the trailing side of the lifting pin so that it is ready for the next sequence. This is achieved by introducing a delay between the start of unlocking and the actual release of the train. The three methods of providing this delay are (in chronological order of their first use): the nag's head, warning and flirt release.

The earliest clocks used a single-arbor system with a pivoted tip (a nag's head) to the lifting piece. The motion of the pin moves the nag's head until a deliberate amount of free play is taken up and only then is the lifting piece itself gradually raised. Once the train is unlocked the lifting piece is suddenly raised further by an overlift lever and almost immediately drops down again. As it does so the nag's head flips back to its original position, either by the force of gravity or a small spring, and drops down on the trailing side of the lifting pin and the train relocks. Multiple strikes are controlled by a countwheel. With this arrangement all four lever arms: lifting piece, locking detent, overlift arm and countwheel detent, are on one arbor and so move together. The system is sturdy, fairly reliable, but not particularly precise.[5]

The alternative later system using warning has two arbors: one with the lifting piece and a warning detent, the other with the locking and countwheel detents. There is also a link piece so that the two sets of levers may be lifted together, but can fall independently. As the lifting piece is raised the warning detent is positioned to intercept a pin on a wheel near the top of the striking train. When the train unlocks a few minutes before the hour it 'runs to warn' and is held temporarily until the lifting piece falls off the lifting pin, releasing the warning and the bell sounds. The lifting piece is now on the trailing side of the pin, ready for the next sequence. As the train is usually held on warn by a wheel further up the train, much less force is required and the drop of the lifting piece is more precise than when unlocking.

## THE MADRID CODICES

Leonardo da Vinci produced many notebooks containing scientific, engineering and other drawings, that now reside in various libraries and collections throughout the world. His drawing and description of a clock striking mechanism is shown on page 27v (verso) of the Codex Madrid, Volume I, compiled between 1493 and 1497. While many of his notebooks have been widely known and studied for generations, the two books now known as the Madrid Codices were only rediscovered in the winter of 1964-5 in the Biblioteca Nacional de Madrid after having been miscatalogued since about 1830. The drawings in the first volume are much neater and more precise than those in the second volume and in many of Leonardo's other surviving notebooks. It has been speculated that they may have been prepared with the intention of publication, which never came to fruition. A facsimile of the two volumes, together with a transcription and English translation of Leonardo's notes, a commentary and an index, was published in 1974.[6] The commentary is confined solely to discussions of a general nature such as the origins of the notebooks, date, comparison with drawings in other Leonardo manuscripts, etc. There is no attempt to discuss or explain the technical details of any of the drawings or their significance.

It should be appreciated that many of Leonardo's drawings do not represent mechanisms or machines that he himself invented. Rather they are more likely to have been a record of items or ideas that he had seen, read about or had heard of, made with the intention of classifying mechanisms and

5. J. Robey, 'Nag's Head Striking', *Horological Journal,* Nov 2011, 494-7.

6. *The Madrid Codices* (1974, McGraw-Hill), Vols I & II facsimile, Vol III commentary by L. Reti and indexes, Vols IV & V Italian transcription and English translation.

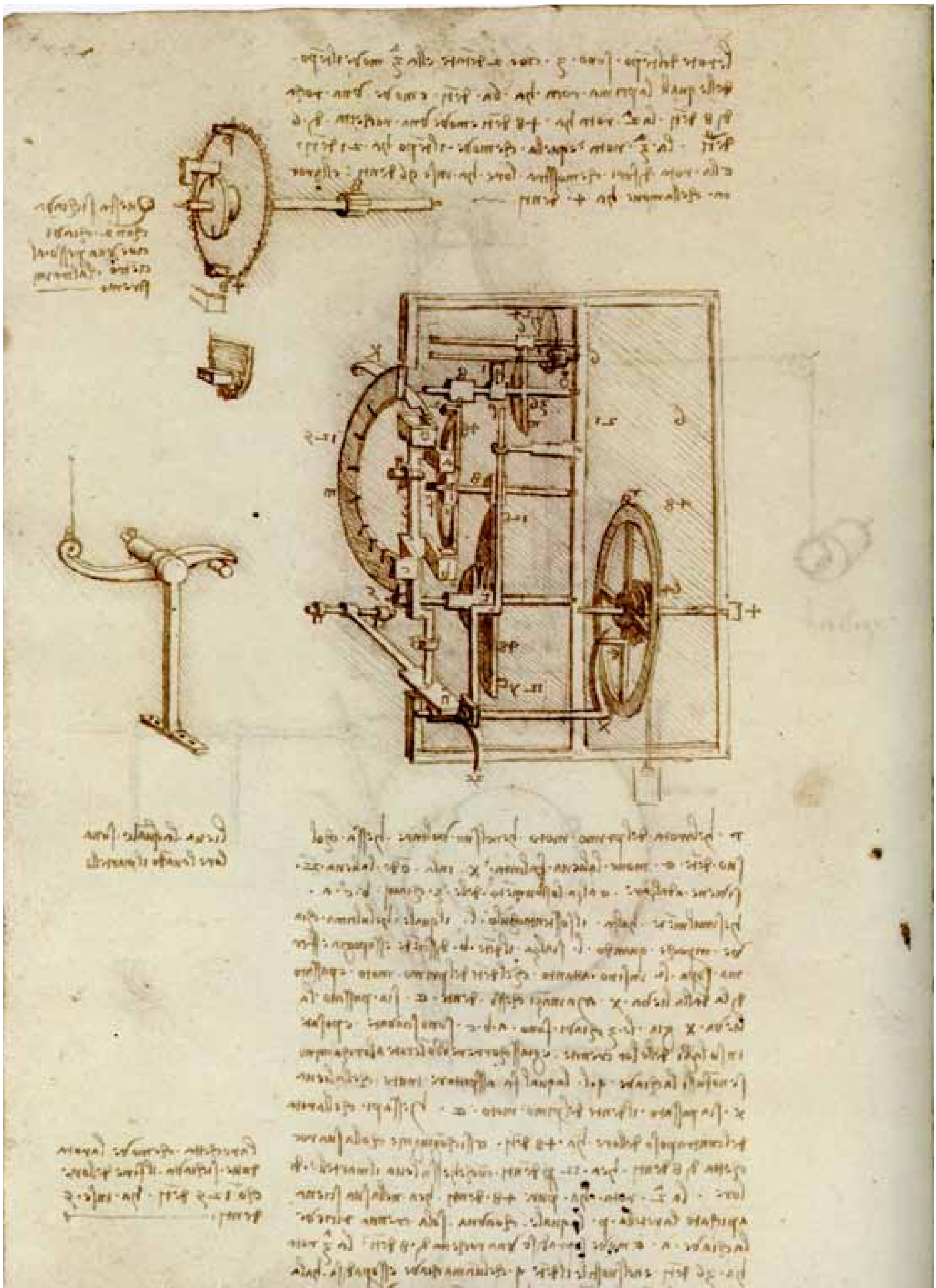

Fig. 1. Page 27v from the Leonardo da Vinci notebook known as Codex Madrid I.

understanding their principles.[7] They usually show the latest technology of the time, often experimental and of an unproven practicality, rather than what was in common current use. Hence, while this new and special type of striking mechanism is shown, there are no drawings of a clock employing the nag's head that was usually employed at that time.[8]

## LEONARDO' DA VINCI'S DRAWING: THE TRAINS

Fig 1 shows page 27v of Codex Madrid I. The centre of the page is occupied by a clock movement with the striking train complete, but only the greatwheel of the going train is shown. Alongside is a sketch of a lever pivoted in the centre with a hammer tail at one end pulling down on a vertical wire to operate a bell hammer. Leonardo's note on this reads: 'Lever for ringing the hours by lifting the hammer'. This type of hammer pivoted on the bell frame and falling under gravity to strike the bell, rather than using the force of a hammer spring, is found on some iron Gothic clocks, both German and French/Flemish. Above is a sketch of what appears to be part of a crownwheel with a small rectangular box-like piece, but with no explanation. Above this is a drawing of the locking wheel of the striking train (see below).

Not only is the text in Leonardo's usual 'mirror writing' but the whole page, including the drawings is a mirror image and as shown the wheels turn in the opposite direction to their correct rotation. To facilitate a clearer understanding of the mechanism the main drawing is shown enlarged and reversed in Fig 2. The movement (almost certainly made completely of iron) is weight driven with a simple vertical bar frame of the type often used for very early timepieces, for the so-called 'monastic alarms' and on some clocks with striking trains.[9] The front and rear movement bars would be fitted to the horizontal members with tenons (not shown) and held with pins, otherwise the pivots of the arbors could not be assembled into their holes.

Leonardo's text relating to the going train reads:

> The escapement has 3 wheels: 2 toothed wheels and a third which moves the escapement. The first wheel has 64 teeth and moves a pinion of 8 teeth, The second has 48 teeth, and moves a pinion of 6 teeth. The third wheel, which moves the escapement, has 21 teeth. The wheel on the outside, which shows the hours, has 96 teeth, and the pinion moved by the wheel has 4 teeth.

Despite the train being called 'the escapement' there is no description of the balance/foliot, the pallets or the crownwheel (although the small sketch probably relates to it). This text is self explanatory.

The going greatwheel of 64 teeth has the usual pulley on its arbor for a rope drive. Although no further wheels in the going train are shown the counts of the second wheel and crownwheel and their pinions are included in the drawing and the text. The inclusion of these numbers makes it almost certain that this is an actual clock that Leonardo had examined. If the drawing was of a proposed new striking mechanism there would have been no need for their inclusion. The clock has a three-wheel going train and would have had a balance or a foliot, with a verge escapement. The counts of the going train are:

| | |
|---|---|
| escapewheel | 21 — 6 |
| second wheel | 48 — 8 |
| greatwheel | 64 — 4 |
| hour (dial) wheel | 96 |

This gives a beat of 1.34 seconds (2,688 beats/hour), identical to 40 per cent of the weight-driven clocks in the *Almanus Manuscript*, where nearly two-thirds of them have an escapewheel of 21 teeth.[10] Three of the *Almanus* clocks (numbers 12, 15 and 22) have identical trains to this one, apart from the pinion of report, while

7. M. Cianchi, *Leonardo's Machines* (Florence, 1988), p. 12.

8. Since the surviving Leonardo drawings are thought to represent only about a quarter of his total work, there remains the possibility that the conventional arrangement might have been included in a now-lost manuscript.

9. See for example L. Krombholz, *Frühe Hausuhren mit Gewichtsantrieb* [Early Weight-Driven Domestic Clocks], (Munich, 1984), pp. 89-94.

10. J. H. Leopold, *The Almanus Manuscript (*1971).

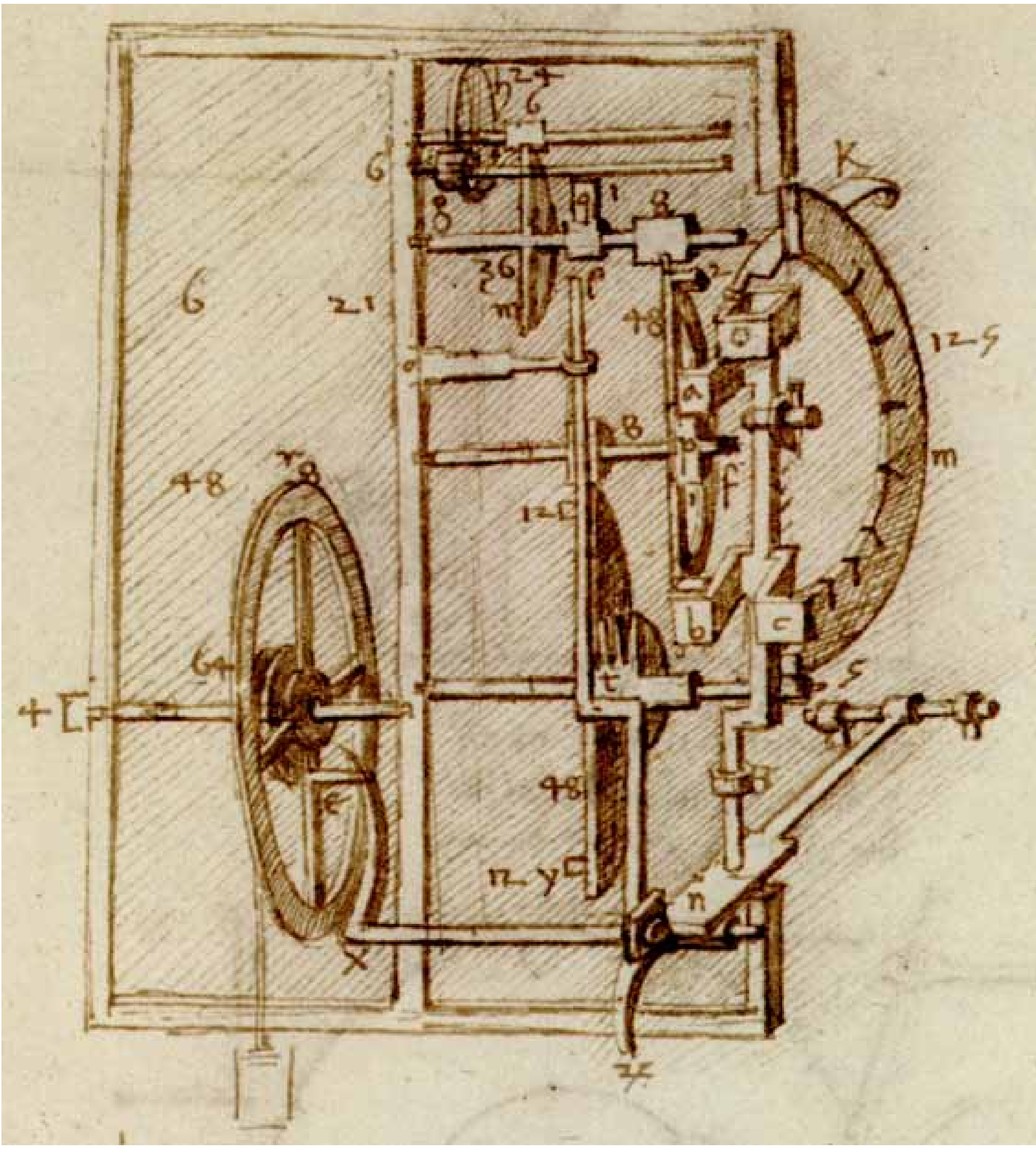

Fig. 2. Reversed enlargement of Leonardo's drawing showing the earliest recorded clock with warned striking.

some others only differ by having a greatwheel of 48 driving a pinion of 6, instead of 64 and 8. The going train is quite normal for this period, with nothing noteworthy about it.

Since the pinion of report of four leaves drives a dial/hour wheel of 96 teeth (not shown in the drawing but stated in the text) the clock must have had a 24-hour dial. Italian hours went from 1 to 24, starting at sunset, rather than midnight. Hence midday varied from about 16 hours in summer to 20 hours in winter. Italian hours were officially abolished in 1755, but in some regions their use lasted until the mid-nineteenth century. Most of the *Almanus* clocks with 24-hour dials have a pinion of report of only three leaves driving a dial wheel of 72 teeth, but three clocks (numbers 13, 23 and 30) have counts of 4:96. While balance-wheel clocks with 12-hour dials normally have a duration of about 12 hours between winding, those with 24-hour dials run for about a day.

To give a clear view of the mechanism Leonardo has shown only half of each wheel of the striking train, which consists of three wheels with the addition of an extra wheel driving a pinion at the top of the train instead of a fly. This method or regulating the speed of striking is known on four Italian spring-driven clocks and an Italian weight-driven clock in the *Almanus Manuscript*.[11] The countwheel has teeth on its outer edge with slots on the inner edge of the rim. The counts (using present-day terminology) are:

| | |
|---|---|
| fly pinion | 6 |
| fly wheel | 24 — 6 |
| warn wheel | 36 — 8 |
| locking wheel | 48 — 8 (2 locking tabs) |
| greatwheel | 48 — 5 (12 hammer pins) |
| countwheel | 125 |

The 24-hour Clock 22 in the *Almanus Manuscript* has a comparable train, but with a 3:75 countwheel drive instead of the 5:125 shown here.

Although a clock with a 12-hour countwheel strikes a total of 78 blows per cycle, with a 24-hour countwheel this increases significantly to 300 strikes per day. The above train provides the necessary 300 half revolutions (since there are two locking pins or tabs) for a full turn of the countwheel. There are two practical problems with the 24-hour striking system. Not only does the indexing of the strike require a considerable degree of precision in both the countwheel and the rest of the train,[12] but it is very easy to lose track of the number of hours sounded, especially towards the end of the day. For these reasons the 12-hour system eventually prevailed and even 24-hour clocks often had a 12-hour countwheel.

## THE STRIKING MECHANISM AND WARNING

Leonardo's text relating to the striking mechanism reads:

> **r** is the wheel of the prime mover. As this wheel turns, its teeth **e** move the sickle-shaped lever X, whence lever Y is raised and lifts the 3-keyed instrument **b c a**. Likewise prop **l**, the last key, is also lifted. When **l** raises, tooth **b** descends and remains at rest, leaning on itself, until the tooth of the prime mover passes beyond lever X. But before tooth **e** surpasses lever X, the 3 keys **a b** and **c** are released and rest on the edges of their notches. The wheels would already have been set in motion were it not for key **q l** which detains the movement until the prime mover's tooth **e** passes lever X. Also note that the wheel of the counterweight of the hours has 48 teeth and is connected with a pinion of 8 teeth. And it has l2 teeth for lifting the hammer of the hours. The second wheel also has 48 teeth, and a small wheel **p** is secured on its back which receives key **a** on its single notch and moves a pinion of 8 teeth above itself. The third wheel has 36 teeth, and on its shaft, tooth **q**, which is the last key. And above this wheel there is a pinion with 6 teeth. The fourth wheel has 24 teeth and moves a pinion with six teeth, substituting a fly. And the wheel of the keys has l25 teeth.
> [Side note:] The pinion which moves the wheel with 125 teeth where the hours are keyed has 5 teeth.

This is a reasonable description of locking and warning and the counts of the wheels and pinions, but the distinction between teeth, pins and 'keys' is not particularly clear.

The following is an explanation of the system using present-day terminology. Instead of arranging the various detents on two pivoted arbors, which became the usual practice, there are two vertical rods, one for warning, the other for locking and the countwheel detent, with a pivoted horizontal link. The hammer tail, shown in the side sketch, is tripped by the usual pins **y** (twelve in this instance) on the rim of the striking greatwheel. The going greatwheel **r** rotates clockwise[13] (when viewed from the front) once an hour and pin **e** depresses the lever X

11. Leopold, 'Almanus Re-Examined', 666. Leopold, *The Almanus Manuscript*, p. 27; the weight-driven clock is stated to be Clock 32, but this is an error for Clock 23.

12. For instance, with a 100mm (4in) diameter countwheel each division (represented by the width of the slots and the raised portion for two strikes) would be only 1mm (0.04in) wide.

13. Hence the dial wheel must have had internal teeth for the hand to turn in the correct direction. The weights for both trains hang on the right-hand side.

pivoted on an arbor.[14] This raises lever **Y** and the 'prop' **l** to act as a warning detent. At the same time the link **n**, pivoted at its far end, lifts the rod with the three 'keys' or detents **a, b** and **c**. When the locking piece b is lifted clear of one of the two locking tabs on wheel **f** the train turns a small amount until the arm or flag **q** on the arbor of wheel **m** contacts the warning detent **l** ('run to warn'). When the lifting piece **X** falls off pin **e** the warning flag **p** is released and the train runs until key **c** (the countwheel detent) falls into a slot and key **b** relocks the train.

The precise purpose of key **a**, which runs on disc **p** on the arbor of the locking wheel, is not explained, but it is likely to have been to improve the accuracy of indexing the 24-hour countwheel. The usual method of doing this was to use a hoop wheel that rotated only a third of a turn per strike with two slots that divided the hoop in the ratio of 2:1.[15] However Leonardo's drawing shows a wheel that makes half a turn per strike, with two locking tabs. The text states that there is only one notch in disc **p**, but this must be incorrect as it would prevent the countwheel from indexing *any* of the odd-numbered strikes. The subsidiary drawing shows two slots in disc **p** and this sketch is likely to have been an addition to correct and clarify the main text. The accompanying note is not particularly informative: 'This is locked with the aid of 2 keys, one near the centre, and one at the extremity'. As shown the only effect of disc **p** and key **a** is to prevent key **c** (the countwheel detent) from running on the raised sections of the countwheel before dropping into a slot. The notched disc allows the detent to contact the rim of the countwheel only when attempting to locate a slot. This action will be familiar to those who have observed the detent during normal countwheel striking with hoop-wheel locking. When locking is on a pin rather than a hoop the detent runs on the countwheel rim until it drops into a slot, without the 'pecking' effect seen with a hoop. One consequence of adding disc **p** (which is effectively a subsidiary countwheel) would be to allow the use of wider slots on the main countwheel to improve the accuracy of indexing and this is probably its main purpose.[16] It may have been a more positive method than that shown in the *Almanus Manuscript* (which merely reduces the number of attempts by the countwheel detent to locate a slot), but its use is not known to the author on any other clock.

The lower end of the locking assembly is shown resting on the link **n**, but in practice it would have been a loose fit in a hole and rested on a collar (shown here part way up the rod). This has a lock screw to adjust its position so that unlocking the train does not occur before the warning detent is in place. This hole would provide location in a horizontal plane, with a further guide shown near the top. The rod must not twist otherwise the keys will not engage properly. To prevent misalignment a fixed square or rectangular bar may have fitted into the box-like structure shown at the top, with the return spring **K** to overcome friction.

## EARLY CLOCKS WITH SIMILAR METHODS OF WARNING

The use of warning on early clocks is very unusual and the nag's head continued to be widely used in Continental Europe, particularly in the Germanic countries, in some instances into the nineteenth century. A very early example of warning is known on a domestic clock which shows several similarities with the Leonardo diagram (Figs 3-5). These images have been published previously and its use of warning has been mentioned,[17] but there is no explanation of the operation of the mechanism.

14. Letting off the strike by a pin on the going greatwheel was the usual method at this period, but a consequence is that the hand must be fixed to the arbor of the dial wheel to preserve the synchronisation of the hand with the time of the strike. Apart from simply stopping the clock and re-starting it at the correct time, the hand can only be set by disengaging the pallets and letting the train run. Later the much more convenient moveable hour hand with the strike let off by a twelve-pointed starwheel on the hand arbor was used.

15. The *Almanus Manuscript*, pp. 24-6 describes this method very clearly, as well as a more sophisticated system using a subsidiary countwheel.

16. I am grateful to Michael Hurst for this suggestion.

17. H. A. Lloyd, 'Gothic Clocks', *The Antique Collector*, June 1962, part 1, 128-9, Figs 10-11. Krombholz, *Frühe Uhren*, pp. 126-6, Figs 110a-110c. Lloyd's Fig. 10 and Krombholz's Figs 110a and 110b are printed the wrong way round, but corrected here in Figs 3 and 4. This clock was in the former Ernst Kupelwieser Collection, Salzburg, and was sold by auction in Vienna in 1977. Attempts to locate its present whereabouts have been unsuccessful.

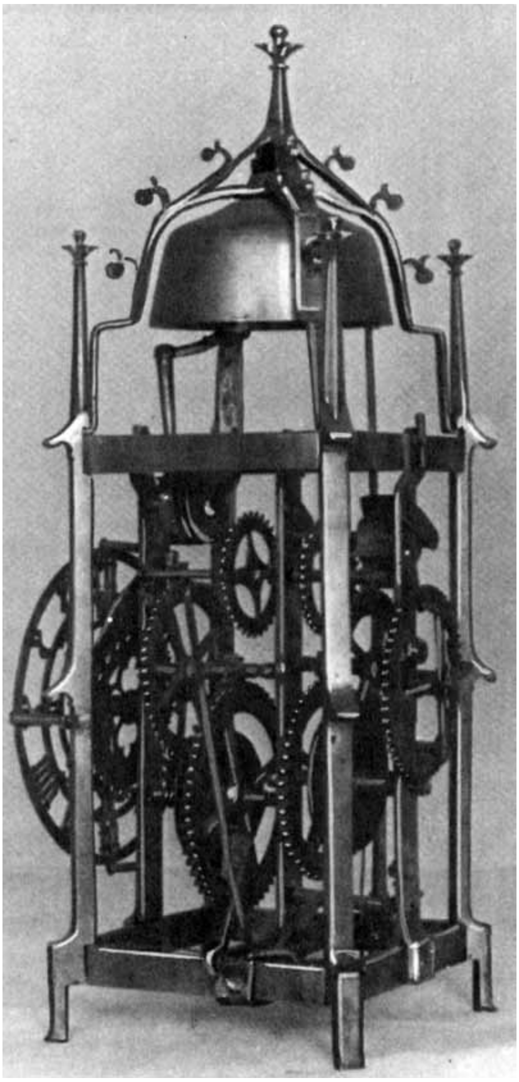

Fig. 3. Gothic iron clock of about 1500 with warning. The skeleton dial is an incorrect replacement.

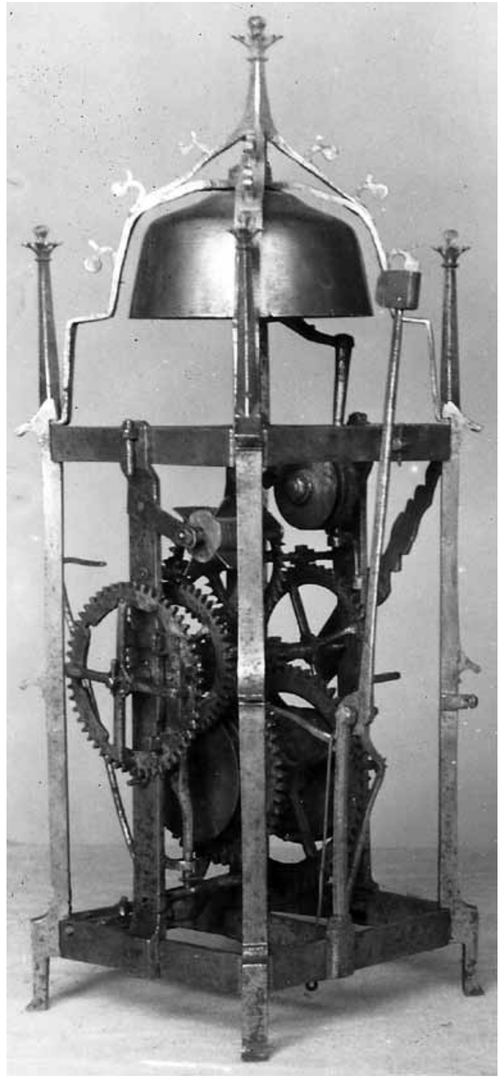

Fig. 4. The warning detent is on the far left. Note the incorrectly replaced fly and the unusual arrangement of the hammer pivoted on a tall post fixed to the lower frame, rather than between the corner pillars.

Although Alan Lloyd's article was written before the rediscovery of the Madrid Codices, the facsimile had been widely available by the time Krombholz's book was published, but no connection with the Leonardo da Vinci drawing was made.

This clock is said to be South German, possibly made in Nürnberg (Nuremberg), about 1500. As the place of manufacture and date of most early iron clocks is based more on speculation than evidence, often dating them optimistically too early, it may well be Italian and later in the sixteenth century. The original dial is missing and the fly is an incorrect restoration. The original balance or foliot escapement is, as often the case, also missing. The lifting piece and warning detent are fixed to an arbor pivoted between the lower frame members. The lifting piece is tripped by the usual pin on the going greatwheel, while the vertical warning detent has a bent-over tip which swings inwards to engage a pin on the third wheel. A short arm presses down on one end of a link pivoted between the movement bars. The other end of the link lifts a vertical rod with a countwheel detent near its lower end and presumably a locking detent at the top. A strap wrapped round the movement bar probably prevents the vertical bar from twisting.

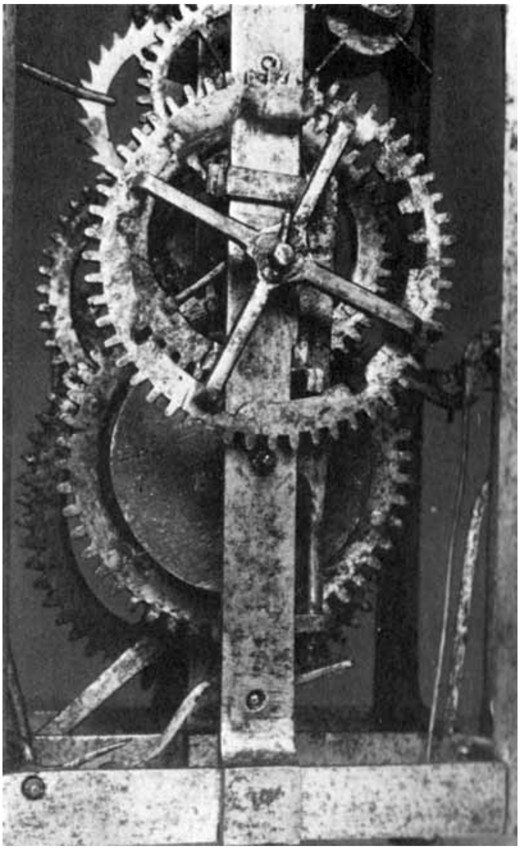

Fig. 5. Detail showing the pivoted link, the vertical rod with the locking/countwheel detents and lifting/warning piece. Note the supports for the vertical rod near its lower end and above the countwheel pivot.

As it is a 12-hour clock there is no need for any provision to improve the accuracy of indexing.[18]

There is a remarkable similarity between this clock and Leonardo's drawing, especially the vertical bar with the locking and countwheel detents, and the link piece, although this is pivoted at its centre rather than one end. It is a transitional system with pivoted lifting/warning detents, as used later. Eventually the locking/countwheel detents were also pivoted, with both arbors set higher in the frame so that the various arms are approximately horizontal.

## FLAIL LOCKING

When discussing the introduction of warned striking the English system now known as flail locking needs to be considered. While not incorrect, the term is misleading as it emphasises the locking aspect, but there is also warning, albeit in a rather unconventional arrangement, and this is often overlooked. Both locking and warning take place on the end of a long double-armed flail on an extension of the second arbor. A separately pivoted locking detent also carries the usual countwheel detent for counting the strikes. Instead of the strike being let-off by a pin on the going greatwheel, its arbor carries a lifting arm with an extension to one side. The lifting arm raises the locking detent, releasing the flail, which rotates one turn and is now held on warning by the extension (effectively a warning piece) on the lifting arm. When the lifting arm has rotated sufficiently the warning piece releases the flail and striking commences until the countwheel detent, which by this time has risen up onto a raised section of the countwheel, drops into the next slot and the flail relocks (Fig. 6).[19]

This differs from what eventually became the conventional system of warning in two main respects:

**a**. Both locking and warning occur on the same arbor. While this was used in the 18th century on some rack-striking longcase clocks made in the northwest of England, it was not otherwise used with countwheel striking.

**b**. The train is not released when a separate lifting/warning piece drops of the lifting pin, but when the flail drops off the warning extension of the lifting arm.

Flail locking is only feasible on turret clocks of the 'door-frame' type, with either iron frames made in the West Country or wooden frames mainly from the eastern counties, where the striking train is set vertically above the going train. This system is not very refined, and is rather brutal in operation. It has been said that

18. G. Brusa, *L'Arte Dell'Orologeria*, plate 152, shows the astronomical clock in the tower of the town hall at Clusone, near Bergamo in northern Italy, made by Pietro Fanzago in 1583. Although this has a similar vertical locking/countwheel detent and pivoted link to that shown in Fig 5 this clock does not have warning. These levers are part of the mechanical system for repeating the strike a minute past the hour (*ribotta*), similar to the more familiar French Comtoise clocks (information from Marisa Addomine).

19. C. F. C. Beeson, *English Church Clocks 1280-1850* (AHS Monograph No. 5, 1971), pp. 38, 81-2; 'Wood-Framed Church Clocks', *Antiquarian Horology* 4/5, 140-1.

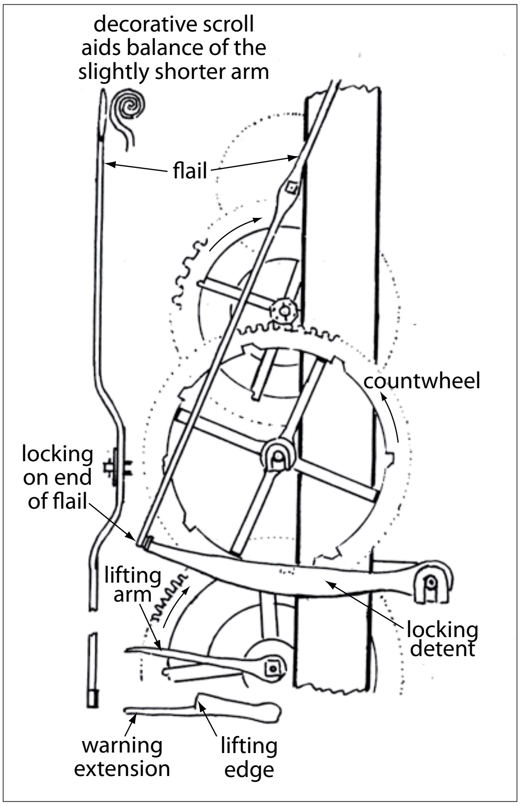


Fig. 6. Flail locking used on some early English 'door frame' turret clocks. After unlocking the flail is held on warn by an extension of the lifting arm. The detail at the bottom shows a plan view of the lifting arm. There are variations in the shape of these components. (Based on Beeson, see note 19.)

> a flail-locking clock is a very crude piece of engineering, with its long flail whirling round to crash against the locking-piece at the end of each striking sequence .... It demands a layout which is awkward, for there must be clearance at front and back for the flail and the fly so that the movement must be free-standing, and there must be room for someone to wind it at one side or the other — which he must do with one barrel set inconveniently high and the other awkwardly low, and in serious danger of being brained by the flail if he chooses the wrong moment to pass through the arc.[20]

The earliest known use of flail locking with a reasonably reliable date is the clock at Cotehele House, Cornwall, which is likely to have been installed at the chapel between 1493 and 1521, with more probability towards the earlier date.[21]

Flail locking appears to be a uniquely English invention that was not used on the Continent of Europe. When more conventional posted-frame turret clocks were made in England, flail locking was not practical and nag's head release was used instead. Only later was warned striking employed, but this aspect has not been thoroughly researched and there is much scope for further investigation.

## CONCLUSIONS

Leonardo da Vinci's drawing on folio 27v of the Codex Madrid I is the earliest documentary evidence for a striking clock using warning rather than a nag's head. This is almost certainly based on an actual clock that he had seen in Italy. Its 24-hour dial and countwheel, as well as the use of a wheel and pinion instead of a fly indicates an Italian origin. A modified version of this layout is known on a sixteenth-century iron Gothic clock, but whether it is German or Italian is not confirmed. Its restored fly might have been to replace an original wheel and pinion. Until this clock can be examined several details will remain uncertain. This arrangement of a vertical bar comprising the locking and countwheel detents, used in conjunction with a rocking link, may be a specifically Italian arrangement, but the author does not have sufficient knowledge of such clocks to state this categorically.

Flemish clockmakers were among the earliest to employ warning on turret clocks, including Jan van Spiere who installed a clock with warned striking in the town hall at Oudenaarde in East Flanders as early as 1510.[22]

Some other iron weight-driven domestic clocks made before about 1600 may have had warning, but they are difficult to identify in the literature. This is mainly due to published accounts rarely mentioning technical details, and generally the one-arbor nag's head system is

20. C. N. Ponsford & J. M. G. Scott, 'Early English Clocks' (see note 1), 59.

21. http://en.wikipedia.org/wiki/Cotehele_clock. This date is based on a National Trust building report of 2004 and revises the previously accepted date of about 1485 or later.

22. Information from Paul Van Rompay and Eddie Fraiture.

assumed. An exception is a clock in the Science Museum, London, said to be German from the 1500s but more likely to be French, which has warning as originally made.[23]

French spring clocks with 'double-decker' movements usually have warning from about 1520 onwards, as do Flemish horizontal table clocks.[24] A spring clock with transverse trains, made in 1581 by the Flemish clockmaker Hans de Evalo when he was working in Madrid, also has warning.[25] A similar spring clock, probably Italian or possibly Flemish, made in about 1580 or earlier, also has warning.[26]

A clock dated 1567 with a brass dial stamped with the names 'John Webbe of Salisbire [Salisbury]' and 'Jemes Porrvis', has warning.[27] However, close examination reveals that this is a modification, made at a very early date. It has many features typical of Flemish/French Gothic clocks as well as some used later on English lantern clocks. When making domestic clocks in Britain began in earnest some time around the end of the sixteenth century — the earliest surviving lantern clocks that can be identified were made by Robert Harvey who died in 1615 — they incorporated warning from the start and it was almost invariably used by later generations of British clockmakers.[28]

While the Italian arrangement illustrated by Leonardo da Vinci was adaptable to other frame configurations, the English system of flail locking had limited application. Both were developed about the same time and neither can claim to have a clear priority. Further study of early Continental clocks, both domestic and turret, as well as early English turret clocks, would clarify the various stages in development from these embryonic systems to the method that eventually became universal.

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23. Inv. No. 1954-184. The countwheel, which is in the centre of the movement, has internal ratchet-shaped teeth advanced or gathered once per strike by a pallet on the locking-wheel arbor. It is an early instance of this uncommon system. The museum description is very basic and makes no mention of these special technical features.

24. Information from Michael Hurst.

25. Tardy, *La Pendule Française* (Paris 1974), 2nd edition, Part 3, pp. 725-32; 5th edition, Part 4, pp. 547-55. This clock was taken to Japan by Jesuit missionaries and presented to the first Shogun, Iyeyasu Tokugawa, in 1611. It is now among his effects at the Toshogu Shrine of Kunozan. It is in a remarkably original condition, including the foliot escapement.

26. British Museum, Waddesdon Bequest, WB 222. The niello medallions, astronomical dial and inscriptions are later, made before 1834. Information from Michael Hurst and Paul Buck.

27. G. Foster, 'An English Gothic Chamber Clock', *Antiquarian Horology* 9/5 (Dec 1967), 18-321; B. Loomes, *Lantern Clocks & Their Makers* (Ashbourne, 2008), pp. 10-12. This clock is currently undergoing a detailed reassessment.

28. The flirt was sometimes used in the eighteenth and nineteenth centuries on rack-striking clocks instead of warning. The nag's head is extremely rare on British domestic clocks, with only one example known, made as late as 1810, see B. Kerridge, *Horological Journal*, Feb 2012, p. 52, letter to the editor.