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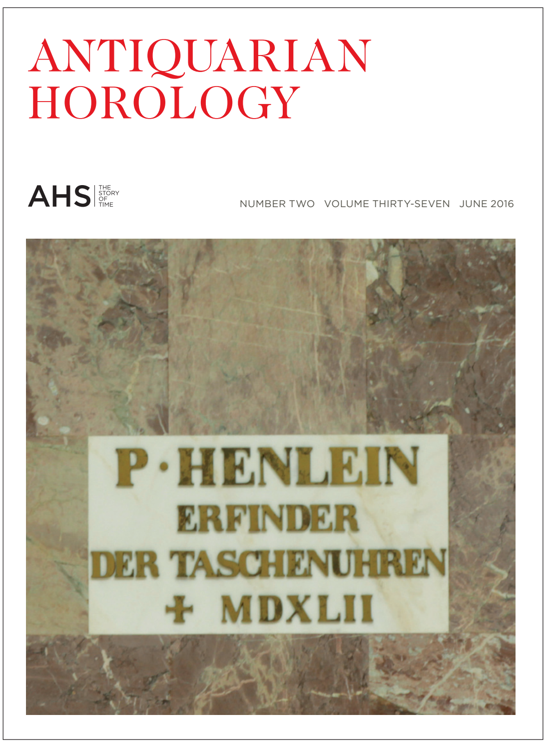


Volume 37, No. 2 (June 2016) contains, apart from the regular sections Horological News, Book Reviews, AHS News, Letters to the Editor and Further Reading, the following articles

Ung petit traictie pour faire horoleiges: A little treatise for making clocks in the fourteenth century

William Linnard*, John A. Robey** and Michael T. Wright***

This article describes a treatise on clockmaking compiled by an unknown clockmaker in about 1380. It is the earliest known practical clockmaking manual in Europe, and accordingly is of great importance for the history and development of horology. A transcript of the original Old French manuscript is reproduced, a literal translation of the complete text in English is here presented for the first time, and the difficult and often obscure text is explained in a detailed commentary, together with the illustrated reconstructions proposed for some of the various mechanisms. From this old treatise we may infer that the second half of the fourteenth century was a period of intense activity and experimentation in clockmaking in France, that several alternative designs of clock mechanisms had already been developed and were known among clockmakers, and that a relatively large number of artisans were engaged in the new craft of clockmaking.

In 1954 Enrico Morpurgo (1894–1972), an Italianist and horologist, then working at Amsterdam University, found an Old French Treatise on clockmaking in the Vatican Library. He published the original text of the Treatise (Fig. 1), together with a modern Italian translation, and also an introduction, notes and conclusions in both French and Italian.[1] Three years later Morpurgo's friend and colleague Paul Zumthor (1915–95), Professor of Romance Philology at Amsterdam University, published an article in French, also including a transcription of the original Old French text of the Treatise, and discussing the linguistic aspects in some detail but the horology only for a non-specialist audience.[2]

This important archival find was noticed, very briefly, in the UK, in 1955.[3] Later, in 1967, a small part of it was quoted by Beeson,[4] but apart from this it seems that for the last sixty years the Treatise has largely escaped the attention of anglophone horologists, and to the best of our knowledge has never been translated into English.

More recently Rettani & Brusa have reconsidered the Treatise.[5] They repeat the transcription of the Old French text and Morpurgo's Italian translation and reproduce larger facsimiles of the original manuscript, together with line numbers linking the original to the transcription. While there is a basic glossary of the medieval horological terms and a general discussion on early clocks, there is little meaningful technical discussion of the text.

*William Linnard (billlinnard@aol.com) has translated the Old French text, Morpurgo's Italian article and Zumthor's French article into English and provided much of the background information.

**John Robey (john@mayfieldbooks.co.uk) has contributed the technical descriptions of the going and striking trains and the striking-work, as well as producing the diagrams.

***Michael Wright (mtw@hand.eclipse.co.uk) has provided notes, mainly on the trains for dial displays.

1. Enrico Morpurgo, 'Ung petit traicte pour faire horoleiges', *La Clessidra*, Vol X, No 11 (October 1954), 14–27.

2. Paul Zumthor, 'Un traité français d'horlogerie du XIVe s.', *Zeitschrift für Romanische Philologie*, Vol 73 (1957), 274–87.

3. Short notice by C. B. Drover in *Antiquarian Horology*, Vol 1, No 7 (June 1955), 102.

4. C. F. C. Beeson, 'The Central Count Wheel', *Antiquarian Horology*, Vol 2, No 7 (March 1967), 204–5.

5. Vincenzo Rettani & Giuseppe Brusa, 'Considerazione su un breve trattato de orologeria del Trecento', *La Voce di Hora*, No 18 (June 2005), 31–50.

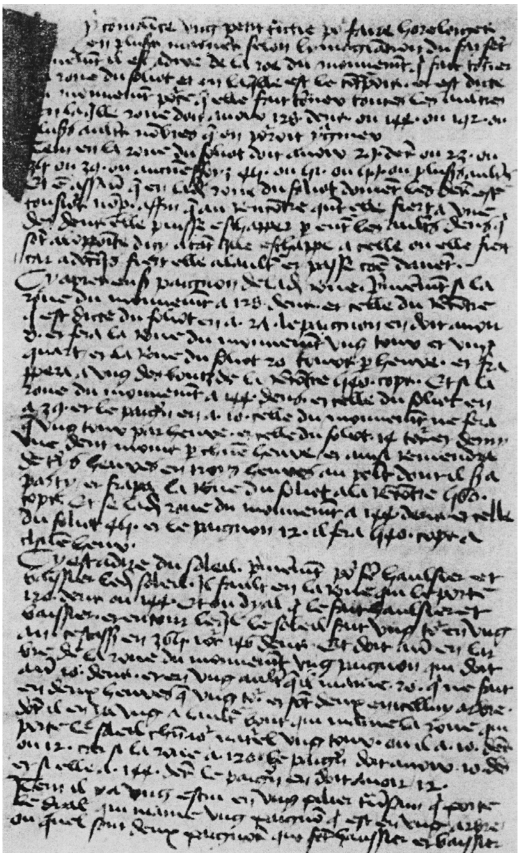


Fig. 1. The first page fol. 64r of the anonymous clockmaking Treatise in Old French.

The Treatise itself is written, apparently by a copyist, in an italic gothic hand containing elements of French gothic. It was transcribed for Morpurgo and Zumthor by Emmanuel Poulle (1928–2011), a graduate of the Paris School of Palaeography and himself the author of a thesis on mediaeval astronomical instruments.[6] Though Morpurgo and Zumthor disagreed with Poulle's transcription of a few individual words, on linguistic, horological and palaeographical grounds the three men confidently dated the manuscript to the last quarter of the fourteenth century. The Vatican Library has recently confirmed its fourteenth-century date.[7] The Treatise is apparently the earliest vernacular manual on making weight-driven mechanical clocks known in Europe. It is interesting to compare it with an incomplete Latin manuscript describing the construction of an early medieval water-clock with a weight-operated striking system from the Pyrenees.[8]

To aid comprehension for the general reader Zumthor gave a summary description of the kind of clock mechanism described in the Treatise: 'It is a clock showing the passage of time by reference to the movements of the celestial bodies. Only the movement is described, not the peripheral pieces.' These 'peripheral pieces' are the escapement and a foliot with adjustable weights for regulation. Morpurgo ended his article with a plea: 'I very much hope that a clockmaker will illustrate it — perhaps with a nice set of design drawings — from the mechanical point of view.' The present authors have attempted, with varying degrees of success, to take up this challenge and also put the Treatise in its historical context.

The original Old French Treatise is included in a collection of fourteen separate individual documents in large octavo which came into the Vatican Library before the seventeenth century; during the period 1860–6 they were bound together into one volume, paginated, and shelf-marked Vat.lat. 3127. The Vatican Library catalogue states that the documents in the volume all belong to the thirteenth and fourteenth centuries, and all are in Latin except for the Old French Treatise which itself has a Latin summary. The other documents in this volume deal with various mathematical and astronomical topics including quadrants, astrolabes and a *horologium viatorum* (a traveller's horologe, presumably a portable sundial). The Old French Treatise on clockmaking (Vat.lat. 3127(10), fol. 64r–66r) contains five pages on three folios, and is bound between a document entitled *Compositio quadrantis* and an untitled document beginning *Equatorium planetarum* …. Most of these documents, including the Treatise on clockmaking, are anonymous and some are untitled; for convenience they are sometimes referred to by the first line of text.

Originally written by an experienced clockmaker for practising craftsmen, i.e. working clockmakers, perhaps in the form of quick notes,

6. See his obituary by Anthony Turner, *Antiquarian Horology*, Vol 33, No 2 (December 2011), 174–5.

7. Information from Andreina Rita, Informazioni Bibliografichi, Biblioteca Apostolica Vaticana.

8. F. Maddison, B. Scott & A. Kent 'An early medieval water-clock' *Antiquarian Horology*, Vol 3, No.12 (September 1962), 348-353.

the Treatise is almost certainly a fair copy, written down by someone other than the original author. The Treatise has conventional scribal abbreviations, minimal punctuation, and some structure into paragraphs, but some words and passages are obscure and some of the notes are garbled and may have been copied down in the wrong order, which makes it difficult to understand some sections. Unfortunately there are no diagrams accompanying the text, which contains no regional or dialect forms that might have helped to pinpoint its place of origin, though it can be assumed to be France or a French-speaking region.

The language is often ungrammatical and shows uncertainty as regards the gender of nouns.[9] The author is inconsistent in his use of terminology; some sentences are clumsy, confused or obscure, and there are a few obvious errors or omitted words. Zumthor points out that the nouns in the Treatise are for the most part clear technical terms but the verbs used are rather general or less precise. Significantly the unknown author of the Treatise gave no definitions of his terms (except for the word dyal) and he was clearly trying to deal with the subject at a general level while recognising the existence of different methods of making clocks.

Technical discussion

This Treatise is primarily concerned with the wheels and pinions and their counts for the going and striking trains, astronomical displays and the levers for operating the strike, with alternative arrangements to assist clockmakers design their own clocks. Apart from the details given by the anonymous writer, which are explained and analysed below, what is not mentioned is also of significance. There are only oblique references to the type of frame, although it is stated that the going train is at the front with the striking train at the rear (known as 'end-to-end' trains) and a bell above. It is reasonable to assume that the frame would have four corner pillars fixed to square upper and lower sub-frames with vertical movement bars attached to the sub-frames at front and rear and a central one attached to horizontal supports. This same construction was used on turret and Gothic clocks until the seventeenth century, and — with the sub-frames replaced by horizontal plates — on 30-hour posted-frame clocks until the nineteenth century.

There is no mention of rope barrels or pulleys with winding ratchets and clicks for the driving weights. Nor is there any reference to the foliot, apart from the foliot wheel (escape wheel) and while the action of the escapement is described there are no details of the verge or its pallets, so presumably these were common knowledge by the end of the fourteenth century.

No dimensions are given and apart from a mention of small clocks at the very end of the main text, the mechanisms described are not size-specific. Morpurgo states 'This proves that the treatise is devoted exclusively to small clocks, i.e. chamber clocks', but this is an incorrect interpretation and the manuscript merely recommends a method of letting off the strike that is more suited to small clocks. Since small clocks are considered as a special case the opposite conclusion can be drawn; it is likely that large clocks are the main consideration, especially since astronomical displays are mostly found on early public clocks.

There are just three references to the materials used: a plate of iron, a rod of iron and an iron wire. Morpurgo states 'This suggests that the wheels were of bronze', but this is another incorrect conclusion. It is more likely that the wheels were of forged iron, this being almost universal on clocks of all sizes until the end of the sixteenth century and on many Continental clocks for another century and a half. The concentration on the technicalities of the movement means that those parts visible to the public, such as the dial and the associated astronomical displays, are virtually ignored.

There is no mention of the profile of the wheel teeth, or whether solid or lantern pinions are envisaged. Methods of adjusting the clock's rate by moving the regulating weights on the foliot and/or altering the driving weight so that the correct time was indicated are not discussed. The omission of these fundamental topics indicates that the writer was addressing those who already knew of such things and only needed advice on what gears were most suitable for different circumstances. A clockmaker without prior knowledge of the wheel work and general construction of a clock would struggle to design or make one from this text.

The count wheel with 78 teeth, being the sum

9. F. Maddison, 'Masculine Clocks in French' (letter to the editor), *Antiquarian Horology*, Vol 21, No 6 (Winter 1994), 554.

of 1 to 12 strikes, indicates that this is a 12-hour clock without a half-hour strike. This shows that in France the day had been divided into the more convenient two sets of 12 hours by the date of this manuscript.

In contrast to the basic considerations of the going and striking trains and the strike-work, which would have applied to almost all clocks of the period, the schemes of wheelwork for astronomical displays may be less widely representative, although they may actually describe those of some clocks of the time.

Since there were few accepted technical terms in the fourteenth century for the components being described, everyday alternatives had to be used, with little consistency. While some are fairly obvious, others are less so, and the present authors have had to make comparisons with known features of later clocks in an attempt to interpret the true meaning. Some terms can be converted unambiguously, e.g. from the description of the 'hours wheel' this is clearly what is now known as a count wheel, but some other terms can have more than one interpretation. For instance, 'tooth' is used for the teeth of a gear wheel, a tab, a flag or a pin, as on a locking wheel. The escape wheel is called the foliot wheel — a convention that is still followed with balance wheel being the wheel that moves the balance, not the balance itself.

In the pages that follow, a transcript of the original Old French and a close literal English translation of the Treatise appear side-by-side on the left-hand page, while on the facing page is an interpretation and discussion. **[A]**, **[B]**, etc, have been inserted to correlate the original text with the commentary. The transcript has been copied from those in Morpurgo's and Zumthor's articles, but using Poulle's readings where they differed; in these transcripts all the scribal abbreviations in the original text are expanded. Zumthor inserted more punctuation than Morpurgo; for punctuation Morpurgo/Poulle has been followed. The translator's interpolations are in square brackets.

One word that has proved problematical is *escieu/esciu*, which has been left in the Old French with an appropriate note in the commentary. In older contexts it seems to mean a non-rotating axle, i.e. in horological terms, a stud. In at least one place it seems probable that such a stud incorporates a stationary worm engaging a pinion on a wheel that either runs on it or on an arbor passing through it (see Fig. 3). One of us (MTW) suggests that this is the author's meaning throughout.

Glossary

Modern equivalents for some of the words in the Treatise as well as the basic astronomical terms used in the commentary.

arbor, axle = three different words (*arbre, axil, escieu*) are used, possibly varying only in size, but see above for *escieu*

counterweight = driving weight, but also used in its modern meaning

detent = lifting piece

dial = component rotating once a day, but in sections **[D]** and **[E]** it is the zodiac wheel rotating once a sidereal day

fan = fly

fan wheel = wheel that drives the fly pinion, not the fly itself. Sometimes used for the locking wheel

foliot wheel = escape/crown wheel

hours wheel = count wheel

meeting and ends of the meeting = verge and pallets

movement wheel = great wheel

pinion teeth = pinion leaves

sidereal day = the time taken by the earth to rotate on its axis relative to the stars, about 23 hours and 56 minutes

sidereal month = the time the moon takes to complete one full revolution around the earth with respect to the stars, about 27⅓ days

synodic month = the time the moon takes to complete one full revolution around the earth with respect to the sun, about 29½ days: equal to one lunation

wheel of the foliot = escape wheel

wheel of the strike = combined striking great wheel and pin wheel

zodiac = a band of the celestial sphere, centred on the ecliptic (the apparent annual path of the sun) and broad enough to contain the moon and planets (the orbits of which are all slightly oblique to that of the earth). Positions around the zodiac can be defined in terms of the twelve named zodiacal 'signs', each measuring 30 degrees of celestial longitude, called by the names given in antiquity to the constellations that then occupied these positions

Transcript of the Old French Treatise

[fol. 64r] Cy commaince ung petit traictie pour faire horoleiges en plusieurs manieres selon l'ymagination du fayseur. Premerement il est a dire de la roe du mouvement qui fait tourner la roue du foliot et en laquelle est le contrepois et est dicte du mouvement pour ce qu'elle fait tourner toutes les aultres; en laquelle roue doit avoir 128 dens ou 144 ou 192, ou plusieurs aultres nombres que on pourroit ymaginer.

Item en la roue du foliot doit avoir 29 dens ou 23 ou 35 ou 39 ou aucunes foyz 45 ou 51 ou 59 ou plusieurs aultres. Et est assavoir que en ladite roue du foliot doivent les dens estre toujours non pair affin que au rencontre quant elle fiert a une des dens elle puisse eschapper par entre les aultres dens qui sont a l'opposite d'icy, a tant qu'elle eschappe a celle ou elle fiert, car adoncques fiert elle a l'aultre et passe come davent.

Cy apres ensuit paignon de ladite roue. Premerement si la roue du mouvement a 128 dens et celle du rencontre qui est dicte du foliot en a 27, le paignon en doit avoir 8 et fera la roue du mouvement ung tour et ung quart et la roue du foliot 20 tours par heure et frappera a ung des boutz de la rencontre 540 cops. Et si la roue du mouvement a 144 dens et celle du foliot en a 39 et le paignon en a 10, celle du mouvement ne fera que ung tour par heure et celle du foliot 14 tour et demy une dent moins par chacune heure, et ainsi reviendra de troys heures en troys heures au point dont il sera party et frapera la roue du foliot a la rencontre 560 cops. Et se ladite roue du mouvement a 144 dens et celle du foliot 45 et le paignon 12, il fera 540 cops a chacune heur.

Cy est a dire du soleil. Premerement pour fere haulsier et baissier ledit soleil, il fault en la roue qui le porte 120 dens ou 144; et ou dyal qui le fait haulsier et baissier et entour lequel le soleil fait ung tour en ung an, c'est assavoir en 365 jours, 146 dens. Et doit avoir en l'arbre de la roue du mouvement ung paignon qui doit avoir 10 dens, et en ung aultre qu'il maine 20 qui ne fait en deux heures que ung tour, et sont deux en icelluy arbre, dont il en y a ung a l'aultre bout qui maine la roue qui porte le soleil chacun jour naturel ung tour ou il a

Literal translation

[fol. 64r] *Here begins a small treatise for making clocks in several ways according to the imagination of the maker.*

[A] *Firstly it is necessary to speak of the movement wheel which makes the foliot wheel turn and on which is the counterweight; and it is called the movement* [wheel] *because it makes all the others turn; this wheel should have 128 teeth or 144 or 192, or several other numbers which could be imagined.*

Likewise the foliot wheel should have 29 teeth or 23 or 35 or 39 or sometimes 45 or 51 or 59, or several others. And it should be known that in this foliot wheel the teeth should always be an uneven number so that on the engagement, whenever it [the pallet] *rests against one of the teeth it* [the other pallet] *can escape between the teeth which are* [diametrically] *opposite here, so that as often as it escapes from the one against which it rests, it then rests on the other, and [the action] takes place as before.*

[B] *Here follows the pinion of the said* [escape] *wheel. Firstly, if the movement wheel has 128 teeth and that of the meeting, which is called the foliot wheel, has 27, the pinion should have 8, and the movement wheel will make one revolution and a quarter* [per hour] *and the foliot wheel 20 revolutions per hour, and will hit on one of the pallets of the meeting* [verge] *540 blows.*

[C] *And if the movement wheel has 144 teeth and that of the foliot has 39 and the pinion has 10, that of the movement will make only one revolution per hour, and that of the foliot 14 and a half revolutions, one tooth less for each hour, and thus* [the engagement of pinion and wheel] *shall come back every three hours to the point from which it shall have started, and the wheel of the foliot will hit on the meeting* [verge] *560 hits. And if the said movement wheel has 144 teeth and that of the foliot 45 and the pinion 12 it will make 540 hits in each hour.*

[D] *Here the sun will be discussed. Firstly to make the sun rise and set, the wheel which carries it must have 120 teeth or 144; and on the dial* [wheel] *which makes it rise and set and around which the sun makes one revolution in one year, that is in 365 days, 146 teeth. And the arbor of the movement* [great] *wheel should have one pinion which should have*

Interpretation & discussion

[A] This describes a going train with only two wheels, each with large numbers of teeth; these were common on some early clocks. The very slow beat of turret clocks (see below) made two-wheel trains practical until the advent of the pendulum, whereas for the faster trains of small clocks three wheels with smaller total counts were found preferable.[10] An uneven number of teeth on the escape wheel is emphasised and the action of the escapement is described, but it is assumed that clockmakers would know about the special shapes necessary for the crown-wheel teeth and the pallets. The latter are called teeth, but the meaning is clearly to the pallets.

[B] Although it states that the great wheel **will** rotate in either 1¼ hours or one hour, this is a decision made by the clockmaker, depending on the weights on the ends of the foliot, not merely a consequence of the tooth counts. The first and third examples give 1,080 beats/hour or a beat of about 3.3 seconds. The calculations for the second example are only approximate, giving about 1,123 beats/hour instead of 1,120 beats/hour or a beat of about 3.2 seconds. All these slow beats would be applicable to large clocks, rather than domestic clocks.

[C] The second example is singled out for special discussion. The author refers to a great wheel of 144 teeth, making one turn/hour, meshing with a pinion of 10 leaves. Here the number of teeth and number of leaves of the wheel-pinion pair do not form a simple aliquot ratio of the form x:1 (as in the other examples), and he is exploring a consequence of adopting it. His 'three hours' is a mistake for 'ten hours', the least interval between moments when any given wheel tooth is engaged with a given pinion leaf. After ten turns of the great wheel the escape wheel makes 144 turns, or a ratio of 14.4 which the writer expresses as 14½ less ⅒ or 'one tooth less [of the pinion]'.

[D] This paragraph describes a simple display

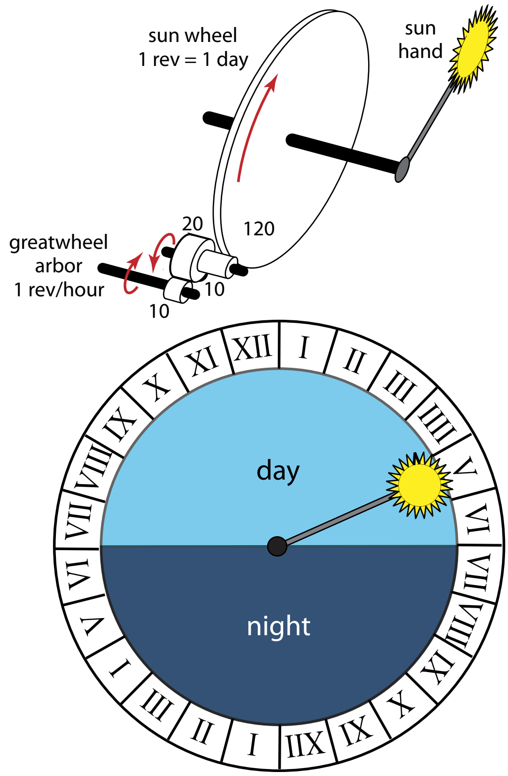


Fig. 2 . Arrangement to give rotation of the sun once a day to indicate the time against a 2 x I-XII chapter ring and a simple sun rise and set.

to show the time and the sun's position in the sky. The dial is defined later in the text as a wheel that rotates daily,[11] not the modern meaning of a plate or face around which hands rotate, However, 'the sun makes one revolution in one year' around the 'dial', which in this context is the zodiac wheel. This sentence is out of order and refers to the position of the sun in the zodiac, which is the subject of the following paragraph. 'The sun rise and set' would not show the actual times of sunrise and sunset, but a simple representation of the sun rotating once a day and indicating midday when it is at the top and midnight at the bottom. The horizon (past which it rises and sets) might have been included in the display.

10. Some domestic clocks used two-wheel trains until the end of the sixteenth century, see: [Jeff Darken], 'An Iron Chamber Clock by Nicholas Vallin 1598', *Antiquarian Horology*, Vol 30, No 5 (March 2008), 695–703; John A. Robey, 'A Large European Chamber Clock', *Antiquarian Horology*, Vol 33, No 3 (March 2012), 335–46. The subject of the latter article is now thought by the author to be French.

11. The origin of the word dial is obscure, but may derive from the medieval Latin *rota dialis*, 'daily wheel', and evolved to mean any round plate over which a pointer rotates.

10 dens ou 12 car si la roue a 120 le paignon doit avoir 10 dens et si elle a 144 dens le paignon en doit avoir 12.
Item il y a ung esciu en ung pilier traversain qui porte le dyal qui maine ung paignon qui est en ung arbre ouquel sont deux paignons qui font haussier et baissier
[fol. 64v] ledit soleil, et celuy que l'escieu maine doit avoir 10 dens ou 15 et celuy qui est a l'aultre bout qui maine le zodiac que j'ay nomme dyal doit avoir 4 dens ou 6: si celuy de l'escieu a 10 dens, l'aultre en doit avoir 4, et se il en a 15, l'aultre en doit avoir 6, et ainsi gaignera il en deux jours et demy une dent du zodiaque.
Aultrement pour faire ledit soleil haulsier et baissier en la roue du dyal doit avoir 108 dens, item au zodiac 274 dens, item au paignon qui le maine 6 dens, item au paignon de l'arbre qui est maine par ung escieu 8 dens; item y doit avoir une petite rouete tenent a l'ecentrique du zodiac ou il a 24 dens qui fait tourner ung paignonnet entre l'ecentrique et le dyal, et audit dyal en a une aultre qui tient avecques celluy et tournent ensemble en ung axil et y a 16 dens, laquelle fait tourner une aultre en maniere d'une petite rouete ou il a 35 dens et en tient avecques cely une aultre ou il a 8 dens et sont perties yceulx dens a travers et boutes parmy le bout de l'arbre du dyal et davent une petite plataine de fer; et ces quatre paignons et celle rouete de 34 dens ne servent de rens au soleil mais taut soulement a la lune et a ses signes.
Cy diray de la lune. Premerement il doit avoir en la roue de la lune 59 dens, et est menee par deux paignons qui sont en ung

10 teeth, and in a another one which it leads 20, which makes only one revolution in two hours, and there are two on this arbor, one of them at the other end which leads the wheel which carries the sun, each natural day one revolution, either it has 10 teeth or 12 for if the wheel has 120 the pinion should have 10 teeth and if it has 144 teeth the pinion should have 12.
[E] *Likewise there is an* **esciu (escieu)** *in a transverse pillar, which carries the dial, which leads a pinion which is in an arbor on which are two pinions which make the said sun rise and set*
[fol. 64v] *and the one which the* **escieu** *leads should have 10 teeth or 15, and the one which is at the other end, which leads the zodiac, which I have named dial, should have 4 teeth or 6; if the one on the escieu has 10 teeth, the other should have 4, and if it has 15 the other should have 6, and thus it will gain one tooth of the zodiac in two and a half days.*
[F] *Alternatively, to make the said sun rise and set the dial wheel should have 108 teeth, and the zodiac 274 teeth, and the pinion which leads it 6 teeth, and on the pinion of the arbor which is led by an axle 8 teeth; also there should be a small wheel connected to the eccentric of the zodiac, having 24 teeth, which turns a small pinion between the eccentric and the dial, and on the said dial another one connected with it and they turn together in one axle, and here there are 16 teeth, which causes the rotation of another in the manner of a roller, where it has 35 teeth, and connected with this another one having 8 teeth and these teeth are arranged transversely and they are so arranged as to occupy a space between the end of the arbor of the dial, and before a small iron plate; and these four pinions and this small*

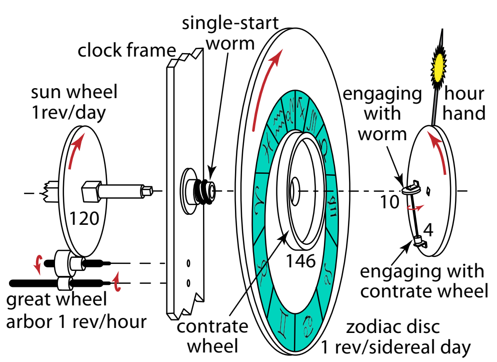


Fig. 3. Mechanism to show the sun's position in the zodiac using a single-start worm.

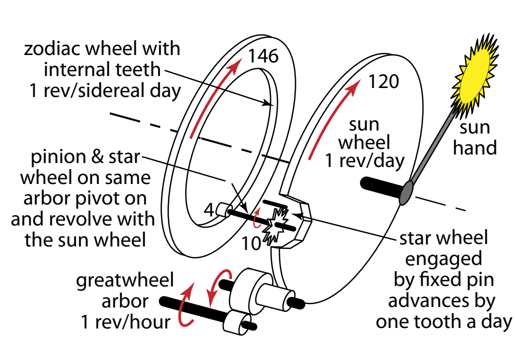


Fig. 4. Alternative mechanism to show the sun's position in the zodiac using a fixed pin.

The sun indicator, which rotates once a day (i.e. there is a 24-hour dial), is driven from the arbor of the great wheel turning once per hour, through the train 10/20 × 10/120 or 10/20 × 12/144 (Fig. 2).

[E] This, and the first sentence at **[D]**, describes a display to show the position of the sun in the zodiac. Here the *esciu* (elsewhere *escieu*) may be a stud carrying the mobile and incorporating a fixed single-start worm with which the pinion of 10 revolving around it is engaged; or the pinion may be carried forward at each revolution by engagement with an adjacent fixed pin.

The sun indicator, showing the hours, rotates once a day. The zodiac ring rotates faster, once in a sidereal day (about 23 hours 56 minutes), so the sun passes right round the zodiac in a year. The zodiac, on a wheel with 146 teeth, is driven through an epicyclic arbor with pinions of 4 and 10 leaves revolving with the sun indicator; at each revolution the pinion of 10 is advanced by one leaf and the pinion of 4 leads the zodiac forward by 1/10 × 4/146 = 1/365 of a turn relative to the sun indicator. The pinion of 10 may be worked by meshing with a stationary worm (Fig. 3), or by engagement at each revolution with a stationary pin (Fig. 4). With the latter ensemble it is easier to ensure a safe action if the pin is closer to the centre than the axis of the pinion (which is likely to be more like a starwheel than an actual pinion), and then the zodiac wheel must have internal teeth.

This apparently involved method of driving the zodiac wheel from the sun wheel avoids a complication if both were driven directly from the clock. Since the two wheels need to move in the ratio 366:365, convenient gearing of one results in inconvenient gearing for the other. While it might be better to drive the zodiac directly from the movement, the clock would have to keep sidereal time, resulting in difficulty in letting off the strike correctly at the hour.

Either of the two suggested mechanisms could be used with a display having a sun indicator showing both the time against fixed chapters (as in Fig. 2) and the place of the sun in the zodiac. The zodiac ring may rotate concentrically with the dial (Figs 5 and 7) or may form part of a so-called 'astrolabe' display in which the zodiac is an eccentric ring within a revolving stereographic projection of the sky (Figs 6 and 8).

[F] Here the word 'dial' is used correctly for the sun indicator rotating once daily, its count of 108 (with an assumed pinion of 9) probably being an option for 10/120 or 12/144. There is then a superior alternative year train (perhaps from a different clock) of 1/8 × 6/274 with a once-per-day input. The wheel of 274 teeth might have been replaced by one of 137 teeth, with changes to one or both pinions.

Then, in mid-sentence, the author begins to discuss a train for a display of the moon's place in the zodiac. Unfortunately, the description of this elaborate train is garbled; some wheel-

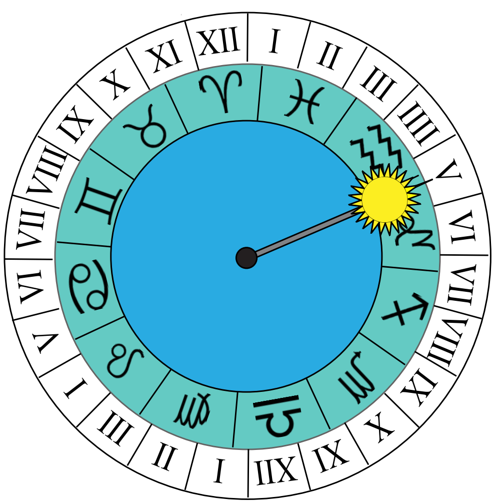


Fig. 5. Concentric astronomical display.

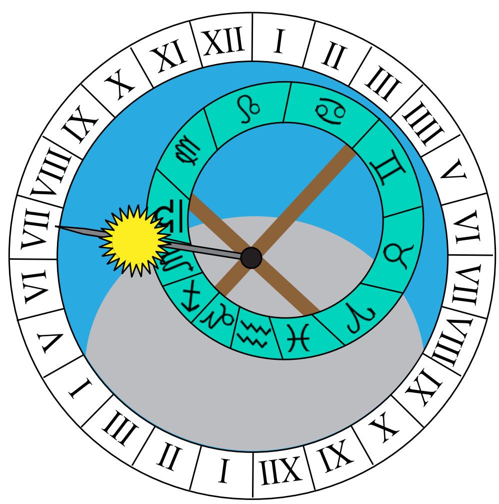


Fig. 6. Astrolabe-type of display.

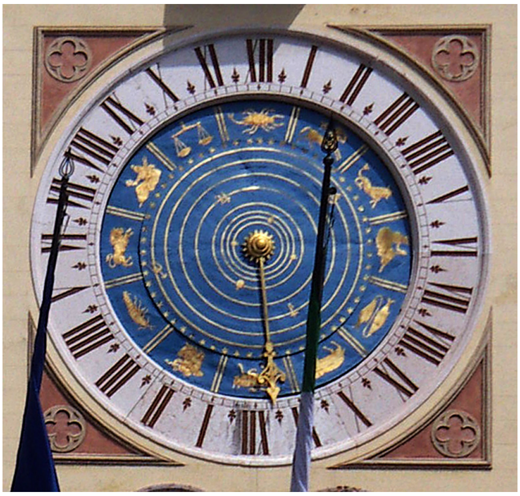


Fig. 7. Concentric type of astronomical clock dial at Bassano del Grappa, northern Italy, 1430.

Fig. 8. Astrolabe type of astronomical dial on the clock on the Old Town Hall, Prague, 1410.

arbre, dont il doit avoir en l'un 6 dens et en l'aultre 12, et est mene celuy de 6 dens par une viz qui est en l'arbre qui porte la roue du soleil, et celuy de 12 dens maine la roue de la lune et la fait tourner chacun jour deux dens, et ainsi elle fait en 29 jours et demy ung tour.

Aultrement, pour faire la lune haussier et baissier et targier chemin en son zodiac, premerement la roue de la lune doit avoir 57 dens et doit avoir au zodiaque 85 dens, et chacun des paignons a 9 dens et doit estre fait l'escieu par troys dens et la viz qui fait tourner le paignon qui fait tourner la lune doit tenir au terrace entre la terrace et le zodiac et doit avoir en l'un des paignons de la lune 6 dens, c'est assavoir a celuy qui est mene de ladite viz, et en celuy qui maine la roue de la lune doit avoir 12 dens, et la roe qui porte la lune en son ecentrique doit avoir 144 dens, et le paignon qui la maine 8 dens, et l'aultre paignon qui est en iceluy arbre doit avoir 16 dens et celuy qui le maine qui part de la roe du mouvement doit avoir 8 dens, et ne fera celuy a 16 dens et celuy de 8 qui est en celuy en deulx [fol. 65r] que ung tour, et ainsi ne gaignera la roue a chacune heure que quatre dens et sera demouree en sa lunaison d'ung tour et adoncques remmendra come davent.

Pour faire les signes de la lune, il fault une roue de 82 dens et ung paignon de 28 dens et fera en 27 jours et demy heures ses signes. Apres la divise du mouvement veil

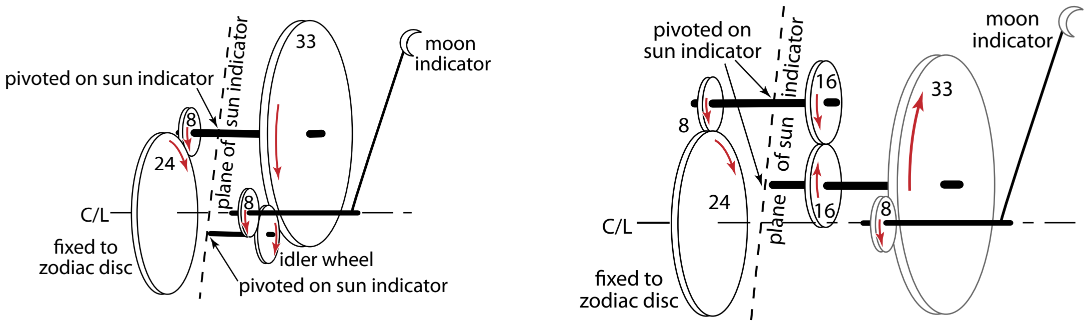
wheel of 34 teeth do not serve the sun but only the moon and its signs.

[G] *Here I will speak of the moon. Firstly the moon wheel should have 59 teeth, and is led by two pinions which are on one arbor, one of which should have 6 teeth and the other 12, and the one with 6 teeth is led by a screw which is in the arbor which carries the sun wheel, and the one with 12 teeth leads the moon wheel and makes it turn two teeth each day, and thus it makes one revolution in 29 and a half days.*

[H] *Alternatively, to make the moon rise and set and to make its slow journey through the zodiac, firstly the wheel of the moon should have 57 teeth and the zodiac should have 85 teeth, and each of the pinions has 9 teeth, and the* **escieu** *should be made with three teeth, and the screw which makes the pinion turn which makes the moon turn should be connected to the plate between the plate and the zodiac, and one of the pinions of the moon should have 6 teeth, i.e. the one which is led by the said screw; and in the one which leads the moon wheel there should be 12 teeth,*

[I] *and the wheel which carries the moon should have 144 teeth in its eccentric, and the pinion which leads it 8 teeth, and the other pinion which is on this arbor should have 16 teeth, and the one that leads it, which comes from the movement wheel, should have 8 teeth; and this one with 16 teeth and the one with 8 which is in it will make in two*

[fol. 65r] [hours — word missing, probably a slip when beginning a new sheet] *only one*



Figs 9 & 10. Epicyclic train mounted on the sun indicator, driving the moon indicator. Directions of rotation are shown relative to the sun indicator, with which the epicylic train revolves. Left: with an idler wheel; right with two equal wheels.

counts seem wrong and others are not given, and even the number of wheels and pinions is in doubt. The phrase 'causes the rotation of another in the manner of a roller' is ambiguous — it may signify two wheels with equal counts, or that the driven one is very small. It may refer to an idler wheel.

This train, apparently generating the motion of a moon-indicator over the zodiac, seems to derive its motion from the slow relative motion (one revolution per year) between the zodiac wheel and the sun indicator. An epicyclic train revolves, with the sun-indicator, once every 24 hours. The zodiac plate rotates faster than the sun-indicator, by one turn per year, while the moon indicator rotates slower, by one turn per synodic month. So, in this frame of reference, the velocity-ratio between the two is 365:29½, or 12.373:1. A two-pair train such as 24/8 × 33/8 (= 12.375) yields a good approximation to the velocity-ratio, so it may be that the numbers 35 and 34, found in the text, are both mistakes for 33. The direction of rotation has then to be reversed. The text may suggest the inclusion either of an idle wheel or of a pair of equal wheels, options that are illustrated in Figs 9 and 10. The display could be either the concentric or astrolabe type with the addition of a moon indicator, though 'the eccentric of the zodiac' suggests an astrolabe dial.

The high step-up ratio is undesirable but, as before, it is simpler to drive the sun- and hour-indicator directly from the movement. The suggested lunar train may be seen as a development of an existing design incorporating sun and zodiac displays. The extra wheels could be simply added at the front without having to alter anything else.

[G] This paragraph describes a display of the phase and/or the age of the moon. The moon wheel rotates once in 29½ days, a good approximation to the synodic month. Fig. 11 illustrates a display in which the lunar phase is represented by a disc having light and dark zones bounded by an eccentric circle, which rotates once a month behind a circular opening; but a display with a rotating globe, half-light and half-dark, is also possible.

Remarkably a screw or worm is used to work the lunar display. This means that the pinion of 12 and the wheel of 59 that it leads must engage at right-angles (Fig. 8). The wheel might have contrate teeth, or the pinion and wheel might simply engage at right-angles, as bevel gears were not introduced until much later.

[H] This paragraph, concerned with other arrangements for displaying the moon's place in the zodiac, is hard to interpret. The mention of an escieu of three 'teeth' is strong evidence for taking this term to imply the presence of a worm: in this case, a three-start worm.

[I] Here, and again at the beginning of the next paragraph, the author seems to begin again, outlining other arrangements for lunar displays. It is not clear how the wheel-counts given could have been intended as parts of trains yielding as output either the sidereal month (about 27⅓ days) or the synodic month (about 29½ days). If the author meant 27½ days, that is of course a rather poor approximation to the sidereal month. He evidently intended to state a more precise period, such as 27 days and so-many and a half hours.

[J] This describes a clock with a striking train

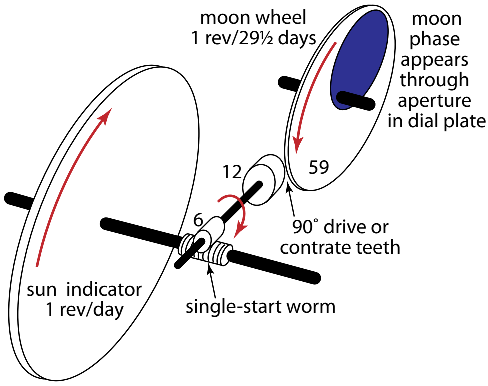


Fig. 11. Phase of the moon using a screw drive.

dire de la sonnerie. Pour faire une sonnerie de 4 roues dont l'une lieve le martel et l'aultre fait tourner l'esventail qui arreste par une cloche qui est respondent a la roue des heures qui est assise entre deulx piliers qui sont ou millieu de l'oreloige, et en ladite sonnerie a troys paignons, dont l'un fait tourner l'esventail et l'aultre fait tourner la roue de l'esventail et le fait tourner la roue qui lieve le martel, l'aultre paignon maine la roe des heures et est au bout de la roe qui lieve le martel. Item il doit avoir de neccessite en la roe des heures 78 dens et en celle de la sonnerie en puet avoir 96 ou120 ou 112 ou 140 ou plusieurs aultres que on puet ymaginer, car il convient que elles se puissent departir en autant de parties egales come il a de chevilles pour lever le martel; la roue de l'esventail est a voulonte et son paignon et la roue de l'arrest ne doit avoir que une dent avecques laquelle dent il arreste car elle ne fait a chacun tour que ung cop et a cause de ce il convient qu'il ait autant de dens au paignon qui maine la roe de l'esventail come il a entre deux des chevilles de la roe qui fait lever le martel et doit avoir autant de dens au paignon qui maine la roue des heures come il a de chevilles en la roe de la sonnerie.
Et ainsi puet estre fait ung horeloige par 6 roues, c'est a dire par les deux du mouvement et par les quatre de la sonnerie. Et si tu veulx faire une cheville en la croix de la roe du mouvement pour lever la descente, tu la doiz moderer tellement qu'elle face a chacune heure ung tour precisement, et ainsi fera 24 tours en ung

revolution; and thus the wheel will gain only four teeth in each hour and will remain in its lunation of one revolution, and will then return as before.
To make the signs of the moon a wheel of 82 teeth is needed and a pinion of 28 teeth, and it will make its signs in 27 days and half hours [word or words omitted; sense obscure, see commentary].
[J] *After dealing with the movement I wish to speak of the strike. To make a strike of 4 wheels, one of which raises the hammer and the other makes the fan turn, which is stopped by a bell* [perhaps = after striking the bell], *which corresponds to the hours wheel which is located between two pillars which are in the middle of the clock, and in the said strike are three pinions, one of which turns the fan, and the other turns the wheel of the fan and makes it turn the wheel which raises the hammer; the other pinion leads the hours wheel and is at the end* [of the arbor] *of the wheel which raises the hammer.*
[K] *Also the hours wheel must of necessity have 78 teeth and in that of the strike there can be 96 or 120 or 112 or 140, or several others which can be imagined, for it is necessary that they can be divided into as many equal parts as there are pins to raise the hammer; the fan wheel is at will, and its pinion,* [i.e. both being at the choice of the clockmaker] *and the stop wheel should have only one tooth* [locking pin], *with which tooth it stops, for it makes only one hit in each revolution; and because of this it is necessary that there are as many teeth in the pinion which leads the fan wheel as there are* [tooth] *spaces between the pins of the wheel which raises the hammer; and there should be as many teeth on the pinion which leads the hours wheel as there are pins in the wheel of the strike.*
[L] *And thus can be made a clock with 6 wheels, that is to say with the two of the movement and the four of the strike. And if you wish to make one pin in the cross of the movement wheel to raise the detent, you must adjust it so that it makes precisely one revolution in each hour; and thus it will make 24 revolutions in a natural day, and will raise the said detent at each hour, and when it escapes it will fall and hit the bell above, making the strike descend* [set in motion?]*;*
[M] *and in front it should have an axle with two pillars at the side of the clock by which will pass*

sounding the hours on a single bell. There is no half-hour or quarter-striking, which did not appear until the fifteenth century or later.[12] The count wheel is located between two pillars (i.e. movement bars) in the centre of the clock. This is a specifically western feature[13] and shows that regional constructional characteristics had already been established by this time.

The fly being 'stopped by a bell' presumably means that the train stops after the bell has sounded, the number of strokes being controlled by the count wheel. The striking train described has three wheels, plus the count wheel: a combined great wheel and pin wheel, a stop or locking wheel and a 'wheel of the fly'. While the pinion driving the count wheel is described correctly, the pinion on the fly arbor is ignored.

There is no mention of a friction spring or a small ratchet and click on the fly to avoid damage or wear when the train is stopped suddenly. The flies on some Gothic clocks are fixed to their arbors.

[K] The 'necessity' that the count wheel has 78 teeth and the count of the pinion that drives it equals the number of hammer pins is not strictly correct. There can be a half or a multiple of 78 with a corresponding pinion count.[14] While it correctly says that the count of the fly wheel and pinion are not important (they only determine the rate of striking), the summary specifies 48 teeth. Here the word tooth is used for wheel teeth and also for the pin on the locking wheel, yet in the next section the correct word pin is used. Here the author refers to the pinion on the same arbor as the locking wheel, which he thinks of as 'leading' in the sense that it is driven and so makes this wheel turn. Only in the summary is the number of hammer pins specified: 12 and a pinwheel of 96 teeth. Fig. 12 shows the wheels of this striking train.

[L] The strike is let off by a pin on the going great wheel, the method used until the introduction of the star wheel in the sixteenth century. When the detent falls it does not hit the bell, but sets the strike train in motion and then the bell sounds, not vice versa as implied in the text.

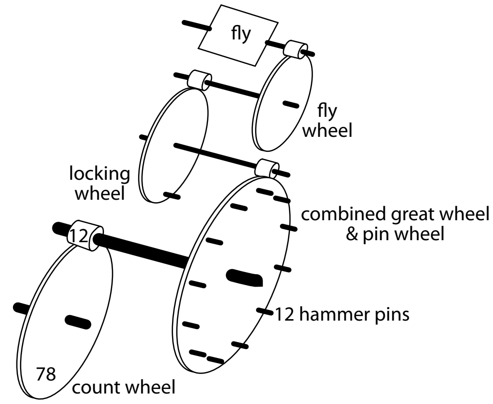


Fig. 12. The striking train with the count wheel in the centre of the movement and strike locking on the second wheel.

[M] The horizontal arbor with the hammer tail (here called a rod) is pivoted at the side of the clock in the usual manner between two pillars, which might be either the corner posts or separate movement bars. The hammer itself is above the movement, it is lifted by a pull wire and falls under gravity.

[N] This is a reasonably clear description of the count wheel, especially for one with 78 teeth. Two different types of construction are described: a count wheel fixed to a separate gear wheel, and an annulus with the teeth on the outside and the notches on the inside. The commonest type on early iron clocks is the one-piece count wheel, with the teeth on the inside and the notches on the outside. Internal count-wheel notches are a specifically French feature.[15] There are invariably eleven notches rather than twelve, with a double-width slot for 12 o'clock and 1 o'clock.

12. Gerhard Dohrn-van Rossum, *History of the Hour* (Chicago & London, 1996), p. 405, note 5.

13. René Schoppig, *L'horloge française à poids* (Paris, 1984), pp. 31, 36; Beeson, 'Central Count Wheel', *Antiquarian Horology,* Vol 2, No 7 (March 1967), 204–5; British Museum, London, Cassiobury Park clock (Reg 19642-3.1); Science Museum, London, Dover Castle clock (Inv 1884-81), Gothic clock (Inv 1954 184). The latter clock is labelled as German, but in the opinion of one of us (JAR) it is French.

14. For instance the count wheels of early English lantern clocks have 39 teeth driven by a pinion of four with eight hammer pins.

15. Schoppig, *L'Horloge*, pp. 30–2, 35–7.

jour naturel et levera ladite descente a chacune heure et quant elle luy eschappera elle cherra et frapera dessus la cloche, si fera descendre la sonnerie, et devant aura ung axil a deux piliers du couste de l'oreloige parmy quoy passera une verge de fer qui viendra dessus les chevilles, ainsi les chevilles le sourdront et leveront le martel o ung fil de fer qui sera attache au
[fol. 65v] bout derriere. Et doiz savoir que la roue des heures a 12 osches l'une plus loing de l'aultre tousjours d'une dent, car a chacun cop que le martel fiert ladite roue des heures passe une dent, et font aucuns ladite roue des heures de deux roues assemblees en ung arbre et tenentes ensemble et sont les 12 dens que j'ay divisees en l'une de ces roues par le dehors et en l'aultre 76 dens qui se divisent par les heures pour chacune une dent come dit est; les autres ne y font que une roue, et sont les 12 dens par dedans; et aucuns n'y font que onze dens car ilz assemblent 12 et ung ensemble, et sont ceulx qui font leur roue de heures double et a troys roues leur sonnerie, car ilz font arrester la roue des heures o les osches de la roue du dehors et o la roue de l'esventail car aucuns y laissent ung braz de la croyz plus loing que l'aultre, si y actaint ung tenon que on fait en la cloche quant elle chiet en aucune des osches de ladite roue des heures et par ceste maniere l'arrest entre en son osche par ung ressort qui prise tousjours dessus, et quant la descente frappe dessus a l'aultre bout elle le fait yssir de son osche, ainsi ne puet arrester jusque a ce qu'il entre en l'aultre osche; et en l'aultre maniere qui arreste par une osche ou il n'a que une dent il a ung contrepois a la chenche qui ne hausse ne n'abesse fors quant la descente fiert dessus la chenche que elle fait ung poy sourdre quant elle ist de la dent, ainsi tient le contrepois la chenche en l'osche comme dessus est dit. Et si tu veulx que la roue du mouvement ne lieve pas la descente, tu dois faire une aultre roue ou il aura 6 chevilles ou 12 ou 24; se il en y a 6 elle fera quatre tours en ung jour naturel car elle passera a chacune heure une cheville qui levera la descente et se il y en a 12 elle fera deulx tours; et se il en y a 24 elle fera ung tour. Et la doiz assoir en maniere d'un dyal ou fere un dyal, car il est dit dyal pour ce qu'il ne fait en ung jour naturel que ung

a rod of iron which will come above the pins, so the pins will make it function and raise the hammer with a thread of iron which will be attached to the
[fol. 65v] *rear end.*

[N] *And you should know that the hours wheel has 12 notches, each one more distant from the last by one tooth, for at each stroke which the hammer makes the said hours wheel passes one tooth; and some* [clockmakers] *make the said hours wheel from two wheels assembled on one arbor and fixed together, and the 12 teeth which I have mentioned are in one of these wheels on the outside, and in the other 76* [error for 78] *teeth which are divided by the hours, as said one tooth for each one; others make only one wheel, and the 12 teeth are inside; and some only make eleven teeth for they assemble 12 and one together,*

[O] *and there are those who make their hours wheel double, and their strike has three wheels, for they stop the hours wheel with the notches of the wheel on the outside and with the fan wheel, for some leave one arm of the cross longer than the other, a tenon which is made in* [runs to?] *the bell when it falls into one of the notches of the said hours wheel, and in this way the stop enters into its notch by a spring which engages always above, and when the detent hits above at the other end it makes it exit from its notch; thus it cannot stop until it enters the other notch;*

[P] *and in the other way* [of making clocks] *which stops by a notch where there is only one tooth, it has a counterweight at the latch, which neither rises nor falls except when the detent hits on the latch which makes a weight rise up when it exits from the tooth; thus the counterweight holds the latch in the notch, as said above.*

[Q] *And if you wish that the movement wheel does not raise the detent, you must make another wheel having 6 pins or 12 or 24; if there are 6 pins it will make four revolutions in one natural day, for at each hour it will pass one pin which will raise the detent; and if there are 12 pins it will make two revolutions; and if there are 24 pins it will make one revolution. And you should set it like a dial, or make a dial, for it is called dial because it makes only one revolution in one natural day. And if the wheel has 6 pins and you wish to make the movement wheel rotate one revolution and a quarter or one revolution and a half at each hour because you cannot adjust*

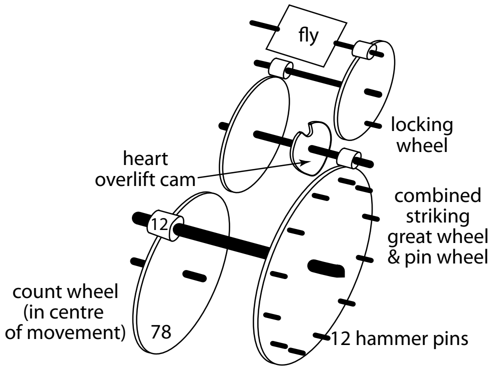


Fig. 13. Alternative locking arrangement controlled by a heart overlift cam.

[O] This is a rather confused and laboured description of the operation of the strike-work. Before the invention of warned striking about 1490[16] the nag's head system would have been used, but there is no mention of this in the earlier section, nor the essential overlift, the latter probably taking place on the hammer pins.[17] The discussion here of a double count wheel appears to refer to a separate single- notch disc (nowadays called a 'heart' cam and sometimes with two notches) on the arbor of the second wheel, with the actual locking taking place on the wheel above, here the fly wheel. The heart also provides the overlift and, as before, the normal count wheel overrides the system to give 1–12 strikes. The cross refers to the arms of the strike-work, not a wheel crossing as before, though they are not normally cruciform and on later clocks some of the detents are combined onto one arm. The tenon is a rearward extension that acts as a detent for the count wheel. The fall of the strike-work is often assisted by a spring, especially on small clocks, though this is not usually necessary on large clocks. Not only is 'hours wheel' used here for both the conventional count wheel and the heart overlift cam, but locking and let-off are said to be by means of a notch, when a pin is actually employed. 'When the detent hits above' probably refers to the overlift of the lifting piece, though its swivelling tip or nag's head is not specifically mentioned (but see below).

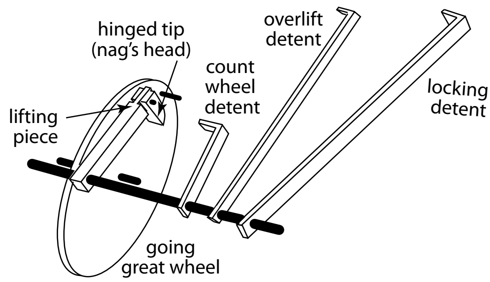


Fig 14. Nag's head striking with four detents on a single arbor.

The final phrase means that locking can only occur when the detents drop into both the notch in the heart cam and one of the notches in the count wheel. Fig. 13 shows the overlift cam and locking, while Fig. 14 shows the various detents of the strike-work.

[P] Again 'tooth' is used to describe a notch, while 'notch' also appears to mean the lifting pin on the going great wheel. The 'latch' with a counterweight is the hinged tip (nag's head), which swivels under gravity on large clocks and with spring assistance on small clocks. It is the swivelling action of a door latch, rather than it dropping into a notch, that is relevant in this context. This is a description of the action of the overlift cam, with a single notch, to raise the lifting piece further (overlift) so that when it falls again the nag's head is now on the other side of the lifting pin, ready for let-off at the next hour.

[Q] This section describes an alternative arrangement for letting off the strike. and is quite straightforward, with the lifting pins being unambiguous. Also unambiguous is the statement that the 'dial' is a wheel that 'makes only one revolution in one natural day'. This method of letting off the strike by having the appropriate number of lifting pins on the dial wheel is basically the same as the twelve-pointed star wheel used later on domestic clocks. However, since the pins are fixed there is not the convenience of a movable hour hand.

[R] If the great wheel cannot be regulated to give hourly rotation this is a useful method, especially for small clocks where a large and/

16. John A. Robey, 'Leonardo da Vinci and the Earliest Known Clock with Warned Striking', *Antiquarian Horology*, Vol 33, No 6 (Dec 2012), 95–9.

17. John A. Robey, 'Nag's Head Striking', *Horological Journal*, Vol 153, No 11 (November 2011), 494–7.

tour. Et si la roe a 6 chevilles et tu veulx faire tourner la roe du mouvement a chacune heure ung tour et ung quart ou tour et demy pour cause que tu ne puez admoderer ton mouvement a chacune heure ung tour pour ce qu'il va trop tost, tu doiz faire ung paignon en l'arbre de la roe du mouvement ou il ait 6 dens ou plus ou moins selon que
[fol. 66r] tu verras estre a faire; et si tu doiz faire 54 dens en la roe ou sont les chevilles, ainsi il aura 9 dens entre deux chevilles, si fera la roe du mouvement et le paignon a six dens tour et demy a chacune heure; et si tu y faiz 12 chevilles, tu doiz faire 108 dens. Manieres bonnes pour petiz horeloiges pour ce come dit est que on ne puet pas admoderer la roe du mouvement qu'elle ne face plus d'un tour a chacune heure et fait l'en incontinent ces petits horeloiges ferir a compte par dedens la cloche ou par dehors, et en est la sonnerie faicte par troys roes.

Reliqua suppleat descretio artificis
Recapitulatio brevis
In horologio sont septem rote:
— prima vocatur rota momenti, et est major, habens dentes 144, sita in capite anteriori, complens circuitum per horas
— 2a dicitur resistens seu reobvians et est minor, habens dentes 45, et est supra primam complens circuitum per quintam partem hore
— 3a anterior dicitur dyalis, minor secunda, habens dentes 48
— 4a datur pro pulsatione campane, levans martellum, habens dentes 96 et 12 cavillas, et est in posteriori, major tribus prescriptis
— 5a dicitur rota horarum inter duo pilaria mediocra, et est minor, habens dentes 78. In circuitu exteriori et in dicta rota sont duo dentes interiores, et in dente largiori ferit 12 ictus quando clencha in ea intrat et priusquam exeat ferit unum ictum et in sequenti proximo duos ictus, et in 3a tres, etc. de singulis sequentibus juxta numerum usque ad 12 horas
— 6a dicitur rota ventaliorum, habens dentes 48, et est superior, et est etiam in dicta rota unum paignonum, habens 8 dentes
— 7a dicitur rota arresti habens dentem unum et est extra in parte posteriori. Explicit. Deo gratias.

your movement to one revolution at each hour because it is going too fast, you should make a pinion in the arbor of the movement wheel which has 6 teeth or more or fewer according to what
[fol. 66r] *you see is to be done; and if you should make 54 teeth in the wheel where the pins are, thus it will have 9 teeth between two pins, if the movement wheel and the pinion with six teeth will make one revolution and a half in each hour; and if you make 12 pins, you should make 108 teeth.*
[R] [These are] *good ways to make small clocks for when, as has been said, the movement wheel cannot be adjusted so that it does not make more than one turn at each hour; and these small clocks are made to strike quickly inside the bell or outside, and the strike* [train] *is made by three wheels.*

[S] [The following text is a summary of the treatise in Latin]
The rest is supplied by the discretion of the craftsman
Short recapitulation
In the clock are seven wheels:
— the first is called the movement wheel, it is large, having 144 teeth, it is positioned in the front part, completing a revolution per hour;
— the second is called the resisting or meeting [wheel], and is smaller, having 45 teeth, and is above the first, completing one revolution in the fifth part of an hour;
— the third, anterior, called dial [wheel], *smaller than the second, having 48 teeth;*
— the fourth is dedicated to striking the bell, lifts the hammer, having 96 teeth and 12 pins, and is behind, and is larger than the three previous;
— the fifth is called the hours wheel, between two central pillars, and is smaller, having 78 teeth. In the external periphery and in this wheel are two internal teeth, and it has 12 notches, each a tooth larger, and when it locks into its notch and before it exits it strikes one blow and in the next two blows, and in the third three, and so on up until 12 hours;
— the sixth is called the fan wheel, having 48 teeth, and is above, and in this wheel there is one pinion having 8 teeth;
— the seventh is called the stop wheel having one tooth and is outside in the rear part.
The end. Thanks be to God.

or heavy foliot is not practical. Since small clocks are considered here as a special case the implication is that most of the rest of the treatise applies to large clocks.

[S] This summary states that there are seven wheels, while the main text refers to a clock of six wheels, the discrepancy being accounted for by the dial wheel. The escape wheel is said to have 45 teeth and rotate in a fifth of an hour, but this gives a beat of 8 seconds, which is far too slow.

A count of 48 teeth for the dial wheel is mentioned here for the first time, and implies a twelve-hour dial and the usual four pronged pinion-of-report.

The two internal teeth in the 'hours wheel' (count wheel) appear to be the combined double notch for the 1 o'clock and 12 o'clock strikes. The notches are here stated to be on the external periphery of the count wheel, while in the main text they are on the inside of the rim.

The counts of the fly wheel and its pinion are given as 48 teeth and 8 leaves respectively, but they are not important as they only govern the speed of striking. Either this actually refers to another wheel or it was simply given as a convenient number to choose. It may confirm that this Latin summary was written by a different man not familiar with clocks.

The stop or locking wheel is said to have one tooth and to be 'outside in the rear part'. How the locking wheel or pin could be positioned outside the rear part is not clear. It may refer to an external fly with a locking pin or arm on its arbor, as was often used on early iron clocks with two-wheeled striking trains, but in both the main text and this summary a three-wheel train is clearly described.

Appraisal

From what few constructional details are given it appears that the author is primarily giving advice on the design of turret clocks of the type found on medieval public buildings throughout Continental Europe. What is described is a posted-frame clock with the hammer arbor pivoted at the side between the corner posts, with the end-to-end trains being either side of a count wheel pivoted between two central movement bars. The dial-work might have called for the use of additional frame bars, and certainly would have done if the dial was at any distance from the clock frame. The bell, worked by a pull-wire, is mounted independently, probably above the movement. The implication is that by the end of the fourteenth century the general layout and construction of clocks was already in the basic form that was to endure for another five centuries. It contains the earliest known mention of count-wheel striking, which uses the specifically French, and later English, feature of a central count wheel. Earlier accounts are either of clocks that do not include striking (de Dondi, 1365)[18] or are very complex, without a count wheel (Richard of Wallingford, 1327).[19]

The Treatise was written for a class of metal-workers already familiar with clockwork. It shows that in France the second half of the fourteenth century was a period of considerable experimentation and ingenuity in clockmaking, and that various traditions of clockmaking, including alternative technical features, had already been developed, especially regarding the arrangements for astronomical displays and striking.[20]

Originally there may have been diagrams to accompany the text as without them it would be difficult for an artisan to make a clock following the text alone. There is a possibility that it may have been a copy of an earlier document, which might explain the errors that have crept in.

The Treatise is the earliest surviving manual for clockmakers in Europe, and as such is of unique importance. It is probable that other similar sets of practical instructions or work-shop manuals were compiled for clockmakers, both in France and in other countries, but they have either not survived

18. H. Alan Lloyd, *Some Outstanding Clocks over Seven Hundred Years 1250–1950* (1958), pp. 9–24.

19. Daryl Bender, 'A Proposal for the Striking Mechanism on the Wallingford Clock', *Antiquarian Horology*, Vol 24, No. 2 (Summer 1998), 134–140; Kenneth J. Ming. 'The Twenty-Four Hour Striking Mechanism Described in the Richard of Wallingford Manuscript', *Antiquarian Horology*, Vol 25, No 1 (Sept 1999), 85–6.

20. For instance the astronomical clocks of Jean Fusoris whose earliest clocks date from the 1390s; see Poulle's obituary (note 6).

or have not yet been rediscovered. The centuries following the compilation of the Treatise saw the appearance of quite detailed descriptions of many notable individual clocks in various parts of Europe, and also the formulation of regulations for clockmakers and their apprentices,[21] but it was not until the second half of the seventeenth century, nearly three hundred years after the Treatise was compiled, that the first books on the craft of clockmaking came to be published, e.g. in Germany Gaspar Schott *Technica curiosa* (1664), in Italy Giuseppe da Capriglia *Misura del tempo* (1665), and in England John Smith *Horological dialogues* (1675) and William Derham *The artificial clockmaker* (1696). The next practical treatise in French for clockmakers, that of Beuriot who explains how to make a lantern clock, did not appear until 1719.[22]

21. G. H. Baillie. *Clocks and watches; an historical bibliography* (1951)

22. Père Beuriot, *Horlogéographie pratique ou la manière de faire les horloges à poids [...]* (Rouen, 1719), partially reprinted in Jean-Claude Sabrier, *Les horloges lanternes françaises: les trois dernières parties de l'ouvrage du Père Beuriot, Horlogéographie pratique rééditée avec une introduction* (Rogers Turner Books reprint).