Chapter 26 **(Oechslin: 7.1)**

Rinderle's clock in Furtwangen (1787)

This chapter is a work in progress and is not yet finalized. See the details in the introduction. It can be read independently from the other chapters, but for the notations, the general introduction should be read first. Newer versions will be put online from time to time.

26.1 Introduction

The clock described here was constructed in 1787 by Thaddäus Rinderle, born Matthias Rinderle (1748-1824). The case was made by Matthias Faller (1707-1791).[1]

Rinderle became a Benedictine and priest in 1772. He studied mathematics in Salzburg and invented optical and mechanical instruments.[2]

The history of the ownership of Rinderle's geographical-astronomical clock is very well known[3] and in 1859 it entered the collection if the Furtwangen horology school, and later the *Furtwangen Uhrenmuseum* where it is now held (figure 26.1). There is also a 16-pages manuscript of the clock, presumably by Rinderle.[4]

Rinderle's clock has two dials on top of each other.[5] The largest dial

[1]See [15, p. 78] and [2].

[2]For a comprehensive biography of Rinderle, see Schmidt's work [15]. The geographical-astronomical clock is covered especially on pages 73-81. A more recent biographical notice is that of Schäffner, but I haven't seen it [14]. There are numerous other mentions of Rinderle, of which I am giving a few in the references section. Lübke mentioned Rinderle's clock, but with a wrong illustration [9, p. 240-241]. In his article on the Johann brothers, Abeler has suggested that Nicolaus Alexius Johann may have been in touch with Rinderle, before or after 1781 [1, p. 203].

[3][15, p. 80]

[4][15, p. 75] The manuscript was reproduced and transcribed in 2007 [19].

[5]The fundamental descriptions of the clock are those of Wenzel [19] and Oechslin [12]. One of the first descriptions of Rinderle's clock is in volume 3 or Ruef's *Freyburger Beyträge* in 1790 [13, p. 494-495]. There we also learn that Rinderle had built a calculating machine

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Figure 26.1: Thaddäus Rinderle's clock (1787). (source: Wikipedia)

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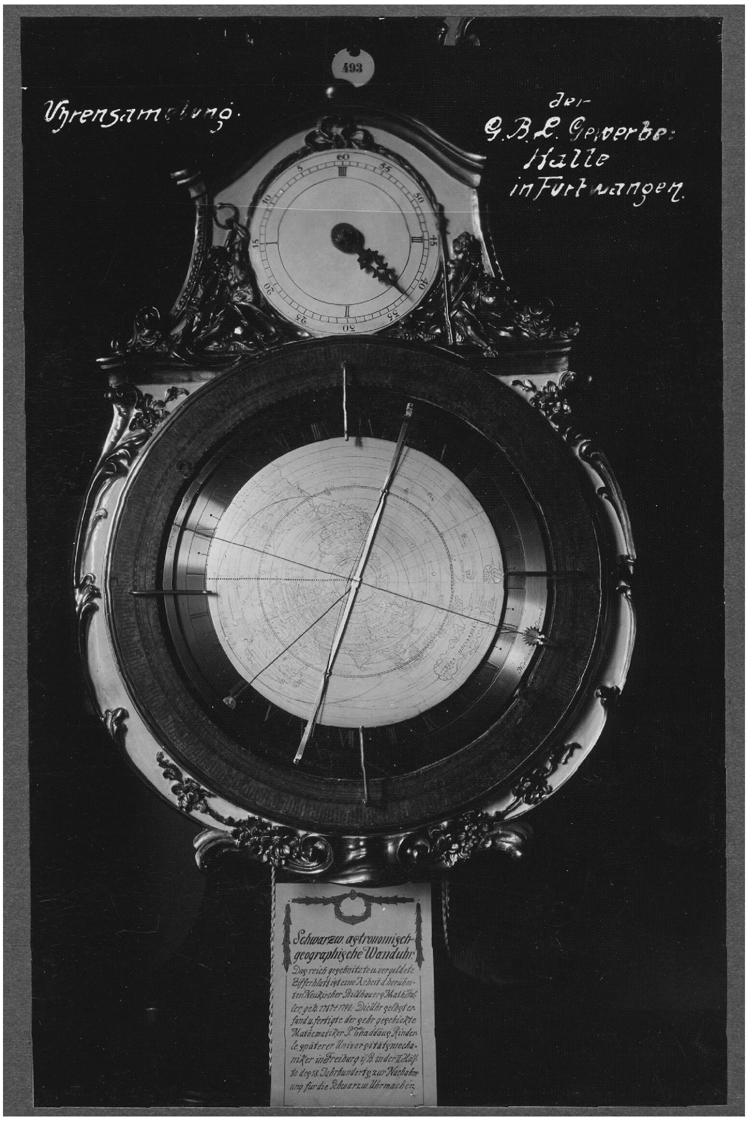

Figure 26.2: Thaddäus Rinderle's clock (1787). (source: `https://global.museum-digital.org`, licence CC BY-SA)

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displays a fixed calendar at its rim, a Northern planisphere, the motion of the Sun (which also serves to indicate the time) and of the Moon, the lunar nodes, and the limit between day and night. The small dial at the top shows the minutes which move counterclockwise.

The clock was studied in the 1980s by Johann Wenzel, but his study was left unpublished. Also at the beginning of the 1980s, Rinderle's clock was faithfully reproduced by Wilfried Dorer.[6] Meanwhile, in 1996, Oechslin described Rinderle's clock [12], not knowing about Wenzel's work. Oechslin did not have the opportunity to disassemble the clock [12, p. 5] and used details on the clock provided by Richard Mühe and Beatrice Techen from the Furtwangen museum.

And when Wenzel's work was published in 2007 [19], it didn't mention Oechslin's work at all and it is unfortunate that the *Furtwangen Uhrenmuseum* did not attempt a consolidate work. The 2007 book also gives a facsimile and transcription of Rinderle's handwritten description of the clock, presumably from 1787. This description does however not enter into the details of the gears. Finally, Hahn also published a summary of the clock in 2008 and suggested a number of improvements in the gears [6].

Now, there are basically two independent descriptions of the clock, that of Wenzel and that of Oechslin, and they do not provide exactly the same teeth-counts and conclusions. I will therefore split this analysis in two parts, one for Oechslin's description, and one for Wenzel's description. I have chosen this order, because it is the order of publication, but also because some errors found in Oechslin's description are corrected in Wenzel's description.

26.2 Oechslin's description

As mentioned above, Rinderle's clock was not directly examined by Oechslin, and this certainly explains some of the problems mentioned in this section.[7]

26.2.1 The base motions and assumptions

When working through Oechslin's plan of the clock, things are somewhat confusing, because one is tempted to assume that the central arbor makes a turn in 24 hours on the main dial and that the hand of the small dial shows the minutes and thus makes a turn in one hour. But these assumptions reveal inconsistencies. For instance, assuming that the arbor of the small dial makes a turn in 60 minutes, Oechslin deduced that the central arbor 7 of the main dial

working on 13 places and for the four operations (see also Schmidt [15, p. 64] and Wenzel [19, p. 37]). Another early description of the clock is that of Steyrer in 1796 [18, p. 23-29]. After his death, Schneller also devoted a few pages to the clock [16]. Several other shorter mentions were published later.

[6] [19, p. 38]

[7] For Oechslin's description, see particularly [12, p. 37, 50-51].

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makes a turn in 26.1333... hours. Moreover, even if we assume that something is wrong in the train from the small dial to the main dial, and that the central arbor makes a turn in 24 hours (as suggested by Oechslin's drawing), we still find very bad values for the motion of the Sun (366.2468... days) and the Moon (27.3964... days).

After spending some time with Oechslin's plan, and before I even read Wenzel's analysis, I came to the conclusion that the central arbor 7 of the main dial is not meant to make a turn in 26.1333... hours, and not even in 24 hours, but in one sidereal day. This arbor carries the planisphere and in that case the motion of the planisphere should be thought of with respect to the stars.

This assumption is supported by the periods which are then obtained for the Moon and the Sun, although the period of precession of the nodes remains somewhat inaccurate.

However, even with this assumption, there seems to be a problem with the small dial. The minute hand does not make a turn in one hour, and it isn't clear what would have to be corrected so that the minute hand turns in one hour. We will see below that there is a solution to this problem, but meanwhile I was looking for an even simpler one, which is that since the hours of the main dial are sidereal hours, a possibility would be that the small dial also shows the sidereal time. And indeed, if we assume that the small minute hand makes a turn in 60 sidereal minutes, then the ratio between the velocity of the minute arbor and that of the central arbor 7 must be 24. This isn't the case with the values given by Oechslin, but it can easily be fixed if the 98-teeth wheel on arbor 7 is given instead 90 teeth, and this is what I will assume below. However, again, we will see below a better solution, but which entails more changes to the gears.

26.2.2 The going work

The clock is weight-driven and regulated by a pendulum. Assuming that the clock is based on sidereal time, I will first express the velocities of the wheels in turns per sidereal days (t/sd), and not mean days. We start with

$$\mathrm{V}_5^0 = 24 \text{ t/sd (counterclockwise)} \tag{26.1}$$

then

$$\mathrm{V}_3^0 = \mathrm{V}_5^0 \times \frac{50}{12} \times \frac{9}{100} = \mathrm{V}_5^0 \times \frac{3}{8} = 9 \text{ t/sd} \tag{26.2}$$

The velocity of the escape wheel then is

$$\mathrm{V}_1^0 = \mathrm{V}_3^0 \times \left(-\frac{100}{9}\right) \times \left(-\frac{72}{8}\right) = \mathrm{V}_3^0 \times 100 = 900 \text{ t/sd} \tag{26.3}$$

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This gives a period of

$$\mathrm{P}_1^0 = \frac{1}{900}\ \mathrm{sd} = 96 \text{ sidereal seconds} \tag{26.4}$$

and since the escape wheel has 36 teeth, this gives a half-oscillation of the pendulum in 4/3 sidereal seconds. This may seem strange, but it is manageable.

However, in order to express these values in seconds we need to choose a value for the sidereal day, because this value is not contained in the clock. So, this also means that the ratios I will give will not have any particular significance with respect to Rinderle. I will assume that a sidereal day is $\sigma = 86164/86400$ mean days, but the reader can experiment other ratios and will obtain different values for the astronomical motions.

So, I now assume that

$$\mathrm{V}_5^0 = 24 \times \frac{1}{\sigma} \tag{26.5}$$

$$\mathrm{V}_3^0 = 9 \times \frac{1}{\sigma} \tag{26.6}$$

26.2.3 The motion of the planisphere

The central arbor 7 of the main dial moves a Northern planisphere. We first compute the velocity of the intermediate arbor 6:

$$\mathrm{V}_6^0 = \mathrm{V}_3^0 \times \left(-\frac{61}{61}\right) = -\mathrm{V}_3^0 = -9 \times \frac{1}{\sigma} \tag{26.7}$$

Then, the velocity of arbor 7 is (with the correction $98 \to 90$)

$$\mathrm{V}_7^0 = \mathrm{V}_6^0 \times \left(-\frac{10}{90}\right) = \frac{1}{\sigma} \tag{26.8}$$

$$\mathrm{P}_7^0 = \sigma \tag{26.9}$$

that is one turn in one sidereal day.

26.2.4 The motion of the Moon

The motion of the Moon on tube 9 is derived from that of the central arbor 7:

$$\mathrm{V}_9^0 = \mathrm{V}_7^0 \times \left(-\frac{23}{103}\right) \times \left(-\frac{17}{104}\right) = \mathrm{V}_7^0 \times \frac{391}{10712} \tag{26.10}$$

$$\mathrm{P}_9^0 = \frac{10712}{391}\sigma \tag{26.11}$$

If we take $\sigma = 86164/86400$, we find $\mathrm{P}_9^0 = 27.3215\ldots$ days. This is an approximation of the tropical month.

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26.2.5 The motion of the Sun

The motion of the Sun on tube 11 is derived from that of the Moon:

$$\mathrm{V}_{11}^0 = \mathrm{V}_9^0 \times \left(-\frac{36}{72}\right) \times \left(-\frac{19}{127}\right) = \mathrm{V}_9^0 \times \frac{19}{254} \tag{26.12}$$

$$= \mathrm{V}_7^0 \times \frac{391}{10712} \times \frac{19}{254} = \mathrm{V}_7^0 \times \frac{7429}{2720848} \tag{26.13}$$

$$\mathrm{P}_{11}^0 = \frac{2720848}{7429}\sigma \tag{26.14}$$

If we take $\sigma = 86164/86400$, we find $\mathrm{P}_{11}^0 = 365.2464\ldots$ days. This is an approximation of the tropical year.

26.2.6 The motion of the lunar nodes

The lunar nodes are shown by a hand carried by tube 14. This hand ends with the symbols ☊ (ascending node) and ☋ (descending node). The motion of this tube is derived from that of the Sun:

$$\mathrm{V}_{14}^0 = \mathrm{V}_{11}^0 \times \left(-\frac{40}{94}\right) \times \left(-\frac{20}{24}\right) \times \left(-\frac{10}{76}\right) = \mathrm{V}_{11}^0 \times \left(-\frac{125}{2679}\right) \tag{26.15}$$

$$= \mathrm{V}_7^0 \times \frac{7429}{2720848} \times \left(-\frac{125}{2679}\right) = \mathrm{V}_7^0 \times \left(-\frac{48875}{383639568}\right) \tag{26.16}$$

$$\mathrm{P}_{14}^0 = -\frac{383639568}{48875}\sigma \tag{26.17}$$

If we take $\sigma = 86164/86400$, we find $\mathrm{P}_{14}^0 = -7827.9624\ldots$ days. This is a very bad approximation of the period of precession of the lunar nodes which is about 6798 days. This bad value may be due to wrong gear ratios. For instance, with a ratio 10/66 instead of 10/76 in the train, we would have found the almost perfect value of $-6797.9673\ldots$ days. The value is negative, because there is a retrogradation of the lunar nodes. See [12, p. 51] on that motion.

26.2.7 The day/night separation

On the front dial, we can also see a (usually) bent line. This is actually a spring which is bent either towards the Sun or against it, and it shows which part of the Earth is lit or not. At the equinoxes, this spring is a straight line. This bending is caused by a fixed cam which is located behind the planisphere. This cam is shown in Wenzel's analysis [19, p. 21].[8] It is the motion of the Sun in one year which causes the spring to bend in one direction or the other. Similar constructions had been used in earlier clocks.[9]

[8]See also [12, p. 141].

[9]See for instance Fowler [3].

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26.3 Wenzel's analysis

Wenzel's analysis published in 2007 [19] assumes that arbor 3, which is the rope arbor, makes a turn in two hours, but there are several differences in the gears with respect to Oechslin's drawing. This is certainly explained by the fact that Oechslin didn't use first-hand data for the clock. First, arbor 6 carries a 73-teeth wheel and not a 61-teeth wheel, which may have been in typo in Oechslin's notes. Second, the central arbor 7 carries a 100-teeth wheel, and not a 98-teeth wheel as in Oechslin's notes. The train between the small dial and the main dial is also slightly different. Oechslin has an arbor 4 with two pinions of 12 and 9 teeth, but Wenzel describes two pinions of 12 teeth [19, p. 27]. If Wenzel's description is correct, and if we assume the small dial to show the minutes,

$$V_5^0 = 24 \tag{26.18}$$

then the velocity of arbor 3 is

$$V_3^0 = V_5^0 \times \frac{50}{12} \times \frac{12}{100} = V_5^0 \times \frac{1}{2} = 12 \tag{26.19}$$

$$P_3^0 = \frac{1}{12} = 2 \text{ hours} \tag{26.20}$$

From this it also follows that the velocity of the escape wheel is

$$V_1^0 = V_3^0 \times \left(-\frac{100}{9}\right) \times \left(-\frac{72}{8}\right) = V_3^0 \times 100 = 1200 \tag{26.21}$$

$$P_1^0 = \frac{1}{1200} = 72 \text{ s} \tag{26.22}$$

and given that the escape wheel has 36 teeth, we obtain a half-oscillation in one second, that is that of a seconds pendulum. We have therefore a much more natural configuration than that implied by Oechslin.

The central arbor 7 then has the following velocity:

$$V_7^0 = V_3^0 \times \left(-\frac{61}{73}\right) \times \left(-\frac{10}{100}\right) = V_3^0 \times \frac{61}{730} = 12 \times \frac{61}{730} = \frac{366}{365} \tag{26.23}$$

$$P_7^0 = \frac{365}{366} = 23 \text{ h } 56 \text{ m } 3.9344 \text{ s} \tag{26.24}$$

This also agrees with my first conclusions (after having analyzed Oechslin's drawing and before having read Wenzel's analysis).

The remaining periods can be obtained like in the case of Oechslin, by taking $\sigma = 365/366$. We thus find

26.3.1 The motion of the Moon

$$P_9^0 = \frac{10712}{391}\sigma = \frac{10712}{391} \times \frac{365}{366} = \frac{1954940}{71553} = 27.3215\ldots \text{ days} \tag{26.25}$$

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26.3.2 The motion of the Sun

$$\mathrm{P}^0_{11} = \frac{2720848}{7429}\sigma = \frac{2720848}{7429} \times \frac{365}{366} = \frac{496554760}{1359507} = 365.2461\ldots \text{ days} \tag{26.26}$$

26.3.3 The motion of the lunar nodes

In the case of the nodes, Wenzel gives the teeth-count 66 instead of Oechslin's 76, as I had suggested above (before having read Wenzel's analysis). We have

$$\mathrm{V}^0_{14} = \mathrm{V}^0_{11} \times \left(-\frac{40}{94}\right) \times \left(-\frac{20}{24}\right) \times \left(-\frac{10}{66}\right) = \mathrm{V}^0_{11} \times \left(-\frac{250}{4653}\right) \tag{26.27}$$

$$= \mathrm{V}^0_{7} \times \frac{7429}{2720848} \times \left(-\frac{250}{4653}\right) = \mathrm{V}^0_{7} \times \left(-\frac{928625}{6330052872}\right) \tag{26.28}$$

$$\mathrm{P}^0_{14} = -\frac{6330052872}{928625}\sigma = -\frac{6330052872}{928625} \times \frac{365}{366} \tag{26.29}$$

$$= -\frac{77015643276}{11329225} = -6797.9621\ldots \text{ days} \tag{26.30}$$

26.4 Summary on the errors and interpretation of the clock

It appears that there are notable differences between the descriptions of Oechslin and Wenzel. These differences are certainly due to Oechslin using some other unreliable source of data for the clock.

In a first interpretation, I assumed that the small dial did not show the (mean) minutes, but the sidereal minutes, but this assumption rested on my trust into most of the train given by Oechslin between the main dial and the small dial. I expected some figures to be wrong, but I intended to minimize the number of errors, and I found that changing the number of teeth of the 98-teeth wheel on arbor 7 to 90 solved the problem. It was perhaps not entirely satisfying, but it was a possible solution.

However, Wenzel's analysis made it possible to go back on the right track, with a small dial really showing the minutes, a rope arbor with a simple period (two hours), and a central arbor 7 making a turn in a sidereal day. But this entailed three corrections in the train, instead of the only one I had tried to find. I am now siding with Wenzel's analysis, which seems to be the best one.

This does not explain why Oechslin's drawing and calculations contain four teeth-count errors, and why these errors were not corrected by him, given that he noticed that some of the periods he obtained were incorrect.

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26.5 References

[1] Jürgen Abeler. Die Gebrüder Johann, Augustinerpatres und Uhrmacher. Bericht über eine Forschung des Wuppertaler Uhrenmuseums. *Mainzer Zeitschrift*, 69:197–205, 1974.

[2] Hermann Brommer and Stephanie Zumbrink. *Matthias Faller — der Barockbildhauer aus dem Schwarzwald*. Lindenberg im Allgäu: Fink, 2007. [not seen].

[3] Ian David Fowler. Die sogenannten „Gutwein-Uhren". *Klassik-Uhren*, 21(3):16–29, 1998.

[4] Pius Gams. Nekrologien der in den Jahren 1802-1813 in der jetzigen Erzdiözese Freiburg aufgehobenen Männerklöster Benedictiner-, Cistercienser-, Norbertiner-Ordens und der regulierten Chorherren. *Freiburger Diöesan-Archiv*, 13:237–272, 1880. [see p. 253 on Rinderle].

[5] Johannes Graf. The first Black Forest clock — How a fake impacted our notion of clock history. In Gianenrico Bernasconi and Susanne Thürigen, editors, *Material histories of time — Objects and practices, 14th-19th centuries*, pages 211–224. Berlin: Walter De Gruyter, 2020.

[6] Hermann-Michael Hahn. Das Uhrwerk der astronomisch-geografischen Uhr von Thaddäus Rinderle — Versuch einer gedanklichen Rekonstruktion. *Chronometrophilia*, 63:62–72, 2008.

[7] Jutta Krimm-Beumann, editor. *Die Benediktinerabtei St. Peter im Schwarzwald*, volume 3/17 of *Germania Sacra*. Berlin: Walter De Gruyter, 2018. [see in particuler p. 563-564 on Rinderle].

[8] Pirmin August Lindner. Die Schriftsteller und Gelehrten der ehemaligen Benediktiner-Abteien im jetzigen Großherzogthum Baden vom Jahre 1750 bis zur Säcularisation. *Freiburger Diöesan-Archiv*, 20:79–140, 1889. [see p. 118 on Rinderle].

[9] Anton Lübke. *Das große Uhrenbuch — Von der Sonnenuhr zur Atomuhr*. Tübingen: Ernst Wasmuth, 1977.

[10] J. Lüroth. Thaddäus Rinderle. In Friedrich von Weech, editor, *Badische Biographieen*, volume 2, page 188. Heidelberg: Fr. Bassermann, 1875.

[11] Julius Mayer. *Geschichte der Benediktinerabtei St. Peter auf dem Schwarzwald*. Freiburg im Breisgau: Herder, 1893. [see p. 224 for Rinderle].

[12] Ludwig Oechslin. *Astronomische Uhren und Welt-Modelle der Priestermechaniker im 18. Jahrhundert*. Neuchâtel: Antoine Simonin, 1996. [2 volumes and portfolio of plates].

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[13] Johann Kaspar Adam Ruef, editor. *Freyburger Beyträge zur Beförderung des ältesten Christenthums und der neuesten Philosophie*, volume 3. Ulm: Wohler, 1790. [see p. 494-495 on Rinderle's clock and calculating machine].

[14] Werner Schäffner. *Thaddäus Rinderle aus Staufen — Mathematikprofessor an der Albertina in Freiburg (1748-1824): über sein Mönchsleben im Benediktinerkloster St. Peter und seine Tätigkeit als Hochschullehrer*. Staufen im Breisgau: Werner Schäffner, 2014. [not seen].

[15] Kurt Schmidt. *Thaddäus Rinderle (1748-1824), Mönch und Mathematiker*, volume 25 of *Studien und Mitteilungen zur Geschichte des Benediktiner-Ordens und seiner Zweige. Ergänzungsbände*. St. Ottilien: EOS Verlag Erzabtei St. Ottilien, 1981.

[16] Julius Franz Schneller. *Rede auf Thaddäus Rinderle, Professor der Mathematik, bei dessen Akademischer Todtenfeier in dem Münster zu Freiburg am 10. November 1825 gesprochen*. Freiburg im Breisgau: F. X. Kerkenmayer, 1826.

[17] Heinrich Schreiber. *Geschichte der Albert-Ludwigs-Universität zu Freiburg im Breisgau*, volume 3. Freiburg: Franz Xaver Wangler, 1868. [see p. 116-118 for Rinderle].

[18] Franz Steyrer. *Geschichte der Schwarzwälder Uhrenmacherkunst, nebst einem Anhange von dem Uhrenhandel derselben, Eine Beylage zur Geschichte des Schwarzwaldes*. Freiburg im Breisgau: Felner, 1796. [see p. 23-29 for Rinderle].

[19] Johann Wenzel. *Die astronomisch-geographische Uhr von Pater Thaddäus Rinderle*. Furtwangen: Deutsches Uhrenmuseum, 2007.

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