Chapter 16 **(Oechslin: 8.8)**

Hahn's globe clock in Karlsruhe (1785)

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.

16.1 Introduction

The clock described here was constructed in 1785 by Philipp Matthäus Hahn (1739-1790)[1] and is located in in a private collection in Karlsruhe.[2] It is one of a number of double-globe clocks made by Hahn. This clock is made of two similar and interconnected parts. These two parts have each a cubic base and are topped by globes. The right part contains the going work and is topped by a geographic sphere. The left part has a calendar dial and is topped by a celestial sphere showing the motion of the sky, of the Sun and of the Moon.

The structure of both parts is similar to that if the double-globe clock in Villingen (Oechslin 8.9), except that in Villingen the going work is in the middle of the two globe components, and not part of one of them.

16.2 The going work

The going work is located in the right part of the double globe clock. It displays the hours on a 24-hour dial and the minutes on an smaller central dial. The clock is spring-driven and regulated by a pendulum. The barrel wheel on arbor

[1]For biographical details on Hahn, I refer the reader to the chapter on the Ludwigsburg *Weltmaschine* (Oechslin 8.1).

[2]See especially the 1989 exhibition catalogue [2, p. 425-426].

1 makes one turn clockwise (from the front) in 44 hours.

$$T_1^0 = \frac{24}{44} = \frac{6}{11} \tag{16.1}$$

The going train leads to arbor 3 which is that of the minute hand. It makes one turn in an hour:

$$T_3^0 = T_1^0 \times \left(-\frac{72}{12}\right) \times \left(-\frac{66}{9}\right) = \frac{6}{11} \times 44 = 24 \tag{16.2}$$

This motion is also that of a tube surrounding that arbor, and this motion is used to obtain that of the hour hand on tube 7:

$$T_7^0 = T_3^0 \times \left(-\frac{12}{48}\right) \times \left(-\frac{10}{60}\right) = 1 \tag{16.3}$$

Tube 7 thus makes one turn clockwise in 24 hours.

The motion of tube 7 is transferred to geographical globe above and to the left component of the double-globe clock as described below.

16.3 The geographic sphere

The geographic sphere is on the right of the double-globe clock and shows the motion of the Earth around a vertical axis. It also shows the limit between day and night, and thus moves a ring according to the motion of the Sun. However, since the orientation of the Earth's axis is not taken into account, this representation is approximative.

The motion of the sphere is derived from the motion of tube 7 in the going work. Tube 7 is coupled to tube 8, and tube 8 carries a 57-teeth which used to transfer its motion to a 57-teeth wheel on arbor 26, whic in turn transfers its motion to a 79-teeth wheel on arbor 27 and finally to another 57-teeth wheel on the vertical arbor 28. That arbor is the central arbor moving the Earth sphere. We have

$$V_{28}^0 = T_8^0 \times \frac{57}{57} \times \frac{57}{79}\frac{79}{57} = T_8^0 = 1 \tag{16.4}$$

Consequently, the vertical arbor 28 makes one turn counterclockwise (seen from above) in one day.

The arbor 28 also carries a 7-leaves pinion which is used to obtain the motion of tube 30:

$$V_{30}^0 = V_{28}^0 \times \left(-\frac{7}{118}\right) \times \left(-\frac{3}{65}\right) = V_{28}^0 \times \frac{21}{7670} = \frac{21}{7670} \tag{16.5}$$

$$P_{30}^0 = \frac{7670}{21} = 365.2380\ldots \text{ days} \tag{16.6}$$

This is an approximation of the tropical year and the same value is given by Oechslin. Tube 30 does therefore make one turn counterclockwise (as seen from above) in one year. This tube seems to move the limit day/night.

The same ratio $\frac{7670}{21}$ was used in the astronomical clock in Basel (Oechslin 8.10) constructed in 1775 and in the double-globe clock of Villingen (Oechslin 8.9).

This, however, is not entirely correct. If the limit day/night moves in one year, then the Earth should actually make one turn in one sidereal day, and not 24 jours as it does now (or seems to be doing). This suggests a construction error, and that the sidereal day motion produced for the left globe was initially also meant to be used in the geographical globe. The same problem occurs in the Villingen clock.

16.4 The celestial sphere

The celestial sphere shows the motion of the sky, as well as the motion of the Sun and the Moon. It is located on top of a similar base as the going work, which displays the day of the week and the day of the month.

The motion of the celestial sphere is obtained from that of tube 7 in the going work. That tube is coupled to tube 8, and tube 8 carries a 57-teeth wheel meshing with a 29-teeth wheel on the horizontal arbor 9 connecting the two parts of the clock and visible from the outside.

In the left component, that arbor transmits its motion to arbor 16, and then to the vertical arbor 17 which is the input to the celestial sphere mechanism. We have

$$\mathrm{V}_{17}^{0} = \mathrm{T}_{8}^{0} \times \left(-\frac{57}{29}\right) \times \left(-\frac{35}{33}\right) \times \left(-\frac{38}{79}\right) \tag{16.7}$$

$$= \mathrm{T}_{8}^{0} \times \left(-\frac{25270}{25201}\right) = -\frac{25270}{25201} \tag{16.8}$$

This is the usual value used by Hahn for the velocity of the sidereal day. Hence, arbor 17 makes one turn clockwise (from above) in one sidereal day.

However, arbor 17 actually moves an entire frame containing gears which are themselves use to produce the motions of the Sun and the Moon. Arbor 17 moves the celestial sphere which rotates around the vertical axis representating the axis of the Earth. But the Sun and the Moon revolve (approximately) around the axis of the ecliptic, which is tilted by 23.5 degrees. The Sun is fixed on tube 25 and the Moon on tube 22. In order to compute the motions of these two tubes, we first compute the motions of tubes 21 (Moon) and 24

(Sun) with respect to the celestial globe (frame 17):

$$\begin{aligned}
V_{21}^{17} &= V_{18}^{17} \times \left(-\frac{53}{53}\right) \times \left(-\frac{53}{66}\right) \times \left(-\frac{3}{66}\right) = V_{18}^{17} \times \left(-\frac{53}{1452}\right) && (16.9)\\
&= -V_{17}^{18} \times \left(-\frac{53}{1452}\right) = V_{17}^{0} \times \frac{53}{1452} && (16.10)\\
&= -\frac{25270}{25201} \times \frac{53}{1452} = -\frac{669655}{18295926} && (16.11)\\
P_{21}^{17} &= -\frac{18295926}{669655} = -27.3214\ldots \text{ days} && (16.12)\\
V_{24}^{17} &= V_{21}^{17} \times \left(-\frac{32}{53}\right) \times \left(-\frac{14}{113}\right) = V_{21}^{17} \times \frac{448}{5989} && (16.13)\\
&= -\frac{669655}{18295926} \times \frac{448}{5989} = -\frac{2830240}{1033719819} && (16.14)\\
P_{24}^{17} &= -\frac{1033719819}{2830240} = -365.2410\ldots \text{ days} && (16.15)
\end{aligned}$$

So, tube 21 makes one turn clockwise (from above) in one tropical month, and tube 24 makes one turn clockwise in one tropical year. The latter is given by Oechslin, and also in sidereal days. The former is also given by Oechslin, in sidereal days, and then in days, hours, minutes, and seconds, but with an incorrect conversion (27.425075) to its decimal representation. The same error appears in the Zurich double globe clock (Oechslin 8.7), but the conversion was correctly made for the double globe clock in Villingen (Oechslin 8.9).

The same value for the tropical month was used in the double-globe clock located in Zurich (Oechslin 8.7) constructed that same year in 1785. And the value of the tropical year was used in the globe clock in Darmstadt (Oechslin 8.6), also in 1785. Both were also used in the double-globe clock in Villingen (Oechslin 8.9).

Finally

$$\begin{aligned}
V_{22}^{17} &= V_{21}^{17} \times \left(-\frac{48}{48}\right) = -V_{21}^{17} = \frac{669655}{18295926} && (16.16)\\
V_{25}^{17} &= V_{24}^{17} \times \left(-\frac{48}{48}\right) = -V_{24}^{17} = \frac{2830240}{1033719819} && (16.17)
\end{aligned}$$

The Moon and the Sun rotate counterclockwise around the celestial sphere in one tropical month and one tropical year.

16.5 References

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

[2] Christian Väterlein, editor. *Philipp Matthäus Hahn 1739-1790 — Pfarrer, Astronom, Ingenieur, Unternehmer. Teil 1: Katalog*, volume 6 of *Quellen und Schriften zu Philipp Matthäus Hahn.* Stuttgart: Württembergisches Landesmuseum, 1989.