Chapter 30 **(Oechslin: 1.1)**

Stuart's clock in Salzburg (1735)

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.

30.1 Introduction

The clock described here was designed in 1735 by Bernard Stuart (1706-1755) and constructed by the clockmaker Jakob Pentele (or Bentele) (1701?-1773) and the cabinetmaker Thomas Ableuthner. It was made for Leopold Anton von Firmian (1679-1744), who was Prince-Archbishop of Salzburg from 1727 until his death. The Prince-Archbishop had a special interest in clocks.[1]

Stuart was born Alexander Stuart in 1706 (on March 31 according to Zauner,[2] or on November 30 according to Gärtner[3]) in Scotland to a noble family.[4]

When he had the required age, he was sent to a new seminary in Germany by his uncle Maurus Stuart who was himself a missionary. In 1725 he entered the Scots benedictine monastery in Regensburg which had been founded in the 11th century, where after having made the vows in 1727 he studied philosophy and theology. He became a priest in 1730 and was then (or in 1728?) sent to

[1] See Husty's account on Leopold's clocks and sundials [12].

[2] [30] This was then for instance copied by Wurzbach [29], although Wurzbach also used Gärtner's account.

[3] [9]

[4] The biographical information given here is drawn from Paricius [21], Stetten [24], Hübner [10], Lipowsky [16], Zauner [30], Pillwein [22], Gärtner [9], Esterl [4], Mayr [18], Wurzbach [29], Lindner [15], Ilg [13], Schulte [23], Fischer [5], Maurice [17, v.1, p. 249, 267], Abeler [1] and Husty [12]. A number of authors are merely copying what was written before them, and there are sometimes simplifications. There is in particular a doubt concerning Stuart's date of birth, as Zauner (1813) and Gärtner (1821) give different dates. I am not sure which one is right. I have tried to provide a consolidated biographical notice, and have added precise sources where needed. The most complete informations on Stuart are probably found in Husty's thesis [11], but I haven't seen it.

the Salzburg Nonnberg nun monastery as a chaplain.[5] This was for him the opportunity to study sciences and to make himself known at the University.

In 1733, he became professor of mathematics at the University of Salzburg, and he applied his knowledge to construction.

In 1735, Stuart designed and had constructed the astronomical clock described in this chapter. This clock is now located in the Salzburg Residenz.[6] Another tall-case astronomical clock probably made around 1730/1740 is attributed to Stuart and Pentele and is also located in the Salzburg Residenz.[7] It carries many dials and has a similar appearance to the great astronomical clock by Frater David in 1769, or the clock made by Pater Aurelius and located in Innsbruck.

In 1735, Stuart also signified to the Prince-Archbishop Leopold that the country was not having enough wood and gave a plan to make the moor stretches arable by removing the peat and using it as combustible.[8] Fischer writes that Stuart drained a large bog near Salzburg after a labour of three years [5, p. 148-149].

For his work on the moor stretches, Stuart was promoted in 1736 by the Prince-Archbishop. According to Paricius in 1753, Stuart was made clerical adviser to the Prince-Archbishop on January 11, 1736 and on April 12 he was made director of the public constructions of the entire land [21, p. 334-336].

From then to 1741, he remained professor at the University, but without giving lectures.

According to Stetten, in 1739 Stuart constructed a theater for the pupils of the Jesuit seminary in Augsburg.[9] In Augsburg, he also built a strong embankment on the river Lech, which Fischer says could still be seen in 1902. [5, p. 148-149]. The Imperial Court of Vienna also employed him as Inspector of Fortresses in Swabia. [5, p. 148-149]. Stuart also built a missionary house in Schwarzach near Salzburg [12, p. 349].

In 1741 he left Salzburg following accusations about construction matters and became director of the constructions in Augsburg.[10]. In 1742, he travelled

[5]Esterl gives the list of chaplains at the Nonnberg nun monastery and writes that Stuart was chaplain from 1728 to 1733 [4, p. 250-251]. This account seems to be based on Gärtner's account [9]. In 1880, Lindner also wrote that Stuart became chaplain of the Nonnberg monastery in 1728 [15, p. 234-235]. Husty also writes that Stuart came to Salzburg in 1728 [12, p. 349].

[6]This clock was mentioned as early as 1792 by Hübner who also mentioned a sundial by Stuart [10]. Wurzbach [29] also mentioned both based on Hübner's account. However, it was sometimes incorrectly dated to 1731, for instance by Doblhoff [2, p. 148]. This may be the source used by Schulte when he also dated the clock to 1731 in 1902. He also mentioned that it is located in Vienna [23, p. 798].

[7][12, p. 350-351]

[8]This is also mentioned by Mayr [18, p. 12].

[9]This was repeated by Füssli in 1779 [8, p. 649]. In 1779, Stetten gave some more details [25, p. 106-107]. See also Lindner [15, p. 234-235] and Fischer [5, p. 148-149].

[10]Jakob Pentele, who built the clock described here, was named a witness in the conflict that opposed the adjunct court architect Johann Kleber and Stuart, see [12, p. 349-350]. Kleber's name appears on the engraving of the 1735 astronomical clock (figure 30.2).

to Saint Petersburg where one of his brothers was a general in the Russian service.[11] There he was offered a 1000 ruble yearly salary if he could improve the teaching of mathematics in the Russian schools.

Because of the Nordic air, he returned to Germany. In 1743 he became abbot of his monastery in Regensburg[12] and the Archbishop of Mainz named him abbot of the Erfurt monastery.

In 1753, Paricius still mentioned Stuart as the current abbot of the Regensburg monastery and of Erfurt [21, p. 334-336]. Paricius also mentioned Stuart's uncle Maurus (1664-1720) who was an earlier abbot of the Scots monastery in Regensburg.

In 1755, because of his weak health, Stuart went to Ferrara. He called his brother Maurus Stuart who was prior in Würzburg, and they made their way to Rome together. Stuart died on his way to Rome.

Demonstrations of Stuart's knowledge are found in Salzburg, Augsburg and other places. He drew the plan of Schloss Leopoldskron.[13] Schloss Klessheim has also been improved by Stuart.[14] He has also proposed a new water pipe system from the Untersberg massif to Salzburg, but this project was not concretized.

Stuart did not publish a description of his astronomical clock, but he has published several issues of almanacs, at least for 1737 and 1738.[15]

Pentele (or Bentele or Bendele), on the other hand, was a Court clockmaker from the Allgäu area. From 1734 to 1740, he worked with Stuart and he also constructed a number of tower clocks [19]. Pentele also had a nephew who became clockmaker.[16]

It was first thought that the case was made by the cabinetmaker Simon Baldauf (1677-1753),[17] but it is now attributed to Thomas Ableuthner from Munich, as it bears its signature.[18]

30.2 Description and analysis of the clock

Stuart's clock is illustrated in figure 30.1. The clock was initially in Salzburg, then vanished at the time of the secularization. It resurfaced in Schloss Laxenburg near Vienna, and from there it went to the *Kunsthistorischesmuseum* in Vienna in 1879 [12, p. 348]. The clock is now exhibited in the Salzburg

[11] See also Fischer's account [5, p. 148-149].

[12] [5, p. 148-149]

[13] This is again mentioned by Lindner in 1880 [15, p. 234-235] and Fischer in 1902 [5, p. 148-149].

[14] Ilg comments on Stuart's improvement of Schloss Klessheim and gives a short biography of Stuart based on earlier accounts [13, p. 241].

[15] Lindner mentions Stuart's almanac for 1738 (*Ephemeris ecclesiastica, astronomica, astrologica, etc.*) [15, p. 234-235].

[16] [12, p. 353]

[17] [27]

[18] See especially [14] and [28].

Residenz which for centuries was the residence of the Prince-Archbishops of Salzburg.[19]

It is a Boulle work, in that its case uses the Boulle marquetry process. Apart from the use of the Boulle process, the clock is also somewhat unusual in appearance, it is 117 cm tall table clock, with three dials in an equilateral triangle, topped by a celestial globe. It is also shown on a copper plate from 1735 (figure 30.2).

Figure 30.1: Bernard Stuart's astronomical clock (1735). (source: Wikipédia)

[19]The clock was described by Döry-Jobaháza [3], but I haven't seen his article. It was also shown at the 1989 Hahn exhibition [26, p. 66]. The case was described by Koller, Loicht and Zehetner [14]. Stuart's clock was described by Frieß [6] and Oechslin [20, p. 52-53, 218].

Figure 30.2: Excerpt of a copper plate of Stuart's clock. (Salzburg Museum, Inv. 1137-96)

30.2.1 The going work

The clock is spring-driven, with a barrel and fusee,[20] and is regulated by a pendulum. There is also a maintaining power device.[21] The fusee arbor 1 makes a turn in 4 hours and drives the arbor 2 carrying the minute hand which makes one turn in an hour:

$$\mathrm{V}_1^0 = 6 \tag{30.1}$$

$$\mathrm{P}_1^0 = \frac{1}{6} = 4 \text{ hours} \tag{30.2}$$

$$\mathrm{V}_2^0 = \mathrm{V}_1^0 \times \left(-\frac{64}{16}\right) = -24 \tag{30.3}$$

$$\mathrm{P}_2^0 = -\frac{1}{24} = -1 \text{ h} \tag{30.4}$$

The 30-teeth escape wheel is on arbor 4 and makes a turn in 30 seconds:

$$\mathrm{V}_4^0 = \mathrm{V}_2^0 \times \left(-\frac{70}{7}\right) \times \left(-\frac{72}{6}\right) = \mathrm{V}_2^0 \times 120 = -2880 \tag{30.5}$$

$$\mathrm{P}_4^0 = -\frac{1}{2880} \text{ days} = -30 \text{ s} \tag{30.6}$$

The pendulum makes a half oscillation in 0.5 s and is about 25 cm long.

30.2.2 The three dials and the globe

The three dials and the globe are driven by the arbor 2 which makes one turn in an hour. This arbor is first directly led to the small dial located between the three large dials. This small dials merely shows the minutes of time.

This motion is then transferred to the three other dials.

30.2.2.1 The lower left calendrical and astronomical dial

From the outside to the inside, this dial shows a annual calendar with a number of feasts, then a ring with the signs of the zodiac (also in counterclockwise order), then a ring for the positions of the lunar nodes, then a ring for the Sun, then a disk for the phase of the Moon.

[20]Excellent illustrations of these parts are provided by Frieß [6, p. 364].
[21]It is also illustrated by Frieß [6, p. 364].

30.2.2.1.1 The motion of the Moon

The motion of arbor 2 is first used to move the hand of the Moon on the central arbor 11 of this dial. We have[22]

$$V_{11}^0 = V_2^0 \times \frac{1}{8} \times \left(-\frac{1}{82}\right) = V_2^0 \times \left(-\frac{1}{656}\right) = 24 \times \frac{1}{656} = \frac{3}{82} \tag{30.7}$$

$$P_{11}^0 = \frac{82}{3} = 27.3333\ldots \text{ days} \tag{30.8}$$

This is an approximation of the tropical month, but not a very good one. The same value is given by Oechslin. The arbor moves a hand counterclockwise and also a disk with a circular opening. This opening shows a part of a disk tied to the Sun, so that we see an approximation of the lunar phase.

30.2.2.1.2 The motion of the Sun

The motion of the Sun on tube 13 is also derived from that of arbor 2, via arbor 5. So, we first compute the motion of arbor 5, then that of tube 13:

$$V_5^0 = V_2^0 \times \left(-\frac{20}{80}\right) = V_2^0 \times \left(-\frac{1}{4}\right) = 24 \times \frac{1}{4} = 6 \tag{30.9}$$

$$V_{13}^0 = V_5^0 \times \frac{1}{15} \times \frac{1}{146} = V_5^0 \times \frac{1}{2190} = 6 \times \frac{1}{2190} = \frac{1}{365} \tag{30.10}$$

$$P_{13}^0 = 365 \text{ days} \tag{30.11}$$

This is an approximation of the tropical year, but a very bad one. The Sun moves counterclockwise and carries a disk which is used to display an approximation of the lunar phase.

The tube 13 also carries a 108-teeth wheel which meshes with a similar wheel on arbor 14. This wheel is first used to drive arbor 15 which makes one turn in four years:

$$V_{14}^0 = V_{13}^0 \times \left(-\frac{108}{108}\right) = -V_{13}^0 = -\frac{1}{365} \tag{30.12}$$

$$V_{15}^0 = V_{14}^0 \times \left(-\frac{24}{96}\right) = V_{14}^0 \times \left(-\frac{1}{4}\right) \tag{30.13}$$

$$P_{15}^0 = -4 \text{ years} \tag{30.14}$$

This arbor will be used to update the dominical letter and the other indications of the computus.

The 108-teeth on arbor 14 also moves a cam which is used to transmit an oscillating motion to the lower right dial for the indication of the lengths of the days.[23]

[22] See Frieß's drawing [6, p. 372].

[23] See Frieß's drawing [6, p. 370].

30.2.2.1.3 The motion of the dragon

The motion of the dragon on tube 9 is also derived from that of arbor 2, via arbors 6 and 7. We compute all these velocities here, as they will be useful later.[24]

$$\mathrm{V}_6^0 = \mathrm{V}_5^0 \times \left(-\frac{32}{192}\right) = \mathrm{V}_5^0 \times \left(-\frac{1}{6}\right) = -1 \tag{30.15}$$

$$\mathrm{V}_7^0 = \mathrm{V}_6^0 \times \left(-\frac{24}{168}\right) = \mathrm{V}_6^0 \times \left(-\frac{1}{7}\right) = \frac{1}{7} \tag{30.16}$$

$$\mathrm{V}_9^0 = \mathrm{V}_7^0 \times \left(-\frac{1}{9}\right) \times \frac{1}{108} = \mathrm{V}_7^0 \times \left(-\frac{1}{972}\right) = -\frac{1}{7} \times \frac{1}{972} = -\frac{1}{6804} \tag{30.17}$$

$$\mathrm{P}_9^0 = -6804 \text{ days} \tag{30.18}$$

This is a (not very good) approximation of the period of precession of the lunar nodes. This period is negative, because the nodes are retrograding. The same value is given by Oechslin.

The tube 9 apparently moves a ring, but it isn't clear what the inscriptions of this ring are. There should at least be the positions of the ascending and descending lunar nodes.

30.2.2.2 The lower right dial with Babylonian and Italic hours

The large lower right dial shows the time, the Italic hours (number of hours since the last sunset) and the Babylonian hours (number of hours since the last sunrise) as well as the durations of the day and the night.

There is only one hand and this hand is on arbor 6, which makes one turn clockwise in 24 hours, as we have seen above.

$$\mathrm{V}_6^0 = -1 \tag{30.19}$$

The mean time can be read on the outer dial, but possibly also on the most inner dial (or these are perhaps the hours counted from midnight).

We have also seen that the motion of the arbor 6 is used to obtain the motion of arbor 7:

$$\mathrm{V}_7^0 = \frac{1}{7} \tag{30.20}$$

$$\mathrm{P}_7^0 = 7 \text{ days} \tag{30.21}$$

This arbor makes a turn in seven days and seems to carry figures for the day of the week in the opening between the two lower dials.

The Italic and Babylonian hours are shown by having mobile 24-hour rings. The ring with the red Roman numerals gives the Italic hours and we can see that it starts at sunset, at the boundary between the light upper sector

[24] See also Frieß's drawing [6, p. 370].

(daytime) and the black lower sector (night). This ring has an oscillating motion as it is connected through a lever to the cam on arbor 14.

The Babylonian hours are given on the second ring from the inside. This ring must be connected to the sector for the daylight.

There are therefore only two motions, and in fact even only one. There is only one lever coming from the cam on arbor 14, and this lever moves symmetrically the sunrise and the sunset, and the two rings for the Italic and Babylonian hours move with the sunset and sunrise.

The only little difficulty is that the black and light sectors are usually longer than they appear. Part of the black sector is hidden by the light sector, and part of the light sector is hidden by the black one. These two sectors are probably not entirely flat, so that one can pass under the other. Similar mechanisms are found on other clocks.

30.2.2.3 The upper dial with the Sun and the Moon

This dial is simpler than the other two. It shows a fixed Northern planisphere, the motion of the Sun (tube 20), and the motion of the Moon (tube 21). The gears of this dial also produce the motion of the celestial sphere at the top of the clock, first through the motion of tube 17.

All these motions are derived from the motion of the central arbor 2. First, we obtain the motion of the intermediate arbor 16:

$$\mathrm{V}_{16}^{0} = \mathrm{V}_{2}^{0} \times \left(-\frac{20}{80}\right) = \mathrm{V}_{2}^{0} \times \left(-\frac{1}{4}\right) = (-24) \times \left(-\frac{1}{4}\right) = 6 \tag{30.22}$$

$$\mathrm{P}_{16}^{0} = \frac{1}{6} = 4 \text{ hours} \tag{30.23}$$

(Oechslin's drawing mistakenly puts a 60-teeth wheel on arbor 16, instead of the correct 80-teeth wheel.)

The arbor 16 carries a 61-teeth wheel which meshes both with the 366-teeth wheel for the Sun (tube 20) and the 365-teeth wheel for the sky (tube 17), and a 57-teeth wheel which meshes with a 354-teeth wheel for the Moon (tube 21).[25]

[25] These two wheels are illustrated by Husty [12, p. 366].

We therefore easily obtain the motions of tubes 17, 20 and 21:

$$\mathrm{V}^0_{17} = \mathrm{V}^0_{16} \times \left(-\frac{61}{365}\right) = 6 \times \left(-\frac{61}{365}\right) = -\frac{366}{365} \tag{30.24}$$

$$\mathrm{P}^0_{17} = -\frac{365}{366} = -23 \text{ h } 56 \text{ m } 3.9344\ldots \text{ s} \tag{30.25}$$

$$\mathrm{V}^0_{20} = \mathrm{V}^0_{16} \times \left(-\frac{61}{366}\right) = 6 \times \left(-\frac{1}{6}\right) = -1 \tag{30.26}$$

$$\mathrm{P}^0_{20} = -1 \text{ day} \tag{30.27}$$

$$\mathrm{V}^0_{21} = \mathrm{V}^0_{16} \times \left(-\frac{57}{354}\right) = \mathrm{V}^0_{16} \times \left(-\frac{19}{118}\right) = 6 \times \left(-\frac{19}{118}\right) = -\frac{57}{59} \tag{30.28}$$

$$\mathrm{P}^0_{21} = -\frac{59}{57} = -24 \text{ h } 50 \text{ m } 31.5789\ldots \text{ s} \tag{30.29}$$

These are approximations of the sidereal day, the mean solar day and the lunar day. The same values are given by Oechslin.

According to Oechslin's drawing, the Moon is set on arbor 23 and the motion of arbor 23 replicates that of tube 20, which is that of the Sun.[26] The photograph of figure 30.1 doesn't show a figure of the Moon, although something seems to be protruding towards the right, between the hours VI and VII. A photograph in Frieß's article [6, p. 367] shows that there should be a disk with the face of the Moon, and it may have gone missing. Because of the motion of arbor 23, this figure should always keep the same orientation with respect to the Sun, and therefore show the phase of the Moon.

30.2.2.4 The computus indications

This clock also shows the dominical letter and golden number in small openings on the left, and the epact and Easter full Moon in small openings on the right. These indications are obtained through the motion of arbor 15 which makes one turn in four years. The 96-teeth wheel on this arbor carries a pin on one side, and four pins on the other.[27] These four pins act on a lever which does itself carry three pins, one that acts on a 7-pointed star wheel on arbor 27, another that acts on a 19-pointed star wheel on arbor 26, and a third one that acts on a 19-pointed star wheel on arbor 25. The pin above also acts on a lever that acts on another 7-pointed star wheel on arbor 27.

The arbor 25 carries the indications for the epacts and Easter full Moon, which are recurring after 19 years in the 18th century. However, these indications were no longer valid in the 19th century and should have been replaced by another series of epacts.

The arbor 26 carries the values of the golden number which repeat after 19 years and remain valid through the centuries.

[26] Frieß shows a 3-dimensional rendering of the involved gears [6, p. 366].

[27] See Frieß's drawing [6, p. 372].

Finally, the arbor 27 carries the values of the dominical letter. These values do normally repeat after 28 years, with single dominical letters for common years and double dominical letters for leap years. There are therefore 14 different possibilities, and it isn't entirely clear from Oechlin's drawing how these 14 possibilities are obtained.

30.2.2.5 The globe at the top

The celestial globe at the top is carried by an inclined arbor 19 whose motion is merely derived from that of tube 17 seen above, using two 108-teeth wheels at right angle.[28] We have

$$\mathrm{V}_{19}^{0} = \mathrm{V}_{17}^{0} \times \left(-\frac{108}{108}\right) \times \left(-\frac{80}{80}\right) = \mathrm{V}_{17}^{0} = -\frac{366}{365} \tag{30.30}$$

$$\mathrm{P}_{19}^{0} = -\frac{365}{366} = -23\text{ h }56\text{ m }3.9344\ldots\text{ s} \tag{30.31}$$

The celestial globe rotates clockwise (from above) in one sidereal day, corresponding to the apparent motion of the stars.

[28] See Frieß's drawing [6, p. 366].

30.3 References

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[29] Constant von Wurzbach. Stuart, Bernhard. In *Biographisches Lexikon des Kaiserthums Oesterreich*, volume 40, pages 112–114. Wien: Kaiserlich-königliche Hof- und Staatsdruckerei, 1880.

[30] Judas Thaddäus Zauner. *Verzeichniß aller akademischen Professoren zu Salzburg vom Jahre 1728 bis zur Aufhebung der Universität. Mit kurzen Nachrichten von ihrem Leben und ihren Schriften.* Salzburg: Mayr, 1813. [see p. 17-18 for Stuart].