EXTRACTS AND REVIEWS

THE MARINE CLOCK OF CHRISTIAEN HUYGENS.

by

W. VOORBEIJTEL CANNENBURG.

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> "And it is surely the most easy and natural manner (of finding the longitudes east or west by means of clocks) which one can imagine; because the sole difficulty arises from the false or erratic running of the clocks. Therefore you sincere students and inventors of things relating to nature, be on your guard and do not be misled into neglecting the elimination of these errors. And study the actual and immutable progression of Nature. By acting thus you will find the *verum Lapidum Philosophorum* (the true philosophers' stone) and skilful navigators will no longer run upon the reefs."

Thus expounded Professor Adriaan METIUS of Franeker in his *Geographische Onderwijsinge* (Lessons in Geography) in 1614. He was not the first who thought that the solution of the burning question of the determination of longitude at sea should be sought in an accurate clock. Since 1530, Gemma FRISIUS had emphatically recommended the same solution in his little work: *De principiis astronomiae et cosmographiae*, and the insufficient accuracy of the clocks of that epoch was the only reason this method of longitude determination remained provisionally unrealizable in practice. During the course of the XVIth century therefore, the solution was sought by various other means (1); among them one, which gained many adherents, consisted in establishing a definite relation between the magnetic variation and the geographical longitude of the place.

This method was recommended for the first time by the Portuguese João de LISBOA in his dissertation on the compass, which saw the light of day in 1514. But a short time afterwards his compatriots, the brothers PALEIRO, improved the method, and one can say without exaggeration that the determination of longitude by means of the variation of the magnetic needle occupied the first place in Spain, France and England during the XVI century, although in Portugal the celebrated Pedro NUNES and also D. João de CASTRO cast doubt upon its accuracy. (2)

What was our attitude here in the Netherlands with regard to that question? To reply to this it is necessary to recall that during the greater part of the XVI century, we were engaged solely in the coastal trade and it was seldom that we departed far from the coasts (3). But towards the end of the century our ships also began to seek merchandise in the east and west and the question of the determination of longitude became an actuality. A start was made with the translation of the Spanish work of

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(1) *Here we shall not take into consideration the systems using the eclipses and the conjunctions, which, in view of the rarity of these phenomena and the difficulty of observing them with accuracy on board ship, were considered, even at that date, as of little service to navigation.*

(2) *For further details on the subject see: A. Anthiaume,* Evolution et Enseignement de la Science Nautique... *Paris,* 1920, 2 *vols in* 8°.

In an unpublished manuscript of the beginning of the XVII century preserved in the Bibliothèque Nationale *of Paris* (N° 19112), *the Frenchman G. le Vasseur expounds, one after the other, three methods for the determination of longitude: 1° by means of the eclipses, 2° by means of clocks, 3° by means of the variation of the magnetic needle. With reference to the second method he states:* S'il se pouvoit faire des orloges artificiels desquels les mouvemens s'accordassent exactement avec le mouvement du soleil, véritablement ceste invention sereit non seulement louable mais aussy fort utile et de grand practique; et n'y auroit aucun doute que les longitudes du monde ne se trouvassent avec autant de facilité que les latitudes» (*If it should be possible to make artificial clocks whose movements would coincide exactly with the movement of the sun, truly this invention would not only be highly praiseworthy but of the greatest utility in practice; and there is no doubt that the longitudes of the globe would be determined with the same facility as the latitudes*).

(3) *In* 1528, *the Zeelandese captain Anthonius Muloc had gone to the Cape Verde Islands in search of salt.* (*see J. Reygersberg.* Dye Cronycke van Zeelandt. *Antwerp* 1551, *small* 4°).

Peter of MEDINA on the art of navigation and although this author did not recommend the method, the promoter of overseas navigation in our country was the well-known pastor Petrus PLANCIUS of Amsterdam, a thorough partisan of the process of deducing longitude by means of the variation of the magnetic needle. The States of Holland offered him an "honourable recompense" if he succeeded in demonstrating its validity (1). The reader will not be surprised to learn that he did not succeed and that with us the question of the determination of longitude at sea remained as burning as before. Following the example of the government of Spain, the States of Holland promised large donations (2) to those who would invent a reliable method, with the reservation that if, in the opinion of six or eight captains "the method was recognised as well-established and certain, the award would be made to the inventor." Many sought to win the prize and in 1610-1611 negotiations were opened on this subject with the Englishman Thomas LEAMER who was residing in Amsterdam. He, however, proved to be very exacting and after having "made difficulties" in disclosing his method for the sum of 10,000 florins, was finally awarded 15,000 florins should it be demonstrated "that he had proved the truth of the bearirngs to the east and to the west". But apparently, nothing good was said of his method as the Admiralty Commission charged with its examination reported unanimously that "it was puerile if not frivolous".

The claims of the celebrated astronomer GALILEO were much better founded. After having discovered the satelites of Jupiter he wished to utilise the eclipse of these moons for the determination of longitude.

No argument is necessary to show that his method, although theoretically correct, was ill-suited to practical application on board ship and we mention it here simply because of the fact that, under the circumstances, GALILEO wished to employ the oscillation of a pendulum for measuring the time interval, using it as a "counter" (3). It is probable that after 1583 GALILEO had discovered the isochronism of the oscillations — independent of the magnitude of the amplitude — but it was reserved to our compatriot Christiaen HUYGENS to make use of this property in perfecting the clocks of that period. In 1637 he constructed his first pendulum clock; the following year already, "to his great joy" he had constructed the "boxhoorns" that is, the cycloidal arcs which should assure a perfectly synchronous beat of the pendulum (4). A short time later he mentioned in his writings the construction of clocks especially designed for use on board ship. It should be stated that HUYGENS well appreciated the drawbacks of a pendulum clock on board moving vessels. He hoped, however, to avoid many of these drawbacks by making use of a Cardan suspension for his clocks and by other means, which succeeded "up to a certain point".

At the start, HUYGENS had found in the person of Alexander BRUCE, second Earl of Kincardine, a collaborator who understood how to awaken interest in England for these new timekeepers. Also it was in that country that they were tried out for the first time, and subsequent to 1662 the Englishman HOOKE, who had himself been work-

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(1) *Here in the Netherlands we have long mistakenly considered Plancius as the intellectual father of the method. See, for instance, De Jonge,* De opkomst van het Nederlandsch dezag in Oost-Indië, *I, page 84 et seq. Honoré Naber in the second part of his* Voyages de W. BARENTS vers le Nord *gives in detail the ideas of Plancius and their influence : (Vol XV of the works of the Linschoten Association).*

(2) *By a resolution of 21st May* 1601, *a reward of* 150 *pounds Flemish had been established. On the subject of this reward and the negotiations with Thomas Leamer and Galileo, see : Baudet,* Leven en werken van W. J. BLAEU. *Utrecht,* 1871.

(3) *Through the intervention of the former Governor General Laurens Reael, Galileo appealed to the States General in* 1636, *after having tried his luck in vain with the King of Spain. The States General appointed an Examining Commission, but although in* 1637 *a golden chain had been presented to Galileo in token of their esteem, the reward which was destined for him if the report should prove favorable, was never made.*

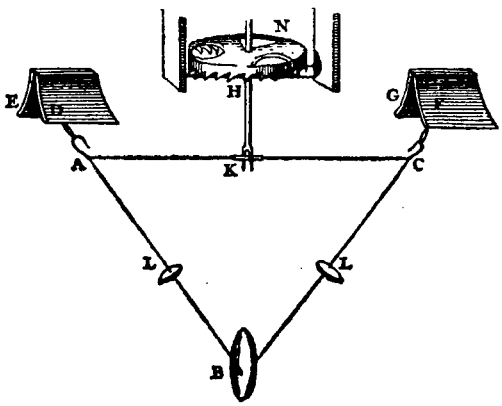
(4) *In order to obtain an absolutely regular movement, it is necessary that the lower part of the pendulum should describe a cycloid instead of a circle. In order to accomplish this, Huygens suspended the pendulum by a thin, flexible metal wire, which by pressing against a small cycloidal arc slightly shortened the pendulum near the end of its oscillation. Huygens introduced these small arcs in all of his later clocks. Everything in regard to the clocks of Huygens has been treated with great thoroughness by Professor J. A. Vollgraff in the various chapters of his* Œuvres Complètes de Christiaan HUYGENS *published by the Hollandsche Maatschappij van Weteschappen of Harlem.*

ing to perfect a portable clock, took part in a conference of the Royal Society on the details of the results of the first tests made during that year. For these trials use had been made of two timekeepers suspended from the midship beam in the centre of the vessel, in such a manner that the pendulums oscillated in the longitudinal plane of the vessel, after which one of the clocks was turned through an angle of 90°. In the two cases the clocks appeared to show slight differences at sea, although at the start, on shore they had been so accurately regulated that, practically speaking, their beats were synchronous (1).

HUYGENS then took the necessary steps to insure that in case his clocks should finally be adopted on board, he would be able to draw some reasonable profit from his invention. At home in December 1664 he obtained the grant of a concession for his "invention relating to clocks with a pendulum movement". A short time later, Louis XIV of France granted him the privilege "of using the pendulum clocks at sea" and in March 1665 this privilege was followed by an English patent for... "A new way of maeking watches and clocks to be used at sea for exact measuring of tyme, towards the finding of longitude and knowing the true course and place of a ship".

Meanwhile there had taken place in 1664 a much more thorough test, when the Englishman HOLMES took these timekeepers with him on his voyage to the coast of Guinea. We read on this subject that HOLMES, after having left St. Thomas first steered to the westward for seventy miles and then profiting by a SW wind, navigated NNW to reach the Cape Verde Islands, off the coast of Africa. After the vessels had covered from two to three hundred miles on this course, the lack of water began to make itself felt and the captains proposed to make a half turn to reach the Barbadoes. According to the timekeeper the vessels were then about a hundred miles to the eastward of what was estimated to be the halfway point of their voyage and not more than thirty miles from the island of Fuego (2). HOLMES then decided to navigate "strictly in accordance" with the clocks and, indeed, they reached the islands the very next day (3). With this excellent result the hopes of HUYGENS himself were exceeded, and in a letter of that period he expresses the hope of soon being able to resolve completely the question of the determination of longitude, thanks to his new clocks. We should note here that the clocks tried out by HOLMES obtained their actuating force from a spiral spring instead of the weights, which were still retained in the first timekeepers of HUYGENS.

It is not certain that the older system was ever tried out aboard ship. It is rather curious, however, that RUYTER, then on his expedition in 1664 and 1665 to the coast of Guinea — which was only a preliminary to the HOLMES expedition, — seems to have had these timekeepers on board his ships, but does not appear to have made use of them (4).



(1) *With regard to these first trials, see : R.T. Gould :* The Marine Chronometer, Its History and Development. *London* 1923.

(2) *One of the Cape Verde Islands.*

(3) *The report of this voyage is extracted from* The Philosophical Transactions *Vol. I. Huygens also reports the details above in his work* Horologium Oscillatorium *in* 1673 *reproduced in the* Œuvres Complètes de Christiaan HUYGENS, *Vol. XVIII.*

(4) *On this subject see :* Œuvres Complètes de Christiaan HUYGENS, *Vol. VI, p.* 171 *and Vol. XVII, p.* 197.

Meanwhile the trials were continued. Thus, while on an expedition from Toulon to Candia, de la VOIJE had a timekeeper on board and the results obtained on that occasion were equally satisfactory. If, at the start, success had seemed assured to HUYGENS, it seems that meanwhile in 1673 he himself wrote that the timekeepers were not at all serviceable in bad weather with the accompanying rolling and pitching of the ship. In order to remedy this fault, he modified the shape of the pendulum in 1671 and gave it the form of a triangle, as shown clearly in the figure.

Further, in order to insure a steady vertical position of the clock as far as possible, when it was suspended in the Cardan ring, he equipped it with a box in which there were heavy weights. This box protected the pendulum at the same time.

The triangular pendulum, however, was not always capable of greatly improving the conditions encountered aboard ship, and after 1674, HUYGENS proposed a new system: that is to say, the replacement of the pendulum by a balance. In spite of that, however, trials were still continued even later with the pendulum clocks. Thus, in 1685 the Amsterdam Chamber of the East India Company, placed a small ketch at the disposition of HUYGENS for trials of his timekeeper on the Zuiderzee. The following year two of the pendulum clocks were suspended in a vessel of the East India Company which was on a voyage to the Cape of Good Hope, whence they were transferred to a vessel returning to the metropolis. At first sight it would appear that the results obtained in the course of this voyage were unfavourable, owing to the fact that no account was taken of the diminution of the force of gravity in the low latitudes, due to the flattening of the earth. But, after HUYGENS had worked out an appropriate correction to be applied to the results, he established the fact that, in any case, in a calm sea, these clocks were capable of improving the estimated longitude very considerably.

This proof was repeated in the years 1690-92 and this time, at least with one of the two clocks, very satisfactory results were obtained. If we consider, however, that the report states that "clock B was defective and not a good piece of mechanism, owing to the fact that it stopped several times and showed irregular movements of the pendulum, and that further, on 4th February after having encountered a strong gale, it accidentally came unhooked from its iron supports, and for that reason could no longer be kept running", we readily appreciate the fact that these clocks were still of no practical value. One gains the impression that those on board who were charged with their maintenance were not equal to the task.

However that may be, HUYGENS did not have complete success with his timekeepers, to which he devoted so much ingenuity and perseverance. He died in 1695 and although among his clocks several have been preserved, (1) not a single specimen of his naval timekeepers has been handed down to us.

Thus it was the happy idea of Mr. Ernst CRONE to have one of the timekeepers constructed as a faithful reproduction, in accordance with drawings contained in the writings of HUYGENS and to present this to the Ned. Hist. Scheepvaart Museum of Amsterdam. The clock does not represent one of the first models ; the actuating force is communicated by means of a spiral spring and the pendulum is of the triangular type, suspended on metallic wires. The instrument, which is a beautiful piece of artistic workmanship, hangs in the Museum on a cross-beam, just as it was suspended aboard ship.

Let us remark further, that this gift contributed to a second and important enrichment of the Museum. HUYGENS published in 1665 a set of precise instructions (2) regarding the use of his clocks aboard ship. Up to now we knew of only one copy of this pamphlet which had been preserved at the observatory of Poulkovo, the pages of which were photographically reproduced in 1926 in the "Complete Works of Chr. HUYGENS". The records in his diaries concerning the timekeepers have recently led to the discovery of a second copy of this pamphlet, and we learn with great satisfaction that Mr. CRONE has not hesitated to acquire this very rare copy and to join it with his gift in such a manner that it shall always remain in our possession.

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(1) *At the Nederlandsch Historisch Natuurwetenschappelijk Museum, Leyden.*

(2) Kort onderwijs aengaende het gebruyck der Horologiën tot het vinden der Lenghten van Oost en West. *An English translation of this appeared in* 1669 *in the* Philosophical Transactions *and one in Latin in* Opera Varia de Chr. HUYGENS *published in* 1724. *A reproduction of the original was inserted in Vol. XVII of the* Œuvres Complètes.