CHRISTIAAN HUYGENS of ZULICHEM

Son of Constantine

T H E   T I M E P I E C E

Province of The Hague
From the publishing house of Adrian Vlaqc

1658

To their Lordships the Most Illustrious and Most Powerful Governors of Holland and West Friesland
Christiaan Huygens of Zulichem
Presents his Greetings.

It is said that the first sundial in Rome was one which was brought with other booty from a certain captured town of Sicily, in the Year of Rome 477, and set up in a public place. Not being precisely designed according to the latitude of that region, and not displaying divisions corresponding to the hours, the Roman people nevertheless, from necessity and for want of something better, conformed to it for ninety-nine years, until at length the Censor Q Marcius Philippus erected one more accurately designed alongside it, and this, of all his official works, was that accepted with the most gratitude.

It seems to me, O Illustrious Lords, being occupied by a similar undertaking today, not less to the public weal, inasmuch as I have everywhere corrected the inconstant motion of clocks – and not just in one city only – that I could have counted upon a like gratitude, to be expected from all, to that which Q. Marcius gained from his own people, since as things and events are accustomed to recur at intervals, so former honesty and inventiveness are accounted to return occasionally on earth. Assuredly, since these virtues are no longer found amongst the greater part of mankind, but on the contrary, widespread imposture and disparagement obtain in all things, I indeed easily foresaw that a like fate would befall my invention as soon as it had begun to be generally known, nor did my misgivings deceive me. For see now, in our own country such conduct is surpassed by the audacity and impudence of certain people, who not deterred by your patent, have slightly modified my invention, and then, if you please, have dared to display it as altogether new, and even more praiseworthy than mine. And those who have seen these things happening in my presence and before my very eyes have warned me repeatedly that I can expect nothing better from abroad. It is certain that elsewhere also will arise men, unjustly envious and eager for fame, who will seize upon this invention of mine and will endeavour to persuade the whole world, if not themselves, that it was not due to my talents; but rather to their own, or those of their own people, by whom the device had been produced for a long time previously. Consequently, the insult would seem to effect all our people, and by the same token even you, O Most Illustrious Lords; you who would never tolerate with equanimity that praise be diverted from your beloved Holland – by plagiarism and fraud – for those inventions of printing and the telescope now renowned all over the world.

I felt myself strongly impelled to ensure to our country the credit for this and for any future discoveries, and so I have followed the way which alone seems proper to this end – to make known the whole idea and construction of the new mechanism, which I the inventor himself, have undertaken to describe in a few words and to produce to the public in a resonably brief volume, which would have been even shorter had I not been led also to answer the objections made against me by some people; objections which I foresaw could undermine the very basis itself of my device.
Indeed, whatsoever the merits of the work – since it could not appear under better auspices – to your Most Illustrious Names and protection, with fitting respect, I come to dedicate and entrust it; and it is not so much these few little pages that I dedicate and consecrate to you, as the invention itself, which it would seem it assured of some measure of distinction in the future.
Deign, therefore, with your accustomed benevolence, to favour one who always refers his studies, in whatever direction, to the public benefit, desiring nothing better than that it may befall to you hereafter to approve similar things of greater importance.
Finally, may God keep in safety the State under your government, and prosper it well.

Christiaan Huygens of Zulichem,

Son of Constantine

THE TIMEPIECE

I thought out a new method of measuring time at the end of the year 1656, and in the next few months began to divulge it in our country, not doupting that on account of its exceptional utility it will soon be spreading far and wide, with many copies of the new work, in fact, already for sale and for sending forth in all directions.
Nevertheless, I yielded not unwillingly to the advice of those who urged that I should publish a written description, as much to oblige those in distant places, whom the new method, perhaps, would otherwise reach later, as in order that I meet the audacity of men of ill-spent leisure, lest – as is customary with them – they should seize upon inventions and, most injuriously, sell them as their own. However, these, if need be, both the time of the given patent, which was granted by the Exalted Governors of the United Provinces on the 16th day of June in the year 1657, can refute; and furthermore, many witnesses whom I told immediately about the recently invented exhibit.
Anyone might easily conjecture that the pendulums of astronomers had provided the opportunity to him who had known that these were used for some years previously by them.
Without doubt, accustomed to the faults in water-clocks and automata of various kinds used for observations, at last, from the original teaching of that most wise man, Galileo Galilei, the astronomers initiated this method: that they should impel manually a weight suspended by a light chain, by counting the individual vibrations of which just as many should be included as would correspond to an equal number

of time-units. By this method they effected observations of the eclipses more accurately than before; in like manner they measured – not unsuccessfully – the sun's diameter and the distances of the stars. But besides the necessary motion of the pendulum failing unless repeatedly by the attendant, a further tedious task was the counting of every oscillation; to this end, indeed, some kept vigil for whole nights with the most wonderful patience, as they themselves testify in their publications.

I, however, perceiving this kind of most equable motion as unique amongst natural things which could be reduced to mechanical construction, sought by what means it was possible to attain this result in the shortest manner, and so find a remedy to the double inconvenience we bore. And having given much thought to a variety of productions I have at last selected this, which I am about to describe in following pages, so that it may be clearer and easier for others. This having been understood, and adapted to public as well as the private use for which, as now made, it originated, the benefit of this invention will indeed extend itself to all, since agreement greater than ever before is being perceived – nay, rather an unanimity almost as great as could be desired – as much between clocks as with the sun itself. Astronomers certainly, are adopting it, so that henceforth there will be no troublesome urging of pendulums nor watchful counting required, and besides accomplishing those things which I have mentioned a little earlier, others, more subtle, will be examined; for example, they will measure the true equality of the days from meridian to meridian, those presuming to deny which being, up to the present, refuted by reason rather than by the certainty of experience.

I omit to speak of the so-called science of longitude, which, if ever it existed, and so had provided the greatly desired help to navigation, could have been obtained in no other way, as many agree with me, than by taking to sea the most exquisitely constructed timepieces free from all error. But this matter will occupy me or others later; now I will submit the diagram of my invention for inspection, and explain the figure as clearly as possible.

The principal part of the timepiece is held between two rectangular plates of equal size, *AB*, *CD*, into which the arbors of the wheels are inserted on both sides. Only the end view of these plates is shown; I have purposely omitted to include, however, four little pillars by which the plates are connected near the corners, so that they may not obscure the other parts. The first toothed wheel is *E*, to the arbour of which is also affixed the pulley *F*. Around this is placed a cord, to which is hung a weight Δ, in a manner I shall explain later. The force of the weight accordingly revolves the wheel *E*. This moves the next wheel *H*, and this turns *L*, of which the teeth are shaped to the likeness of those in a saw. Close by this wheel stands the vertical arbour *MN*, having two pallets, one engaging the upper teeth of the wheel *L*, the other the lower teeth, and this they do by a continual change, so that the arbour does not turn in a circle but has a to-and-fro motion now in this, now in that direction, whilst the wheel *L* revolves. I forbear to explain this movement at length, for it is found in many common clocks, from which, indeed, up to this point mine does not differ, but very greatly in the details now following. For to the verge *MN* is fixed a pinion *O*, the leaves of which engage the teeth of the wheel *P*, which is of that kind called by our clockmakers crown wheel. It is quite unnecessary to cut teeth around the centre periphery, but only in the upper part, since the pinion *O*, like the verge *MN* to which it is affixed, has an alternating motion, moving the wheel *P* similarly. And since the diameter of *P* is greater than that of the pinion *O*, it follows that its movement is a still smaller fraction of its circumference than that of the said pinion *O*, the object of which I shall explain elsewhere.

The arbour of the wheel *P* is extended somewhat through the plate *CD*, and has conjoined a crutch *QR*, the lower end of which is bent and perforated at *R*, so that the brass rod *IT* goes freely through this wide aperture. The rod is in fact suspended at *S* by a thread *SI*, and at its lower end supports a weight *T*, which is raised or lowered if need be by turning a screw underneath.

From the above explanation the principle of the whole invention (the further details in the figure will be mentioned later) will be perceived, noticing in the first place that if the rod *SIT* did not pass through the crutch-fork *R*, or was not present at all, the crutch *QR* would them undoubtedly be caused to oscillate violently by the force of the weight Δ, is obedient to the motion of the pendulum, yet for a short time in each vibration, it also assists this movement. In this way the continual motion of the pendulum is accomplished which, unless the rod were connected with the mechanism, would soon fail and come to rest; but with each swing of the pendulum the pallets *M* and *N* receive corresponding impulses from the contact of the teeth of the wheel *L*.

These are indeed the details of my mechanism which require precise explanation because the point of the whole invention turns on them.

In the diagram there is also a third plate *YZ*, parallel to the former and spaced a distance apart from the plate *AB*, in which space is observed a pinion *V*, having a common arbour with the wheel *E*. Engaging with this pinion are the teeth of the wheel *X*, to the centre part of which is joined a pipe, r, projecting beyond the plate *YZ*, and carrying the first hand of the timepiece Λ. Within r itself is disposed another pipe, affixed to the plate *YZ* upon which the wheel *X* turns. The arbour by which the wheel *X* is revolved at the same time transmits motion to the wheel *H*, to which is attached another hand Σ, longer than the index Λ. This indicates exact seconds. To give the actual minutes a hand Ψ much shorter than either of the former is fitted to the extremity of the arbour *DV*, which is extended through the dial-plate *YZ*. Indeed, this smaller indicator, carried close to the plate *YZ*, shows the true minutes in a small separate circle. Above this the hour-hand A turns, and beyond this again the seconds hand Σ to which I have referred. But these, and also the disposition and teeth-numbers of all the wheels, may be arranged in various ways; I have here set out one example as sufficient, and that supported by experience. So too with the number of teeth in each wheel, I have chosen that which seems to combine best with this scheme.

In the circumference of the individual wheels *E H* there are 72 teeth, six leaves each to the pinions *G* and *K*. The wheel *L* has twenty-five teeth, the pinion *O* ten leaves, the wheel *P* twenty teeth, or some part of this number, because, as I have said, it is not necessary to cut all the teeth. The length of the pendulum *SIT* is about five-sixths of a Rhenish foot, which latter approximates to the old Roman foot, and each simple vibration occupies half a second exactly, which interval may be achieved without difficulty by solar observation or by comparison with another timepiece of this kind. The pendulum length agrees also with the train, and provides exquisite equality of movement which even suffices for astronomical purposes. Nevertheless, by placing exactitude of performance above appearance, with the application of a fourfold longer pendulum, or one still longer – the wheel-teeth being also increased at the same time – we may safely rely on still slower oscillations. Thus now in great public clocks, with eminent success. I have seen very long pendulums of that kind substituted, in one place twelve feet, in another twenty feet long, with pendulum-weights of twenty-five or thirty pounds.

Returning to the diagram, it is clear that to one turn of the wheel *E* the wheel *H* turns twelve times, and that which follows, *L*, one hundred and forty-four times, in fact. This having 25 teeth, it impels the pallets *M*, *N*, by 3,600 alternations, and the pendulum *SIT* makes just as many double vibrations. Since in one hour there are exactly 3,600 seconds, in that space of an hour the wheel *E* is turned once. For this reason the circle for the hand Ψ is divided into 60 parts, which indicate the minutes. Because in fact the wheel *H* turns twelve times in an hour, it is revolved once in the space of five minutes, and at the same time the hand, Σ; therefore the circle beneath this index I have divided into 5 principal parts, and these again into 60 smaller parts, which denote the seconds. Finally, the hand Λ in its circle is intended to mark off twelve hours, and hence, so that it turns once in this time, to the pinion *V* are assigned six leaves, and the wheel *X* seventy-two teeth.

Now I shall explain the method by which the weights Δ*Z* are attached to the timepiece. For this I have arranged by a new device, so that when the main weight Δ is wound up it may not stop or in any way hinder the going of the timepiece on that account, which was especially necessary in this invention in case a small amount of the time be lost every day, and lest during the winding up op the weight the movement of the pendulum should be weakened. Accordingly an endless cord is prepared, returning upon itself, suitably connected by its extremities. This first embraces the pulley *F*, which has sharp iron spikes, by which the cord is held better within it; a part of the cord passes round another pulley to which the main weight Δ is hung. Ascending hence, it passes above the pulley Ω, and conversely descending the cord supports another pulley weighted with the smaller weight *Z*, whence it returns again to *F*. The pulley Ω (which is here represented between the plates *AB*, *YZ*, for illustration, but is usually affixed more conveniently to the case containing the entire movement) has serrated teeth, as in the wheel *L*, adjoining its circumference, and, pressing from above, a spring click Θ so that it may be turned in one direction by pulling on the cord II, thereby raising the weight Δ. The click meeting the teeth prevents a contrary motion. The groove around the circumference of the pulley I have mentioned is so shaped as to compress and grip to some extent the cord lying within it, so that it is less liable to slip out; to this end also the counterweight *Z* is applied. With this arrangement, half the weight of Δ is always applied to the cord Φ, and it will also maintain motion in the timepiece whilst it is drawn upwards by pulling the cord II.

I have so far explained the matters pertaining to the construction of the mechanism; it remains to make clear how greatly it excels all others which have been used up to the present time. The causes of very many of the uncertainties and inequalities in these are sufficiently well known. Thus even the smallest fault in the due arrangement and polishing of the wheels is followed by a notable inconstancy in the continuous movement. Then, indeed, by the oil which it is customary to add to the pivots, drying and vanishing, the clock goes slower, and notwithstanding, the absence of these inconsistencies, clocks are sensitive with cold, for example, the commonly exhibit sluggishness; equally with heat, they go faster.

It is true nature and poverty of a pendulum that it will necessarily always maintain uniformity, from which it will never deviate unless the length be altered; it is evident, therefore, that by my invention I have removed altogether those inconveniences to which I have referred, so that unless it happens that by some impediment the timepiece is stopped, no slowing or inequality of the motion need be feared. Yet I know, certainly, that for some this is possibly a double cause for doubt arising. First, it may be noticed that mine differs from the free pendulum because with every vibration it receives a momentary contact and impulse from the crutch *QR*. Then, although it retains the properties of the simple pendulum, producing all of them, notwithstanding this some have observed in it double inequalities for which they have searched minutely. This because the truth of the contact with the crutch is not to be denied. But we know it is very gentle by reason of the weight *T*, which so governs the whole it not only controls the movement of the pendulum but also minimises the extent of the constant arc in the same way. Consequently the crutch of itself produces nothing violent or less equable in the movement of the pendulum than if the motion were not wholly beholden to it, and the pendulum *SIT* simple, and impelled, as hitherto was the custom, by hand, This, indeed, the best experience confirms. The two inequalities observed in the pendulum itself, however, some deny altogether; of these, one I admit, but it is scarcely prejudicial to my timepiece. The other I have no doubt in affirming to be evidently of no account.

It is asserted with truth that wide and narrow oscillations of the same pendulum are not traversed in absolutely equal time, but that the larger arcs take a little longer, which it is possible to demonstrate by simple experiment. For if two pendulums, equal in weight and length, are released at the same time, one far from the perpendicular, the other only a little deflected, it will be perceived that they are not long in unison, but that of which the swings are smaller outstrips the other. Yet, as I have said, my timepiece is less liable to an inequality of this kind, because all the vibrations are of equal amplitude.

Nevertheless, it remains not entirely free from inequalities, although these are very tiny, and as is needful, I desire to pursue the matter. Since it is affected by either the intemperance of the air, or by any faults in the mechanism so that the crutch *QR* is not always activated by the same force, it is necessary to increase or diminish the oscillations of the pendulum, it may be by small fractions. With large arcs the swings take longer, in the way I have explained, therefore some inequalities in the motion of the timepiece exist from this cause, and, although it may seem to be negligible, whilst clocks were so constructed that the movement of the pendulum was somewhat greater, I have used an appliance as a remedy for this also. At the present time, certainly, this method is not the cure, which I now effect by applying the pinion *O* and the wheel *P*, from which it follows (and not otherwise by this) that however narrow the vibrations of the pendulum may be, the verge *MN* is turned by its motion as much as is necessary. For with the wheel *P* arranged twice or thrice the diameter of the pinion *O*, it follows that although the permitted oscillation of this wheel is but small, it nevertheless turns the pinion through a sufficiently large part of its circumference. Therefore, by rendering all the swings short, even though they should vary in length, sometimes longer and sometimes shorter, experience confirms, notwithstanding, that individual times are distinguished by no remarkable difference. In this connection, increasing or doubling the weight Δ does not thereby accelerate the movement of the pendulum or alter the working of the timepiece, which was not so in all others hitherto in use.

Godfrey Wendelin, an astronomer famous for his researches, was the first and only man, as I believe, to report another inequality of the pendulum; writing of his own experience of the oscillations of the same pendulum being faster in winter than in summer, and that by a notable difference. But as he confessed in that examination to have used only sandglasses, together with sundials and common mechanical clocks himself, perhaps not too much attention should be given to his account; many will doubt that he has made a correct observation. To me, certainly, it was not given to observe anything of this kind. On the contrary, indeed, with small timepieces having half-foot pendulums, and with large clocks in which the pendulum approximates to some 24 feet, I have experienced a constant length to agree both in winter and summer time indifferently. During the winter at least a seventh part of its length is lost, if that which Wendelin states be true.

Therefore on this point also affirming the equal and constant motion of my machine, I now insert the conclusion of its description; diligent artificers whom I have informed of the principle of this invention have been able to add much to it, and they will discover without difficulty how to apply it to various kinds of clocks, also to those which were made long ago in the old style. I have indeed seen in the workshop of him whose labours I first employed for these constructions completed pendulum clocks which go, not by a weight, but by the force of a spring. In this kind of work, up to the present time the differing power of the spring when wound up and when run down was equalised by the aid of a fusee round which was coiled a gut line; now these are disused. For the teeth are brought together with the barrel itself, in which the spring is enclosed.

Although it is admitted that by this method the motion of e pendulum is not equally vigorous in the beginning and at the end [of the spring power], nevertheless the effect is not to reduce the time of the concluding oscillations, as has been proved earlier. The manner of adjusting and apportioning the spring-tension, in fact, is such that no slight loss in time-keeping occurs during the working of the timepiece.

I pass over clocks of this kind which have been contrived to sound the hours by one and the same motor, either a weight or a spring, which serves also for turning the hand of the timepiece, since all these have no connection with my invention except as occasioned by the opportunity it presents.

The End

(English translation by Ernest L. Edwardes in Antiquarian Horology Volume 7, No. 1, December 1970)