

NOTES ON THE MECHANISM OF CLOCKS.

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There is much doubt about the date of the beginning of clockmaking owing to the uncertain meaning of the terms employed by early writers. The word *horologium* may mean either a sun-dial or a clepsydra, or a clock in the modern sense. We may, however, take it for certain that large clocks, made throughout of iron, were in use in abbeys and other buildings in the thirteenth century, and in the following century they were fairly numerous. The movement of these early turret-clocks consisted of two wheels, the great wheel and the escapement wheel, with a verge and balance. The length of the balance in these great clocks made possible the simplicity of the mechanism. There is in the Victoria and Albert museum a fine example of this period, the fourteenth century, brought from Dover castle (fig. 1). The balance of this clock oscillates in about four seconds, thus giving eight seconds for the escape of one tooth of the escapement wheel, and this wheel, having thirty-three teeth, revolves in nearly four and a half minutes. To the arbor of this wheel is fixed a pinion of seven leaves, and the great wheel which actuates it has ninety-six teeth, and therefore revolves, with accurate regulation, in an hour. The motion of this wheel was communicated to the hour-wheel which revolved in twelve hours and carried the hand. The hour-wheel is now wanting.

There is in the national museum at Nuremberg a clock of a very curious and primitive character: the dial, probably original, is divided into sixteen hours, a period which covers the longest day. The first hour was the hour after sunrise, whatever the time of year, so that at the equinox noon would be the sixth hour, while at the summer solstice it would be the eighth hour, and at the winter solstice the fourth hour. If this represents the principle on which the clock was used, it would have been stopped at night and adjusted by the watchman when he wound it in the morning.

The early sun-dials were constructed on this method, the hours marked upon them being from 1 to 16. In Italy the sun-dials were arranged on a similar plan, but there the hours were counted from sunset to sunset, and the hours marked upon them were therefore from 9 to 24; nine

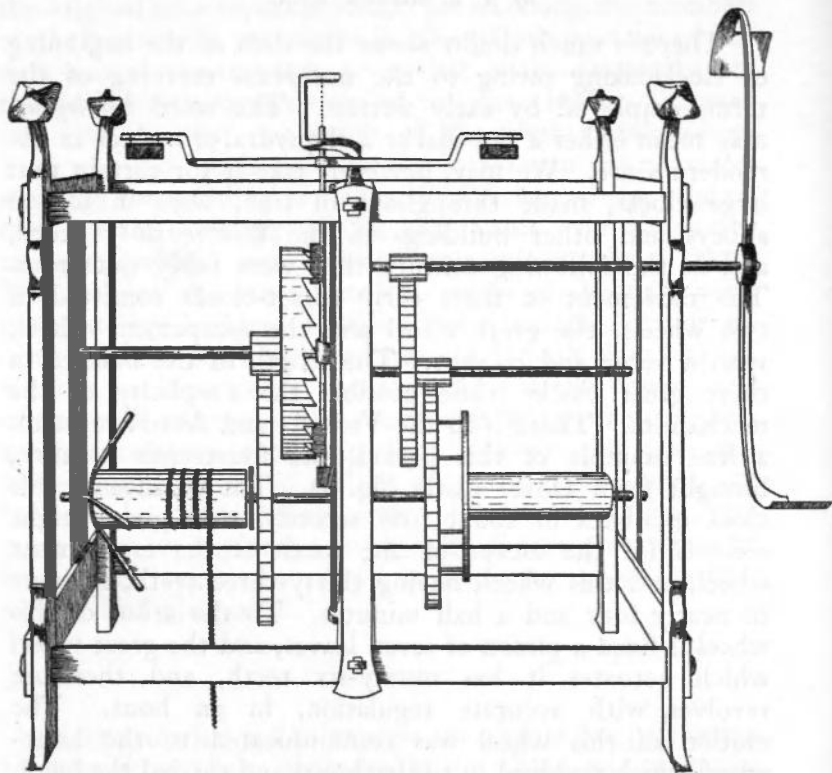


FIG. 1. IRON CLOCK FROM DOVER CASTLE, FOURTEENTH CENTURY.

in the summer would thus represent 5 o'clock in the morning of our reckoning and the twenty-fourth hour would be 8 p.m. the hour of noon varying from the sixteenth hour at midsummer, to the eighteenth hour at the equinox, and to the twentieth hour at mid-winter.

These dials were in general use in Italy as late as the early part of the nineteenth century and may still be met with painted on public buildings. Dials of this construc-



A GROUP OF SIXTEENTH-CENTURY TABLE-CLOCKS, WITH A CLOCK-WATCH OF ABOUT 1600.

tion depend upon the *length* of the shadow as well as on its *direction*.

In the fifteenth century the domestic or chamber clocks made their appearance. These also were clocks actuated by weights and were fixed to a wall. The small size of these clocks admitted only of a short balance vibrating in a second to a second and a half. This short balance led to the introduction of a third wheel (placed between the great wheel and the escapement wheel) in order that the great wheel might still revolve in an hour; and the train of three wheels then introduced has been in use ever since for thirty-hour clocks moved by weights (plate II, no. 1). These clocks were made during the fifteenth and until the end of the sixteenth century, and during this period no essential change was made in the mechanism. The oscillating bar which was used in the earliest form of escapement was weighted at each end by a movable pellet which would enable the clock to be regulated with fair accuracy. There were, however, certain inconveniences attending this, from the care constantly needed and the possible loss of a pellet; and to remedy this a carefully-adjusted balance-wheel was substituted for the bar, and any final regulation would be transferred to the weight which moved the clock (plate III, no. 1). A cylindrical iron box, sometimes decorated, and containing shot or pieces of lead, was used in order that the weight might be accurately adjusted, and for the cheap wooden clocks made on this principle in the seventeenth century a bag of pebbles answered the same purpose.

The train of wheels which enables a clock to strike the hours was a very early addition; it was of the utmost importance in a monastery when it was necessary for a monk to watch by night to announce to the community the religious duties which they had to fulfil, and it was of great importance also to a town clock.

In Caen in Normandy a striking clock was placed on the bridge in 1314: it was made by Beaumont, a native of the town.

In 1324, the English benedictine, Wallingford, abbot of St. Albans, constructed an elaborate instrument for the abbey, showing the months, the days of the week, the course of the planets, etc.

Padua had its first public clock in 1344, made by Jacques de Dondis. In England we have an elaborate clock still in existence made by Peter Lightfoot for the abbey of Glastonbury; and there is the famous clock of Courtrai which in 1332 Philip the Bold carried away and set up in his town of Dijon. In these as in many of the early clocks, the makers were not satisfied with merely endeavouring to tell the hour, but aspired to instruct the beholder with regard to the phases of the moon, the age of the month, the days of the week, etc. and to entertain him by figures striking the hours and quarters, and processions, generally of sacred characters, set in motion at the time of striking. The church of St. Mary Steps at Exeter has in the tower three figures, one for the hour and two for the quarters. At Wells there are four equestrian knights who move rapidly in opposite directions. This same device may be seen outside the tower of the church at Monnikendam in Holland. In the clock of old St. Paul's the hours were struck by figures, and there is the famous clock at Venice with many complicated movements. Evelyn, the diarist, mentioned that when in Venice he was told of the fellow who kept the clock, that, stooping his head near the bell to mend something amiss at the instant of striking, the hammer struck him so forcibly that he reeled over the battlements and broke his neck.

The domestic clocks of this type of the fifteenth and sixteenth centuries were made throughout of iron, as were the turret clocks already mentioned. A decorative character was given to them in the first place by the corner-posts which gave rigidity to the movement. These posts were in the form of Gothic buttresses, terminating in pinnacles of various design, while the bell and its supports also added to the grace and beauty of the clock (plate II, no. 2).

The most elaborate is that in the Victoria and Albert Museum: it is an admirable example of Gothic ironwork, but the decoration of the canopy perhaps rather overwhelms the clock itself. The clock has the balance-wheel and is in a very fine condition. The dial, from indications connecting it with the movement, appears to be original, but if so, the clock, judging from the outline of the dial, must be later than 1500.

In the Ryksmuseum at Amsterdam is a very interesting clock of this type of the sixteenth century, which was taken by Barentz on his expedition to find a north-east passage to China. The clock was left for nearly three hundred years in the hut which he built at Nova Zembla. In 1875 the hut was opened and the clock and other objects were brought to Holland and finally set up in the Ryksmuseum. We have thus in this clock an untouched specimen of sixteenth-century clock-making: the finer parts of the mechanism have suffered, but the clock is otherwise in very fair condition, and shows the escapement which has the balance-wheel, as in plate III, no. 1.

The numerals on these clocks were painted on the plate of iron which formed the front. In Barentz' clock the paint has disappeared, leaving the bare iron. In de Veer's account of the expedition, written in 1599 and illustrated with copper cuts, there is an illustration showing the interior of the hut with the clock hanging against the wall.

There is one of these clocks in the museum at Northampton, and a very beautiful example is in Paris in the Cluny museum. There are three or four in the national museum at Munich. In these, however, the original escapement is wanting, and in the Cluny and Northampton clocks the dials are not original. These clocks would seem to have been a favourite subject of representation with the workers in intarsia in the fifteenth and sixteenth centuries. We have one of the panels in the Victoria and Albert Museum, another is in the Louvre, and they are to be met with in Italy, giving a very accurate portrait of a balance clock: the dial in these is shown as revolving with a fixed pointer. These clocks with the balance escapement would keep very fair time if in good condition and if carefully tended, but they were much more subject to disturbance than a clock ruled by a pendulum. The wearing of the pallets would alter the rate considerably, as would also the thickening of the oil. De Veer mentioned in his account of the Barentz expedition that the freezing of the oil stopped the clock: they could not make it go even with a heavier weight, and were therefore forced to rely upon the hour-glass.

The wheels of these iron clocks, both of the large turret-clocks and the small house-clocks, were constructed in the same manner: a bar of iron was bent round into a circle,

the two ends welded together and the ring thus formed hammered to the requisite thickness. The centre and the crossings (or spokes) of which in the early clocks there were four, were made partly by cutting and partly by hammering ; and four notches were cut in the inner rim of the circular piece and the ends of the spokes welded or riveted into

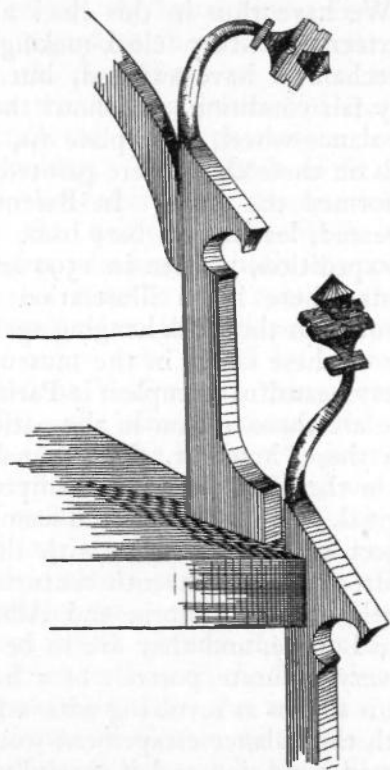


FIG. 2. PINNACLE OF SIXTEENTH-CENTURY CLOCK ILLUSTRATED
IN PLATE II, NO. 2.

them ; the outer rim was then divided into teeth. There is a good deal of variety in the form of the pinnacles of these Gothic clocks : fig. 2 shows more clearly than in the photograph one of the angles of the clock given in plate II, no. 2, which was in the collection of the late Mr. Norman Shaw. The clock is of the middle of the sixteenth century.

In the construction of these clocks no screws are used, but the framework is pinned or wedged together, as are the various parts of the movement (plate II, no. 1 shows the wedges). This clock is of about 1500 or very early in the sixteenth century.

In the last quarter of the fifteenth century a new motive power was invented, the result of which was the production of another type of clock. This invention was the application of the coiled spring instead of the weight, so that clocks could be made portable; these are commonly known as table-clocks, and we have many examples of them in both the British and the Victoria and Albert museums. The first form was simply that of a drum, the dial being on the top (plate I). The escapement of these clocks was the same in principle as that of the clocks already described, but a modification was made: the somewhat heavy balance of the Gothic clocks was suspended by a cord above the movement in order to diminish the friction, while for convenience in using the table-clocks the dial was placed at the top, and the small and light balance placed underneath the movement, so that it could no longer be suspended, but was pivoted below the movement. Plate I gives a group of these table-clocks of the sixteenth century with a clock-watch of about 1600.

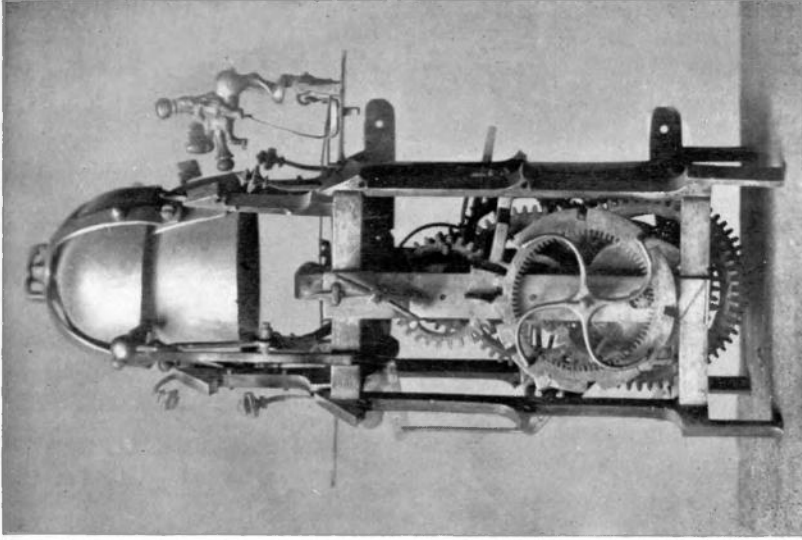
Careful representations of these early table-clocks are to be met with in portraits of the period. There is quite a small example shown in Holbein's portrait of Gisze, the merchant of the Steelyard in London, the picture being dated 1532.

Clocks of architectural design were also made fairly early in the century, the movements were small and finely made, iron being still the material employed, and they were enclosed in cases of copper or brass, richly gilt. In these upright portable clocks the dial was in front and the balance again placed at the top, but enclosed in the case and no longer suspended as in the Gothic clocks. During this period, too, a few of these finely made clocks, enclosed in their gilt cases, were driven by a weight instead of the spring, as in the instance of that given by Henry VIII to Anne Boleyn on their marriage in 1533. This clock was in Horace Walpole's collection and is shown affixed to the wall in a print in his catalogue; it was bought at the sale

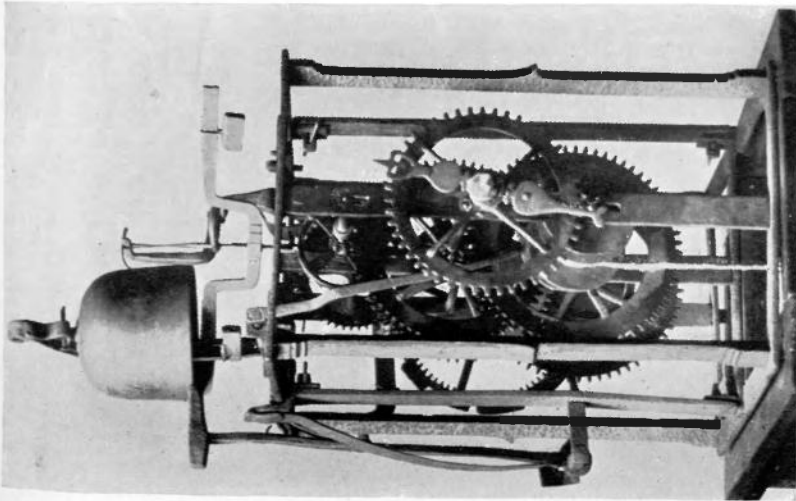
of the Strawberry Hill collection in 1842 by Queen Victoria, and is now at Windsor. In the latter part of the seventeenth century, a brass movement with pendulum was substituted for the iron works of Henry's time.

Towards the latter part of the sixteenth century brass was gradually introduced for the plates and wheels of clocks, and became very general after 1600. In the early seventeenth century our lantern-clocks began to be made: the great majority of these were entirely of brass, both works and cases, and with the balance escapement. This went on until the middle of the century when the greatest invention in the history of clock-making, the application of the pendulum, created a new regulating power and made the clock at last a really trustworthy machine.

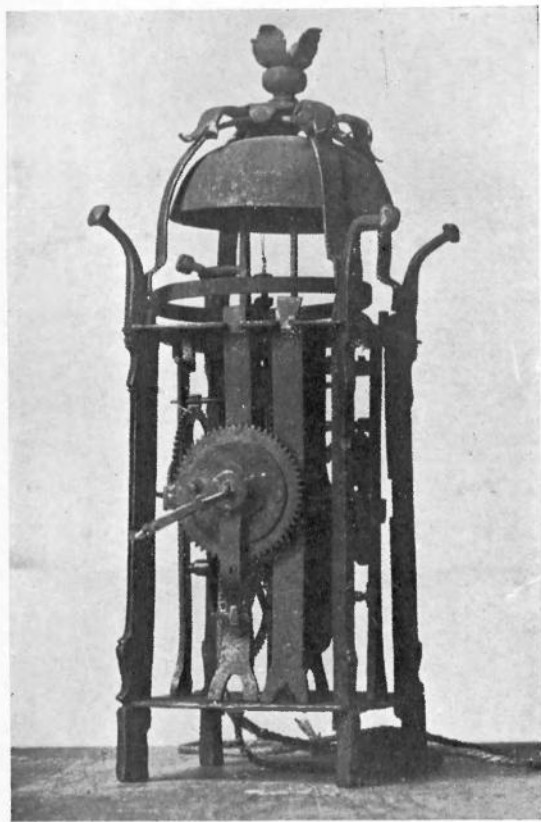
It would perhaps be appropriate at this point to say a word on the history of the first watches, which were simply a development from the early drum-clocks. These first watches were in fact round clocks, made flat enough to be carried in the pocket. A drum-clock such as appears in the picture of Gisze, in the Berlin gallery, would be about two inches in diameter, and one-and-three-quarter inches in height; the first watches were about this diameter and flattened to a thickness of about five-eighths of an inch. The movement, wheels and plates, were entirely of iron and encased in a box of brass or copper gilt. The only addition which was made was a metal cover to protect the hand; the cover being pierced usually with twelve openings to allow the position of the hand to be seen. The covers were not hinged but merely pressed on, as in the clocks, and were decorated with a similar projecting moulding. In all its details the mechanism of these clocks and watches was practically the same. The period of these early examples of watch-making is about 1500, or possibly a little earlier. As the sixteenth century advanced, the form was gradually modified: the covers were hinged to the case and the mouldings disappeared soon afterwards: the edges taking the more convenient rounded form, and by the middle of the century brass was taking the place of iron, both for plates and wheels. In the latter part of the century very varied designs made their appearance, among them the oval form, sometimes called the Nuremberg egg, was popular, the cruciform, the tulip, the pear-shaped and the



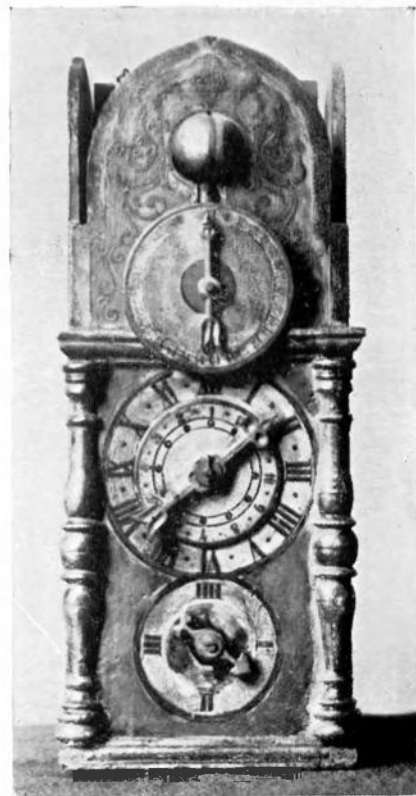
NO. 2. IRON CLOCK, SIXTEENTH CENTURY.



NO. 1. IRON CLOCK, OF ABOUT 1500.



NO. 1. IRON CLOCK, LATE SIXTEENTH CENTURY.



NO. 2. WOODEN CLOCK, SEVENTEENTH CENTURY.

shell are well-known varieties. The material for these cases, included, besides metal, such substances as crystal, jasper, onyx, turquoise, and other stones, and these fine examples of the watch-maker's skill were furnished with an outer case of metal, covered with leather or shagreen and decorated with piqué in gold or silver. The finest watches of this period are the work of French makers. They excelled both in the finish of the mechanism and in delicacy and beauty of decoration.

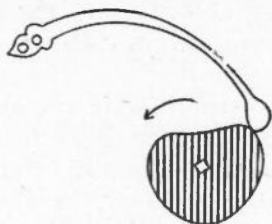


FIG. 3. THE STACKFREED.

(When fully wound as above, the stud at the end of curved spring presses upon the disk: as the disk revolves in the direction indicated, the pressure becomes continuously less.)

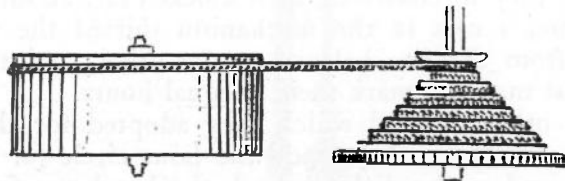


FIG. 4. FUSEE.

(The spring fully wound as above, pulls at that part of the fusee where the leverage is least. As the spring unwinds it acts upon the fusee with gradually increasing leverage, thus equalising the power.)

A great difficulty which the early makers of watches and portable clocks had to contend with was the inequality of the strength of the spring, which, if unchecked, would cause a very varying rate in the timekeeper. The first effort in this direction was the stackfreed (fig. 3), a device not very satisfactory, which gradually gave place to the fusee (fig. 4) fairly early in the sixteenth century, probably before the end of the first quarter. The stackfreed continued for some little time longer, but is rarely met with

after the middle of the century, while the fusee was employed throughout the sixteenth, seventeenth and eighteenth centuries and well into the third quarter of the nineteenth.

While on the subject of the mechanism of clocks, it would perhaps be of interest to say something of the ingenuity shown by the Japanese makers. In Japan the day of twenty-four hours was divided into twelve periods of approximately two hours each ; there being six of these periods from sunrise to sunset, and six from sunset to sunrise, their lengths varying according to the season of the year. Sunrise and sunset are always called 6 o'clock throughout the year.

In a summer day there were six long periods, and in a summer night six short periods, the order being of course reversed in winter. The difficulty thus presented to the Japanese by the equal hours of the European clocks they overcame by two different methods, both highly ingenious. One plan was that, instead of the one balance, they supplied their clocks with two balances of unequal length, a longer balance for the summer days and a shorter one for summer nights ; they so contrived their clocks that, at sunset and at sunrise, a cam in the mechanism shifted the train of wheels from the one balance to the other, and thus the clock was made to mark their unequal hours.

The other method which they adopted for the same purpose was this : they made the hour circle (or dial) to revolve, and as the dial revolved, the hand was fixed and the hours passed under it. The hour numerals were engraved on small plates of metal which were adjustable in a slot in the revolving metal band, and every fortnight or so they were adjusted to the changing seasons, being placed closer together or wider apart according to the time of the year.

Perhaps, however, the most ingenious invention in this connexion, with which the Japanese have to be credited, is in the arrangements for the striking in their long case clocks. These clocks seem to have been always small, usually from 20 to 30 inches long, the smallest about 9 inches, and the largest I have seen does not exceed 40 inches.

The hour numerals in these clocks are not placed in a circle, but are arranged in a vertical line down the front

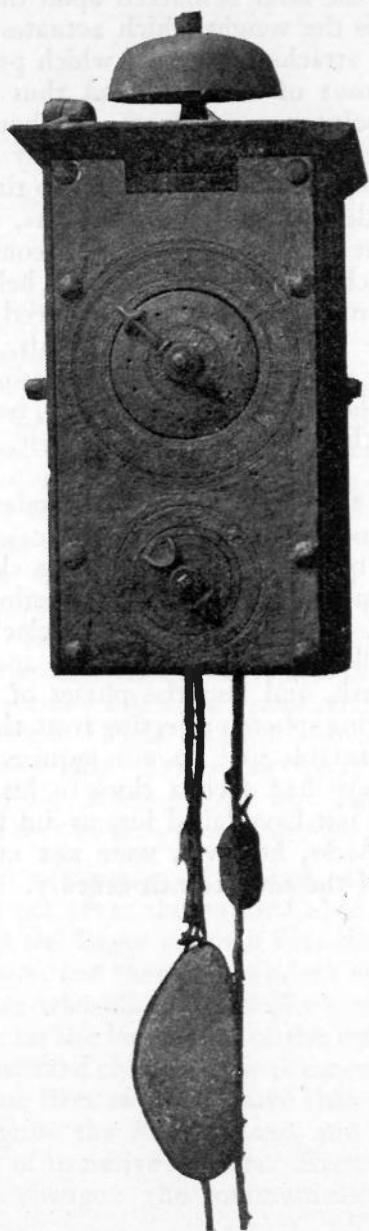


FIG. 5. WOODEN CLOCK, SEVENTEENTH CENTURY.

of the case and the hour is marked upon them as follows : Inside the case is the weight which actuates the clock, and to the weight is attached a pointer which projects through a slot in the front of the case, and thus as the weight descends, the pointer passes from one hour to another. These hours are adjustable in the same way as those in the circular dials, and are shifted from time to time in the same manner. This descending weight consists, not of a mere lump of lead, but is actually a metal box containing a complete striking mechanism of spring, wheels, bell, etc. Behind each metal disk on which the hour is engraved is a projecting pin, and as the striking weight descends, a small lever attached to it is caught by this pin, releasing the train of wheels, and the hour is struck ; and thus, however long or short the hour, the striking is adapted to it, and marks the true time.

Plate III, no. 2, and fig. 5 are early wooden clocks, made throughout of wood, wheels, frames and cases. The regulating power is a balance as in the early iron clocks. In fig. 5 this wooden balance is seen through an opening in the upper part of the dial. Plate III, no. 2, is a clock of elaborate construction, striking hours and quarters and showing the days of the month, and also the phases of the moon by means of a revolving sphere projecting from the dial. These clocks are very durable and do not require oiling, and if Barentz could have had such a clock in his hut at Nova Zembla it would not have failed him as did the iron clock. These wooden clocks, however, were not made until the second quarter of the seventeenth century.