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# The methods of using the outflow water-clock by the public Ancient Egyptians

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## Abstract

The Ancient Egyptian used different kinds of clocks to measure the time through the Egyptian history, one of them was the water-clock that is considered the most complicated with its two kinds (inflow – outflow). While the outflow water-clock was the most difficult to use and the popular of both the two kinds not only in Egypt but also in Greece and Rome. Some of these clocks did not have scales or dots around its inner surface of the bowl, which led to the big question that how did the hour-watchers use those kinds of the unmarked clocks? So, the aim of this search is to identify the methods that the common people used to deal with this kind of the unmarked clocks.

To solve this riddle I suggest two solutions; the first one is to use the measures of capacity to measure the enough suitable volume of water they need to put inside the bowl to measure a certain period of time. Anyway, we have enough number of preserved measuring vessels and other vessels with inscribed capacities on their outer surfaces. While the second solution is using the cubit to measure the depth of the water inside the bowl (instead of the quantity marks on its inner surface) and according to that they used it to measure the time. So this style of unmarked clocks was uncomplicated instruments, which can be easy made and use and did not need a high educated man to deal with.



**Key Words:** Water-clock, Measures of capacity, Cubit .

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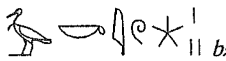
The movements of the Sun, Moon, and stars were and still easy to observe, and the early Egyptians hardly escaped being conscious of them. They began to observe and study the heavenly bodies very early on their history and they were among the first astronomers in the world.

Time "keeping" is simply a matter of counting cycles or units of time. The earliest clocks that have survived till now were invented in Egypt. They began measuring hours with the use of the heliacal positions of the Decans[1] to tell time at night starting from the Old Kingdom; when we have few mentions for some individual decans dated back to that period. The Ancient Egyptian used different kinds of clocks for that purpose, they were used mainly by the priests to determine the time during the day and night so that the temple rites and sacrifices could be performed at the correct hour.

There were three different kinds of clocks used by the Ancient Egyptian: **1-** Star clocks, which depended on the motion of the decans; **2-** Water clocks which were used mostly at night; **3-** Sun clocks (with their three kinds the gnomon, the shadow-clock and sundial) which depended on measuring time by observing the shadow length or its direction.

All the monuments of the water clocks that had been discovered until now could be classified in two different kinds. The first method is the 'outflow,'[2] (fig. 1A) which was allowing the water to drip out, so the clock is taken the form of a bowl with a small hole in the bottom, which allowed water to drip out at a stable rate. The second method is the 'inflow'[3] (fig. 1B), which was allowing water to fill a container at a stable rate, with markings on the inside of the bowl to mark hours as the water level rose.

[1] The Decans,  *b3kiw*, are thirty-six groups of stars of the southern group, constellations, or subdivisions of constellations, rising at particular hours of night. Some constellations cover more than one decan; on the other hand there are decans following a constellation. However, all of them placed within a wide belt start with Sirius, located south of the ecliptic. Each one is rising heliacally for 10 days apart and invisible for 70 days. Each period of 10 days was marked by the heliacal rising of the next decan.

[2] Like the Karnak outflow water-clock (fig.2), which dated back to the 18th Dynasty. It was found broken in pieces at Karnak Temple at Luxor in 1904 by Legrain, G. and restored for the Cairo Museum. It is now at the Cairo Museum, under no.4940.

[3] Like the Edfu inflow water-clock, which dated back to the Greco-Roman Period. It was found at Edfu in 1901, and it is now in the Egyptian Museum at Cairo.

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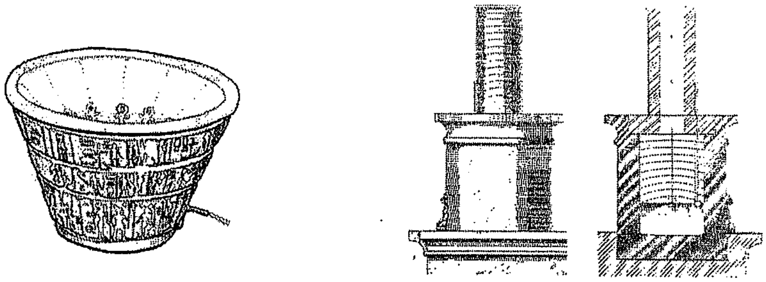

-A- -B-

Fig.1: **A**, Outflow water clock. **B**, Inflow water-clock.

cf., **A**, *Mathematical Models of Water Clocks*, Rochester Institute of Technology, New York, 2004, p.1. **B**, Borchardt, *Zeit.*, taf.10.

The earliest water clocks used the flow of water to measure the passing time. In its simplest form (outflow water-clock), consisted of an alabaster bowl, wide at the top and narrow at the bottom, marked on the inside with horizontal "hour" marks. The bowl was filled with water that leaked out through a small hole in the bottom. The clock kept uniform time, because more water ran out between hour marks when the bowl was full than when it was nearly empty and the water leaked out more slowly.

Fourteen outflow water clocks or their fragments were discovered till now, but most of them dated back to the Greco-Roman Period, except only two dated back to the New Kingdom. The earliest one dated back to the 18th Dynasty.

Among all of those outflow water-clocks, there are only two in very good conditions. The first one is the Karnak clock (fig. 2) which is now in the Egyptian Museum at Cairo. It is dating back to the New Kingdom (18th Dynasty), and is considered the most completed specimen. The other is dating back to the Roman Period during the reign of the emperor Hadrian (fig. 4). There are seven of those kind of clocks found only at Rome, which refer to that the Romans borrowed them from the Egyptians to be used for measuring time, and they did not even tried to remove or change their ancient Egyptian decoration.

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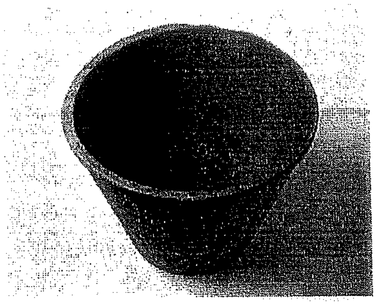

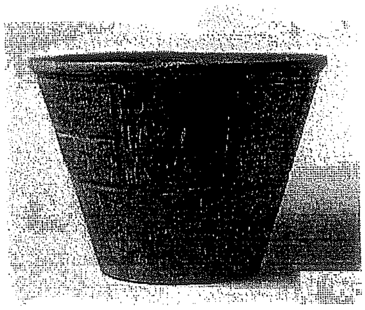

**Fig. 2**: Karnak outflow water-clock

cf., Leblance, Ch. et Nelson, M. "Le Clepsedre de Karnak." p.139.

The outflow water-clock designed by the Ancient Egyptians to be carved around its inner surfaces with a series of vertical dots in 12 scales one for each month, which divided the night in a specified month into 12 hours. Each scale ended in the bottom of the clock by one of the three signs ☥ *ʿnḫ* 'life,' *ḏd* 'stability' and *wꜣs* 'dominion.' On its rim the names of the civil months are inscribed.

In addition, the outer surface used to be decorated with many astronomical (decans - planets - triangle decans) and other different religious scenes (especially the scenes of the king making offering before the deities of the months.) On some of them we can easily recognize the small figure of the god Thoth 'the patron of time' as a baboon mounted over the aperture; which represented the intercalary thirteenth month.

Its surfaces should have been somewhat steeper. As a run-away physicist, the reviewer will observe that this model presupposes that energy losses due to surface tension and the effects of adhesion can be neglected; this is a reasonable assumption as long as the water leaves in a jet, but certainly no longer when it starts dripping (as does the Karnak clock). Surface tension will slow down the outflow, to an extent that depends on adhesion effects and the actual geometry of the aperture.

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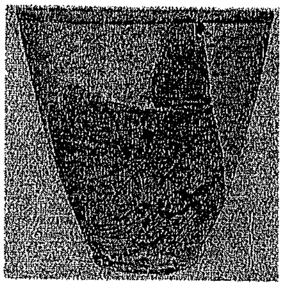


**Fig. 3**: Greek pot water-clock, and models show how it was used.
cf., Young, S. "An Athenian Clepsydra," *Hesperia*, vol.8, no.3, Athens, 1939, fig.1.

A commonly use of that simple form of the outflow water clock was by the Greeks and the Romans, and they called it "clepsydra" or (water thief).[4] This small earthenware vessel (fig. 3) had a hole in its side near the base. They used this type of clepsydra in the courts[5] for allocating periods to speakers. In important cases, when a person's life was at stake for example, it was filled. However, for more minor cases, it was only partially filled. If proceedings were interrupted for any reason, such as to examine documents, the hole in the clepsydra was stopped with wax[6] until the speaker was able to resume his pleading. In addition, that it was also used for measuring the time during the day, but this kind again has not any scales on its inner surface.

One of these water clock is of black granite (fig. 4) dating back to the reign of the emperor Hadrian[7] and found at Rome. It has no scales or dots

[4] Murray, J. "Horologium," *A dictionary of Greek and Roman Antiquities*, London, 1875, p.615; Sloley, R. W. "Ancient Clepsydrae," *Ancient Egypt*, British School of Archaeology in Egypt, vol.2, London, 1924, p.49; .Sloley, R. W. "Primitive Methods of Measuring time," *JEA*, vol.17, The Egypt Exploration Society, London, 1931, p.176; Brauw, M. "Klepsudra," *A Glossary of Athenian Terms*, Center for Hellenic Studies on-line Discussion Series, www.stoa.orgprojects. com, 2003.

[5] Boegehold, A. "Three Court Days-Papers on Greek and Hellenistic Legal History," *Vortrage zur Griechischen und Hellenistischen Rechtsgeschichte*, nos. 24-26, Böhlau Verlag, California, 1991, p.185.

[6] Murray, J. op.cit., p.615; West, S. "Cultural interchange over a Water-Clock," *The Classical Quarterly*, vol.23, no.1, Oxford University Press, Oxford, 1973, p.63.

[7] It is now in the Äegyptisches Museum at Berlin, under no.19556. It was found in 1859, within the temple of Fortuna beyond the Porta Portese at Rome. Wiedemann, A. "Bronze circles and purification vessels in Egyptian temples," *Proceedings of the Society of Biblical Archaeology,*

represented around the inner surface of the bowl. While, its outer surface is decorated with different religious scenes. The vignette is the god Ra-Horakhty representing as a falcon with the double crown; standing above damaged king's Horus names. Under the vignette, there was originally a small statue for the god Thoth, the patron of Time was once mounted over the aperture (it is unfinished and not opened, and a metal gutter was used for the same purpose), representing the intercalary thirteenth month, separating the first and the twelfth months; it is now destroyed.

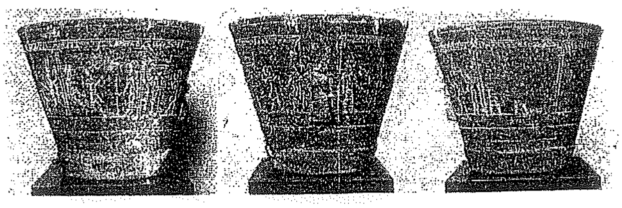

**Fig. 4**: Hadrian Water-clock, Äegyptisches Museum, Berlin.
cf., Roullet, Imp. Rome, figs.334-336.

The metal gutter in this example gives us evidence that it was used by the Romans inside the temple of Fortuna where it was found. So the question here is how did they used it to measure the time without all the regular scales and dots that should be represented on its inner surface? while we found these scales on the inner surfaces of all the other seven clocks and the fragments that found at Rome and used also by the Romans for the same purpose. That big number of the clocks which were discovered in Rome refer to that they depended on this Egyptian technology to measure time, and they did not even tried to remove or change its ancient Egyptian decoration.

I suggest that this kind of the unmarked clock was used by the Ancient Egyptian common people and later by the Greeks and Romans to tell time at night indoors. The majority of those common people were farmers and workers,

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vol.23, Society of Biblical Archeology, London, 1901, p.274; Borchardt, "Die Altägyptische Zeitmessung," *Die Geschichte der Zeitmessung und ser Uhren,* band 1, Berlin, 1920, p.9; Porter, B. and Moss, R.L.B. *Topographical Bibliography of Ancient Egyptian Hieroglyphic Texts, Reliefs and Paintings*, Oxford, 1927, vol.vii, pp.415-416; Roullet, A. *The Egyptian and Egyptianizing Monuments of Imperial Rome*, Études Préliminaires aux Religions Orientals dans l'Epmire Romain, tome vintiéme, Leiden, 1972, p.145.

they could not deal with this complicated regular kind of the outflow water-clock (like karnak water clock) that need professional astronomer or hour-watcher to deal with.

So to solve this riddle I suggest two solutions; the first one that is using the measures of capacity to measure the enough volume of the water they need to put inside the bowl, which is could be suitable for a certain time. While the second solution is using the cubit to measure the depth of the water inside the bowl they need to put until getting to a certain limit. According to that, this style of the unmarked clocks became uncomplicated instruments can be easy made and use and did not need the man to be high educated to deal with.

## 1- Using the measures of Capacity:

A very interesting text (fig. 5) of Amenemhet funerary autobiography from his rock cut tomb in Sheikh-Abd-el-Gurna.[8] He was a high official lived under the reign of three kings of the 18th Dynasty: Ahmose, Amenhotep I and Thumosis I. He tells of having constructed a water clock with corresponding scales in honor of King Amenhotep. Amenemhet, "while reading in all of the books of the divine-word ... found that the longest night was 14 if the shortest was 12 hours" which Clagett[9] suggests in a note that the 14 be understood as "fingers"[10] in a water clock and not as a number of some universal time unit – certainly justified, since even the winter night is divided into 12 hours in the corresponding water clocks. He continued:

> I made a Merkhet[11] reckoned among the year; it was for the good fortune of the deceased King of the Upper and Lower Egypt Djesekara (Amenhotep I). 15| ---- season---

[8] The site is in western bank of Luxor, where many tombs from the 18th and 19th Dynasties were discovered.

[9] Clagett, M. *Ancient Egyptian Science*, vol.2: Calendars, Clocks and Astronomy, American Philosophical Society, Diana Publishing Co., Philadelphia, 1995, vol.2, p.461.

[10] It is one of the standard divisions of the cubit that was used by the Ancient Egyptians for measuring length. With the usual notation and demoting 1 fingerbreadth by *f*, and it is equal about 1.875 cm.

[11] The text uses the word *mrḫyt*, which is literally means 'instrument of knowing,' was a fairly general term, applied to all three kinds of clock the (shadow, astral, and water clocks). However, in this text it refers to the water-clock, that is clear from his words "the water runs out only through a single exit;"

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every. Never was made the like of it since the primeval of time. I made this remarkable instrument in honor of the deceased King of the Upper and Lower Egypt Djesekara (Amenhotep I); dividing it[12] in half, 16| ---- [and then the halves into halves, and finally the four thirds into thirds. It was correct][13] at the beginning of [the harvest,] the summer and winter seasons, for embracing the moon at its times and for every hour at its times. The water runs out only through a single exit."[14]

From the preceding text, it is clear that he claim his clock was precise for all seasons, and it quite clear how much of Amenemhet's discovery was made in books and on the scales of existing water clocks and how much by his own observation. In any case, it is obvious that the construction of a water clock at least as precise as anything known was an object of pride.

While in (line 15) he calls the water clock as *dbḥ(t)*[15] which Faulkner identified it as 'measure of offerings,' it used the determinative of the small vessel that used in measuring grain and liquids specially the water. That is considered an evidence about using the measures of the capacity vessels in measuring the volume of the water they need to put inside the bowl, especially when they deal with the unmarked clocks.

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[12] The writer means dividing each scale on the inner surface into half.

[13] This addition was suggested by Borchardt, who suggests that the sign ( )"r" that can be seen in the beginning of this line may be the sign that was used for frictions and thus would presumably have had three vertical strokes underneath it to indicate "third." He explains that to arrive at the 12 individual hours not only is division by 2 necessary but also by 3. Another possibility is that the use of division into thirds, if it was actually in the inscription, may have been a reference to the fact that, as we have seen in the outflow water-clock (no.1), the successive monthly scale lines decrease or increase in length by 1/3 of a finger's breadth.," Borchardt, *Zeit.*, pp.61-62.

[14] This text translated by Borchardt, *Zeit.*, pp.60-62, Clagett, *Ancient Egyptian Science*, vol.2, p.457, Sloley, *Cleps.*, p.45, and retranslated by the writer of this search in his Ph.D. thesis: Soliman, W. S. *Instruments and Means of Measuring Time in Ancient Egypt - A comparative study with the Greco-Roman period*, Minia University, 2008, vol.1, pp.166-169.

[15] Faulkner, R.O. *A concise dictionary of Middle Egyptian*, Griffith Institute-Ashmolean Museum, Oxford, 1981, p.312.

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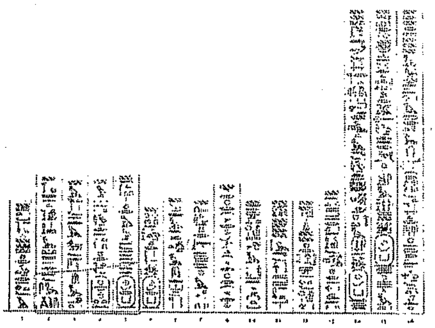

**Fig. 5**: The inscription of Amenemhat about the construction of the outflow water-clock.

cf., Borchardt, *Zeit.*, taf.18.

Another text on a papyrus from Oxyrynchus[16] dating back to the 3rd Century A.D. is considered among the most important written materials that reveals something about the kind of "books" that are likely to have inspired the reconstruction and to understand the technique of the outflow water-clock. It is consists of two pages from a papyrus codex, each page in two columns. Column I and the beginning of Column II give rules for a board game and their mythological astronomical motivations.[17]The rest of the text contains descriptions of astronomical instruments (water-clock).

It computes the volumes of water corresponding to successive hours. The dimensions that recorded on the papyrus is given closely correspond to

[16] Oxyrhynchus is the name of the chief town of an ancient district in Middle Egypt, on the west bank of Bahr Yousef west of the Nile, at modern Bahnasa. So called by the Greeks after a fish worshipped there, it became famous particularly through the excavations for papyri carried out by Grenfell, B.P. and Hunt, A.S. in the winter of 1896-1897 and in the years 1903-1907. The papyri are chiefly Greek documents and literary from the time of Augusts down to the 8th Century. Poethke, G. "Oxyrhynchus Papyri," *The Coptic Encyclopedia*, vol.6, Maxwell Macmillan Publication Company, New York, 1991, pp.1857-1858. Among these papyri are some very important astronomical texts giving a picture of the practice of technical astronomy of the lat Greco-Roman Period.

[17] Neugebouer, O." Astronomical papyri and Ostraca: Bibliographical Notes," *Proceedings of the American Philosophical Society*, American Philosophical Society, vol.106, no.4, Philadelphia, 1962, p.387.

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those of all clocks of which fragments have been found and for which measurements can be obtained.

The papyrus deals; in lines 31 to 87, with the construction of a ώρολόγιον or time-piece (water-clock),[18] shaped something like a flower-bowl,[19]as the following:

> "The calculation of the time-piece is thus given. Make a frustum with an upper line of the 24 fingers, a base of 12 fingers, and a depth of 18 fingers. If we added the 24 fingers to the 12 fingers of the base the result will be 36 fingers; 1/2 of this is 18, multiplying, on account of the round surface, by 3 we obtain 54; 1/3 of this is 18, 1/4 is 13.5; 18 multiplied by 13.5 makes 243[20]...."[21]

It is also clear that the writer of Oxyrynchus papyrus deals with a kind of a standard outflow water-clock refers to it by the word "frustum"; without any referring to whatever the inner surface of the clock is marked or not, which means that the equation was used for both.

According to the papyrus, the ancient Egyptian theory about that type of clocks evidently was that in a vessel constructed according to these proportions the water-level sank equal heights in equal times (which is not in fact true) because the clear difference of the length of the hours and the cone shaped of the clock which makes the volume different from section to another according to the depth.

[18] Borchardt, *Zeit.*, p.10f.
[19] Grenfell, B.P. and Hunt, A.S. *The Oxyrhyncus Papyri*, part III, Egypt Exploration Fund: Graeco-Roman Branch, London, 1903, p.142.
[20] This number refers to the volume.
[21] Ibid, p.145.

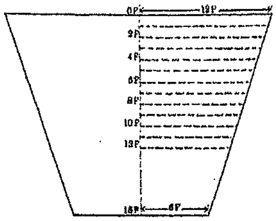

**Fig. 6**: The dimension of the outflow water clock according to the Oxyrynchus papyrus.

cf., Borchardt, *Zeit.*, p.11, abb.1.

It gives dimensions for the standard outflow water-clock: its profile was the frustum of a cone having an upper radius of 12 fingers, a lower radius of 6 fingers, and a height of 18 fingers.[22] The calculation proceeds to find the volume of all the 12 sections (months scales). First the mean diameter in found thus:- (24+12) ÷ 2 = 18; then the mean circumference by multiplication by 3 - result 54; next the mean sectional area, by multiplying the diameter by one – quarter of the circumference (54 x 1\4 =13.5). This gives the volume of one section of depth 1 finger-breadth *f* .[23] So to know the volume of the whole frustum we have to multiply 13.5 by the number of the fingers (13.5 x 18 = 243) which is the final number given by the writer of the papyrus.

According to the last equation, Sloley[24] suggested that the volume of the frustum (or the outflow water-clock which taken the form of a vessel of the dimensions given above) equals 4752 *cu.f.* If the convert of the one cubic cubit (*cu.c.*) equals 144 Liters (*L.*),[25] so that is given us the following:

1 *cu.c.* = (28 x 28 x 28) *cu.f.* = 144 *L.*

21952 *cu.f* = 144 *L.*

So the volume of the water-clock equals (4752 *cu.f.* x 144 *L.*) ÷ 21952 *cu.f.* = 31.1720 *L.*

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[22] Borchardt, *Zeit.*, p.11.
[23] Ibid, pp.11-12; Sloley, *Cleps.,* p.46.
[24] Sloley, *Cleps.,* p.46.
[25] http://www.convertcenter.com/cubic-cubit

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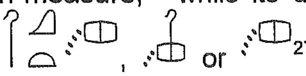
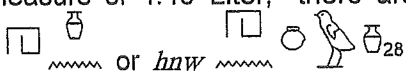
Because of the wide desert that is consider an important large part of the land of Egypt, the Ancient Egyptians used quarries of the fine stones around its desert to produce a various styles and sizes of vessels starting from the Pre-dynastic period and through its history. The Ancient Egyptians used some of those stone vessels made of copper, bronze, silver, granite or alabaster as measures of capacity that have special styles and inscriptions. I suggest that these kinds of vessels, that we have a big collection of them within the museums around the world, used for measuring the volume of water necessary for the unmarked outflow water-clocks.

In their measure for the volume of the liquids, the Ancient Egyptians appear to have symbols employed in this, and they all in connection with the *ḥḳ3t* – measure, that was mainly used for corn-measure,[26] while its divisions used for the liquids. Emerges from the *ḥḳ3t*  [27] which Faulkner identified as "corn-measure of 4.45 Liter," there are different other measurements, start with *hin*  [28] which Faulkner identified as "measure of about 1/2 *Liter.*" It is shown by the Rhind Mathematical Papyrus[29] to have contained 1/10 *ḥḳ3t*. In the last century, ancient Egyptian measures of capacity have been determined mostly on the basis of this papyrus. It is not known, however, if the relation given there between the measure and cubit is exact (or meant to be so), nor how long it remained valid.

[26] Faulkner, R.O. op.cit, p.178; Gardiner, A.H. *Egyptian Grammar: Being an introduction to the study of Hieroglyphic*, Clarendon Press, London, 1963, § 266, no.1.
[27] Ibid.
[28] Faulkner, R.O. op.cit, p.158.
[29] The Rhind Mathematical Papyrus, is named after Alexander Henry Rhind, a Scottish antiquarian, who purchased the papyrus in 1858 at Luxor, Egypt; it was apparently found during illegal excavations in or near the Ramesseum. It dates to around 1650 B.C. to the Second Intermediate Period. It was copied by the scribe Ahmes, from a now-lost text from the reign of king Amenemhat III (12th Dynasty). Written in the hieratic script, this Egyptian manuscript is 33 cm tall and over 5 meters long. One of the Mathematical problems that it deals with is 23 problems from practical weights and measures, especially the *ḥḳ3t*. Chace, A.B., Bull, L., Manning, H.P. and Archibald, R.C. *The Rhind Mathematical Papyrus*, Mathematical Association of America, Oberlin, 1929, vol.1, p.49; Gillings, R.J. *Mathematics in the time of the Pharaohs*, 1972, MIT Press, Dover reprint, New York, 1982, p.45; Wikipedia, the free encyclopedia http://en.wikipedia.org/wiki/Rhind_Mathematical_Papyrus

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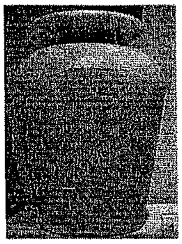

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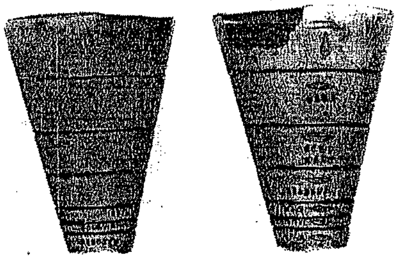

-B-

**Fig. 7A**. Alabaster measure of liquid capacity, with the cartouche of Thutmose IV, Rijksmuseum van Oudheden, Leiden. **B**. Bronze measure of liquid capacity dated back to the Greco-Roman period, Egyptian Museum, Cairo.

cf. **A**: www.livius.org/a/1/egypt/measure_rmo.JPG **B**: Lucas, A. and Rowe, A. "Ancient Egyptian measures of capacity," pl.x.

On the outer surfaces of the Egyptian Museum collection of the measure capacity vessels (figs. 7A and B), it is clear that there is another fractions of the *hin*, which is *ḏ3* that is equal about 2\3 of *hin*.[30] So .from all the information above we can get the following:

1 *ḥḳ3t* = 10 *hin*

1 *ḏ3* = 2\3 *hin*

Actually there are many ideas about the volume of the *hin* measure; for example Gardiner suggests that it is about 0.503 *L*.;[31] that is almost the same by Faulkner, while in Erman-Grapow it is given as 0.45 L.[32] and according to Rhind Mathematical Papyrus 300 *hin* = 1 *cu.c.*,[33] or 1 *hin* = 0.48 *L*. So we can say that the average of the number that mentioned before:

1 *hin* = 0.48 *L*.

1 *ḥḳ3t* = 4.8 *L*.

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[30] Lucas, A. and Rowe, A. "Ancient Egyptian measures of capacity," *Annales de Service des Antiquities de l'Egypte*, tome 40, Le Caire, 1940, p.81.
[31] Gardiner § 266, no.1.
[32] Erman, A. und Grapow, H. *Worterbuch der Aegyptishen Sprache*, Hinrichs' sche Buchhandlung, Leipzing, 1962, vol.2, p.493.
[33] Gillings, R.J. op.cit. p.163.

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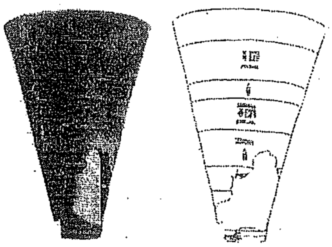
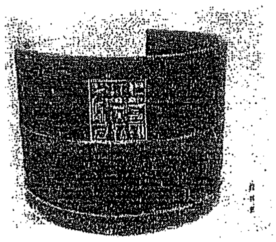
So the calculation proceeds to find the volume of all the 12 sections (months scales) or let us say for the whole water-clock, is as the following: First the volume of the water-clock equals 31.1720 L., and if 1 *hin* equals 0.48 L., so the volume equals 31.1720 ÷ 0.48 = 64.9416666 = c. 65 *hin* or 6.5 *ḥkꜣt*.

According to the last number; if we used one of the Egyptian Museum vessels, for example the silver vessel[34] (fig. 8A) which is 1 *hin* capacity, so the Ancient Egyptian hour-watcher needs to use it sixty-five times to fill the water-clock with enough water to measure twelve hours (which is the full capacity of the clock.) Therefore, I suggest that they used bigger vessels for more easily using, as for example the granite vessel of Tuthmosis III (fig. 8B) which is about 40 *hin* capacity,[35] or the alabaster jar of Hatshepsuit (fig. 9), which is about 35 *hin*,[36]and both could be used one time to fill the clock with majority of the needed volume and then the hour-watcher had to used smaller vessels to finish his duty.



- A -



- B -

**Fig.8:** **A,** Silver measure of liquid capacity dated back to the Greco-Roman period, Egyptian Museum, Cairo. **B**, Granite measure of liquid capacity dated back to the time of Tuthmosis III, Egyptian Museum, Cairo.

cf. Lucas, A. and Rowe, A. "Ancient Egyptian measures of capacity," **A**. pl.xi and p.83; **B**. pl.xiii.

[34] It is in the Egyptian Museum at Cairo, under no. j.28493, and founded at Alexandria in 1888. It is about 16.5 cm. height and dated back to the Greco-Roman Period. Lucas, A. and Rowe, A. op.cit. pp.73-74.

[35] It is in the Egyptian Museum at Cairo, under no. j.36925, and founded at Karnak temple in 1904. It is about 24.1 cm. height and dated back to the 18th Dynasty. Ibid, pp.76-77.

[36] It is group of a vessel fragments in the Egyptian Museum at Cairo, under no. 17\17 12\1, It is dated back to the 18th Dynasty. Ibid, pp.79 and 88.

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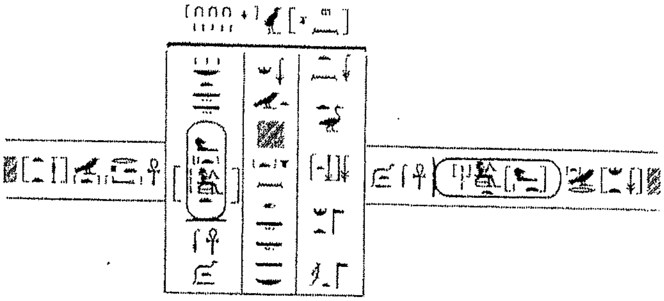
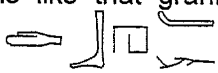


**Fig. 9:** The inscription on an alabaster jar fragment of Hatshepsuit, Egyptian Museum, Cairo.

cf. Lucas, A. and Rowe, A. "Ancient Egyptian measures of capacity," p.88.

That shape of vessels like that granite one of Tuthmosis III, which mentioned before was called  *dbḥ*.[37] It is the same word that in his inscription about the construction of the outflow water-clock, Amenemhat called the water clock as *dbḥ(t)* in (line 15), which gives evidence that both the water-clock and that kind of *dbḥ* vessels were connected together in the same function.

[37] Peet, T.E. *The Rhind Mathematical Papyrus*, London, The University Press of Liverpool limited and Hodder & Stoughton limited, 1923, p.26; Lucas, A. and Rowe, A. op.cit. p.85. In addition to that Faulkner mentioned it as  *dbḥw* 'measure of offerings.' Faulkner, R.O. op.cit, p.312.

## 2- Using the cubit:

The cubit was used by the Ancient Egyptians to measure the lengths. They used different standard measures like the finger width (digit) *ḏbꜥ*, palm *šsp*, hand *ḏrt*, fist *ꜣmm*, span *spd*, foot *bw*, shoulder or *rmn* and a measure called the cubit *mḥ*. All of them are divisions the last measure (unit) or the cubit that I suggest it was used also to measure the depth of the water in the water clocks.

The Cubit was based on the length of the arm from the elbow to the extended fingertips on an average person[38] and was standardized by a master cubit of black granite, against which all the cubit sticks in use in Egypt were measured at regular intervals. They, however, used cubits of two lengths; the small cubit and the royal cubit, which were the official measures.

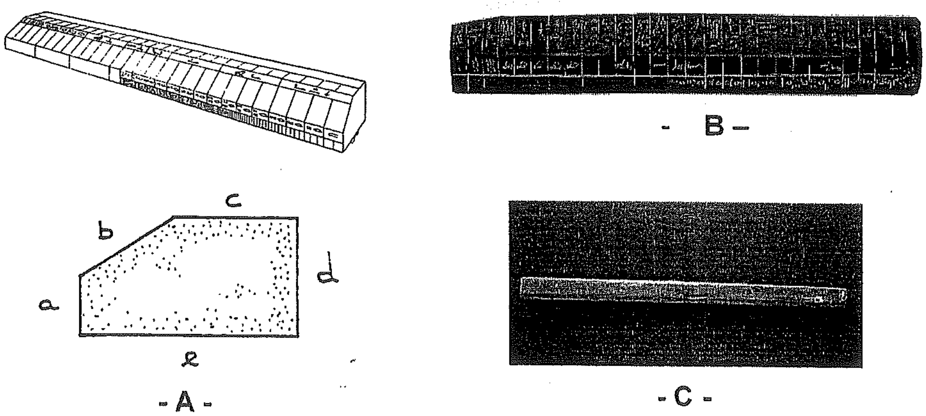



**Fig. 10**: **A**, The divisions of the standard cubit. **B**, A Royal Cubit, Louver Museum, Paris. **C**, An un-inscribed wooden cubit

Cf., **A**: Roik, E. Das Längenmabsystem im alten Ägypten, p.7. **B** and **C**: http://www.egyptarchive.co.uk/

[38] "The Cubit," *The New Encyclopedia Britannica*, editor: Mc Henry, R., vol.5, Library of Congress, Chicago, 1995, p.1182.

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The short cubit *mḥ* of six palms was about 45 cm.[39] length, and it was used in every day measuring.[40] The royal cubit *mḥ nswt* of seven palms was between 52.3 cm. to 52.5 cm.[41] This kind was the base of the official Egyptian measuring system used with the ancient clocks and in the construction of temples etc.

Most of cubits that were discovered till now are belonging to the standard cubit which is the Royal-cubit that consists of 7 palms or 28 digits, in wood or stone, in square or pentagonal sections, and had dome divisions (fig. 10A and B).[42] There are also some other which have not any inscriptions but their marks refer to the 7 or 8 palms only (fig. 10C).

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[39] Roik, E. *Das Längenmabsystem im alten Ägypten*, Hamburg, 1993, p.13.

[40] Robins, G. *Proportion and style in Ancient Egyptian Art*, University of Texas Press, London, 1994, p.41.

[41] Petrie, W.M.F. *The Pyramids and temples of Giza*, London, 1883, p.28; Scott, N.E. "Egyptian Cubit Rods," *Metropolitan of Art Bulletin*, vol.1, no.1, New York, 1935, p.70; Arnold, D. *Building in Egypt: Pharonic Stone Masonary*, Oxford University Press, New York, 1991; p.8; Roik, E. op.cit, p.13.

[42] The divisions of the regular cubit are as the following:

a- Forefront: Reading from right to left the subdivision of the digit in the upper register, the 14th digit on a cubit stick was marked off into 16 equal parts or (fingers). The next digit was divided into 15 parts, and so on, to the 28th digit, which was divided into 2 equal parts. Thus, measurement could be made to digit fractions with any denominator from 2 through 16. The smallest division is 1/16 of a digit. Sometimes they used to write the letter ( *r*) beside the number to refer to the friction.

b- Surface: This face is inscribed with the names of the larger divisions of the cubit. The first three fingers are labelled as , then , over the fourth is written or palm (a hand without the thumb), over the fifth is hand , over the sixth is fist (a clenched hand with the thumb extended), over the seventh is one stretched finger hand , over the eighth is two stretched fingers hand or two palms . The next four fingers belong to the small span or the twelfth finger, and the fourteenth is the great span . Another division, which suggests the length of the forearm from elbow to wrist , falls at the end of the fourth palm. Next, comes the *rmn*, the upper arm or shoulder, five palms long; and over the sixth and seventh palms respectively are written (short) cubit

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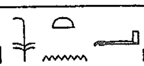
In the next table, I show a summary of the different measures, their relation to the digit and their equivalent:

| | | | | |
|---|---|---|---|---|
| 1 Royal cubit *mḥ nswt* | | 7 palms | 28 digits | c.52.5 cm. |
| 1 Small cubit *mḥ* | | 6 palms | 24 digits | c.45 cm. |
| 1 Shoulder *rmn* | | 5 palms | 20 digits | c.37.5 cm. |
| 1 Foot *bw* | 2/3 small cubit | 4 palms | 16 digits | c. 30 cm. |
| 1 Span *spd* | 1/2 small cubit | 3 palms | 12 digits | c.22.5 cm. |
| 1 Fist *ꜣmm* | 1/4 small cubit | 1.5 palm | 6 digits | c.11.25 cm. |
| 1 Hand *ḏrt* | | 1.25 palm | 5 digits | c.9.375 cm. |
| 1 Palm *šsp* | 1/6 small cubit | | 4 digits | c.7.5 cm. |
| 1 Finger or Digit *ḏbꜥ* | | | | c.1.875 cm. |

and  royal cubit. Each digit was associated with a god whose name was written above it.

c- Upper-side: Each cubit divided into 7 palms, and each palm into 4 digits, giving the standard 28 digits, with the names in hieroglyphs for each division. It carries also a list of the provinces, that is to say, the 22 provinces of Upper Egypt plus six of Lower Egypt on one of its other sides.

d- Rear: Hieroglyphic text, often inscribed with the name of the owner.

e- Under-side: Hieroglyphic text. Schwaller de Luicz, R.A. *The temple of Man*, Hong Kong, 1998, p.285; Sarton, G. "On a curous subdivision of the Egyptian Cubit," *ISIS*, vol.25, no.2, Brussels, 1936, p.400; Schiaparelli, E. *Relazione sui laori della missione archeologica italiana in Egitto (anni 1903-1920) vol. II, La tomba intatta dell'architetto Cha nella necropolis di Tebe*, Turin, 1927, p.172.

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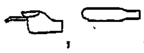
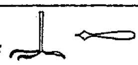
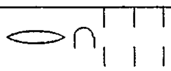
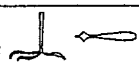
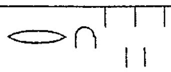
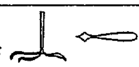
From all the fragments of the outflow water clocks and the Oxyrynchus papyrus, it is clear that the depth of all these clocks are fixed, which is 18 *f.* (digits) (fig. 6). So the easiest way that the hour-watcher can do if he deals with an unmarked water-clock just to place a cubit vertically inside the bowl, then filling it with water, and when the level of the water get to the 18 *f.* mark on the surface of the cubit that means the volume of the water inside is enough to measure 12 hours period.

In the next table, I will show the relation between the numbers of hours that we need to measure and the marks of the water level on the surface of a cubit:

| To measure | The level of the water should get to this mark on the cubit |
|---|---|
| one hour | , or seven *f.* |
| Two hours |  or eight *f.* |
| Three hours | Always empty but belong to the palm of , or nine *f.* |
| Four hours | Always empty but belong to the palm of , or ten *f.* |
| Five hours | , or eleven *f.* |
| Six hours | Always empty but belong to the palm of , or twelve *f.* |
| Seven hours | Always empty but belong to the palm of , or thirteen *f.* |
| Eight hours |  (1\16 of the cubit) belong to the palm of , or fourteen *f.* |
| Nine hours |  (1\15 of the cubit) belong to the palm of , or fifteen *f.* |

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| | |
|---|---|
| Ten hours | ∩ II (1\14 of the cubit) belong to the palm of , or sixteen *f.* |
| Eleven hours | ∩ I (1\13 of the cubit) belong to the palm of , or seventeen *f.* |
| Twelve hours | ∩III (1\12 of the cubit) belong to the palm of , or eighteen *f.* |

All the previous information are going around the decorated cubit and the way to use them in measuring the depth of the water; but for some other cubits which have not any inscriptions but their marks refer to the 7 or 8 palms only, they were used in the same way by placing the cubit vertically inside the clock then filling the bowl with water and counting the number of the palms that overflowed by the water to identify its limit.

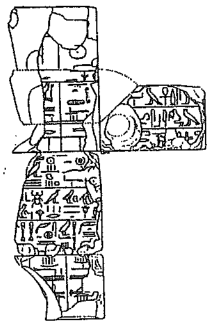

**Fig. 11**: An inscription on a fragment of a cubit, Metropolitan Museum of Art, New York.

cf. Scott, N.E. "Egyptian Cubit Rods," p.73.

One of the cubit fragments (fig. 11) in the Metropolitan Museum of Art at New York has the no.41.160.102, its base is divided into three horizontal registers, each filled with an inscription. The texts of these three lines are very corrupt. The scribes must have copied them from older piece. The topmost

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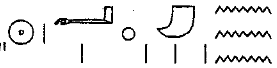
register is divided into two parts. The first begins, " The hour according to the cubit . . . . A *sṯꜣ* jar of copper filed with water." It then goes to give quantities[43] according to the divisions of the *ḥin*, which is the  *ḏꜣ*.

From that text, it is clear that using the cubit to measure the time with the help of the water-clock, which is referred to by the scribe as *sṯꜣ* jar "measure of capacity."[44] Moreover, using the word *ḏꜣ* which is one of the Egyptian way of computing volume (as explained in this research before) also connects between the two ideas of using both the cubit and measures of capacity for measuring the time and dealing with the water-clock.

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43 Scott, N.E. op.cit, p.73.

44 Faulkner, R.O. op.cit, p.255; Gardiner § 266, no.1.

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## الملخص العربى

## وسائل استخدام عامة الشعب فى مصر القديمة للساعات المائية ذات التدفق الخارجى

استخدم المصري القديم العديد من أنواع وسائل قياس الوقت على مر العصور، وكان منها الوسائل الشمسية المعتمدة على طول وتحرك ظل الشمس، والوسائل النجومية التى تعتمد على تحرك النجوم فى السماء، والمائية التى كانت فى العادة تستخدم ليلا لمعرفة الوقت عن طريق الساعات المائية. لقد أخذ الإغريق والرومان العديد من هذه الساعات وأدوات قياس الوقت من مصر واستخدموها فى بلادهم.

استخدمت الساعات المائيّة (أكثر الساعات تعقيدا" وشعبية بين جميع انواع الساعات القديمة) خلال الليل خاصة عندما تكون النجوم الدوارة غير مرئية بواسطة مراقبي الساعات فى المعبد. وربما كان خدم المعبد يتبادلون الأدوار في مراقبتها أثناء الليل، وكانت تستعمل لتحديد ساعات الواجبات التى كان يقوم بها الكهنة. كان اختراع الساعة المائية لحل مشكلة اختفاء الشمس بسبب السحب فى بعض الأيام.

عرف المصريون نوعين من هذه الساعات وهى: ذات التدفق الخارجى (حيث تقوم فكرة عملها على خروج الماء من الساعة بطريقة منتظمة، ويقاس الوقت بملاحظة أرتفاع الماء داخل الأناء)، والأخرى ذات التدفق الداخلى (حيث تقوم فكرة عملها على تنقيط بطريقة منتظمة الماء داخل مستوعب مدرج يشير تدريجه للوقت). لكن أكبر عدد من هذة الساعات المائية اكتشفت حتى الأن تنتمى إلى النوع الأول. لكن بعض منها وجد من غير اى تدريج أو نقاط مرسومة على جدارها الداخلي كما هو معتاد، مما يرجح فكرة أستخدامها بواسطة عامة الشعب الغير متعلمين والذين من الممكن أن يجدوا صعوبة فى فهم واستخدام النموذج التقليدي من هذه الساعات.

لذا فالغرض من هذة المقالة هى محاولة تفسير وتخيل طريقة أستعمال هذه الساعات التي لا تحتوى على اى نقوش على سطحها الداخلي. ولقد فسر الكاتب هذة اللغز فى طريقتين: أولهما هو أستعمال أواني قياس حجم السوائل فى قياس حجم الماء الكافي لوضعه داخل الساعة لقياس عدد معين من الساعات. وثانى هذه الحلول هو استخدام عصا القياس Cubit لقياس عمق المياة داخل الساعة والكافى لقياس فترة محددة من الوقت.