Illustrations of water clocks in light of the manuscript of “ktāb ʿlm s-sāʿāt wālʿml bhā” by Rḍwān bn Muhammad al-sāʿātī (658 AH/1259 AD) Preserved in the Kopruli Library in Istanbul under preservation number 949

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Abstract: The research deals with the study of illustrations of one of the most important Arabic manuscripts related to the science of clocks, which is “ktāb ʿlm s-sāʿāt wālʿml bhā” (The science of clocks and working with them), dated 658 AH / 1259 AD, by its author, Radwan bin Muhammad Al-Khorasani. The manuscript includes clocks created by his father, Muhammad bin Ali bin Rustum Al-Khorasani, one of the most important watchmakers in the Arab civilization. Absolutely he was the one who created the clocks, located at the door of the Eastern Umayyad Mosque in Damascus. The author discussed these machines and how they worked, as they deteriorated after the death of his father, and he had to repair them. The research aims to study some illustrations of the manuscript, as it is one of the important manuscripts that includes a type of water clock, the names of its parts, and how it works, explaining this with illustrations that refer to the author’s text.
The research also deals with scientific representation through study and analysis in terms of the parts of the clock, its function and method of work, explaining the technical method of those drawings, following the descriptive and analytical approach.

Keywords: Bankamat; Archimedes; Mechanical engineering; Giron’s door; Time

Introduction: Arab scientists excelled in the science of tricks known nowadays as mechanical engineering; our scientists left for us a massive fortune of manuscript books that reveal the level of innovation and progress that Islamic Arabic civilization had achieved, including the manuscript of the book “ktāb ʿlm s-sāʿāt wālʿml bhā” (The science of clocks and working with them), that

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includes only one branch of the science of tricks which is clocks and watches science known in the Arabic lexicons as science of Bankamat.

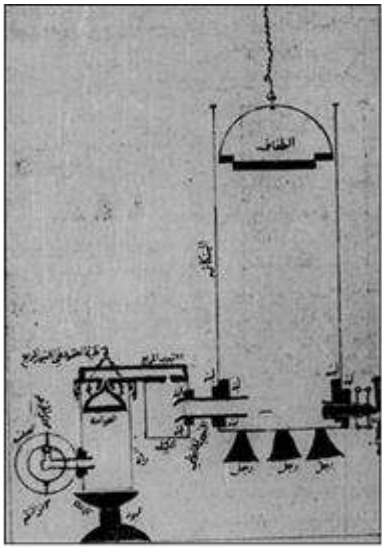
Definition of science of Bankamat: (science of clocks machineries); it is a science that assist in finding machines that can estimate the time, its subject is about creating certain moves inside some bodies that are done by moving limited distances, the aim is to recognize times of prayers without monitoring planets movements and refer to machines to calculate their altitude. This science is extracted from numerology, mathematics and physics; including engineering and chemistry as subsidiary sciences.

Arab scientists had combined both theoretical and practical science; the best model to prove that is this manuscript book "ktāb ʿlm s-sāʿāt wālʿml bhā" (The science of clocks and working with them), as it includes basics for the science of watches, applied on water clock that existed at the Umayyad Mosque in Damascus, that its machinery deteriorated after the death of the author's father, and the author had to fix it.

Identification of the manuscript: Koprulu Kutuphanesi; A library in Istanbul, Türkiye is keeping a copy of the manuscript "ktāb ʿlm s-sāʿāt wālʿml bhā" (The science of clocks and working with them) under documentation number: 949. It was written in Naskhi calligraphy, dated back to the year 685 H- 1259 AD, it is copied and it carries the signature of its copyist Belk bin Abdallah al-Kipchaki, it was copied in Cairo, it discussed machinery of water clocks by their names and how they function in details, and clarified with some scientific illustrations.

The author of the manuscript: He is Radwan bin Muhammad bin Ali bin Rostom Al-Khorasani al Saati. Place of birth is Damascus; he lived during the era of two Ayyubid kings. The most famous books he left are: (Notes to the Law for ibn Sina- finishing the qulanj message- selected poems). He died in the year 618H, out of excessive bilirubin in the blood.

The descriptive approach: Illustration 1: The entire water machinery No. of the page in the manuscript: The back of page 20.



Description:

The water machinery consist of bankan (water tanks) it is a rectangular pot , based on 3 legs and contains a floating device "al tafaf", hanging by a chain outside the bankan, a tap is installed at the tip of the right side, while on the left side opposite to it there is a tube that connects the water tank and the measuring pot; the square tube acts like a cover for both the measuring cup and (al robaa) the quarter cup. 2 holes are opened in the tube; one is above the measuring cup for the water to ascend through it, and the other is above the quarter cup for the water to descend, the quarter is a rectangular pot based on a base followed by a column then another base, inside of it there is the floating device hanging from above

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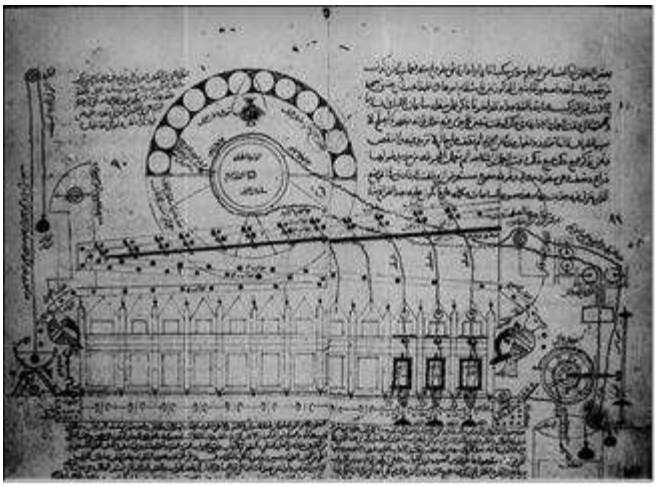
by 2 chains, by the left side of the quarter a tray is installed with the names of the 12 horoscopes written on it, with another plate called al Gazaa (the trunk plate), which the author described as a rounded plate with a diameter less than the horoscope tray to be contained inside it, the trunk has a welded collar contained within the tray till it reaches its bottom, they touch that they become one for the ultimate quality of shape and function. The illustrator expressed it by drawing a circle that represents a rounded cupper tray in the center of the horoscope tray, it has 2 tubes; one has its tips connect from inside the quarter pot to the center of the trunk plate, and the other from the center of the plate upward till the edge of the circle of the trunk plate, it has a head looks like a pointer with the phrase (mori al gazaa) (pointer of the trunk) written on it, the same shape is corresponding to it in the edge downward with the phrase (mori al nazir) (pointer of the analogue) written on it. The author wrote that the 2 pointers are the fragments similar to the astrolabe pointer; one is the trunk pointer located in front of the water exit, corresponding to it is the analogue pointer. This illustration is no different from the other illustrations in the manuscript as explanatory phrases were written for all parts of the image.

Illustration 2: The whole clock with all its parts.

No. of the page in the manuscript: The face of page 46.



Description:

The image clarifies the external and the internal composition of the water clock understudy, the parts were drawn with extreme accuracy and innovation. The author left two corresponding papers inside the manuscript for the drawing of the clock in its final form. He pointed out the parts in clarification phrases for each one of them, likewise; he did in all the drawings of the manuscript, as it appears to be an educational, clarifying manuscript. In the right side of the image, the entire water machinery parts were drawn and above them are the daytime desks that were invented by the author's father, they appear with their minimal details like the pins in the left side of the desks that the strings connected to the floating device are fixed upon them. The moving rolls are above the desks where the strings are surrounding them linked from the top by the circle of the night hours which are twelve vessels in white, in front of it there is a lamp that lighten the vessel standing

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in front of it, down to the night hours there are tubes that have little black circles inside representing the cupper shooters that pass through them and they end up at the head of each bird in the right and the left sides of the clock. In front of the bird's peak (the hawk) there are two small circles in black expressing the fall of the cupper shooters from its peak and they gather at the square pot underneath the bird's peak.

Between the right bird and the left bird there are 12 doors that open when an hour passes by, the crescent shape appears only during daytime; night hours appear through the movement of the circle of night hours.

The analytical study:

Industry of water clocks was known before the Islamic Arab civilization and was developed along ages, continuous renovations in its shape and composition were added. The ancient Egyptian was able to create a water clock to measure time, that consisted of a pot made of stone or metal or pottery that has a base with an opening for the water to be discharged at certain time that can be identified. Such kind of watches spread in ancient Egypt; China also knew water clock, and sundial and solar clock, but during the Han dynasty (202 BC-221 AD), Chinese engineers were able to develop those tools, they made the water clock to resemble a true building, it was designed to measure a whole day, 24 hours. The invention of the huge water clock was attributed to an Egyptian engineer called Ctesibius who worked in Alexandria around the year 300 BC. Books mentioned that the Greek scientist Archimedes (287-212 BC) is the mayor of this invention. He was known with being fond of building machines; it looks like the Chinese clock mentioned earlier is close to Archimedes clock with more enhancements and improvements. Some interpretations of Greek books have reached us about Archimedes water clock; it consisted of 3 tanks (pots), the first one from beneath the water tank where the excess water, affecting the accuracy of the clock movement, was being collected, connecting to the tap responsible for the discharge of excess water, the second water tank includes the floating part that is hanging by a chain from the upper tank. The roll tank was called this way due to the presence of a roll fixed on portable axis, and the position of shooters collecting, and the cupper mirror responsible for creating a sound when hit by the cupper shooter that comes out of the bird's peak, and (al Makly) the pot with its tip inside the water tank where the extra water is collected and discharged and moved through the tube till gets inside the collected water tank, and the quarter that is installed in the right side of the water tank with a tube connecting the water tank and the quarter for the water to exit to the quarter with the floating device. The trunk is beneath the quarter, it wasn't clear in the translated Archimedes manuscript as all its parts were in the understudy manuscript "clocks science".

Clocks of the Islamic Arab civilization; the Arab scientists were ahead of many other civilizations in knowing most types of clocks regarding manufacture and design with the most accuracy, they kept on developing and adding to the watches till they became smaller and more accurate and don't depend on strength of external power such as water.

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Water clocks, constructed by Muhammad bin Ali bin Rostom Al-Khorasani, were created that way from the beginning, but was preceded by other water clocks, such as the one in Bab al-Zayda, the southern door in the Umayyad Mosque in Damascus, also known as the clocks' door.

Muhammad bin Ali bin Rostom Al-Khorasani, had created new clocks during the reign of Nur al-Din Zengi ,after entering Damascus in 549 H/1154 AD, they were placed on the eastern door of the Umayyad Mosque (Bab Geron) Giron's door, and he managed their functions, maintenance, and control of those clocks. It is clear that Muhammad bin Ali bin Rostom Al-Khorasani clocks basically relied on Archimedes design and those who are previous to him of scientists, yet he added some adjustments for certain parts to improve their functions, and added other parts he invented to elevate the accuracy of the clock. He adjusted the length of the bankan (water tank), made it in the height of the person who pours the water, so it is full by 2 jars of water, as it used to be very long and it was filled by 20 jars of water which consumed a long time and hardship in pouring the water. He also added supportive pieces for the tubes that connect the water tank with the measuring parts and the quarter tube to prevent any malfunction to the tubes during the movement of the clock.

He invented some parts that increase the accuracy of the clock and improve its functions:

- He invented the semicircle that covers the night pots, and the double roll that the strings linked to the covering semicircle are spinning upon.
- He made the horoscope tray in the form of a complete circle, while Archimedes made it only half circle.
- He invented the birds with spreading wings and made them prominent so when the shooter falls, the birds kneel to Allah and their peaks open so the shooter falls on the mirror and each bird returns back to its original location.
- He invented the crescent moons appearing behind doors, that was unknown previously in water clocks.

Closure and most significant results:

- The study clarified the inventions belonging to Muhammad bin Ali bin Rostom Al-Khorasani the maker of the water clock understudy, such as the square tube, semicircle covering the night pots, daytime desks, double roll, horoscope tray and others.
- The research paper highlights the author being keen to clarify his manuscript using illustrations that resemble reality and focus on clarifying the idea more than the technical part whether in using colors or perfecting the drawing to help us to identify the artistic style for such kind of scientific manuscripts.
- The research clarifies the level of scientific progress reached by Muslim scientists in developing water clocks, as its composition was merely simple, and huge ones were installed by the Chinese civilization and the Greeks, but Muslim scientists invented new parts to improve the function of the clock and add glamor and innovation to it.
- The study identified the main parts invented by Archimedes that were mentioned in the manuscript and could be proved through the Arabic translations that have reached us; they

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are al bankan (water tank), the quarter, the floating device, al tafaf (the floating device) and the cupper mirror.

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