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A review of Early Muslim Control Engineering

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A REVIEW OF EARLY MUSLIM CONTROL ENGINEERING

During the period of Islamic-Arabic extraordinary activity in Science and Technology (9th-13th century) there are some recorded contributions to the area of Automatic Control mainly in the development of water clocks using float valve regulators, different level controls using float valves or combination of syphons and the development of On-Off control.

The Islamic Arabic Automatic Control Technology had as a basis the Greek Technology of two scientists namely Philon of Byzantium (Rhodes and Alexandria) of the second half of the third century BC (his book "pneumatica" was translated from Arabic into French and German in 1902 and 1899 respectively) and Heron of Alexandria of the first century AD (his book "pneumatica" was translated from Greek into English and German in 1851 and 1899 respectively).

It is noted in Greek technology the language is Greek but the scientists need not be Greek as in the case with Islamic-Arabic technology.

It is known that there are hundreds of thousands of manuscripts dealing with Islamic Science and Technology to be edited and it is assumed that some of them deal with technology. This report is based on the following references [1-6].

PART I - AUTOMATIC CONTROL IN WATER CLOCKS

1. "The work of Archimedes on the Building of Clocks"

This is an Arabic book whose arabic author is called pseudo-Archimedes with the earliest reference to it in "The Fihrist "of Al-Nadim (died 955 AD). From the literary style and the technique of its drawings this clock book seems to be an Islamic work based on Greek-Roman technology as mentioned in[1]. This clock used a float level regulator, which makes it a feedback device. A large float drove the whole apparatus. The description of the complicated clock is so thorough that it could be reconstructed almost completely. This book did have considerable influence on the two great horological books of Al-Jazari and Ibn Al-Saati and other Arabic authors like Ibn Al-Akfani.

2. "Al-Jami bain Al-Ilm…" by Al-Jazari[5]

This book was written in 1206.Al-Jazari is from Al-Jazira the area between Tigris and Euphrates. Sarton[6] mentions "This treatise is the most elaborate of its kind and may be considered the climax of this line of Muslim achievement "The distinctive feature of the book is its practical aspect. The book is rich in minute discription of various kinds of devices. Hill[3] maintains "It is impossible to over-emphasize the importance of Al-Jazari`s work in the history of engineering. Until modern times there is no other document from any cultural area that provides a comparable wealth of instructions for the design, manufacture and assembly of machines" "Al-Jazari did not only assimilate the techniques of his non-Arab and Arab predecessors, he was also creative. He added several mechanical and hydraulic devices. The impact of these inventions can be seen in the later designing of steam engines and internal combustion engines, paving the way for automatic

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control and other modern machinery. The impact of Al-Jazari`s inventions is still felt in modern contemporary mechanical engineering." Hill[4] translated the book to English in 1974. A German translation was made in 1915.The chapter on water clocks describes 10 water clocks, the first two of them use float valve regulators. The various time-indicating mechanisms are propelled by a float .The other clocks are regulated differently. Al-Jazari mentions an old machine, which he inspected, in which a musical automaton was powered by a vertical water wheel. In his comments on this machine he clearly implies that he knew how to control the speed of such a wheel by means of an escapement.

3. "Book on the Construction of Clocks and their Use", Ridwan b.Muhammad Al-Saati Al-Khurasani (1203)

This book describes the monumental water clock built by Ridwan`s father at the Jayrun gate in Damascus. A German translation was made in 1915. A large float drives the clock, float valve regulator and the device for varying the length of the hours are incorporated.

4. "The Book of Secrets about the Resulte of Thoughts", Al-Muradi of Andalusia(11th century)

This is the earliest description in Arabic of water clocks. This book deals with water clocks and other devices using automata. The treatise consists of 31 models of which 5 are essentially very large toys similar to clocks in that automata are caused to move at intervals, but without precise timing. The prime movers are water wheels that can be overshot or undershot depending on the intensity of flow. There are nineteen clocks, all of which record the passage of the temporal hours by the movements of automata. The power came from large outflow clepsydras provided with concentric siphons. This power was transmitted to automata by very sophisticated mechanisms, which included segmental and epicyclic gears and the use of mercury. These are highly significant features; they provide the first known examples of complex gearing used to transmit high torque while the adoption of mercury reappears in European clocks from the thirteenth century onwards. Unfortunately, the only known manuscript of this work is badly defaced and it is not possible to understand exactly how the clocks worked .A weight driven clock with a mercury escapement appears in "Libros del Saber" a work written in Spanish at the court of Alfonsos of Castille about 1277 and consisting of translations and paraphrases of Arabic works A novel feature in this treatise is the use of mercury in balances. Al-Zarquali built two large water clocks on the banks of the river Tagus at Toledo in 11th century[2].

5. "Kitab Mizan Al-Hikma (The Book on the Balance of Wisdom)", Al-Khazini (1121-1122)[2]

The eighth treatise of this work described two steelyard clebsydras. The main one, called the Universal Balance, was designed for 24-hour operation, and consisted of an iron beam divided into unequal arms by a fulcrum. An outflow clepsydra equipped with a syphon was suspended on the end of the short arm, and two movable weights, one large and one small, were suspended from the long arm, which was graduated into scales. As water discharged from the clepsydra, the weights were moved along the scale to keep the beam in balance. At any moment the hour of the day could be told from the position of the large weight, its minutes from the position of the small one."

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Part II - Automatic Control of Banu Musa

"Kitab Al-Hiyal" (The Book of Ingenious Devices) by Banu Musa bin Shakir (9th century). The three sons of Musa organized translation and did original work in "Bayt Al-Hikma"(House of Wisdom) which is the science academy in Baghdad the greatest scientific institution since the Museum and Library of Alexandria. Banu Musa were the main supporters of the translation movement which gathered momentum as that important epoch of the Islamic scientific awakening reached fruition in the 9th century. They extended their patronage to Thabit Ibn Qurra, to Hunain Ibn Ishaq and to many other translators and scholars. They have more than 20 works which are known including the seminal engineering book "Kitab Al-Hiyal" translated into English by Donald Hill in 1979 and parts of it into German by Wiedemann and Hauser in 1918 and Hauser in 1922.The book was edited in Arabic by Ahmad Al-Hassan in 1981.

The written Arabic heritage in mechanical technology begins with the Banu Musa book. It is possible they knew Hero`s mechanics written in Alexandria in the first century and translated by Qusta Ibn Luqa at the time of Banu Musa.Hero's other books may have been known to the brothers for he enjoyed great fame among Arabic scholars in the 10th century. Banu Musa describe hundred ingenious devices. Hill identified twenty five devices resembling the ones of Hero and Philo(3rd century BC)books. There exist also other parts of the Banu Musa machines which resemble certain elements in Hero and Philo work. There are Banu Musa machines which bear no resemblance to either Hero or Philo. These include the fountains and dredging machine designed to salvage submerged objects from the bottom of rivers and seas and so on. Banu Musa made use primarily of the principles of the science of hydrostatics and aerostatics. Banu Musa use of automatic valves, delayed-action systems and their application of the principles of automatic control testify of creative mentality. Hill notes the use of crankshafts for the first time in the history of technology.

In two models, they used a mechanism similar to the modern crankshaft, thus outstripping by 500 years the first description of the crankshaft in Europe. Mayr[1] mentions that they use syphons, float valves, Philon`s oil lamp, water wheels, etc. Some control systems work with nonmoving parts combining the principle of Philon`s oil lamp with some cleverly arranged syphons. They have contributions in technological refinements and new applications. They install throttling valves directly in the pipe requiring no constant force to keep them closed. These appear first in the book of Banu Musa. Also they introduce improvements on Philon`s oil lamp by ingenious combination of syphons added to the original system. Most important is the use of On-Off control with upper and lower limit for the controlled variable. Systems of this class are widely used in modern technology. The float valve used by Banu Musa, Al-Jazari and other Arabic engineers emerges again in the middle of the 18th century in Europe and in England.

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