Lecture

on

Sub: Fluid Machines

Code : MEC 206

Topic : Introduction to Fluid Machines

by

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What is machines ?

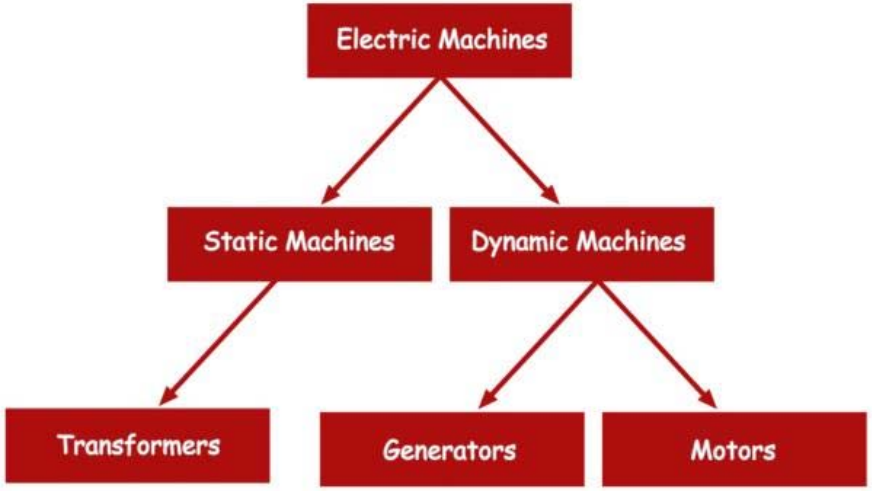
- A **machine** is a device which receives energy and transform it into some useful work.
- A kinematic chain is the assemble of links in which relative motions of the link is possible and the motion is definite. If one link of the kinematic chain is fixed it is called mechanism. If mechanism is required to transmit power, it becomes **machines**.
- A machine (or mechanical device) is a mechanical structure that uses power to apply forces and control movement to perform an intended action. Machines can be driven by animals and people, by natural forces such as wind and water, and by chemical, thermal, or electrical power, and include a system of mechanisms that shape the input to achieve a specific application of output forces and movement.

What is fluid machines ?

- A fluid machine is a device which converts the **energy stored by a fluid** into **mechanical energy** or *vice versa* .
- The energy stored by a fluid mass appears in the form of **potential, kinetic and intermolecular energy**. The **mechanical energy**, on the other hand, is usually transmitted by a rotating shaft. Machines using liquid (mainly water, for almost all practical purposes) are termed as hydraulic machines.

What is electrical machines ?

- An **electrical machine** is a device which converts mechanical energy into electrical energy or vice versa. **Electrical machines** also include transformers, which do not actually make conversion between mechanical and electrical form but they convert AC current from one voltage level to another voltage level.



Electric Generator:

An **electric generator** is an electrical machine which converts mechanical energy into electrical energy. A generator works on the principle of electromagnetic induction. It states that whenever a conductor moves in a magnetic field, an emf gets induced within the conductor. This phenomenon is called as generator action.

Electric Motor:

A motor is an electrical machine which converts electrical energy into mechanical energy. When a current carrying conductor is placed in a magnetic field, the conductor experiences a mechanical force and this is the principle behind motoring action.

Transformers:

Transformers do not actually make conversion between mechanical and electrical energy, but they transfer electric power from one circuit to another circuit. They can increase or decrease (step-up or step-down) the voltage while transferring the power without changing the frequency, but with the corresponding decrease or increase in the current. Input power and output power of an electrical transformer should ideally be the same.

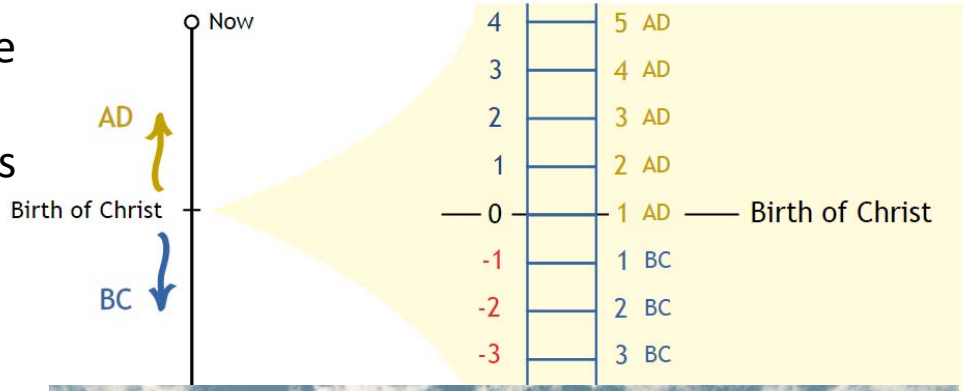
Historical background of fluid machines

5000 BC wind power has been in use by the ancient Egyptians

4000–3000 BC Early uses of water power was used for irrigation in Mesopotamia

2500–2000 BC Minoans invented the shaduf

2000 BC Egyptians invented the shaduf



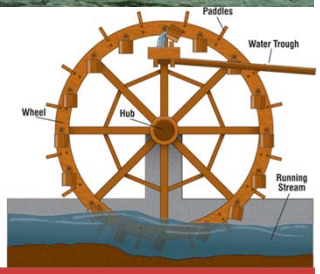
The **shaduf** was widely spread in the ancient world, and several ancient civilizations (Egyptians, Mesopotamians, Chinese, and Indians) dispute its origin.

Stavros I. Yannopoulos, Gerasimos Lyberatos, Nicolaos Theodossiou, Wang Li, Mohammad Valipour, Aldo Tamburrino and Andreas N. Angelakis, Evolution of Water Lifting Devices (Pumps) over the Centuries Worldwide, *Water 2015, 7, 5031-5060; doi:10.3390/w7095031*

Bazza, M. Overview of the History of Water Resources and Irrigation Management in the Near East Region. *Water Sci. Technol Water Supply* ***2007, 7, 201–209.***

Laessoe has reported that the shaduf was invented in India.

The early water wheel history of the watermill in India is obscure/ unclear. Ancient Indian texts dating back to the **4th century BC** refer to the term **cakkavattaka** (turning wheel), which commentaries explain as arahatta-ghati-yanta (machine with wheel-pots attached). On this basis, Joseph Needham suggested that the machine was a **noria**.



Laessoe, J. Reflections on modern and ancient oriental water works. *J. Cuneif. Stud.* ***1935, 7, 5–26.***

Historical background of fluid machines

Pre-historic times

1700BC

Babylonian emperor Hammurabi planned to use wind power for his ambitious irrigation project

1200–800 BC

Early use of gravity fed as water lifting in ancient Persia (Qanat, collection of roof rainfall from roof, and horizontal well)

1600 BC

Chinese invented the *Jiégāo (Chinese shaduf).*

800–200 BC

Other methods for water pumping in Persian Empire (Persian shaduf, mohte, Persian wheel, zawafa, sakkia, and Persian Noria)

287–212 BC

The invention of the Archimedean screw is usually attributed to **Archimedes** of Alexandria. The basic principle of the Archimedean screw probably existed in a more primitive form in ancient Egypt.

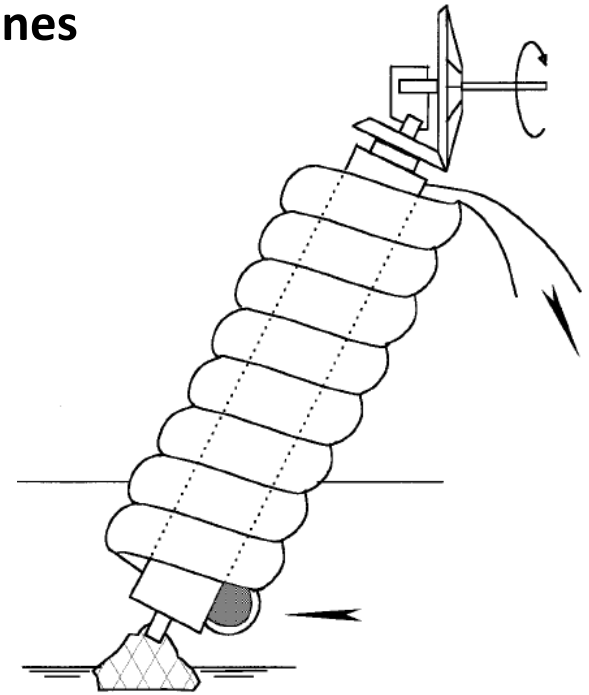
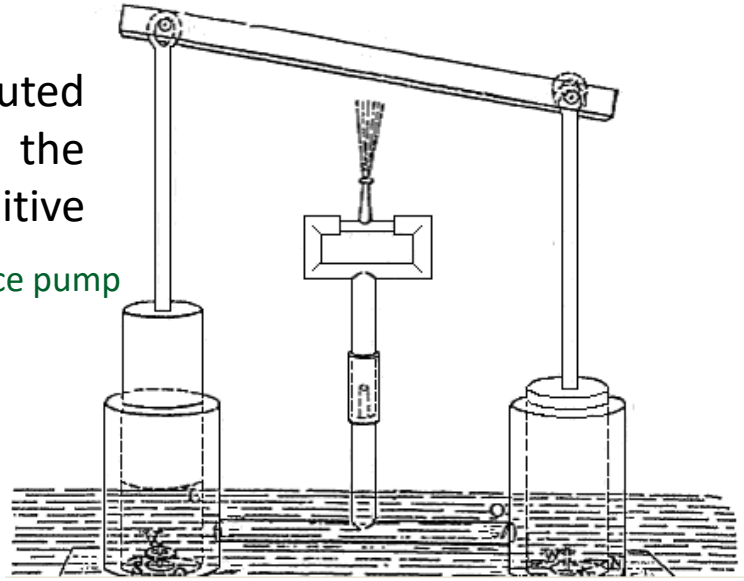


Fig. Schematic diagram of an Egyptian screw or Cocleon—a device for raising water for irrigation.

Ktesivius force pump

285–222 BC

The engineer **Ktesivius** of Alexandria has invented the force pump. Water is allowed to flow through a one-way valve into a cylinder and then it is pushed out by the action of a piston, through another one-way valve into a delivery pipe



One of the most scenic and successful applications of wind power (and one that still exists) is the extensive use of water pumping machines.
A very vivid example of this is to be found in the island of Crete. Here, even today, literally hundreds of sail-rotor windmills pump water for crops and livestock

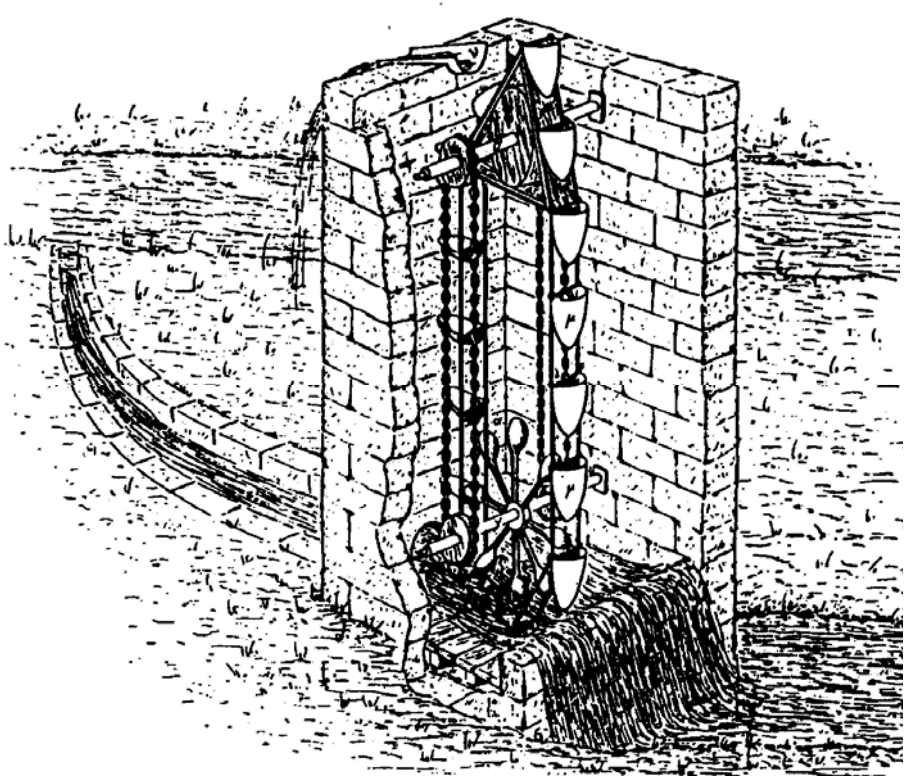
Water pumping sail-wing machines in the plateau of Lassithi in the Island of Crete

A series of Archimedes' water-screws in their modern form (in which the walls are not attached to the screw), as implemented in the waste water treatment plants (WWTPs) around the world. As an example, the pump station of WWTP in Bottrop, a city in west central Germany, on the Rhine-Herne Canal, which serves 1,350,000 e.p. (equivalent population), is shown in Figure

View of the pump station of the WWTP in Bottrop, Germany

Historical background of fluid machines

The piston pump invented by Ktesivius has the advantage that it will lift water to any height, consistent with the pump and the delivery pipe being able to withstand the hydrostatic pressure.
However, it has significant drawbacks. First, the pumping mechanism is submerged in water; and second, if the water-level falls, the cylinder will not fill.
The solution to these problems lies in the use of a suction pipe on the inlet of the pump. Not only does the suction pipe allow the pump to be placed above the water; it also accommodates changes in the water level. In theory, the suction stage can be as high as 10 m, the height to which atmospheric pressure will support a column of water, but in practice, 7.62 m is the maximum height of water lift.



Philon's paddle-wheel driven bucket-chain

260–180 BC

In Hellenistic Alexandria **Philon** Byzantius has invented the chain pump for lifting water from rivers to higher places (water gardens and farms).

200 BC

Waterwheel with pots attached or with compartments for the water

200 BC

Windmills began in India in 200 B.C as evidence by the famous Sanskrit classic "Arthasastra" by Kautilya.

Kautilya ; V. K. Subramanian (1980). Maxims of Chanakya: Kautilya. AbhinavPublications ,Kautilya and the Arthaśhāstra: A Statistical Investigation of the Authorship and Evolution of the Text. Leiden: E.J. Brill.

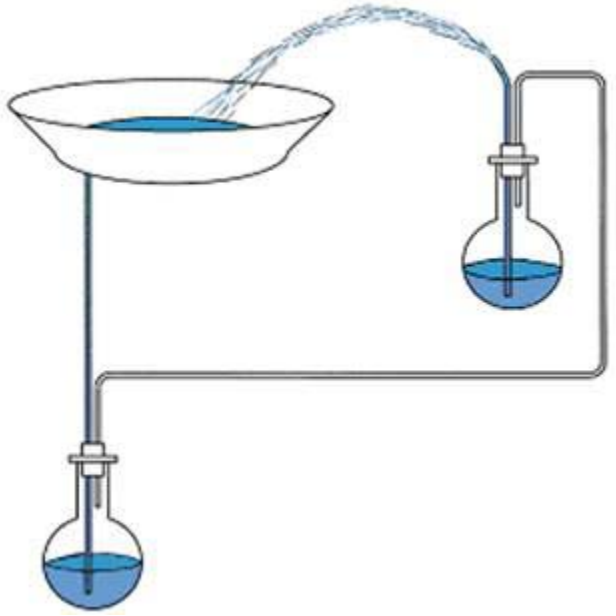
Historical background of fluid machines

10-70 AD

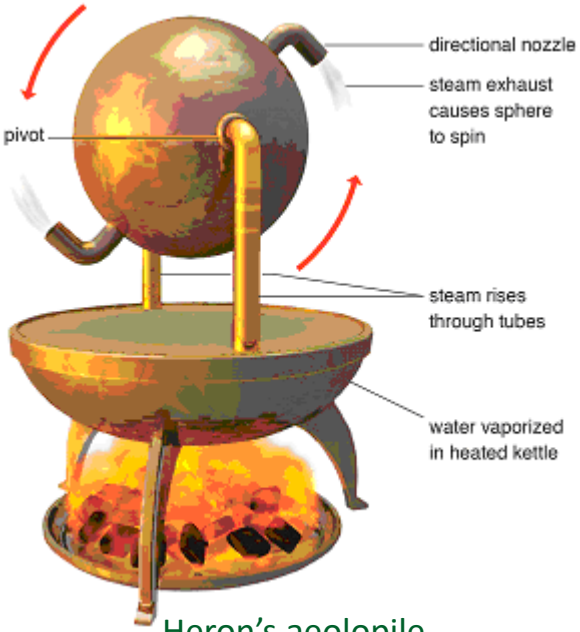
The magical fountain was invented by **Heron** of Alexandria (*ca. 10–70 AD),* Egypt. It shot water higher than the available level of its reservoir, defying apparently the hydrostatic pressure. It consisted of one open and two airtight containers placed one above the other (Figure). The middle airtight container was filled with water and a pipette started a little above its bottom and led to a nozzle above the upper open container.

When water was poured into the upper open container, it flowed through a pipe, into the lower airtight container. The confined air in this lower container was pressed and it displaced the water of the middle container through another pipe, forcing it to rise to the nozzle and to form a small spurt (sudden discharge). The spurt of water supplemented the water of the upper open container (maintaining the level constant). Thus, this process was self-supporting and it continued automatically until all the water from the middle container was emptied.

Heron described the construction of the aeolipile (a version of which is known as Heron's engine) which was a rocket-like reaction engine and the first-recorded **steam engine**.



The magic fountain of Heron



Heron's aeolopile

Historical background of fluid machines

~200 AD

Chinese also used chain pumps that lifted water from lower elevation to higher elevation.

1200 AD

Chinese invented windmill for irrigation

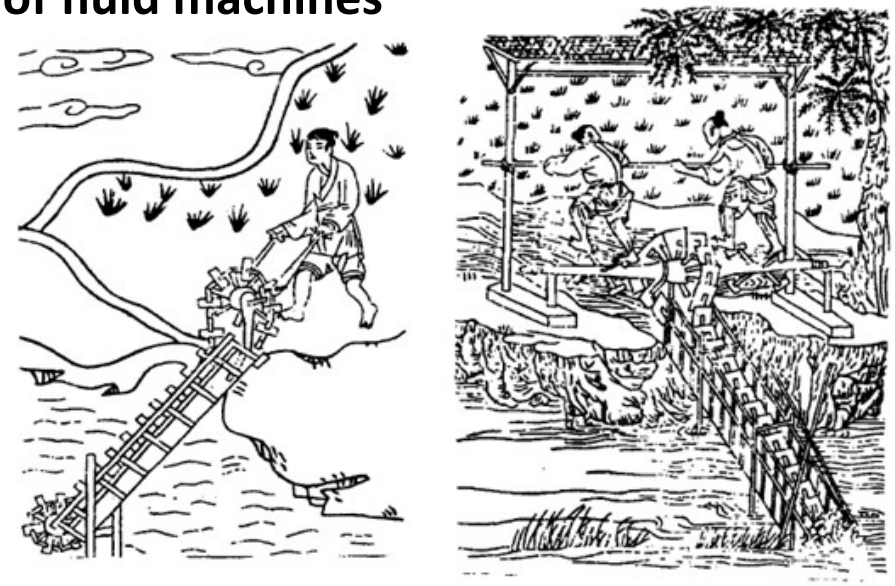
618–1270 AD

Chinese invented the *dragon backbones is suitable for lifting water 1–2 m,* during the Tang and Song dynasties

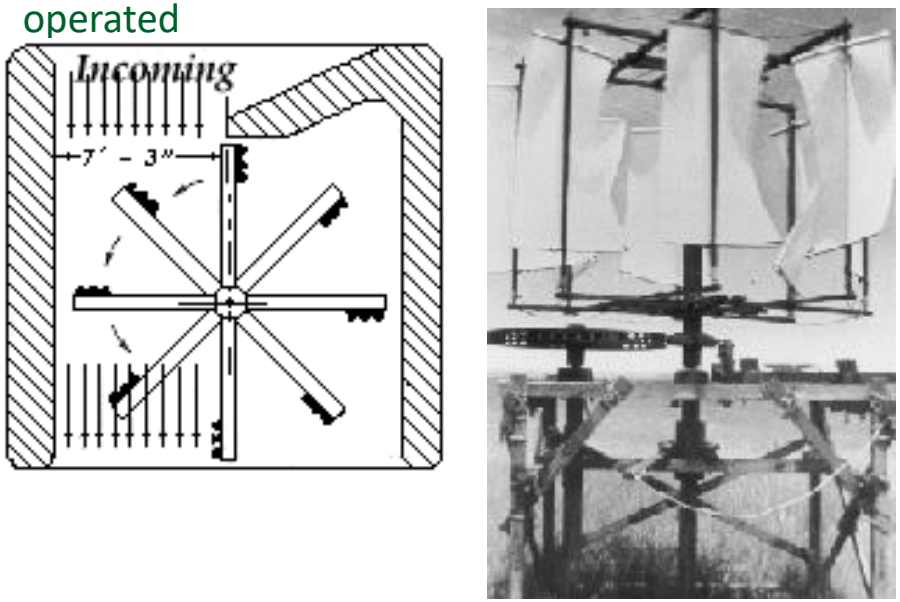
330–1600 AD (Byzantine Period and Venetian Rule)

The first windmills were developed in order to automate the tasks of grain-grinding and water-pumping and the earliest-known design is the vertical-axis system developed in Persia *500–900 AD.*

In India, during the Mughal period (*early 15th–late 18th century), the introduction of the Persian* waterwheel and the use of animal power increased the sustainability and the availability of irrigated areas.



Dragon backbones (a) hand-operated; (b) foot operated



The Persian panemone: (a) A design of the Persian panemone; and (b) A 19th-century American approximation

Historical background of fluid machines

1206 AD

Ibn Ismail ibn al-Razzaz al-Jazari (1136–1206 AD) was an important Arab Muslim scholar, astronomer, inventor and mechanical engineer from al-Jazira, Mesopotamia. Al-Jazari invented five machines for raising water, as well as watermills and waterwheels with cams on their axle used to operate automata.

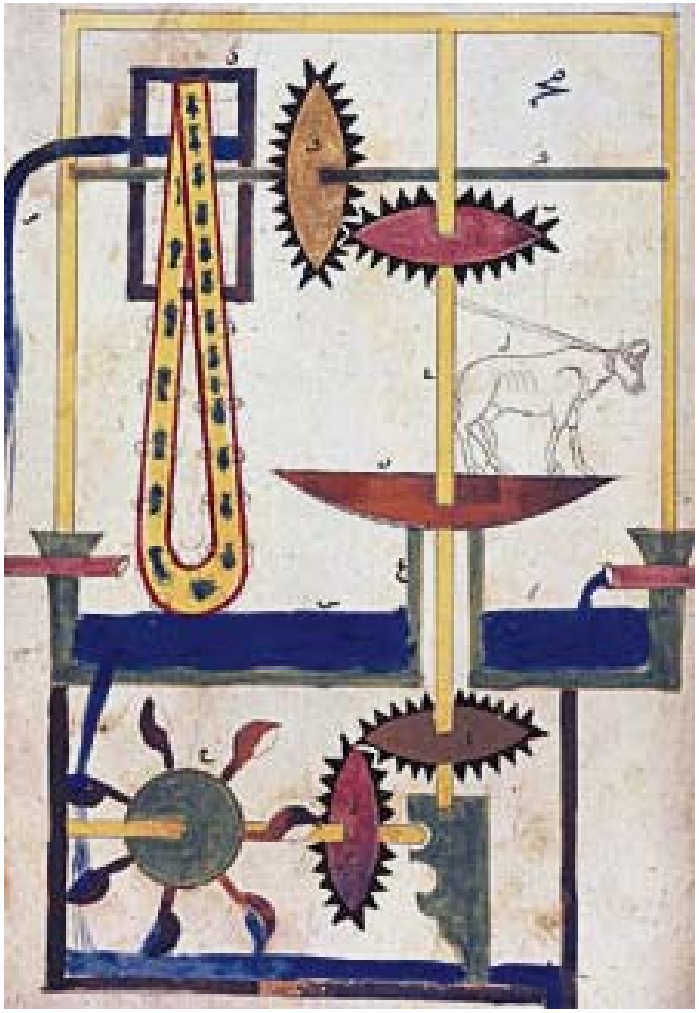
European History

1270 AD

The first windmills to appear in Western Europe were of the horizontal-axis configuration. The first illustrations (1270 AD) show a four-bladed mill, mounted on a central post, which was already fairly technologically advanced relative to the Persian mills.

1300-1600 AD

The piston pump made its first appearance in the writings of Mariano di Jacopo (1382–1453), alias Mariano Taccola, an Italian engineer who was considered a forerunner of Leonardo da Vinci. This piston pump had a suction pipe incorporated in it. In 1580, the sliding vane pump was invented, followed shortly thereafter by the gear pump.



Al-Jazari's hydropowered saqiya chain pump device

Historical background of fluid machines

Early Modern History

1650-1700 AD

The piston vacuum pump would come along in 1650. It consisted of a piston and an air gun cylinder with two-way flaps and was invented in 1650 by von Guericke, a German scientist and politician. Also, the “plunger pump” was invented in 1675 by Sir Samuel Morland (1625–1695), a notable English 17th century academic and mathematician. **1698 AD**

Thomas Avery invented a pump that operated on steam to create a vacuum to draw water.

1580

Sliding vane pump invented by Ramelli; Serviere invents the gear pump

1650

Otto van Guericke invents his piston vacuum pump

1674

Sir Samuel Morland patents the packed plunger pump

1687

Denis Papin, French inventor, develops the first true centrifugal pump, one with straight vanes used for local drainage

1738

Ural hydraulic machinery plant established.

Plenty Ltd established

1790

Thomas Simpson establishes his pump business in London.

Hayward Tyler established (https://haywardtyler.com/)

HAYWARD TYLER

Historical background of fluid machines

Modern History

1830 Screw pump invented by Revillion

1840 Henry R. Worthington invents the first direct-acting steam pump

1851 John Gwynne files his first centrifugal pump patent

1857 Henry R. Worthington produces the first horizontal, duplex, direct-acting steam pumps for boiler feed.

1860 Allweiler founded—A.S. Cameron invents the first reciprocating stream pump

1870 Osborne Reynolds, UK Prof., develops an original design of a centrifugal pump

1874 Charles Barnes of New Brunswick invents the vane pump

1897 Preston K. Wood makes the first deep well turbine pump in Los Angeles, California

1899 Robert Blackmer invents rotary vane pump technology, a pump design that was an important departure from the old gear principle and predecessor to today's sliding vane pumps.

1901 Byron Jackson develops the first deep well vertical turbine pump

1905 Multistage centrifugal pumps are developed

1908 Hayward Tyler creates its first electric motor for use under water and develops the wet stator motor for use as a boiler circulation glandless motor-pump

1916 Aldrich produces the first direct motor-driven reciprocating pump

1923 Ruthman Companies designs the world's first sealless vertical pump

1927 Aldrich produces the first variable stroke multi-cylinder reciprocating pump

1940 Axial-flow and jet pumps have been used as compressors in jet engines. Jet pumps are used in wells that are deeper than 60.69 m.

1956 Flygt introduces the submersible sewage pump