Clocks and watches

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The article in the November/December 2006 **CL** examined how man's need to measure time led to the development of the calendar, which is in common use in our homes and offices on a daily basis. In this article, we will continue to examine how man developed a means to measure time in even smaller increments, which led to the development of clocks and watches through the ages.

Before we can begin to examine how clocks evolved over time, we need to know what basic elements a clock needs. Firstly, it requires a regular, constant and repetitive action to mark off equal increments of time. This was achieved by means of an escapement, which is a type of transformer, which converts power generated via springs, water or weights, into a constant mechanical motion. Secondly, it needs a means of keeping track of the increments of time and should be able to display the result - clock hands or some other visual display.

Thus the history of timekeeping can be seen as a search for a mechanism, which would best meet these requirements.

Sun clock, merkhet and water clock

As early as 3500 Before Common Era (BCE), the Egyptians used sun clocks to divide the day into parts. The shadow cast by an obelisk, which had been carefully constructed and geographically positioned, enabled people to divide the day into morning and afternoon. The addition of markers to the base of the obelisk could indicate further subdivisions of the day.

The merkhet, the oldest known astronomical tool was developed around 600 BCE. This made it possible to measure the night-time hours. Two merkhets were used to establish a north-south meridian, by lining them up with the Pole star. The crossing of this meridian by certain stars indicated the hour.

The Greeks began using the clepsydra, or water clock around 325 BCE. The clepsydra works on the simple principle of the flow of water either into, or out of, a container. The water would drip at a nearly constant rate from a small hole near the base of the container. Markings on the side of the container measured the hours. As you can imagine, this was not a very accurate method of calculating time, as water tends to drip faster when the container is full, due to pressure, while it will drip more slowly as the container empties.

During the third-century Common Era (CE), the Chinese further developed the clepsydra to drive various mechanisms, which illustrated astronomical phenomena. Su Sung built an elaborate clock tower, which stood over 30 feet in height, with doors that opened to reveal manikins which rang bells or gongs, or held tablets indicating the hour.

What is interesting to note is that water clocks were still in common use in North Africa during the early part of the twentieth century.

Mechanical clocks

During the Middle Ages, (500-1500 CE), there does not appear to have been many advances made in technology with regard to improving the devices used for timekeeping. It seems that the sundial, sometimes placed above doorways, was the favoured device in use during this period.

During the early part of the fourteenth century, large mechanical clocks, which were weight-driven and used a verge-and-foliot escapement, began appearing in the towers of a number of large Italian cities. The mechanism used in these clocks, comprised a freely swinging horizontal bar (the foliot) attached to a centrally-located vertical shaft (the verge). The mechanism was driven by gravity. As the weight wrapped around the spindle descended, the spindle turned and a toothed crown-wheel on the spindle made the escapement oscillate. The passage of time was measured by moving a hand around a marked clock face.

Variations of the verge-and-foliot mechanism were used for more than 300 years.

The next technological advance came around 1500-1510 in Germany, with the invention of the spring-powered clock. A spring, instead of gravity, was used to power clocks. Although these clocks were still not particularly accurate because the clock slowed down when the mainspring unwound, the spring-powered clock was the precursor to more accurate timekeeping.

Although Galileo Galilei is credited with the invention of the pendulum in 1582, it was Christian Huygens, a Dutch scientist, who made the first pendulum clock in 1656. The mechanism in this clock used a 'natural' period of oscillation. It is amazing to find that this clock had an error of less than one minute per day. The following year Huygens developed the balance wheel and spring assembly, which reduced the clock's error to less than ten seconds a day.

Around the mid 1660s, a clock was built with a tall case which concealed the weights and pendulum. These became known as grandfather clocks.

Clocks and navigation

While pendulum clocks were becoming more and more accurate, there was still one particular hurdle to be overcome. As the Explorers left the safety of the shores to explore uncharted seas, they needed a means of determining where they were. The Greeks had developed the systems of latitude and longitude. Measuring latitude was not a problem, but measuring longitude was a different matter. The mariner needed to know the speed at which the ship was travelling, to be able to calculate the distance covered each day. Every degree of longitude corresponds to four minutes of time. The navigator needed to know the time at the starting point, as well as the local time. By comparing the two times, he was able to calculate the current longitude relative to the initial longitude. Ships began carrying clocks on board to help with calculation.

However, these early clocks, while reasonably accurate on land, were subject to the effects of the ship's movement at sea and were

thus not very accurate. In 1714, Queen Anne of England offered 20 000 pounds to anyone who could find a way to determine longitude to within half a degree. The prize was awarded in 1759 to John Harrison, a carpenter and self-taught clock-maker, who built a marine chronometer with a spring and balance wheel, which was tested on a voyage to the West Indies and was able to determine longitude to within one-half degree.

The Library Service has the award-winning drama series, **Longitude**, made by Granada Film, in stock. This excellent drama tells the story of Harrison's quest for the first marine chronometer, which is paralleled by the story of Rupert Gould's obsession to restore the clock centuries later.

The Quartz clock and the new era

Perhaps the next major development in the evolution of the clock is the discovery by Pierre Curie in 1880 that the application of pressure to a quartz crystal caused it to vibrate at a constant frequency. WA Marrison built the first quartz clock in 1928. He replaced the pendulum and other mechanical oscillating devices with the vibrating quartz crystal. It became possible to measure the accuracy of the clock up to a millionth of a second.

One would have thought that the clock had reached its ultimate achievement in accuracy. This was not so. English physicists L Essen and J Perry constructed an even more accurate clock, the atomic clock, in 1955.

Today, the satellite-based Global Positioning System (GPS), uses atomic clocks to determine its position. Each satellite beams down a signal giving its position and the mean time determined by four atomic clocks it carries on board. The signal is picked up on a device, which is small enough to be hand-held, which then computes its latitude and longitude. The on-board atomic clocks are accurate to one second in 30 000 years, while ground-based atomic clocks can be accurate up to one second in 1 400 000 years!

Greenwich Mean Time

Initially in the eighteenth century, the 'time of day' varied from town to town. This made it very difficult for the mail coach service to keep to a timetable, because coachmen had to adjust their watches to give the correct local time.

With the introduction of the railway network in England in the nineteenth century, the problem became worse. As a result the railroads in England decided to adopt London time, as determined by the Royal Observatory at Greenwich, for their network. By 1855 all public clocks throughout Great Britain had adopted GMT (Greenwich Mean Time).

The greater distances involved in the United States caused even greater confusion than in Britain. In order to bring some order into the existing chaos, regional time zones were introduced. In 1869, Charles Dowd tabled a plan to divide the entire United States into four time zones. At 12 noon on 18 November 1883, the entire nation switched over to, what had previously been referred to, as railroad time. The four-zone time system was legalised in 1918.

Just as coach travel and the railways had led to the adoption of uniform time in Britain and the United States, the invention of Marconi's wireless telegraph in 1899, was the main impetus for a worldwide system of measuring time. The last country to adopt the Greenwich Meridian was Liberia, which did so only in 1972.

History of watches

As strange as it may seem, the Egyptians used a portable shadow clock as early as 1500 BCE.

Prior to the 1600s, timepieces were typically driven by weights and as a result were impractical as portable timepieces.

So-called pocket watches invented in Tudor, England during the sixteenth century, were very large cumbersome items, often worn around the neck. They served more as decoration than timekeepers, as they were not particularly accurate.

Although spiral springs were used from 1500, it was not until the use of the spiral-balance spring-driven mechanism in 1675, that portable timepieces became more accurate. The minute hand was added and the dial was subdivided into minutes. Charles II introduced long waistcoats in 1675 and it became the fashion for men to carry their watch in their pocket, instead of wearing it around the neck.

During the 1700s, small technical developments and modifications were made. Perhaps the greatest development during this period was the use of 'jewelling', invented by John Arnold. 'Jewelling' refers to the use of precious stones, such as rubies, as bearings to reduce friction. By 1800, an accurate watch, in the form of a pocket chronometer, was available. A second hand was added.

Up to 1840, watches were all hand-finished and as a result parts were not inter-changeable. It was the Swiss who believed that there was a market for cheaper, machine-made watches. They began manufacturing watches in volume around 1880. During the First World War, the army found that wristwatches were more convenient to use than pocket watches. When the war ended, soldiers were allowed to keep their wristwatches.

After 1945, wristwatches were made more robust, with mechanisms to make them waterproof, shockproof and able to function in extremes of pressure.

Battery-powered watches were marketed in 1952. The new technology was embraced and developed by Asian watch manufacturers, particularly those in Japan. This enabled the production of cheap, accurate watches accessible to all.

The rich and famous, on the other hand, still covet wristwatches with designer labels, such as Rolex, Tag Heuer, Audemars Piquet, Omega or Cartier, to name a few. Yet, cheap or expensive - they all do one thing - tell the time.

To find out more about this interesting subject, see the following web sites:

Early history of clocks

www.perseus.tufts.edu/GreekScience/Students/Jesse.CLOCK1A.html

General history of clocks

www.atimetoremember.net/clockhistory.html

http://physics.nist.gov/GenInt/Time/early.html

www.mystical-www.co.uk/time/clocks/htm

www.maa.org/devlin/devlin_12_99.html

www.usgennet.org/usa/topic/preservation/science/inventions/chpt5.htm

Verge escapement

http://en.wikipedia.org/wiki/Verge_escapement

History of alarm clocks

http://clockhistory.com/alarmClockHistory/index.html

Grandfather clocks

www.grandfatherclocksplus.com/cgi-bin/gfcp/history.html

www.clocktypes.com/history_gransfather_clocks.html

http://theclockdepot.com/history_of_the_grandfather_clock.html

Cuckoo clocks

www.clockstop.com/perl/csCuckooClocks.pl

Mystery clocks

www.roger-russell.com/mysteryclocks/mysteryclocks.htm

History of watches

www.clocksonly.com/watch_history.html

www.nawcc.org/museum/nwcm/galleries/pocketwatch/pocketwatch.htm

www.lussori.com/watch-history.html

www.watches.co.uk - Click on Information

Learning about time

www.arcytech.org/java/clock/index.html