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MECHANICAL AND ELECTRICAL CLOCKS.

(By A. W. TOURNAY-HINDE.)

In February of the present year the author was asked by the Council of this Association if he could furnish a paper to fill a gap that had been caused by the withdrawal of a treatise that was to have been presented to you at this meeting. At that time a controversy was in progress in the columns of the "Sydney Morning Herald" as to whether our public clocks and methods of showing time were not somewhat "behind the times." As for many years past the author had taken a very great interest in the mechanical side of Horology, purely as an amateur hobby, he thought that it might possibly prove interesting to the members of this Association if he were to repeat a lecture on the subject that, as President of the Northern Engineering Institute of N.S.W., he had the privilege of delivering to that body.

Engineers were always interested in mechanical contrivances, and clocks, although they were not generally looked upon as machines, were machines, nevertheless.

They were, moreover, machines in which accuracy of construction was of prime importance, if they were to fulfil their intended functions properly, and a vast amount of ingenuity had been shown by many fine master minds in bringing Clockwork Mechanisms to their present perfection. Doubtless many of those present had, at some time or another, attempted the repair or cleaning of a household clock that refused to go, with more or less success, and if any information that the author could impart proved of assistance, he would feel to a large extent repaid. It was, however, to the larger question of the accurate timekeeping of our public clocks that he intended to refer more particularly, but before doing so proposed to roughly review the history of clock and watch making up to the present time, and to then deal with the more recent systems of public timekeeping by means of electric clocks.

Although clock mechanisms appeared to be comparatively simple to the casual observer, there was much in connection with the subject that was really complex, especially when dealing with the question of compensating the errors of pendulums, balance wheels, and hair springs. These matters, however, concerned the horologist and clockmaker, and the author proposed to deal with the subject as far as possible from an engineer's point of view, and confine the paper to a record of what had been done and touch lightly upon what it was possible to do in connection with clocks and public timekeeping.

The origin of clocks and clockwork was involved in great obscurity, notwithstanding the statements made by many writers that clocks (horologia) were in use as early as the 9th Century, and that they were then invented by an Archdeacon of Verona, named Pacificus. There appeared to be no direct evidence that they were machines at all resembling those which had been in use for the past five or six centuries. But it might be inferred from various allusions in the old writings of the 12th Century to horologiums (clocks), and to the fact of their striking spontaneously, that genuine clocks existed then.

In the 13th Century there was a record showing that a clock was sent by the Sultan of Egypt to the Emperor Frederick II. This record stated that the clock "Resembled a celestial globe, in which the sun, moon, and planets moved, being impelled by weights and wheels, so that they pointed out the hour day and night with certainty."

A clock was erected in a former clock tower at Westminster, London, with some great bells, in 1288, and history says it was paid for out of a fine imposed upon a corrupt Chief Justice, and that later on the bells were gambled away by Henry VIII.

In 1292 a clock was mentioned as existing at Canterbury Cathedral which cost £30.

At St. Albans, an abbot named R. Wallingford was said to have made a clock showing various astronomical phenomena, and the record states that there was not such an one in all Europe.

In 1876 a clock was exhibited at the Scientific Exhibition in London of that year. It bore the date 1348, and it came from Dover Castle. The clock was in working order, and was going during the exhibition, although, by the date on it, it was then no less than 528 years old. This clock, the author believed, was now in the South Kensington Museum, London.

A few notes relative to the systems of measuring time might be considered, and of these the most ancient and most obvious method was Solar Time. It was marked by the diurnal revolution of the earth in relation to the sun. Uncivilised tribes used the appearance of the sun each day as a means of marking off periods of time, and the approximate monthly period of full moon for longer periods.

With civilised races the appearance of the sun right overhead indicated midday. The sun did not appear at its greatest height above the horizon at regular periods, and if the arrival of the sun at this position was checked by a mechanical timekeeper, such as a chronometer or good clock, it would be found that midday or the greatest height of the sun above the horizon was sometimes 16 minutes 18 seconds sooner, and at others 14 minutes 28 seconds later, than 12 o'clock mean time. The diurnal revolution of the earth might naturally be supposed to bring each place to the meridian at equal periods. This would be the case if the earth had no other movement but its rotation upon its axis. But as the earth revolved it advanced at the same time in its orbit, and as the meridians were not perpendicular to the ecliptic, the days were not of equal duration. "True time" and "Mean time," the latter of which was the time in everyday use.

only coincided about the 25th December, 15th April, 14th June, and 31st August. These dates even changed, because the two points in the earth's orbit in which it was at its greatest and least distance from the sun moved forward 12secs. of a degree every year, and the equinoctial and solstital points 50secs. of a degree backward.

Sidereal Time was also measured by the diurnal revolution of the earth, which turned on its axis, not in 24 hours as was popularly supposed, but in 23 hours 56 minutes 4.1 seconds. A star would, therefore, always appear at the meridian about 3 minutes 56 seconds sooner than it did on a preceding day. This fact afforded an easy method for anyone to check the rate of a clock or watch. Choose a window having a northern aspect, from which the steeple of a church, a chimney, or some other fixed point can be seen. Attach a card to the window, with a small hole in it, so that by looking through the hole one of the fixed stars (not a planet) can be seen to disappear behind the chimney. Note the time by your watch, and on the following night the same star will disappear 3 minutes 56 seconds (nearly four minutes) earlier. Say that the time of disappearance of the star was ten minutes to eight on the night the first observation was made, the next night the star should disappear at 13 minutes 56 seconds to eight, if the rate of the watch be correct.

Sun Dials were one of the earliest methods of recording time, and the pattern, with a vertical dial, was common on many old buildings

Another form of sun dial was the one with a horizontal dial, a specimen of which could be seen in the Botanical Gardens, and another in Hyde Park, Sydney.

Sun dials only show sun time—that is, they were sometimes as much as a quarter of an hour fast or slow as compared with mean time or clock time.

A form of sun dial that had recently been produced was Homan's Solar Chronometer, and the author was indebted to one of your worthy past Presidents, Mr. J. L. C. Rae, for bringing it under his notice. Its principal feature was that, by an ingenious method of adjusting the dial to suit the date, this sun dial gave readings in "Mean Time" instead of Solar Time. In small communities, such as on some of the islands in the Atlantic or Pacific, where a regular observatory could not be maintained, these sun dials had been found very serviceable.

We now come to clocks—that is, Mechanical Clocks proper. Generally speaking, a clock consisted of a train of wheels driven by a spring or a weight, and the train was permitted to run down at a fixed rate to correspond to mean time. In the case of a clock, this rate was determined by the pendulum, and before proceeding to describe the various means used to drive clock pendulums the author proposed to show how a pendulum controls the clock's going, so that more or less correct time was shown by the hands connected to the wheel work.

The claim to the invention of the pendulum, like the claim to many inventions of note, was disputed. It was probably made by many persons at the one time, when the conditions of science had become ripe for it. The discovery of the property of isochronism in a pendulum, viz., its ability to vibrate varying lengths of arc in practically the same time was commonly attributed to Galileo, who noticed the phenomenon in a chandelier suspended by a long chain in a church at Florence. There appeared, howeevr, little doubt that Huyghens was the first who mathematically investigated, and, therefore, really knew the true properties of a pendulum, which could now be found explained in any mathematical book on mechanics. He discovered that if a simple or ideal pendulum, viz., a sphere suspended by a cord having no weight, can be made to describe, not a circle, but a cycloid, of which the cord would be the radius of curvature at the lowest point, all its vibrations, however much they might vary in the length of arc, would be performed in the same interval of time.

The author then gave a very entertaining resume of the history of watch and clock mechanisms, from the earliest examples of the art up to the present day. His remarks were illustrated by a large number of very interesting lantern slides, showing various forms of pendulum compensation, and details of the gradual development of the various escapements, and other parts. Views were also shown of the interior of a modern Swiss watch factory, the author pointing out that it was one of the few cases where, in a factory turning out a mechanical appliance, all the operatives were sitting, and not standing.

All the mechanical devices that have so far been described depend for their operation on the energy given up by falling weights, or the gradual release of stressed springs. As far back as 1840, notwithstanding the limited knowledge then available of electricity, a man named Alexander Bain produced a clock driven electrically. There have been numerous inventors who have endeavoured by various means to automatically electrically rewind a spring connected with the clock gear at short periodical intervals, so as to avoid hand winding, but Alexander Bain must be considered as the originator of the method most usually adopted in connection with electric clocks at the present day, viz., instead of the pendulum being driven by the clock train, he drove the pendulum by means of an electric magnet, and in turn caused the pendulum to drive the clock. Owing, however, to the limited knowledge at that time as to how satisfactory electrical contacts should be made without interfering with the natural action of the pendulum, Bain's clock was not as reliable as the ordinary weight or spring driven clock, and did not come into use.

About 1856 Foucault suggested a method of making a more reliable contact, without interfering with the swinging pendulum. Dr. Hipp about this time, using Foucault's idea, evolved a satisfactory method of making an electrical contact for driving a pendulum, in such a manner as not to seriously interfere with the action of the pendulum, and this principle, with various slight modifications, was perhaps more used that any other in connection with primary electrical clocks. The escapement originally was known as Hipp's Electric Escapement. Mr. T. J. Murday had given a great deal of attention to this form of escapement, and had designed and patented many modifications of it during the last twenty years. One very valuable feature of the escapement was its governing property, viz., its ability to maintain the pendulum swinging over a practically constant arc, thereby ensuring good timekeeping.

In this case the pendulum was driven by the impulse given by an electric magnet, and the swinging pendulum could be used either to drive a clock through the necessary gear; or merely to actuate a small wheel, which made a complete revolution every half minute, and once during every revolution made an independent electric contact and sent a current through a number of dials in series. The dials were fitted at the back with a step by step electro-magnetic mechanism, which, when actuated by the current, advanced the hands of each of the dials half a minute.

An interesting and simple variation of this idea of electrically maintaining the swing of a pendulum for the purpose of driving a clock was to be found in a device by Herbert Scott.

In both the devices just referred to the strength of the impulse imparted to the pendulum depended on the strength of the current, and as the battery (if one be used) gradually failed in the course of time, the impulses gradually become weaker. This was by some considered a defect. If the matter was given a little attention, however, the defect, if it was one, hardly existed, as, although the strength of the impulse might gradually become smaller, it must, on account of the governing property of the device, occur more frequently, and, therefore, the energy actually delivered to the pendulum practically remains constant.

Through the courtesy of Messrs. Prouds, Ltd., the author was able to exhibit several forms of Mr. T. J. Murday's latest modification of the Hipp Electric Escapement. It would be noticed that in some cases, instead of the impulse being imparted to the pendulum solely by magnetic pull, Mr. Murday made use of a lever pivotted about its centre, which carried at one end of it an armature and at the other a small wheel, the whole arrangement being so contrived that the pull of the armature to the magnet depressed the end of the lever carrying the small wheel, which latter struck an impulse pallet attached to the pendulum. Mr. Murday informed me that he considered this a better method than relying on the magnetic pull.

Although reference had only been made to pendulums operated electrically, many of the devices referred to were also used to drive balance wheels, similar to those used in watches, but made on a much larger scale, a notable example of this being the "Eureka" clock, which could now be purchased at almost any clock dealer's shop. In this case also the balance wheel drove the train of wheels that operated the hands.

Other inventors, following on the lines of the gravity clock escapements, have produced various devices for electrically driving a pendulum by similar means, viz., the small weight that directly drove the pendulum was lifted electrically instead of by the clock gear, and the pendulum in turn drove the clock. The earliest of these devices was by Shepherd, of Hendon, England, who installed a self-wound clock of this type in the Greenwich Observatory in 1852. Other similar devices followed, viz., by Froment, of Paris, who showed a clock so controlled at the Paris Exhibition in 1855. Similar inventions were those of Houdin-Detouche, Geist, and others.

About 1897 Hope-Jones and Bowell brought out an improved form of electric gravity escapement, very similar in appearance to the three-legged gravity escapement of Denison. Later on this device was modified so that, instead of the gravity arm giving an impulse to the pendulum every swing, the arm was supported on a catch and released at every thirtieth swing, or, in other words, every half minute, thus greatly simplifying the mechanism. The gravity arm was replaced on its support (ready to give the next impulse) electrically; and the same current that actuated the magnet that replaced the gravity arm, also traversed the series of dials in circuit with the clock, and moved forward the hands. This method was now known as the Synchronome System, after the name of the Company responsible for exploiting it.

In January, 1912, Mr. W. H. Shortt, A.M.I.C.E., described, in a lecture given before the British Horological Institution, an ingeniously modified form of the "Synchronome" Switch, to which he gave the name of "Inertia Escapement." It was designed for the use of Observatories or other places where very accurate timekeeping was essential, and where it was usually necessary to record the vibration of the pendulum second by second, instead of every half minute. It is to some extent a reversion to the older electrical forms of gravity escapement, but with one very prominent difference. In the older forms of gravity escapement the strength of the impulse given to the pendulum was nominally constant; this would be alright if all the other factors controlling the swinging of a pendulum were also constant. As a matter of fact, they are not; and taking one disturbing factor alone, viz., that of variations in barometrical pressure, a pendulum impelled by impulses of constant strength vibrated over a wider arc when the barometer was low than it did when the barometer was high, as was pointed out during the discussion on pendulums earlier in the lecture. In Mr. Shortt's mechanism he proposed to overcome this defect by artificially loading the shaft or rocker carrying the gravity arm, thereby giving it an additional amount of inertia, so that the speed at which the gravity arm descended was not that due to gravity alone. The impulse to the pendulum was given at every vibration, but the duration of the impulse varied, for when the pendulum was inclined to swing through a longer arc due to lessened air friction, owing to the lowering of the barometer or other causes, its speed through the air was greater than when performing shorter arcs. The duration of the impulse was, therefore, shorter when the speed was higher, and longer when the speed was slower, thereby automatically tending to keep the arc of oscillation of the pendulum constant. At the lecture referred to Mr. Shortt showed that when the length of the arc was artificially increased beyond the normal, the speed of the pendulum, when passing the impulse point, became so fast, that the impulse lever in falling failed to hit the pallet wheel, showing that when the arc through which the pendulum swings was too long, no impulse was received. On the other hand, with a very small arc the speed of the pendulum was so slow that the impulse lever was practically driving the pendulum throughout the arc. This modification of the Synchronome Switch gave it somewhat similar governing properties to that possessed by the Hipp and Murday Electric Escapements previously described.

To such a degree of accuracy had these methods of driving pendulums electrically been brought, that pendulums can now be constructed to operate with an error of not more than 1 in 1,000,000, or, in other words, they do not vary from mean time by more than 1/12 of a second per day, or about 1½ minutes per year.

These two or three examples of electrically operated clocks were sufficient to show the advance that had been made in the subject. There were many other electrical clocks regularly manufactured in Europe, but time did not permit of a full description of them. In some cases the makers used a weight-driven clock as the master clock, and caused it to send out half-minute electrical impulses to control the outside dials. An example of this arrangement was that of Grau-Wagner, of Wiesbaden. In this system the electrical impulses sent out were alternating in character—that is to say, the current at each impulse was opposite in direction, and the mechanism for moving the hands of the dials consisted of a small polarised alternating current motor, that made a half revolution forward at each impulse. Mr. G. B. Bowell had also devised a motor form of dial movement in which the half-minute impulse currents, which in this case were not alternating, but were in the one direction, actuated a very simple form of polarised motor.

The ability to satisfactorily operate a clock electrically presented many advantages. It was no longer necessary in large establishments, Railway Systems, and Public Places, to separately wind and regulate and to keep in repair each individual clock. One electrically-driven pendulum, which was located in a quiet, suitable position, such as in a cellar, as near mother earth as possible, and away from vibration, dirt, and other disturbing causes, could operate a large number of dials, all of which showed the same time, and were of so simple a character in their mechanism that they hardly required any attention.

In the principal cities of Europe and America, many of which were smaller than Sydney and Melbourne, there were Companies who supplied the correct time by means of hourly time signals sent out electrically. The various sets of electrical clocks, or even the old-fashioned spring or weight driven clock, if connected to the Time Company's Circuit, could be synchronised hourly. Considering the size and population of Sydney or Melbourne, it seemed an anomaly that, up to the present time, practically very little had been done to bring about such a system of Time Control of our public and other important clocks. So far back as 1874 the Standard Time Company of London have sent our hourly impulses in all directions from their Central Station in Queen Victoria Street, London, for the purpose of synchronising clocks. The Western Union Telegraph Company also sent out hourly synchronising currents to all parts of the United States. In Berlin there was the excellent similar institution of the Normal Zeit Gesellschaft, whose service was so arranged that it included a "reporting back" system, so that each clock reported its performance back to the Central Station.

This method of reporting back was first developed by Mr. Murday for the Standard Time Company of London, and afterwards adopted by the Normal Zeit Gesellschaft.

The mechanical Turret clock, with its heavy barrels, ropes and driving weights, and its pendulum, situated in the tower or upper part of Public or other buildings, where the clock was subject to all the conditions that usually militate against satisfactory timekeeping, should be considered as a relic of the past. Electrically operated dials, since they were not disturbed by the conditions mentioned, could be placed anywhere, and the current impulses for correctly operating these dials furnished either by a master clock in the basement of the building, erected there for that purpose, or they could receive current from any electrical half-minute time system that was to hand.

In the short time available the subject had necessarily been treated in a very general manner, and there was much more that might have been described of an extremely interesting nature if time had permitted. For those who cared to study the subject further, the author would refer them to the works on the subject mentioned in the appendix hereto, and at the same time desired to gratefully acknowledge his indebtedness to those sources for much of the information given herein. The appendix also contained a list of the electrical clock installations running in Sydney so far as the author had been able to obtain the information.

APPENDIX.

"ELECTRIC CLOCKS."—F. Hope-Jones, M.I.E.E., Member British Horological Institute, published by Geo. Tucker, Salisbury Court, Fleet Street, London, E.C.

"JOURNAL OF THE INSTITUTE OF ELECTRICAL ENGINEERS."—Vol. 29, pp. 119, 1900.

"MODERN ELECTRIC TIME SERVICE," by F. Hope-Jones, member, read before the Institute of Electrical Engineers, London, February 17, 1910.

"PRECISION TIME-KEEPING," by W. H. Shortt, A.M. Inst., C.E., read before British Horological Inst., January 16, 1912.

List of Electric Clock Systems at present in operation in Sydney.

Establishment.	Master Clock.	Turret Dials	Ordinary Dials.	Location of Dials, &c.
Crau-Wagner System				
Tramway Office, corner of Elizabeth and Hunter Streets	Weight driven electric wound	...	36	Circular Quay, Fort Macquarie, Traffic Superint'd't's Office
Central Railway Station	Weight driven hand wound	...	18	On Railway Platforms.
Ultimo Power House	,,	...	8	At Ultimo Power House and later on at White Bay Power House.
Saunders' Jewellers Shop	,,	3	6	On premises.
Grace Bros. Store, Glebe	,,	4	16	,,
Farmer & Compy., Market Street	,,	...	46	,,
Murday's System				
Harbour Trust Offices	Murday-Hipp Electric Regulator.	6	...	Electrically driven Turret Clocks at Ferry Wharf Circular Quay. Synchronised from Electrical Regulator in Harbour Trust Office.
Public Works Dep.	,,	...	6	On premises, also controls programme of electric bells at fixed hours. Special programme on Saturday and silent on Sunday.
Tooth's New Brewery	,,	...	6	On premises.
Proud's Jewellery Shop	,,	...	3	,,
T. A. Edison, Ltd.	,	...	2	,,
Hotel Sydney	,	...	9	,,
Synchronome System				
General Post Office	Synchronome Elec. Regulator	...	16	,,
Registrar Gen'r'l's Department	,,	...	23	,,
A.M.P. Society	,,	...	16	,,
Anthony Hordern's Store	,,	...	50	,,
Tooth's Old Brewery	,,	...	7	,,
Orchard's Jewellery Store.	,,	2	5	,,