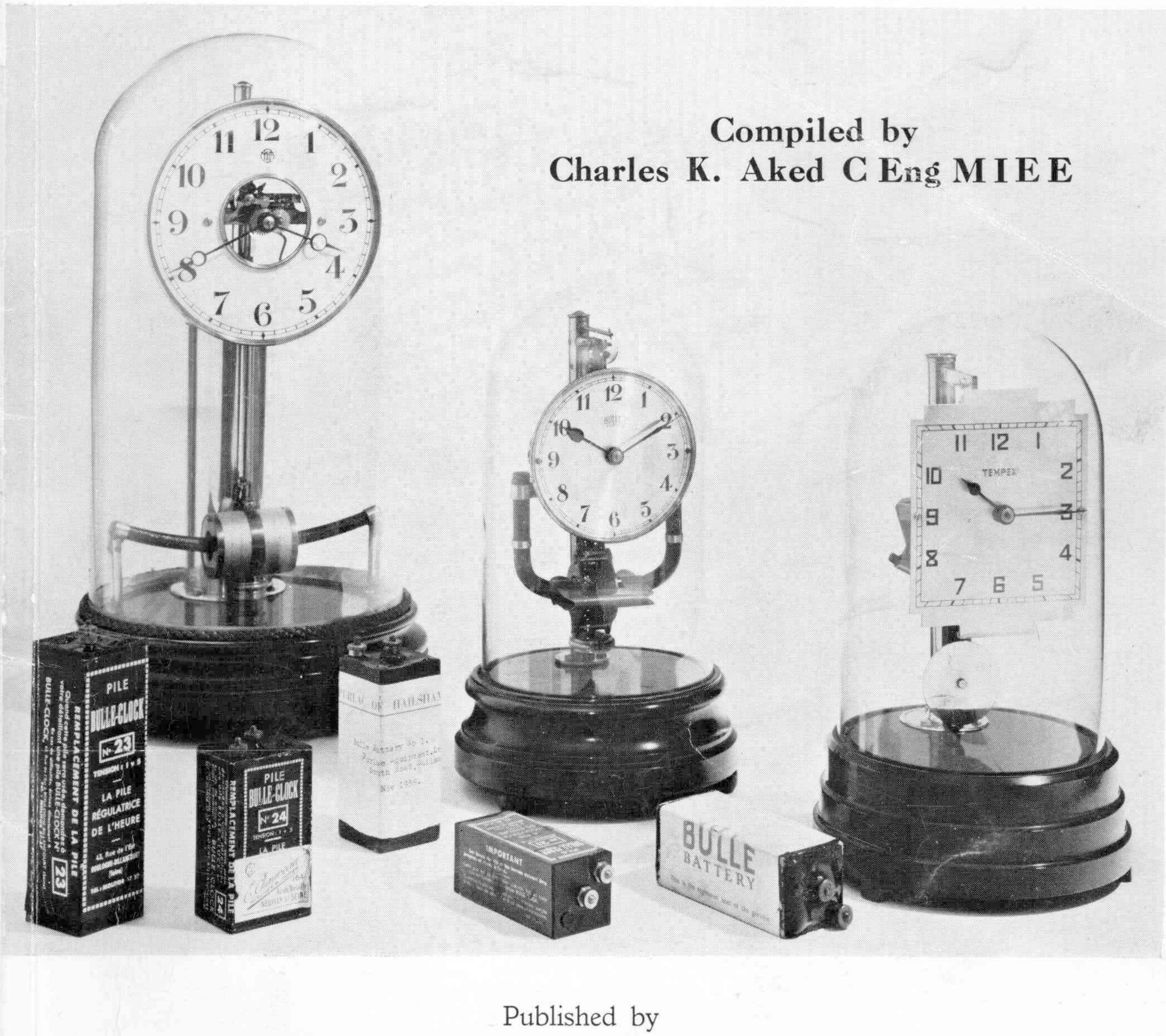
Electrifying Time

An Exhibition held at the Science Museum to commemorate the centenary of the death of ALEXANDER BAIN 2nd January 1877

Open 15th December 1976 to 11th April 1977

Compiled by
Charles K. Aked C Eng MIEE



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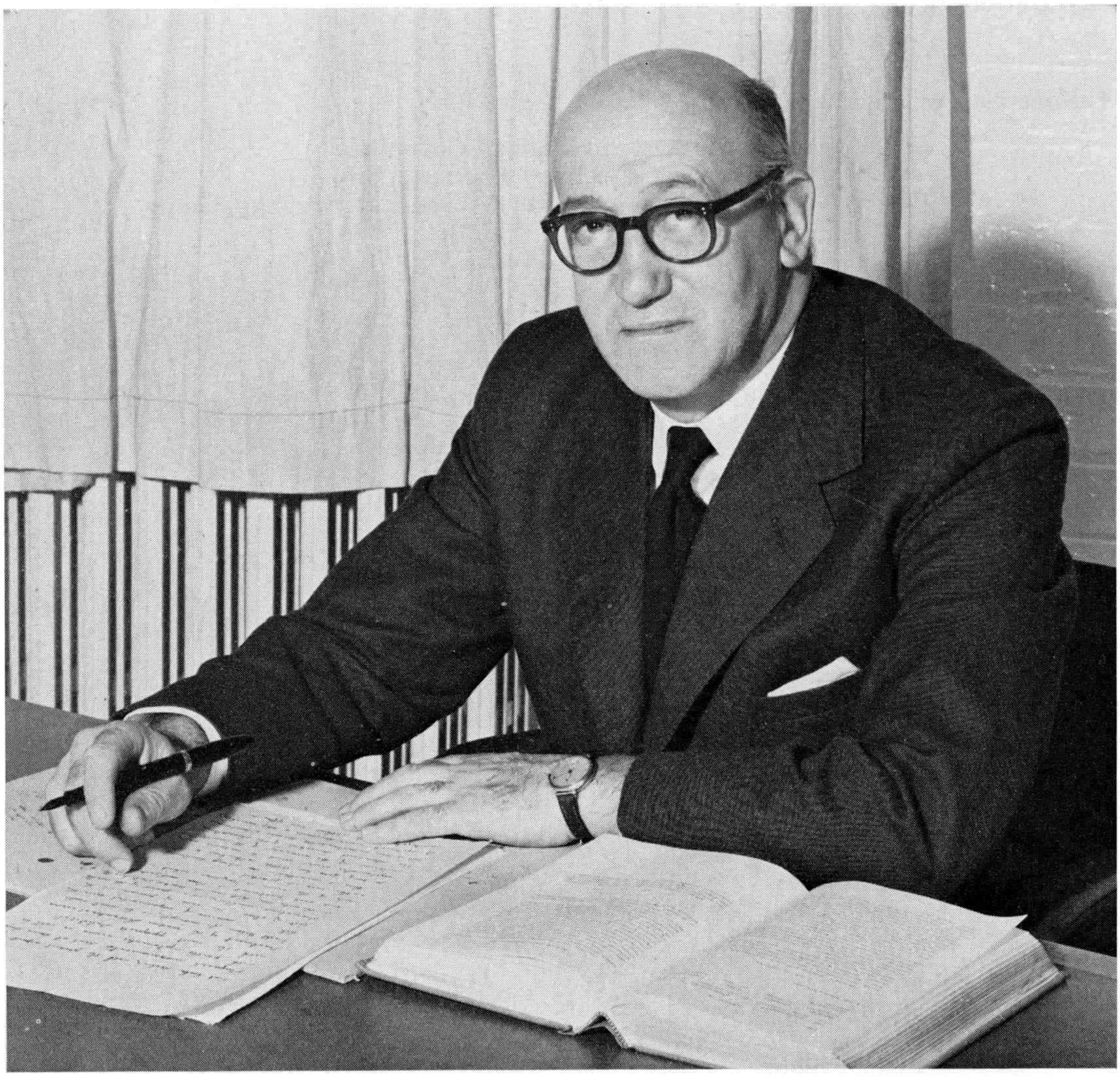

Dr. L. Essen, F.R.S., pioneer of the Atomic Clock, the standard for timekeeping in the modern world.

FOREWORD

From the dawn of civilization until a few years ago the standard used for measuring the passage of time was the rotation of the earth on its axis, and the unit the astronomical second, was a fraction of the time of rotation. We now have a new standard in the form of a spectral line of the caesium atom and a new unit which is defined as a certain number of cycles of the radio wave transmitted from this atom.

The atomic clock is the culmination of a gradual transition from mechanical clocks to electrical clocks. The first step, a small step it is true, was made by Alexander Bain who died 100 years ago; and at every stage of the transition England has taken a leading role. It is appropriate, therefore, that the world's first exhibition devoted to this revolution in timekeeping should be held at the Science Museum. The Museum authorities and the Antiquarian Horological Society are to be warmly congratulated on their initiative.

L. Essen, F.R.S.

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PREFACE

When in 1970 a few enthusiasts gathered in the Science Museum and founded the Electrical Horology Group within the framework of the Antiquarian Horological Society it is doubtful if they envisaged any national recognition of their studies of the application of electricity to timekeeping within their lifetimes. The decision of the Science Museum to stage an exhibition commemorating the centenary of the death of Alexander Bain following an approach by the first Chairman of the Electrical Horology Group was, therefore, received with satisfaction. It is the first exhibition in the world showing the evolution of the application of electricity to timekeeping from its first successful use in 1842 by Alexander Bain, the Father of Electrical Timekeeping, through to the use of quartz crystal in modern timepieces. Although the Science Museum have many excellent examples of electrical timekeepers in the Time Measurement Gallery, and is in fact the largest of its type in the world, this exhibition provides an opportunity for seeing for the first and perhaps the only time, further unique examples from other museums and private collections. It is a marvellous chance for the collector and researcher alike to see and study these clocks at first hand. It is to be hoped that the exhibition will stimulate interest in this little-explored field of horology and perhaps encourage the investigation of the history of firms who made and marketed the early examples, as well as evaluating the mechanical differences. These clocks were manufactured in highly competitive days when few makers kept records, thus the Organizing Committee has had a monumental task to perform in providing the necessary information to make this exhibition the total success it deserves to be.

On behalf of the Electrical Horology Group of the Antiquarian Horological Society I wish to thank the staff of the Science Museum for their unfailing co-operation and the Director, Miss Margaret Weston, for the opportunity of participating in this event.

F. G. Alan Shenton,
Chairman Electrical Horology Group.

INTRODUCTION

Electrifying Time is an exhibition for the layman, enthusiast, and expert horologist alike. For the first time many examples of electric clocks and watches are brought together in an exhibition devoted entirely to electrical timekeeping. The Director of the Science Museum, Miss Margaret Weston, has shown great faith in sponsoring the exhibition under the financial and other restrictions that are being experienced today. Encouragement has also been given by the Council of the Antiquarian Horological Society, together with financial support in the production of this catalogue.

Credit too must be given to the Electrical Horology Group of the Antiquarian Horological Society which in its existence of only five years has done much to further historical research into developments all but forgotten until quite recently. Without the great efforts made by the Electrical Horology Group the present exhibition could not have been presented.

Grateful appreciation is expressed to all those individuals and firms who have so generously loaned exhibits. Personal acknowledgements cannot, unfortunately, be made to individuals because of security; acknowledgements to firms and public bodies are given elsewhere in the catalogue.

We must not forget that the exhibition is being held to commemorate the centenary of the death of Alexander Bain, a lone genius of vision who, like so many other inventors, was not recognised in his time. He laid the foundations of electrical timekeeping, recorded for us in his Patent No. 8783 dated 1841, and made the first electro-magnetically operated pendulum clock in the world in 1842. Only in recent times has Alexander Bain received any of the credit due to him for his single-handed achievements in the sphere of electrical timekeeping.

Complementary to the exhibition may be found the extensive electrical horology displays in the Time Gallery on the first floor of the Science Museum. The exhibits are mainly the result of the perspicacity and far-sightedness of Frank Hope-Jones, another early pioneer of electrical horology, who donated a large number of the electrical timekeeping exhibits before his death in 1950. Here again the Science Museum must be congratulated for the acumen displayed in forming such a collection at a time when old electrical timekeepers were regarded as fit only for the rubbish dump. It was to prevent the constant loss of valuable examples of the art of electrical horology that the Electrical Horology Group was formed, alerting collectors to the danger of unique examples being lost for ever. An awareness now exists throughout the horological world that electrical timekeepers are no longer to be despised, they are fascinating examples in their own right.

Should you, as a visitor, possess some electrical timekeeper of uncertain vintage; perhaps you might like to consider donating it to the Science Museum to help build up the collection. Although it is the largest in the world, nevertheless there are gaps which require to be filled to make the collection fully representative of the art and science that inventors in England did so much to bring to perfection.

Charles K. Aked.

ELECTRIFYING TIME

A Short History of Electrical Timekeeping

Electrical horology has its origins much earlier than is realised by most horologists and before discussing electric clocks it is desirable first to review the early history of electricity and magnetism. Electrical effects in the form of lightning have been known to man from the earliest times but he was, of course, completely unaware of the natural force involved. The first man-made electricity was discovered by the rubbing of amber, a pale yellow translucent fossil resin of ancient pine trees found in many parts of the world and regarded as a precious stone at one time. Amber has the power to attract light objects to it after it has been rubbed. Thales of Miletus, 640-546 B.C., father of Greek philosophy, ascribed the effect to the presence of a soul in amber.

Fig. 1. Diagram from Gilbert's *De Magnete,* 1600 — forming a magnet by hammering a piece of iron in the earth's magnetic field.

Thales knew too of the power of attraction of lodestone on small pieces of iron. Lodestone is a magnetic oxide of iron which occurs naturally in certain parts of the world. Thales also ascribed a soul to lodestone to explain its curious power. Long before the Greeks, the Chinese were aware of the power of the lodestone and it was called by them the love-stone or thsu-chy, and the stone which snatches iron, or ny-thy-chy. There is a legend, now discounted, that the great Emperor Hoang-Ti, in the year 2635 B.C., had a chariot constructed incorporating the lodestone and which indicated the cardinal points. However the Chinese appear to be the first to have made use of the lodestone for indicating the North pole of the earth and finding their way across the featureless tracts of China. Although the knowledge of the use of the lodestone for navigational purposes was lost and found many times thereafter, it was from these beginnings that the mariners' compass was later evolved. The Greeks and Romans of Thales' time did not know of the direction-indicating property of the lodestone and it was left to Peter Peregrinus to record the knowledge of magnetism, such at it was, in the thirteenth century A.D. under the title of *Epistola de Magnete.*

Dr. William Gilbert, 1540-1603, physician to Queen Elizabeth I, was the first to explain the nature of magnetism in his classical treatise *De Magnete* published in 1600, see Fig. 1. He turned a globe from lodestone and called it *terrella,* or little earth, and showed that it caused effects similar to those of the earth's magnetic field, thus demonstrating that the earth is a huge magnet. Amongst other things he showed that magnets have two poles and that steel retains magnetism whereas soft iron will not. He further showed that the north-seeking pole of a magnet repels a similar pole but is attracted by a South-seeking pole. In like manner a south-seeking pole repels a similar pole but is attracted by a north-seeking pole.

Dr. Gilbert also performed experiments with amber and found that whilst iron could only be magnetised by a lodestone or other magnet, many substances could be electrified. He called this mysterious force "electrics" from the Greek word signifying amber. He also classified substances into two groups, those which could be electrified and those which could not. William Gilbert therefore was the founder of the science of electricity and magnetism.

Baron Otto von Guericke, 1602-1686, of the famous Madgeburg hemispheres experiment, made the first "frictional machine" for producing electricity. He used a globe of sulphur mounted on a spindle and rotated the globe against the friction of his hands or silk pads. His device produced electricity in greater quantity than had been previously possible but it was what we now refer to as "static electricity", i.e. high voltage, extremely small currents, and hence very little power although capable of many spectacular effects. Sir Isaac Newton replaced von Guericke's globe of sulphur by a globe of glass and improved the working of the machine but beyond that seems to have made little contribution to the science. The discovery of the Leyden jar by Musschenbroek, 1692-1761, and his pupil Cuneus about 1745, (and independently by von Kleist, Bishop of Pomerania), which allowed charges of electricity to be stored and enabled even more spectacular effects to be demonstrated, caused great excitement in the scientific circles of Europe and America. Musschenbroek was the first man to experience the effect of the discharge of a Leyden jar through the human body and had no desire to repeat it, however there were others more foolhardy and it became a common parlour trick to discharge a Leyden jar through many people, sometimes up to a thousand, in order to enjoy the spectacle of seeing so many all jump at once.

Stephen Gray, 1696-1736, discovered that the substances which Dr. Gilbert was unable to electrify, nevertheless could conduct charges of electricity. Working with Granvil Wheler he found that charges of electricity could be conveyed several hundred yards along pack thread providing it was supported on silk cords to avoid contact with any object. His work is fully reported in *Philosophical Transactions* for 1731, volume xxxvii, p. 18. J. T. Desaguliers, 1683-1738, showed that the charge was conveyed more effectively by moistened pack thread although the supports had to be kept dry to prevent the charge leaking away.

In 1678 Swammerdam demonstrated to the Duke of Tuscany the contraction of a frog's muscle hanging by a thread of nerve bound by a silver wire and held over a copper support. When the silver wire touched the copper support the muscle twitched as though alive. More than a century later, in 1786, the Italian physician Luigi Galvani, 1737-1798, noticed that dissected frogs' legs twitched in the vicinity of electrical machines when in operation and also that when two dissimilar metals were placed in contact with the nerve and muscle of a frog's leg, the muscle twitched when the metals were touched together, see Fig. 2. He attributed the effect to the production of electricity in the frog leg. However a fellow-Italian, Allesandro Volta, 1745-1827, demonstrated that the electricity was generated by the two dissimilar metals when immersed in a salty fluid. Further he produced the first practical source of current electricity by inventing the famous Volta's pile. Another battery invented by Volta was his famous "Crown of Cups" or "Couronne de Tasses". Volta reported his findings to the Royal Society and they were printed in *Philosophical Transactions*, 1800, volume XC pp. 403-431. A diagram from this report is shown in Fig. 3.

Shortly afterwards, in 1802, Romagnosi of Trente found that a wire carrying an electric current caused a compass needle to move. He did not publish his findings and his discovery dropped into oblivion. Professor Hans Christian Oerstedt, 1770-1852, rediscovered the effect almost by accident in 1819. Further effects due to electric currents in conductors were demonstrated by Andre M. Ampère, 1775-1836. His theories of the electric current were formulated into his "Electro-dynamics" to distinguish it from the earlier electrical effects known as "Electro-statics". Ampère also discovered the solenoid, or spiral coil of wire, which behaves like a bar magnet when an electric current flows through it. Dominique Arago, 1786-1853, another Frenchman, found in 1820 that the solenoid's magnetic

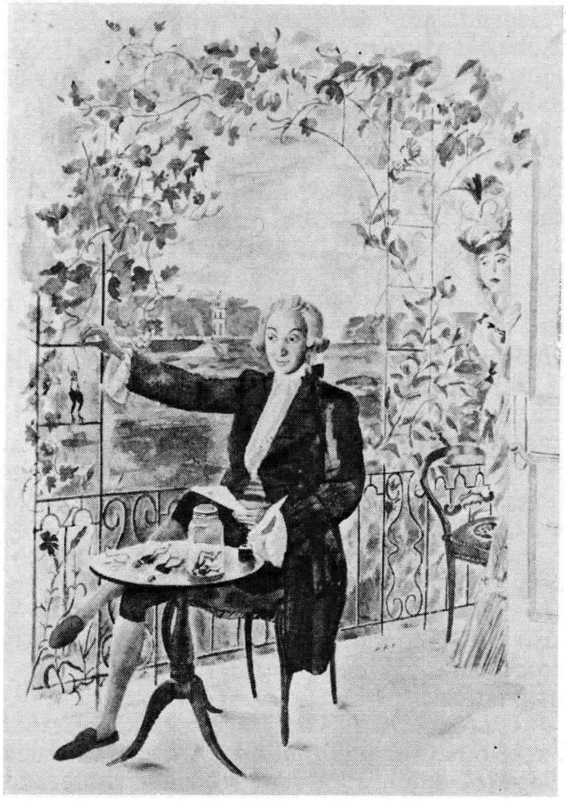

Fig. 2. Luigi Galvani shows the contraction of a frog's legs by an electric current.
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field could be considerably increased by inserting a soft iron bar within it, a discovery also made independently by Humphrey Davy, 1778-1829. When the current ceased to flow through the solenoid the soft iron lost its magnetism completely. William Sturgeon, 1783-1850, used these discoveries to make the first electromagnets in 1825. He improved the effect by bending the soft iron bar into a U-shape and winding many turns of bare copper wire on the limbs. It is said that he used his wife's silk wedding dress to provide the insulation of the bare copper wire from the iron core. If so her remarks have not been recorded ! When Sturgeon passed an electric current through the copper wire he found the bar to behave exactly like a strong permanent magnet but when the current ceased the iron bar returned to its original unmagnetised state. These effects could not be displayed for very long for the primitive cells that were then in use could supply current for short periods only. It was not until John F. Daniell, 1790-1845, invented his famous two-fluid Daniell cell in 1838 that a reliable steady current source became available.

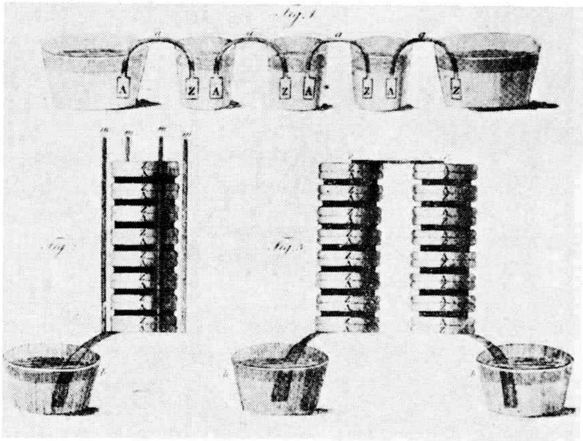

Fig. 3. Diagram from Volta's communication to The Royal Society.
By courtesy of The Royal Society.

The scene is now set to consider electrical horology. One of the first allusions in writing is made by Alexander Cummings in his account of the "Properties of the Magick Alarm: by means of which many pleasing and surprising Tricks may be played, in the manner of Comus, like playing an organ or ringing a bell at fixed time". Whilst the writer had not discovered the actual account of the apparatus used, it is obviously electrically operated since item six of his account states, after an initial deletion,

> *If a Stranger attempts to remove it from its place :* it will instantly Electrify him. This may be very useful to frighten Thieves or House breakers. *Or to drive away Rats that have got possession of Granaries.*

Item one states that

> It will Play an Organ, Ring bells etc. at any desired time *within Ten days and begin without fail, within a few moments of the hour of Night or day appointed :* without any immediate communication with its owner for several days before its performance.

Cumming apparently anticipated electric clock alarms and radios for arousing sleepers by one and a half centuries !

About the same time James Ferguson, in his treatise *An Introduction to Electricity*, 1st Edition published 1770, pages 26-30, described a clock and an orrery driven by electrostatic motors. Fig. 4 shows the plate from his book which illustrates the devices. In the preamble on page 25 Ferguson writes,

> It must be confessed they do not properly belong to the class of electrical experiments because they might properly be put into motion by water, wind or weights. Yet, as it is not unpleasing to see them move by electricity . . . All the wheels and trundle-heads are made of card-paper, the axles of common knitting wires, the trundle-staves of wood, the frames (in which the ends of the axles turn round) of thick brass wire and the supporting foot of wood. The biggest wheel, which resembles the water-wheel of a common breast-mill, is five inches in diameter; and all the rest of the wheels much in the same proportion thereto, as the figures represent them. The whole work is made so free, easy and light, that a force equal to one grain weight, acting on the great wheel, will put all the rest in motion.

The clock and orrery described and illustrated by Ferguson were only demonstration models as he states on page 25, ". . . and, for the amusement of those who attend my lectures, I set these models in motion by a stream of electric fire". As Ferguson's models were driven by static electricity and since the only source available at that time was the electrostatic machine turned by hand, it was hardly a practical proposition, nor could timekeepers be made using this principle.

Circa 1809 J. A. De Luc invented an electrical device to which he gave the name electric column. It consisted of a very large number of pairs of silver and zinc discs separated by paper, mounted within a glass tube or within three glass rods to keep them in position. Connections were taken to the outer extremities of the column and De Luc

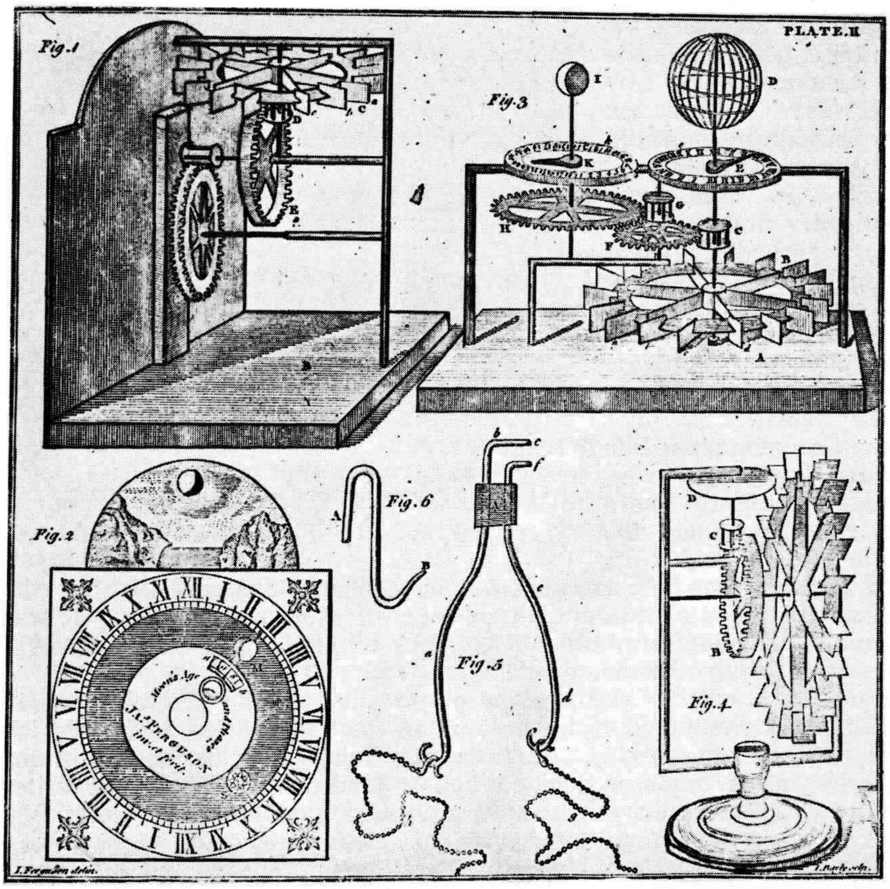

Fig. 4. Ferguson's electrically driven clock and orrery.

found that he could show static electricity effects by means of his column. He devised an electrically driven pendulum working from his column consisting of a gilt-coated pith ball suspended by a silk thread which oscillated between two brass balls or two bells connected to the column. The electrostatic forces of attraction and repulsion of the charges on the bells and gilt ball caused the ball to oscillate rapidly between the bells. De Luc was not interested in an electrical timekeeper but rather in trying to find the relationship between atmospherical electricity and the weather. In fact he called his pendulum and column the "Aerial Electroscope". However another experimenter, F. Ronalds of Hammersmith, London, succeeded in 1814 in constructing a "Galvanic Clock" which made use of a modified De Luc's pendulum. About the same time workers on the Continent were also engaged towards the same end.

In the summer of 1815 an electrically operated clock was displayed in the window of the store belonging to J. G. Zeller in the Rosengasse, Munich, Germany. It was the work of Professor Ramis and was for sale at 30 Carolin or 600 Gulden, a price evidently regarded as high. The clock was driven by two electric columns containing two thousand elements enclosed in glass tubes. In spite of the high voltage of the columns they were quite safe to touch since the voltage collapsed if the connections were contacted. Professor Ramis's clock appears to have had a compound pendulum fitted with an upper extension carrying a small hammer which was alternately attracted and repelled by the potential of some four thousand volts existing between the two bells mounted on the top of the columns. As the hammers struck the bells in turn it gave a fine ringing sound according to accounts of the time. Although actual details of the clock's construction have not come to light Fig. 5 illustrates the outward appearance of Professor Ramis's clock.

De Luc's electric columns are now known as Zamboni piles and still have applications today, e.g. night vision binoculars and telescopes. Zamboni himself demonstrated a similar clock to that of Professor Ramis to the Art Society of Geneva many years later in 1832. He must have been aware of the applications of De Luc's pendulum and Professor Ramis's clock. It is also of interest to note that at the Clarendon Laboratory at Oxford there is a

Zamboni pile connected to two bells between which hangs a brass ball suspended on a silk thread. The pendulum has been working continuously and ringing the bells for over one hundred and thirty years !

Francis Ronalds also made use of static electricity with clocks when he constructed his telegraph in the grounds of his house in Hammersmith. Clocks were used at both transmitting and receiving positions to allow synchronisation and identification of the letters passed over the telegraph. Ronalds also made use of the pendulum of an ordinary spring driven clock to generate the static electricity required for the operation of his telegraph by means of his ingenious "Pendulum Doubler of Electricity". The modus operandi of his device is too complex to describe here. This was one of the last attempts to harness static electricity with telegraphs and clocks, and whilst the description used by the writer is dated 1823, it is certain that Ronalds used his device as a modification of the revolving doubler which Nicholson or Bennet invented earlier. Thus we must leave the field of static electricity with the observation that no acceptable practical time-measuring device resulted from its employment as the motive power.

We have already seen that the magnetic effects of a current were known by 1819-20 as a result of the work of Ampère and Arago. To give some idea of the great step forward as a result of these discoveries, the prize question set in Natural Philosophy for 1810 reads: "Philosophers have long bestowed great value on seeking to discover the connexion that subsisted between electricity and magnetism, which exhibit phenomena so similar and so different . . . The Royal Society, thinking that this part of experimental philosophy may be considerably improved, offers a prize to the writer, who, taking experience for his guide and support, shall give the best exposition of the material connexion between electricity and magnetism". Henceforth, with the discovery of the connection between electricity and magnetism, inventors always made use of magnetic fields created by electric currents to provide the motive power for electro-mechanical devices.

In 1826 Georg Simon Ohm, 1787-1854, propounded his now famous law connecting voltage, resistance and current in an electrical circuit. The basis of his law was contained in his paper published in 1827 in Berlin, *Die Galvanische Kette mathematisch bearbeitat*. Also in 1826 a young man called Carl August Steinheil, 1801-1870, built an observatory and workshop at Perluch near Munich. He was a member of the Scientific Acadamy of Bavaria and became a Professor of Munich University in 1835. Steinheil erected a telegraph system about this time which made use of the principle of the two bells first used by De Luc. He had already studied time measurement and realised that just as messages could be sent by telegraph, a good clock could be arranged to report its time to any other place or to any number of other clocks by employing the agency of galvanic currents. He was granted a privilege by the King of Bavaria on the 2nd October, 1839, and built a master clock fitted with contacts which he placed in the Educational Institute in Munich. The master clock sent out current pulses to simple clocks fitted with a magnet passing through a solenoid which moved an anchor escapement in reverse thus driving the hands of the clock. Daniell cells from England were used to provide the power for the current pulses. Steinheil used either a rocking contact, developed by

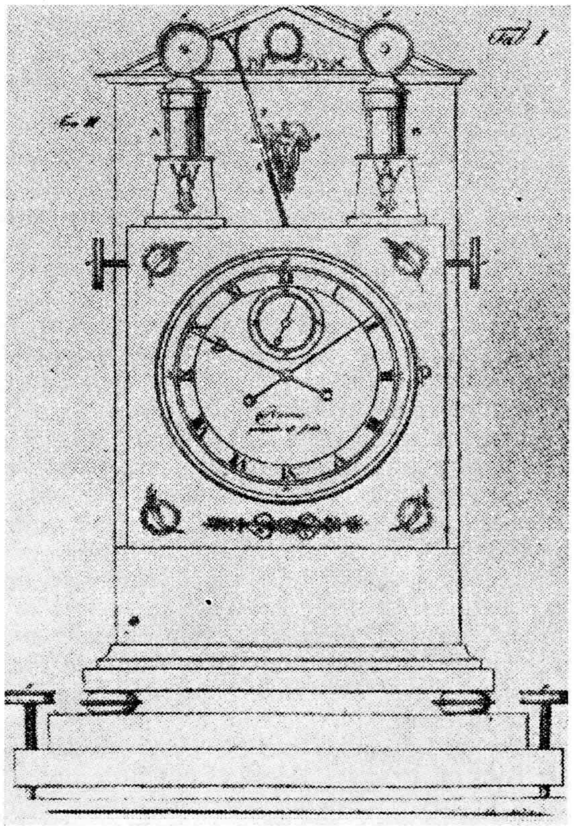

Fig. 5. Professor Ramis's electrostatic clock, circa 1815.

Dr. Loher — Privatarchiv Steinheil.

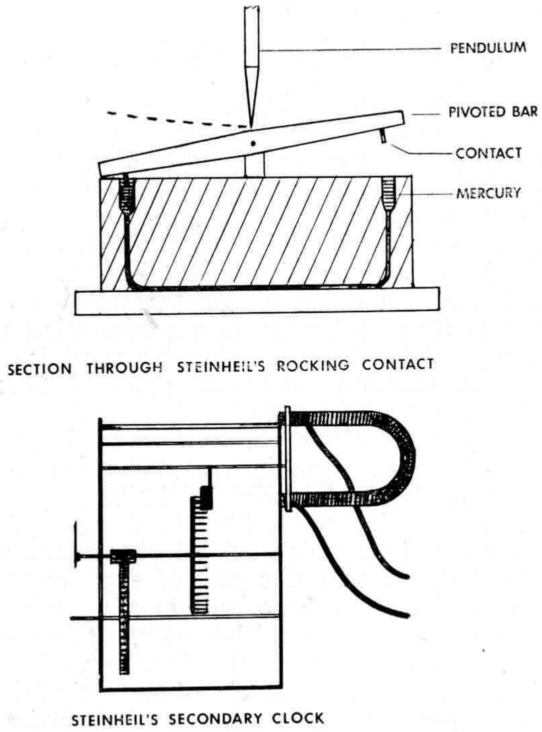

Fig. 6. Steinheil's rocking contact and secondary clock.

Fig. 7. Drawing of Alexander Bain, from an old photograph.

Gauss, or a similar type invented by himself but where the contacts dipped into mercury, operated directly by the pendulum as shown in Fig. 6. His improved type of contact was supposed to take only one hundredth part of the impulse given to the pendulum in the master clock. Another method he used was the closing of contacts every half-minute by one of the wheels in the train of the master clock. The half-minute current pulses were used to drive a secondary clock of a type different from that for the pendulum contact. How successful the systems used by Steinheil were in practice is yet to be discovered.

In the early 1800's great interest was shown in the development of electrical science and applications of electricity to telegraphic communication, particularly in England although there were very few who understood the fundamental laws governing the behaviour of electrical circuits. Even quite brilliant men of science were unable to explain phenomena which could now be elucidated by a ten year old schoolboy. Popular lectures and demonstrations on scientific subjects were the order of the day. A young Scotsman named Alexander Bain, a nineteen year old apprentice to Mr. Sellar, watchmaker, of Wick, attended such a lecture on light, heat, and electricity at Thurso in 1830. He may not have known it at the time but it was to be the turning point of his life. Bain was completely fascinated by the lecture and lingered afterwards listening to the remarks of the lecturer to some of the audience who remained behind. He then returned to his father's farm at Watten thirteen miles away, followed by a walk to Wick next morning of eight miles ! Many years later Bain, see Fig. 7, wrote in his book *A Treatise on Numerous Applications of Electrical Science to the Useful Arts,* published in Edinburgh, circa 1870, "The listening lad was cold too, for it was a bitterly cold night, so he made his way home as fast as he could; but he never forgot the lecture, nor the subsequent conversation". He goes on to say: "He had but little opportunity to learn much until he came to London, early in 1837, when he began to attend lectures at the Adelaide Gallery and Polytechnic Institution; and seeing the beautiful electro-magnetic apparatus in action at these places, his attention was drawn to consider how they could be applied to useful purposes. The application of this mysterious power to the mechanism of his own business (clockwork) was naturally the first to suggest itself; and shortly afterwards he thought on various ways to applying it to telegraphs. It may be well to state here that at that time he was entirely ignorant of what was done by others in this direction. He had seen no books on the subject, nor had he acquired any information previously, except a little in relation to frictional electricity".

Fig. 8. Professor Charles Wheatstone.

Bain in 1837 was working in Clerkenwell as a journeyman clockmaker. Some writers aver that he did not complete his apprenticeship and that his father had to pay compensation, which Bain later repaid. From the dates quoted previously there would appear to have been ample time for him to have served his full apprenticeship. In the spring of 1838 he spoke to a friend, Mr. M'Dowall, regarding his intended electric clock. By July 1840, Bain had succeeded in producing rough models of both his electric clock and a printing telegraph. He was in need of a patron since he had little money of his own and spoke to Mr. Baddeley, Editor of the *Mechanics Magazine,* who introduced him to Professor Charles Wheatstone, see Fig. 8, on 1st August, 1840. Two weeks later Bain took his models to Wheatstone who gave him £5 with a further promise of larger sums of money for two models of the printing telegraph. Alas for Bain he could not have gone to a worse man for he was advised by Wheatstone to postpone for the time being all proceedings in his work and not to mention it to anyone. Wheatstone exhibited a model of an electric clock, supposedly of his own design, before the Royal Society of London on 26th November, 1840. On the 10th October previous, John Barwise, Chronometer Maker, St. Martin's Lane, London; and Alexander Bain, Mechanist, Wigmore Street, London, had applied for the first electric clock patent in this country. The patent was not granted until the 11th June, 1841, and sealed 10th July, 1841, as Queen Victoria could not sign the letters patent because of one of her confinements. Contrast Bain's treatment with that of Steinheil who made application on 20th September, 1839, and received his privilege on 2nd October, 1839. Had Alexander Bain received encouragement or if he had had money at his disposal, his application might very well have preceded that of Steinheil's. When one reflects that Alexander Bain was a young man with no formal education or advantages of any kind, it is remarkable that he could compete with university professors on equal terms in the fields of electrical horology and telegraphy.

In January, 1841, Barwise, on behalf of Bain successfully served an injunction on Wheatstone thus preventing him from exhibiting his electric clock model in the Adelaide Gallery as his own invention. Soon afterwards, 18th March, 1841, Bain's clock was displayed at the Polytechnic. This clock was an ordinary spring driven pendulum clock fitted with contacts operated by the pendulum which controlled currents to operate secondary clocks. Bain laid claim to the invention of the Electro-Magnetic Clock in the *Inventor's Advocate* of 24th March, 1841. These incidents served to stir up a bitter dispute between Bain and Wheatstone which was never reconciled. At this point in time it is clear that Wheatstone did not act as a gentleman in the matter. The dispute went to the length of some unknown person acting on behalf of Wheatstone on 22nd May, 1841, offering a sum of money to the proprietors of the *Inventors Advocate* if Bain's letters were excluded from the journal. A full account of the conflict is given in the book written by John Finlaison, *An Account of Some Remarkable Applications of the Electric Fluid . . . by A. Bain; with a vindication of his claim to be the first inventor of* *the Electro-Magnetic Clock, etc., etc.,* published London, 1843.

Bain's Patent No. 8783 of 1841, Barwise being included presumably for providing the money to take out the patent, shows quite clearly that Bain was a genius. Most of the applications of electricity to horology are anticipated by this single patent. Briefly the points covered in the patent are as follows:—

1. The application of a pendulum having operating contacts to provide electric current to move other clocks.
2. The use of electromagnets to drive clocks.
3. The application of a central clock to impulse any number of other clocks.
4. The use of a central clock to wind up any number of other clocks.
5. The use of a central clock to regulate the pendulums of any number of other clocks.
6. The application of a central clock to set the hands of an ordinary clock to time.
7. The use of a central clock to set the hands of other clocks to agree with those of the central clock.
8. The application of conducting wires insulated in any of the usual ways and twisted together with hemp to form a flexible rope.
9. The use of electricity as the motive force in lieu of springs or weights.
10. The use of a balance for making and breaking contacts for transmitting electrical currents to other clocks.
11. The use of an electric current for the striking of a bell of a clock by means of an electromagnet.
12. The transmission of impulses from one clock to another in a series circuit of clocks.

At the end of his patent Bain made it clear that he envisages uniform time distribution throughout the whole country by means of his system. One item mentioned in his patent but not claimed as an improvement is his ingenious method of providing his battteries with fresh chemicals by means of an automatic dispensing disc. This single patent justifies Alexander Bain being given the title of "Father of Electrical Horology".

Bain continued to carry out further work in connection with electric clocks and telegraphs and took out several other patents. Patent No. 9745, issued 27th May, 1843, covers the electromagnetic pendulum driven by the interaction of a solenoid and a consequent pole permanent magnet and drawing current from the earth battery which he had devised, consisting of a simple cell formed by a zinc plate and a copper plate or a mass of carbon buried in moist soil. Such an arrangement gives a relatively constant output voltage at low currents and hence a constant driving force to the clock. Bain developed the solenoid arrangement to allow his pendulums to function on the very small power available from his earth battery, the great advantage being that his battery would deliver current for an indefinite period, whereas the commonly available battery arrangements in the middle of the last century required a great deal of attention to maintain them and they were also very expensive to install and keep running. Since Bain did not discover the principle of the earth battery until 1842 in connection with his telegraph experiments, he must have worked very hard to develop his new type of clock in the time, see Figs. 9 and 9a. Another notable achievement was Bain's time transmission from Edinburgh to Glasgow in 1846. In the same year, after a legal wrangle, he was paid £7,500 by the Electric Telegraph Company who took over his patents, the company undertook to make the clocks, provide the working capital, and Bain was to receive half the profits. Bain's old rival Professor Wheatstone, was associated with the company and

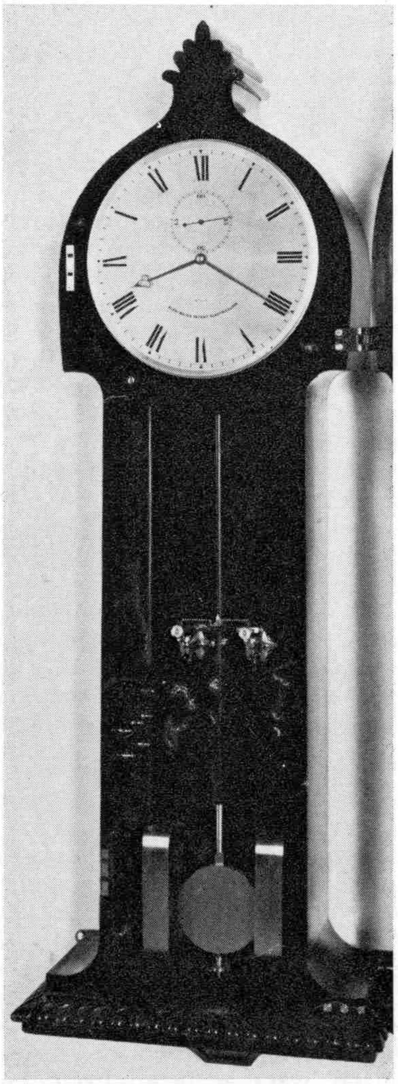

Fig. 9. Bain electric wall timepiece.
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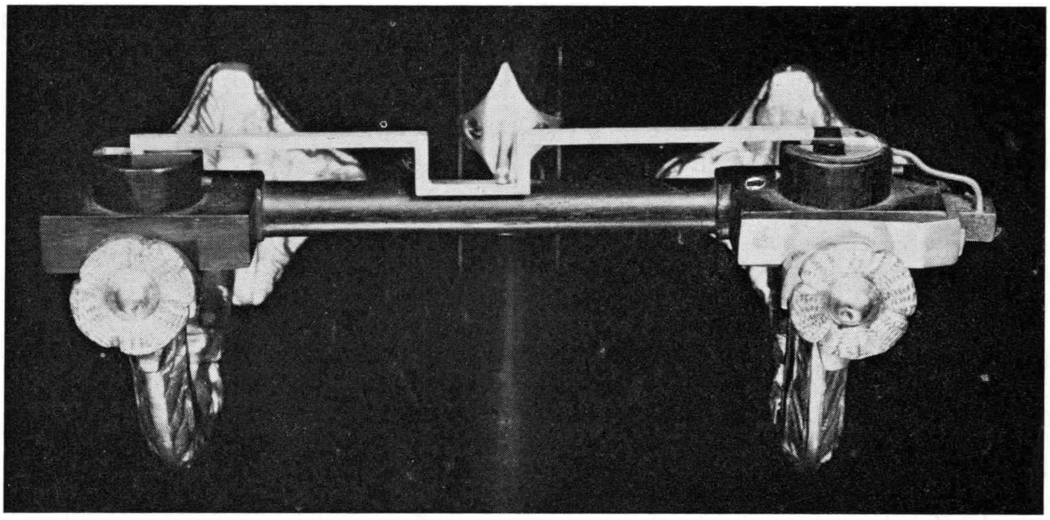

Fig. 9a. Bain electric wall time-piece. Details of contactor.

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resigned as a result of the decision. Bain's association with the company did not last long however and he went into independent production of clocks. The events of Bain's later life are not well known and his last years were not good. He was given a Civil List Pension by Mr. Gladstone amounting to £80 per annum which he drew for some four years, and died after a short period at the Broomhill Home for Incurables, Kirkintilloch, 2nd January, 1877. Alexander Bain was before his time and can now be seen to have been an inventive genius with a prophetic vision.

Another early inventor making use of electricity as a motive force for clocks was Dr. Matthäus Hipp of Neuchâtel. He devised the now-famous Hipp toggle contact system for maintaining a pendulum in motion. Although the first clock using this principle was not made until 1842, he stated that he first thought of the idea in 1834. The arrangement consists of a freely pivoted steel trailer mounted on the pendulum which moves over a notched steel block fixed to a spring blade carrying an electrical contact, see Fig. 10. When the amplitude of the pendulum swing falls below a fixed amount the trailer falls into the notch and as the pendulum swing reverses the trailer is pressed down and the electrical contact on the spring blade touches a fixed contact. Current then passes through an electromagnet mounted beneath the pendulum and attracts an armature fixed to the pendulum. Just before the vertical position the trailer is released from the notched block, the current ceases and the magnetic field from the electromagnet collapses, thus allowing the pendulum to pass freely after receiving a powerful impulse. Not until the amplitude of the pendulum swing falls again to the critical level does the preceding action repeat itself. Hipp's system is most ingenious and reliable and continues in use today for those clocks not requiring the highest performance and it is widely used in "waiting train" systems where the system is used to provide a source of power only to a clock train, the actual timekeeping being provided by an accurate master clock delivering synchronizing signals. The Hipp toggle has been reinvented many times by electrical horologists and is a great favourite with amateur horologists because of the ease of manufacture. Even crudely made clocks built on this principle are capable of a good standard of timekeeping, however if the notched block of the toggle is not correctly designed the pendulum will occasionally stop through the steel trailer fouling the block.

A well known variation of the Hipp toggle was due to Lemoine and consists of a mica vane affixed to the trailer. As the mica vane was usually of a butterfly shape, clocks employing Lemoine's variation are called "Electric Butterfly" clocks. There is little advantage gained over the original arrangement which has the basic weakness that the upper limit of pendulum swing is determined by the battery voltage and condition, hence the rate varies with the battery output, although it is precise enough for ordinary clocks. Naturally the pendulum must have temperature compensation to achieve a good performance.

One of the points made by Bain in his early patents was that the amount of impulse given to the pendulum could be made independent of the battery voltage by causing the force from the electromagnetic device to store energy in a spring or weight and then using the constant amount of stored potential energy to impulse the pendulum. Providing the battery voltage was greater than the minimum to achieve operation, no variation of battery voltage could affect the going of the clock. Charles Shepherd in 1849 devised an arrangement whereby an electromagnet raised a weighted arm which was released by the pendulum to give a constant impulse. His system is described in Patent No. 12567 of 1849 and it was selected to be used at the Great Exhibition of 1851. Due to trouble with the contacts it failed ignominiously and the time at the Exhibition was given by a large clock made by Dent to the design of Lord Grimthorpe. Thus Lord Grimthorpe was able to say in his book *Clocks, Watches and Bells,* "These clocks never answered in any practical sense; nor would anything but the strongest evidence, independent of the inventor, convince me that any independent pendulum directly maintained by electricity can succeed in keeping good time for any considerable period". It is to be feared that the precarious nature of the contacts used in electric clocks at this period and the condemnation of Lord Grimthorpe served to bring electrical horology into disrepute. The manufacturers of mechanical clocks in England were facing too much competition from abroad to welcome electricians into the fold and were only too pleased to witness the failure of electric clocks.

One of the improvements Shepherd incorporated in his clock was the provision of two contacts and two separate batteries to drive his secondary clocks. By doing so he ensured that the secondary clocks were impulsed by reversal of current and not dependent on the indifferent contacts available. He, of course, like many others before him, used the pendulum to operate the contacts directly; hence the contact pressure available was light and uncertain in action. However one of Shepherd's original secondary clocks in a slightly modified form still continues to function at the main entrance to the Royal Observatory at Greenwich. Shepherd's system was tried at Greenwich in 1850 as a result of Sir George Airy's interest, he then being the Astronomer Royal.

Froment, in France, devised a simpler and improved version of Shepherd's clock in 1854 and it was invented completely independently by Sir David Gill on almost similar lines, see Fig. 11. A great deal of money was expended by Gill upon his clock but he never achieved success with it during protracted tests at the Cape Observatory. The trouble, as usual, was the uncertainty of the contacts; but I believe that Gill's clock has been tried out since with perfectly satisfactorily results. His clock could never have met the requirements laid down by the British Association in 1879 when he was appointed to form a committee to secure improvements in astronomical regulators. Yet he laid down the complete specification for such a clock, his reason for failure resting with his contact system.

The difficulties of devising consistent contact systems were early recognised and the causes of failure were known. Gold and silver contacts were used to avoid failure but it only needed a speck of dust to render them inoperative with the light pressures available from a pendulum. Professor Wheatstone devised his own solution to the problem. Using a very large weight driven mechanical clock with

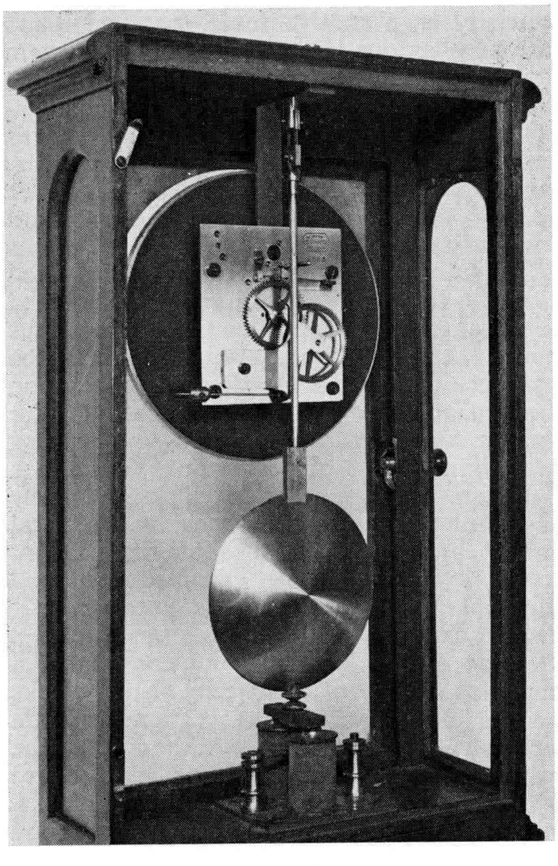

Fig. 10. Pendulum with Hipp toggle below bob.

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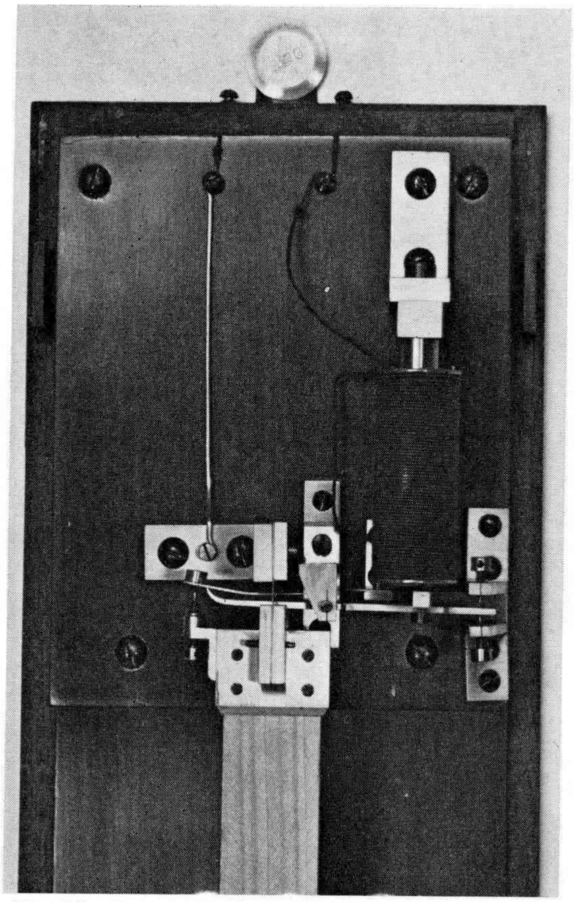

Fig. 11. Froment's electrically driven pendulum.
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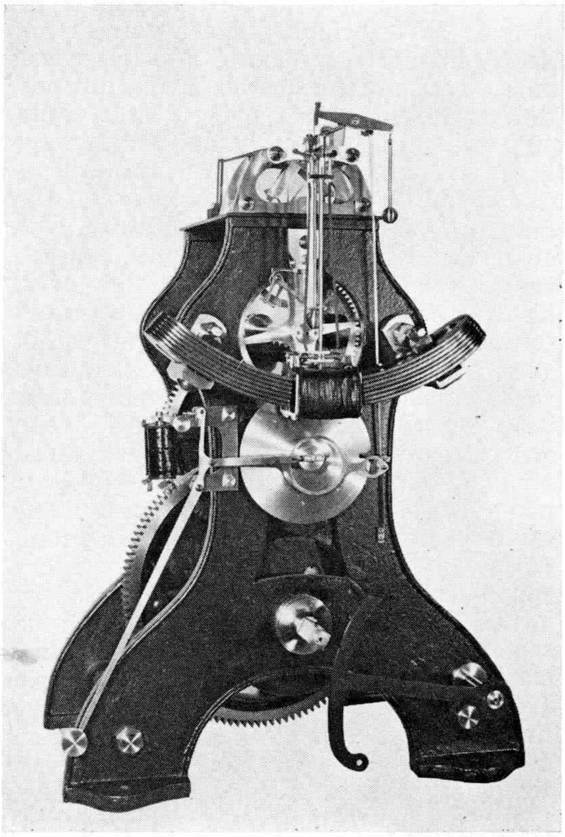

Fig. 12. Wheatstone's master clock, circa 1870.
Crown copyright, Science Museum, London.

a pendulum carrying a coil passing over two large permanent magnets, he induced currents within the coil which reversed at each swing. The current thus induced was used to drive secondary clocks without the need for contacts of any kind. He outlined his proposal to use the magneto-electric current discovered by Michael Faraday in a paper read to the Royal Society in 1840. Unfortunately for Wheatstone he had got rid of his troublesome contacts at the expense of devising one of the world's worst timekeepers in the whole history of horology, see Fig. 12. He might just as well have put his pendulum in a bucket of water as use it to act as a miniature electric generator. His system was given a brief trial at London University and in the Royal Institution about 1873, the scheme failed and was abandoned on the death of the inventor in 1875. Wheatstone's original master clock may be seen in the Science Museum at South Kensington. Had Wheatstone allowed his pendulum to perform the timekeeping unencumbered and used the clock train to let off a separate train to actuate the generating mechanism, he would have succeeded. Martin Fischer, of Zurich, in 1900 managed to produce Wheatstone's system in a suitable form when he produced the Magneta clock system. His master clock was a very high quality mechanical movement with a dead beat escapement and compensated pendulum functioning in the normal way. Each minute the clock releases a powerful weight driven train which rocks an armature of a generator within the poles of a powerful permanent magnet and the current pulses are used to drive secondary clocks, up to sixty or more in number. Exceedingly robust movements and very heavy weights are used so that the Magneta system is hardly recognisable as an electric clock. The outstanding advantage is, of course, the absence of contacts. Another anticipation of Wheatstone's was the use of continuously rotating discs in his secondary clocks driven by his pendulum generated currents, i.e. synchronous electric motors almost eighty years before they were introduced by H. E. Warren of America, and which now form the largest single group of time indicators in the world, the common synchronous electric clock.

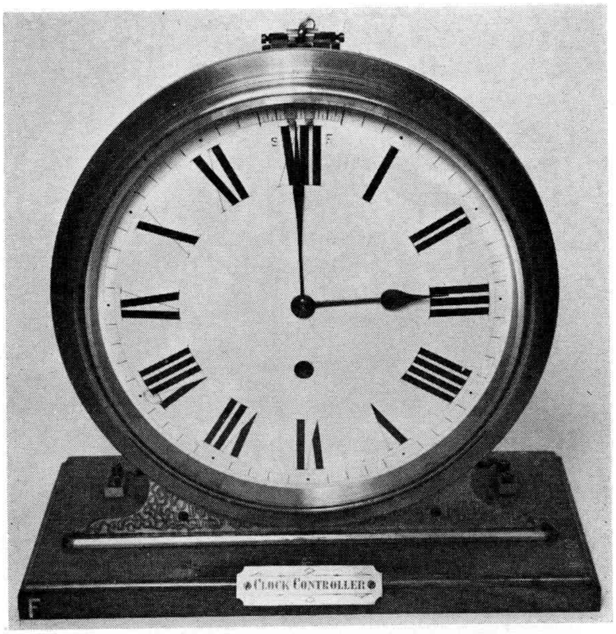

Fig. 13. Lund's clock controller, patented 1876.
Crown copyright, Science Museum, London.

One might be tempted to enquire what motive lay behind this search for electrically driven clocks and electrical time systems. The answer is that no one had yet succeeded in keeping a large group of mechanical clocks in absolute step. E. J. Wood in his book *Curiosities of Clocks and Watches* tells the story of the Emperor Charles V of Austria who abdicated about the middle of the sixteenth century and retired to a monastery with his watches and clocks. He endeavoured to make his clocks "accord" but all in vain, upon which he is supposed to have said, "What an egregious fool must I have been to have squandered so much blood and treasure in an absurd attempt to make all men think alike, when I cannot even make clocks keep time together". The rapid growth of the railways in Britain during the middle of the last century supplied the incentive to find means of ensuring that clocks did in fact tell the same time. A pioneer of synchronising clocks was the stationmaster at Chester in 1857, R. L. Jones. He adopted Alexander Bain's system of sympathetic pendulums driven by a master clock providing the current pulses to keep the pendulums in step. A fair degree of success was claimed although it was not generally adopted because a temporary loss of current pulses, whilst not stopping the secondary clocks, could mean the wrong correction being applied when the pulses were restored. Also the secondary clocks had to be rewound by hand and unless fitted with maintaining power, would require a correction by hand after each winding. Essentially there was little advance on Bain's work and the system died a natural death.

Attention was directed from electric clocks as such to the perfection of electrical synchronizing systems which would allow the correction of ordinary clocks at suitable intervals. One of the first services for the distribution of time, although not electrical, was due to John Pond, the Astronomer Royal 1811-35, who put forward a scheme for the sending of Greenwich time from the Observatory. He appointed his adopted son John Henry in June 1836, to carry a chronometer showing Greenwich time to the principal watch and clockmakers in London. On one day of each week the watch was re-certified as to its accuracy. Previously clockmakers were compelled to send their own men to Greenwich or to make transit observations of a star. Sir George Airy, Astronomer Royal 1835-81, in his annual report of 1849 stated, "The general utility of the Observatory will be increased by the dissemination throughout the kingdom of accurate time signals by an original clock at Greenwich". E. B. Dennison (Lord Grimthorpe) wrote in a letter dated 5th February, 1862, "The Westminster Clock is at last going to be made to report its time rate to Greenwich, for which I made preparation three years ago (1858 or 1859). The rate has seldom varied more than two seconds a week since last May, and *I do not trust the carrying of watches to report on such small rates.* The King's Cross clock is still the best, with the spring remontoire, but it has much lighter work to do".

By 1864 the Magnetic Telegraph Company initiated the control of public clocks by electric time signals from the Glasgow Observatory, followed by a similar service in 1865 from the Liverpool Observatory. Greenwich Observatory was reported by Sir George Airy to be sending synchronizing signals via a telegraph line to the Lombard Street Post Office Clock in 1869. The service from Greenwich to the Post Office expanded rapidly in addition to that given by private telegraphic companies, these however were taken over by the Post Office in 1870. The famous firm of Barraud and Lund in 1877 instituted a time signal service by electric currents sent out each hour from their own regulator which was corrected by signals from Greenwich. A limited area in London was served and the service eventually became the Standard Time Company. Lund also took out a patent in 1876 for the forcible correction of the minute hands of clocks, which method was adopted by some firms and railways in 1892, see Fig. 13. F. J. Ritchie, in a paper read before the Royal Scottish Society of Arts in 1878, reviewed the electrical time services and stated that the annual cost was too great for most watchmakers. He mentioned his system of sympathetic pendulum's, i.e. electrically driven pendulums driving secondary clocks and controlled by a master clock, similar to R. L. Jones's system except that the secondary clocks did not require winding; and of course anticipated by Bain forty years earlier. After dealing with Bain's work and his systems for hourly correction of clocks, and paying tribute to the ideas of Bain, Ritchie goes on to describe his system for the hourly correction of clocks by electrical signals from a master clock, which had taken him almost twenty years to develop. His scheme utilised ordinary weight or spring driven movements which were adjusted to have a gaining rate of two-to-five minutes a day. The minute hand of such clocks would arrive at the hour a few seconds early. An electric current from the master clock sent out fifteen seconds before the hour stopped the escape wheel of the clock until the exact second of the hour, the pendulum swinging idly meanwhile; at the cessation of the current on the exact hour, the clock recommenced its going corrected to the nearest second. Ritchie's system allowed only the correction of clocks with a gaining rate but it was a relatively cheap method and reliable in action, whilst the circuits could be checked at any time except during the synchronization period. The alternative scheme involving forcible correction of the hour hand, was not really suitable for large turret clocks with massive hands acted on by the wind, etc. A successful system which has withstood the test of time was evolved by the Self-Winding Clock Company of America, in this the secondary clocks are rewound electrically and also reset at the hour by signals from a master clock, see Fig. 14. The system is still in use on some Underground railways of London. From these early attempts grew the present time distribution services including the Post Office Speaking Clock, or TIM, and the radio time signals from Greenwich.

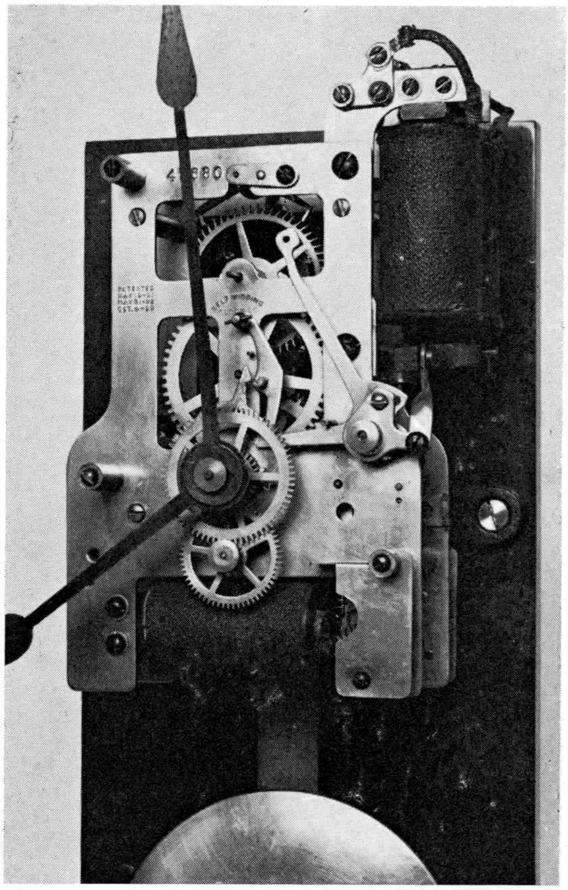

Fig. 14. Secondary clock by Self Winding Clock Co., U.S.A.
Lent to The Science Museum, London, by Metropolitan District Railway Co., London.

Examination of horological books published during the last decades of the nineteenth century will reveal a fine disregard for electric clocks, evidence of the disrepute into which they had fallen as a result of their indifferent performance in practice. J. W. Benson in his *Time and Time Tellers,* published in 1875, writes "Electric Clocks are now seldom made". Similarly J. F. Kendall in *A History of Watches and other timekeepers,* published in 1892, say of electric clocks, "... but however well they appeared to perform at first, none of them have secured a lasting place". He quotes the experience of C. V. Walker, who after many years of trial of a clock at London Bridge controlled by signals from Greenwich, pronounced the system to be impracticable. Only three years later however the first step was taken which was to lead to the absolute and undisputed supremacy of the electric clock for timekeeping purposes. The collaboration of F. Hope-Jones with G. B. Bowell led to the invention of the so-called Synchronome switch described in a

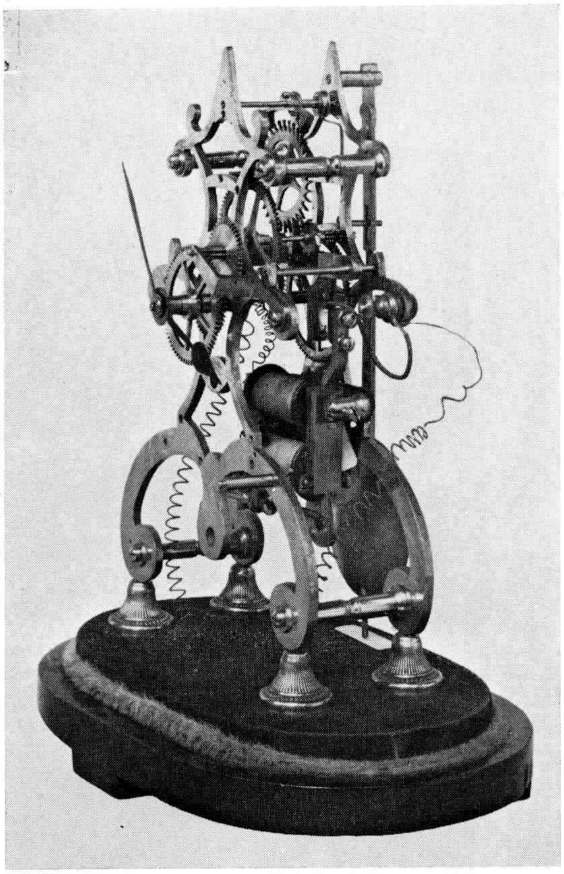

Fig. 15. Hope-Jones and Bowell synchronome remontoire.
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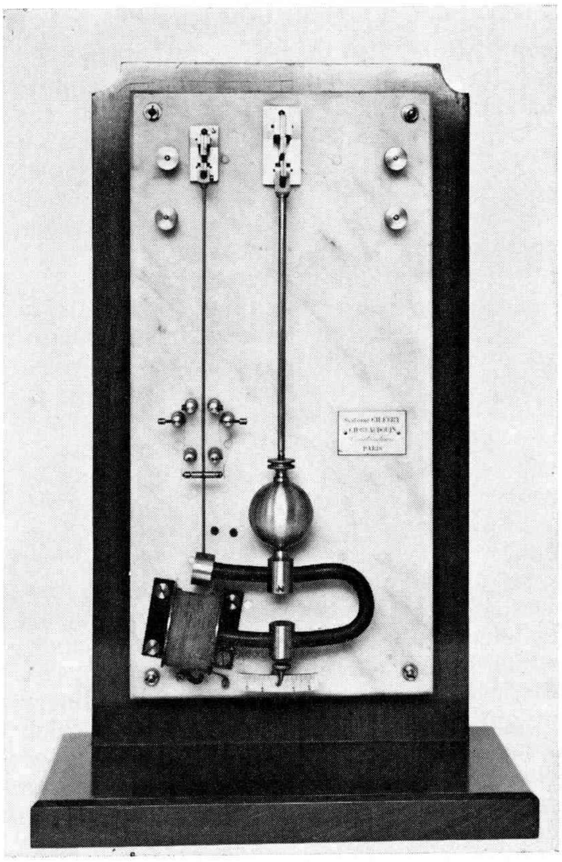

Fig. 16. Professor Charles Fery's electrically maintained pendulum.
Lent to The Science Museum, London, by Prof. Chas. Fery, Paris.

lecture before the British Horological Institute in 1895. Essentially it was an electrically reset gravity arm driving a pendulum through an anchor escapement. For his first model Hope-Jones used a skeleton clock which he reputedly played with in his nursery days, see Fig. 15. Though somewhat crude it served to show how absolutely reliable half-minute current pulses could be derived for driving secondary clocks. What Hope-Jones and Bowell achieved where others had hitherto failed was the principle of allowing the pendulum to measure the time without having to drive any electrical contacts directly. Their pendulum dictated the time when the contacts would operate but did not take part in the consequent operation. A much more powerful force to close the contacts was ensured by having a massive gravity arm and the force to raise the arm was applied through the electrical contacts. By causing the armature to be arrested by a stop, the inertia of the gravity arm caused the contacts to open decisively and rapidly. Hope-Jones was so proud of his Synchronome switch that he propounded it as a basic law for electric clocks which, of course, it is not. Nevertheless Hope-Jones's electric remontoire of 1895 was quite suitable, when fitted to a Graham dead-beat escapement with a compensated pendulum, to provide an accurate and, what is more important, a completely reliable electric time signal system giving half-minute advancement of secondary clocks.

The next real step was independently taken by several workers, notably Campiche, Lowne, and W. E. Palmer. It consisted of a count-wheel driven by the pendulum and arranged to give an impulse to the pendulum at half-minute intervals. Palmer patented his arrangement in 1902 and its only real fault was that the impulse to the pendulum was not in accordance with the requirements for good timekeeping. Hope-Jones saw in the count wheel arrangement the final piece of his electric clock jigsaw puzzle. He married the count wheel to his Synchronome remontoire, as is described in his Patent No. 6066 of 1905. He tried to avoid the incorrect impulsing of the pendulum by Palmer's arrangement and used a long, flexible spring similar to that employed by Campiche. Not until three more years had passed did Hope-Jones place the impulse plane directly on the pendulum and allow the gravity arm to impulse it via a small roller. His clock was now able to out-perform all but the most accurate astronomical regulators and Hope-Jones began to put his not inconsiderable energies into making it a commercial success and branching out into other fields. To Hope-Jones must go the credit for raising the electric clock from being an object of derision to a universal recognition of its outstanding possibilities.

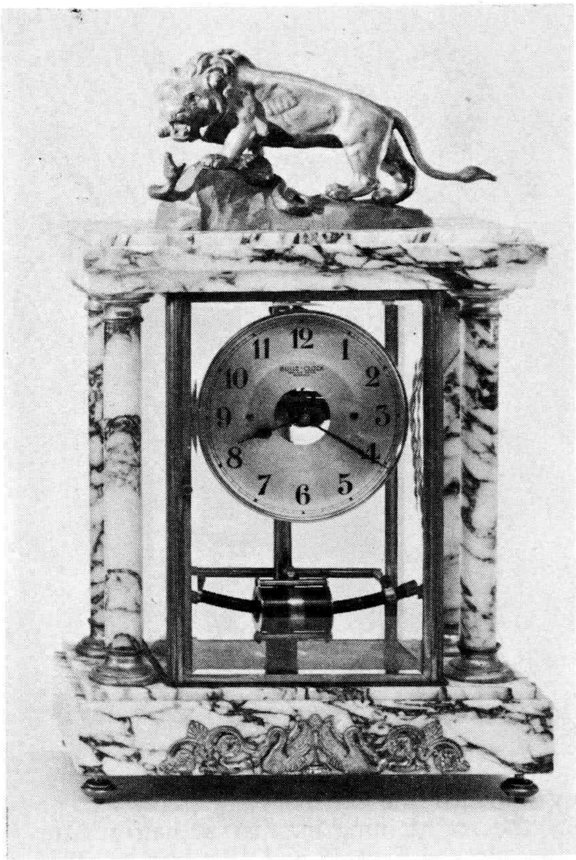

Fig. 17. Bulle electric clock.
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Little has been said about workers on the Continent and America. Basically they ignored developments in England and lagged behind as a result. Some interesting clocks resulted, for example Professor Charles Fery's clock of 1908, see Fig. 16. He used a horseshoe magnet attached to a pendulum and used one limb for impulsing and the other to actuate contacts via a subsidiary pendulum. By this means he hoped to have a pendulum completely free from contact with any solid body. Since the work to operate the contacts comes from the pendulum via the magnetic field, the arrangement has no real advantage. Fery's use of high resistance solenoids was however a step in the right direction.

Another attempt to utilise Bain's principles was made by Bentley of Leicester. Utilising a pendulum carrying a solenoid and using an earth battery, he made improvements to the contact system by using a roller and fitting an amplitude controller. It was intended as an electric clock and not used for impulsing secondary clocks. Considering the late date of its development, about 1910, it is difficult to see why Bentley adopted the system. A similar system was adopted by Favre-Bulle in his well known "Bulle" clock, about 1921, i.e. a solenoid of many turns carried on the pendulum and passing over a consequent pole magnet, see Fig. 17. Silver was used for the contacts and the clock train driven via the physical movement of the contact system. Many thousands of these clocks were made and are still giving reasonable service today.

Bain in his earliest patent mentions the use of a balance but it was not until the early 1900's that they began to appear in any number. Some examples are the well known Eureka clock, see Fig. 18, Murday's Electrically Driven Balance-Wheel Clock, Reid's electric clock where he used a torsion pendulum, almost an electrically driven 400 day clock; and electric clocks developed for use at sea, i.e. marine timekeepers for distributing time to secondary clocks throughout a ship. The early directly operated electric clocks using balances combined all the disadvantages of the early electric clocks together with the normal lower standard of timekeeping when using a balance. They had the doubtful quality of portability as a bonus.

Hope-Jones, in association with William Hamilton Shortt, brought about the final development of the electrically driven pendulum clock with the so-called Free Pendulum first installed in the Edinburgh Observatory at the end of 1921. Basically it consisted of two Synchronome pendulum clocks, one pendulum serving as a slave to perform all the

Fig. 18. Eureka clock.
By courtesy of Dr. F. G. A. Shenton.

work whilst the other swung freely except for the maintaining impulse at half-minute intervals, see Figs. 19 and 19 a and b. The actual free pendulum was built to a much higher quality of workmanship and design than the normal Syncronome clock and the impulsing gravity arm so light that an auxiliary electrically reset gravity arm was used to reset it mechanically, the whole mechanism being enclosed in a cylinder from which the air had been exhausted. The two pendulums were linked electrically as follows. A slight losing rate was given to the slave pendulum and at the end of a nominal half-minute period its gravity arm was released and its contacts closed allowing the current from a battery to operate an electromagnet which released the gravity arm of the free pendulum. A jewelled pin on the gravity arm then fell on to a small impulse wheel fitted to the pendulum. Should the arm fall too soon the pin rode on top of the wheel until the correct moment for impulse as determined by the free pendulum. After impulse the gravity arm released the electric gravity arm and actuated the secondary clock via its contacts and reset both gravity arms simultaneously. The current in the secondary clock circuit also actuated a hit and miss synchroniser evolved by Shortt and accelerated the slave clock pendulum as necessary. Shortt's original clock in Edinburgh was not quite as described for the impulse was given below the pendulum bob. Its performance for the first year of operation indicated that a great step forward had resulted and it was not long before astronomical observatories all over the world renounced their mechanical clocks and made use of the Synchronome Shortt Free Pendulum Clock. About one hundred of these clocks were made, all by the same man, and as he has now retired at the age of over seventy years, it is hardly likely that any more will be manufactured. They are now quite obsolete for astronomical purposes since much more accurate time measurement instruments are available today but horologists would not be able to recognise these instruments as clocks except for their time presentation.

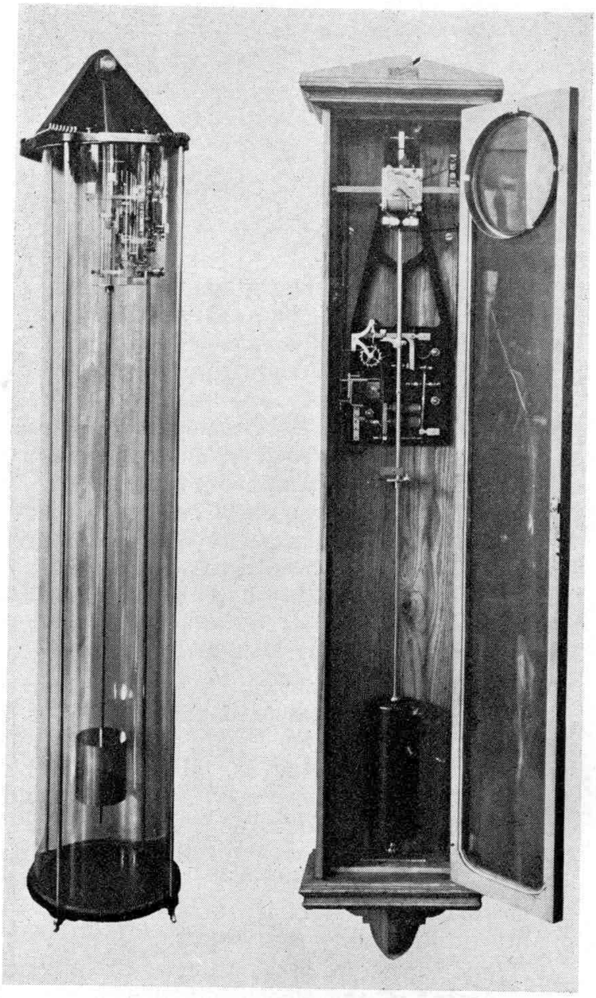

Fig 19. Shortt free pendulum (left) and slave pendulum with synchronizer (right).
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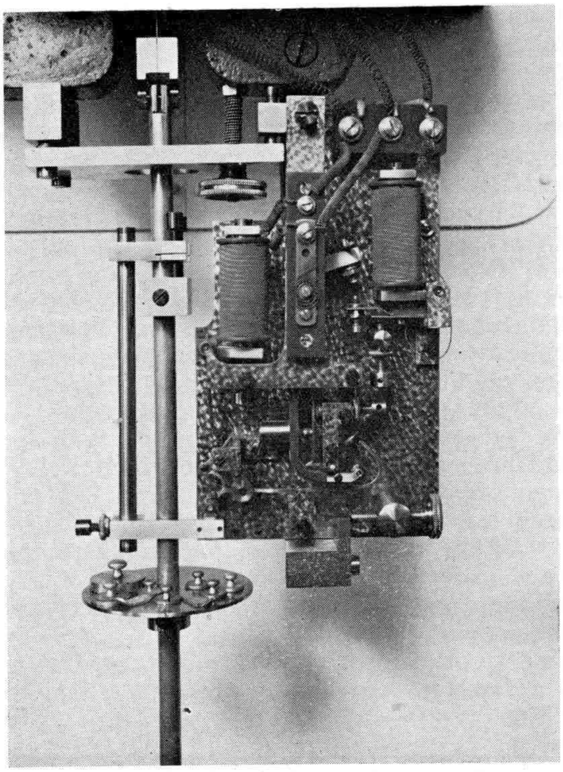

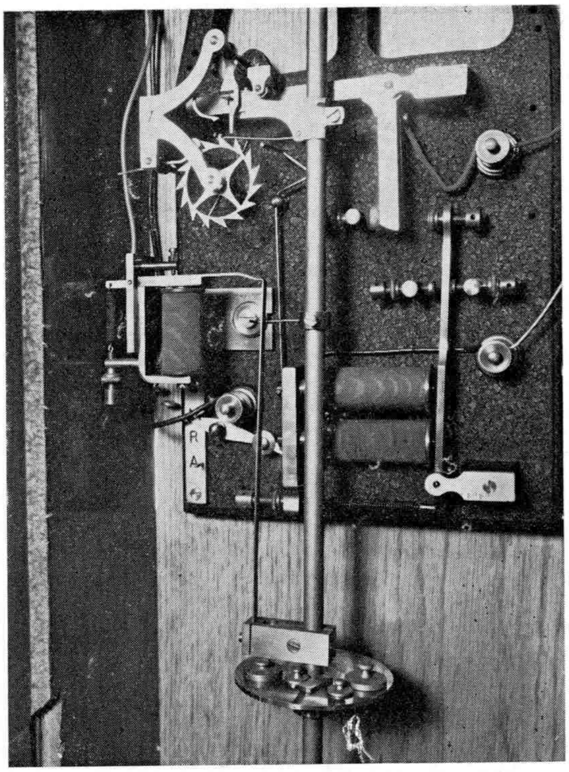

Fig. 19a (left). Impulse mechanism of free pendulum.
Fig. 19b (right). Synchronome electric clock used as a slave pendulum and fitted with Shortt's synchronizer.

Of necessity many interesting developments have been omitted and for these the reader is advised to read the material listed later. Interest in electrical horology as an historical subject is growing and there are workers in associated fields examining the origins of the various devices used.

The present position of electrical timekeeping is that the pioneer work of H. E. Warren and W. A. Marrison in the United States which led to the invention of the synchronous clock and crystal clock respectively has had far-reaching consequences for us all. There are more electric clocks in use today than Alexander Bain ever envisaged and his dream of universal time distribution has come about through the use of synchronous clocks driven from the public electricity supply system, these clocks forming at present the largest single group of all those in use.

Progress in electronics, later accelerated by Space Age research, resulted in transistors, solid state equivalents of thermionic valves, which allowed first the harnessing of reliable electronic circuits to conventional clocks and watches for control and impulsing; and secondly the development of the quartz crystal clock and its miniature counterpart, the quartz crystal watch with the advent of integrated circuits. With this miracle of technology it is now possible to produce a timekeeper which is all-electronic and without a single mechanical moving part. These modern timekeepers are at least an order of accuracy better than their mechanical counterparts, require little attention, and will ultimately be far cheaper, in fact they are already at the throw-away stage for the cheapest models.

At the moment, apart from maintenance and special commissions, it seems that the long and hallowed art of mechanical timekeeping is about to come to an end. Only the remnants of several hundred years of the production of mechanical timekeepers will remain for the practitioners of the conventional art of mechanical timekeeping.

The taking over of precision timekeeping from the mechanical timekeeper, and here we include all electromagnetically operated clocks, by the quartz crystal clock was slow but inevitable, however its supremacy was short-lived as the standard of timekeeping for the world. In its turn the quartz crystal timekeeper yielded to the awesome accuracy of the

Atomic Clock where the motions of an electron in the caesium atom constitute a basic timekeeper of Nature's own devising. Maintaining the long tradition that the measurement of time is the most accurate of man's measurements, the atomic clock is the most accurate of man-made instruments for making physical measurements. The standard involved is beyond the understanding of all but a few minds, for when we consider accuracies with errors of one part in 10^{11} or 10^{12} and even less, the reality means very little to non-mathematicians. With the availability of these new standards, man's basic timekeeper, the rotation of his own planet around the sun which had served him from his first creation, ceased to be the primary standard of timekeeping. The small irregularities of motion of the earth, long suspected by astronomers, are readily revealed by the atomic clock.

Looking back over the history of the evolution of the electric clock, one cannot help reflecting upon the lack of co-operation between the mechanical and electrical horologists. Electric clocks were regarded with suspicion by the professional guardians of timekeeping, even hostility, yet the electro-magnetically operated clock is basically a mechanical clock using electro-magnetism as a simple method for control and impulsing. W. H. Shortt's free pendulum could have been achieved by purely mechanical methods, in fact a free pendulum of greater potential had been designed and made by Lord Kelvin at Glasgow about fifty years earlier. Although his work was made public it did not excite one word of comment and was completely ignored by professional horologists.

What is also so very striking is that most of the fundamental steps leading to the advances in the accuracy of timekeeping were made by amateurs, with the solitary exception of Alexander Bain. Frank Hope-Jones and G. B. Bowell were electrical engineers when they invented the Synchronome remontoire, W. H. Shortt was a railway engineer, unconnected with horology, yet he alone took the performance of the pendulum to its practical limit of about one milli-second a day, thus providing a new time standard for the whole world for a brief period of about fifteen years.

In a sense all the groping efforts of mankind to perfect the art of timekeeping by mechanical means ultimately came to naught after tens of centuries of effort. The hard won progress was all negated by the work of W. A. Marrison with quartz crystal clocks. His lecture to the British Horological Institute on 6th November 1947—"The Evolution of the Quartz Crystal Clock" sounded, although it is unlikely that any of the professional horologists present realised it, the death knell of the mechanical timekeeper. Marrison correctly forecast that the supremacy of the quartz crystal clock was only temporary and would yield to the use of atomic spectral lines and radio frequency techniques as the standard timekeeper of the morrow. His conjectures then are the realities of today.

How Alexander Bain would have marvelled could he have foreseen the future. His first steps were small, just as when man first put foot on the moon, and yet have led to giant steps for mankind. Controversy dogged his initial attempts and his work for a long time was unrecognised, being ignored by contemporary horologists and later ridiculed by those who had access to better technological methods, there being only a very few who had an understanding of his principles in connection with electric clocks. It has taken one hundred years from the date of his death on 2nd January, 1877, to gain the richly deserved credit for his brilliance against almost impossible odds.

Have we reached the ultimate limit on improvements in timekeeping? The answer is most definitely no. We have no understanding of the nature of time, this awaits a person of a better insight and intelligence than has ever yet lived on earth. If we could know what it is we are measuring, the possibilities are that we could then measure it more accurately. Mankind is not content to remain still even when success is apparently almost complete, Nature on the other hand does not yield her secrets lightly. Where the next fundamental step should be taken may not be apparent here and now, although it seems almost certain to be in the realms of atomic physics and associated electronics. The man in the street will neither know, nor care, why scientists follow these will-o-the-wisps, for the immediate time to the nearest second is more than adequate for everyday life, and a second or so error in a thousand years concerns him not at all since he will not be there to witness it. To a few, and the reader may be among the coterie, the measurement of time is one of the most exciting subjects in the world of today.

BIBLIOGRAPHY

The literature on electrical horology is extensive but no comprehensive list has hitherto been published. A great deal of information on the subject is scattered throughout technical journals, proceedings of institutions, patents, etc. Much of the published material was ephemeral and is now difficult to come by, particularly trade publications which are often the only source giving details of adjustment and maintenance of electric clock systems.

A selected list of literature on electrical horology has been drawn up from a preliminary list of over three hundred references. With few exceptions it does not include details of patents or references to articles in the technical press. Members wishing to consult the material listed and who live within travelling distance of London will find it convenient to visit the National Reference Library of Science and Invention at Holborn, or the British Museum. There is little electrical horology literature at the Institution of Electrical Engineers where most of the material was donated by the late F. Hope-Jones.

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LIST OF ALEXANDER BAIN'S ELECTRIC CLOCKS AND LOCATIONS:

MUSEUMS

1. BRITISH HOROLOGICAL INSTITUTE, Upton Hall, Newark, Notts.
Wall clock signed A. BAIN'S PATENT, ELECTRIC TELEGRAPH COMPANY, circular silvered dial, ebony stained case.
Illustrated in *Clocks and Watches 1400-1900* by Eric Bruton, plate No. 51.

2. CLOCKMAKERS' COMPANY MUSEUM, Guildhall Library, Aldermanbury, London.
Wall clock signed ALEXANDER BAIN PATENTEE NO. 235, circular silvered dial, oak case in Gothic style.
Illustrated as the master clock in Bain's experiments in synchronization between clocks at Edinburgh and Glasgow, page 26 of his book *A Short History of the Electric Clocks . . .*
Presented by the late A. W. Marshall in 1973, and restored by Thomas Mercer Ltd., St. Albans.

3. HUNTERIAN MUSEUM, Glasgow University, Glasgow, Scotland.
Wall clock signed ALEXANDER BAIN PATENTEE, circular silvered dial, stained wood case.
Illustrated in *Old Scottish Clockmakers . . .*, 2nd edition, 1921, Edinburgh, plate facing page 32.

4. MUSEUM OF THE HISTORY OF SCIENCE, Oxford.
Longcase clock signed PATENT ELECTRIC CLOCK, A. Bain Invenit, No. 108, square silvered dial, stained wood case.

5. MUSEUM OF VINTAGE AND VETERAN CARS, Edinburgh, Scotland.
Private Museum, Proprietor J. H. Farr.
Wall clock signed ALEXR. BAIN'S PATENT ELECTRIC CLOCK No. 105, silvered dial, carved wood case lined with velvet.
Illustrated as the frontispiece in Turner and Devereux's Occasional Paper No. 3—*Alexander Bain's Short History of the Electric Clock (1852),* edited by W. D. Hackmann, Wellcome Research Fellow, Museum of the History of Science, Oxford.

6. NATIONAL MARITIME MUSEUM, Old Observatory, Greenwich.
Wall clock signed PATENT ELECTRIC CLOCK, A. Bain Invenit No. 175, silvered dial, birds-eye maple case of attractive appearance.

7. ROYAL SCOTTISH MUSEUM, Edinburgh.
   a. Wall clock on back-board only, painted dial signed ALEXANDER BAIN'S PATENT ELECTRIC CLOCK.
   Described in the Royal Scottish Museum's "Things to See", page 23, where the clock is described as the original model. This is considered unlikely.
   b. Longcase clock, signed ALEXANDER BAIN, INVENTOR, white painted dial.
   c. Longcase clock, signed A. BAIN, INVENIT, ELECTRIC TELEGRAPH COMP., No. 102, square silvered dial.
   d. Wall clock, signed ALEXANDER BAIN'S PATENT ELECTRIC CLOCK, silvered dial, rectangular case.

8. SCIENCE MUSEUM, Exhibition Road, South Kensington, London.
   a. Wall clock, mechanism only mounted on replacement mahogany back-board, dial and case now missing.
   Illustrated Plate 3b and described on page 4 of this catalogue.
   b. Longcase clock, dial now missing, coil pendulum bob and bar magnets in brass tube fixed to base of case.
   Similar to clock illustrated in Plate 3a of this catalogue.
   c. Wall clock of superior quality, signed ALEXR. BAIN'S PATENT ELECTRIC CLOCK, No. 113, silvered dial, elegantly carved case.
   Illustrated in Fig. 9 on page 8 of this catalogue, and described in *Descriptive Catalogue of the Collection Illustrating Time Measurement,* Dr. F. A. B. Ward, page 84.

9. WATTEN HALL, Watten, Caithness, Scotland.
Wall clock mounted on mahogany or maple back-board, this clock has never been fitted in a case, signed A. BAIN PATENTEE, silvered dial. Coil pendulum bob and strip magnets secured to back-board.

Similar to the first clock listed in the Royal Scottish Museum collection. It was presented by Alexander Bain to one of his relatives and eventually passed to Alexander Sutherland, school-master, Gersa, Watten; on his death the clock was presented to the Wick Council and placed on view in the Carnegie Library and Museum. It has now been given back to the Watten Hall Committee to be placed in their new hall in Watten. There are strong grounds for believing this clock to be the oldest remaining Bain clock known. Although converted at one time to Hipp Toggle working, the original contacts were left in situ, only the slider having been lost, and it is now restored to working order.

PRIVATE COLLECTIONS

1. Skeleton mantel clock, signed on tablet fixed to base of clock, silvered chapter ring, mounted on square mahogany base and originally covered by glass dome.
All the parts of this clock are stamped No. 1 and it was evidently manufactured under license from Alexander Bain. Made in an architectural style and of good quality, it is fitted with a centre seconds hand, and has terminals marked Cu and Zn for connection to an earth battery.
2. Longcase clock with painted dial, signed BAIN'S ELECTRIC CLOCK, mahogany case with lower glass panel to observe pendulum in motion. Restored to original contact system from crude Hipp Toggle conversion.
Illustrated in Plate 3a of this catalogue.
3. Skeleton mantel clock, signed A. BAIN'S PATENT ELECTRIC CLOCK, silvered chapter ring, mounted on ebony stained wood base fitted with groove to take a protective glass dome.
Illustrated in Plate 2 of this catalogue and described on page 42. The trefoil shaped hour hand and straight minute hand style was favoured by Alexander Bain.

ALEXANDER BAIN'S PATENTS

No. 8,783 of AD 1841 — Electric Clocks. (Barwise and Bain).

No. 9,745 of AD 1843 — Electric Time-Pieces and Telegraphs.

No. 10,838 of AD 1845 — Electric Clocks and Telegraphs, &c.

No. 11,584 of AD 1847 — Electric Clocks, &c.

No. 14,146 of AD 1852 — Electric Telegraphs and Timekeepers.

Alexander Bain also took out patents unconnected with electric clocks, although these are of interest they cannot be listed here.

ALEXANDER BAIN'S LITERATURE

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The Petition of Alexander Bain. (See Moigno, 1852). Traite de Telégraphic électrique, 632 pp., Atlas of 22 plates, 2nd Edition, Paris, 1852.

A Short History of the Electric Clocks, with explanations of their principles and mechanisms, and instructions for their management and regulation. Chapman and Hall, London, 1852.

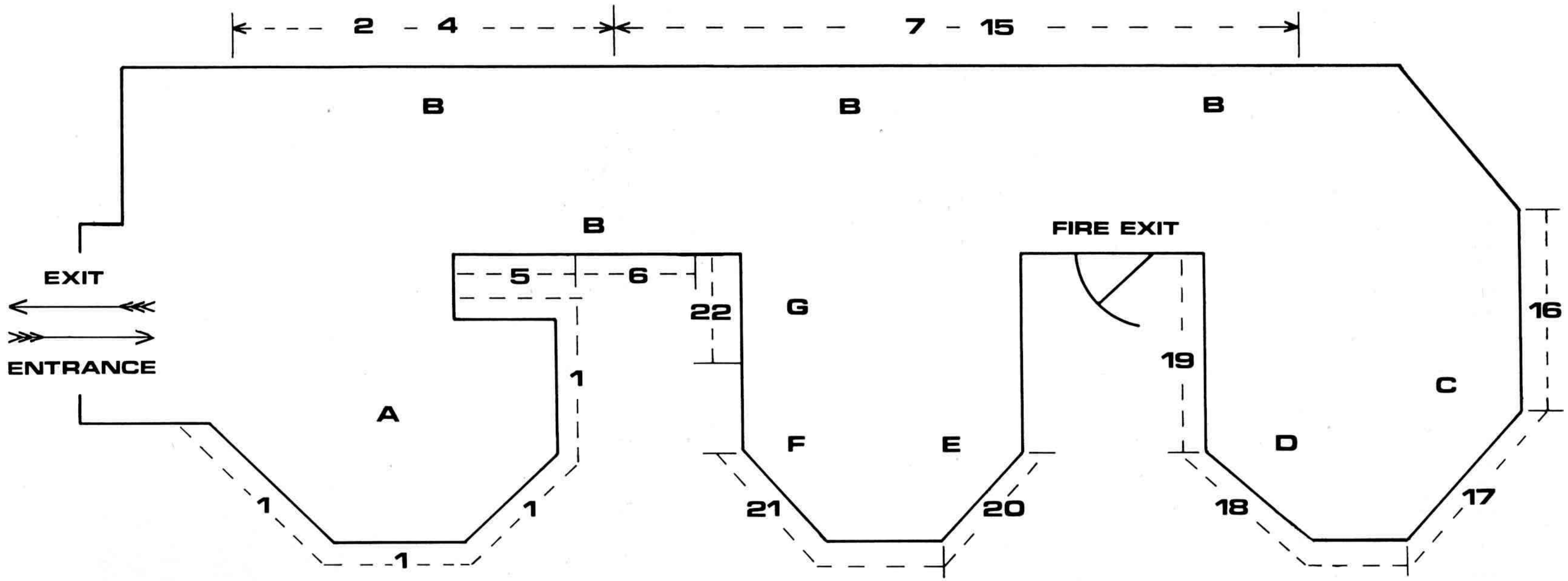
Electric Clocks. A three page pamphlet, probably produced for the 1851 Exhibition in which Bain exhibited his electric clocks and received the Exhibition Council Medal, Class X. The material is taken from the preceding work.

Mr. Joseph Whitworth's Special Report, presented to the House on February 6th, 1854, chapter xi, page 28, Electric Telegraph. (The report is headed "New York Industrial Exhibition").

A Treatise on numerous applications of Electrical Science to the Useful Arts. Part 1, 35 pp., printed for the author by Schenck & McFarlane, Edinburgh. Part 1 deals with the history of electrical telegraphy and Bain's first printing telegraph, published about 1868, Part 2 is mentioned which would have dealt with electric clocks, evidently it was written by Alexander Bain but never published as the sales of Part 1 did not meet expectations.

For further details of the bibliography connected with Alexander Bain consult Turner and Devereux's *Occasional Paper No. 3,* edited by W. D. Hackman, published 1973, London.

ELECTRIFYING TIME



A. Alexander Bain
B. Evolution of Electrical Timekeeping
C. Electrically maintained pendulum and balance wheel clocks and watches
D. Gravity Escapement electric clocks
E. Electrically wound clocks
F. Quartz Crystal watches and clocks
G. Unusual electric clocks

** Numbers refer to sections in exhibition list of exhibits*

PLAN OF EXHIBITION

Electrifying Time

LIST OF EXHIBITS

Electrifying Time — List of Exhibits

ENTRANCE TO EXHIBITION

Facing the entrance is a large portrait of Alexander Bain (1810-1877). On the left is: Atomic Time — a Quartz Crystal Clock synchronised by radio signals controlled by the caesium atomic standard at Rugby. Loaned by the National Physical Laboratory.

1. ALEXANDER BAIN

1. **Copies of Documents and Literature associated with Alexander Bain.**

   Including a letter from Alexander Bain in reply to an enquiry about electric clocks, *The First Electric Clock* by W. A. Marrison, Baptismal Certificate, *Alexander Bain* by Alexander Steuart, Copies of the *Literary Gazette* showing the letters between Bain and Wheatstone in the controversy about the priority of invention of the electric clock, *An Account of Some Remarkable Applications of the Electric Fluid to the Useful Arts . . .* By John Finlaison, *Conspectus of Electrical Timekeeping* by C. K. Aked.

2. **Longcase Electric Clock by Alexander Bain, circa 1845.**

   Privately owned and recently restored from a Hipp toggle contact conversion. The pendulum bob is a solenoid swinging over a consequent pole bar magnet, see page 45.

3. **Alexander Bain's Electro-Chemical Telegraph Receiver.**

   This was capable of silent high-speed operation and gave a permanent record of a message on chemically prepared paper tape.
   Loaned by the Post Office.

4. **Mural view of St. John's Church, Loughton, Essex, showing Alexander Bain's clock dial.**

   This church was the first building in the world to have an electrical turret clock installed, only the dial of which now remains.

   In this exhibit is also a **letter from Matilda Bain to Archdeacon Hamilton,** stating that her husband Alexander Bain is in America but is expected back shortly, and **a copy of the Churchwardens' Accounts** showing some of the expenses incurred in installing the electric turret clock.

   Loaned by the Vicar and Churchwardens of Loughton Parish Church.

5. **Wall Electric Clock by Alexander Bain, circa 1845.**

   The contacts have been restored in this clock.

   Loaned by the National Maritime Museum, Greenwich.

   Slide projection with commentary illustrating Alexander Bain's life and career, the sequence lasts about ten minutes.

Evolution of Electrical Timekeeping

2. ELECTROSTATIC CLOCKS (1814-1839)

The forces of attraction and repulsion which exist between charged bodies had been used in the eighteenth century to operate electrostatic devices such as the electric chimes. In this device a ball suspended on a silk thread vibrates between a pair of bells which are charged to a high potential with electricity of opposite sign. This may have suggested the possibility of an electrically operated pendulum clock but it only became feasible with the introduction of the dry pile, a battery which could continuously charge bodies to a potential of several thousand volts. Sir Francis Ronalds in England in 1814, Professor Ramis in Germany and Carlo Streizig in Italy, both in 1815, independently produced electrostatic clocks working on this principle.

1. **Zamboni Pile made by Watkins and Hills.**

   Paper discs coated on opposing sides with tin-foil and manganese dioxide are stacked into piles within glass tubes.

2. **Pendulum maintained by dry piles.**

3. **Electrostatic pendulum with Zamboni dry piles dated 1830.**

   Loaned by the University of Padua, Italy.

   Print showing Sir Francis Ronalds' electrostatic clock of 1814. See page 40.

   Portrait of Sir Francis Ronalds (1788-1873).

   Print of Professor Ramis's electrostatic clock of 1815.

   Portrait of Guiseppe Zamboni (1776-1846).

3. THE BEGINNINGS OF MODERN ELECTRICAL TIMEKEEPING (1839-1850)

In 1819 Oersted demonstrated that a wire carrying an electric current could deflect a magnetic needle, and shortly afterwards Ampere showed that if the wire was formed into a long coil it had the properties of a bar magnet. Surprisingly a further twenty years elapsed before Steinheil and Alexander Bain first used electromagnetic forces to operate electric clocks. Bain's comprehensive patent of 1841 laid the foundation of modern electrical horology. Among the points covered by this patent was the use of electromagnets to drive clocks, and the application of a central clock to impulse any number of other clocks. He also envisaged uniform time distribution throughout the country.

1. **Mantel electric clock by Alexander Bain with the inverted sliding switch patented in 1847.**

   The inverted arrangement was intended to prevent particles of dust interfering with the action of the electrical contacts.

2. **Earth battery of the type patented by Alexander Bain in 1843.**

   Model made in the Science Museum workshop.

   Print of Alexander Bain's first electromagnetically operated pendulum clock of 1841.

   Print showing Alexander Bain's electromagnetic clocks of 1845 and 1847.

   Figures 1-4 from Bain's **A Short History of the Electric Clocks.**

   Print showing the use of a central clock to impulse a number of other clocks.

   Print showing the Edinburgh-Glasgow experiment for the synchronizing of pendulum clocks in 1846.

4. DEVELOPMENTS ABROAD

On the Continent Matthäus Hipp solved the problem of producing a reliable switch for maintaining a pendulum in motion, the solution of which had eluded Bain. Hipp is said to have conceived the idea in 1834 whilst suffering from insomnia, however a clock incorporating the device was not constructed until 1842. Electrical contact is made only when the arc of vibration of the pendulum falls to a pre-determined value. As contact is not made at each swing of the pendulum, it is possible to use a much firmer contact without interfering unduly with the motion of the pendulum. Because contact does not take place at precise intervals, the electrical impulses cannot be used for driving secondary clocks.

1. **Mantel electric clock by Matthäus Hipp of Neuchâtel.**
   Portrait of Matthäus Hipp (1813-1893).

5. CHARLES SHEPHERD AND THE GREAT EXHIBITION OF 1851

It was inevitable that the latest horological wonder, the electric clock, should be selected to provide the time at the Great Exhibition which was held in Hyde Park in 1851. Dials on the South, East, and West ends of the Exhibition Hall were to be remotely controlled by a Shepherd master clock situated among the other exhibits in the horological section of the exhibition. The clock proved to be a disaster and had to be replaced by a mechanical clock designed by Sir Edmund Beckett who later designed the clock at the Houses of Parliament. The sonorous bell of the Shepherd clock effectively tolled the death knell of the pure electric clock in this country and it was not resurrected until the end of the century. Sir Edmund Beckett expressed the prevailing attitude to electric clocks when he wrote: "and anyone who sets to work to invent an electric clock must start with this axiom that every now and then the electricity will fail to lift anything, however small, and if his clock does not provide for that it will fail too".

1. **Shepherd Electric Clock of 1852.**

   Loaned by the National Maritime Museum, Greenwich.

   The novel feature of the Shepherd clock is the way in which the pendulum is impulsed. A gravity arm drops on the pendulum at each alternate swing and is reset by means of an electromagnet. This has the advantage of constant impulse and independent of the state of the battery. Alexander Bain had already appreciated this fact and had used the constant force of a bent spring to impulse a pendulum. Although the Shepherd clock at the Great Exhibition proved to be unreliable, the clock exhibited was installed at the Royal Observatory in 1852 and provided the time signal there until 1893.

2. **Electrically Operated Time Ball.**

   Loaned by the National Maritime Museum, Greenwich.
   Time Balls were used to enable watches and clocks to be set before the advent of radio time signals, generally arranged to drop at 1 p.m. precisely each day, however, this example operates at hourly intervals. The ball is raised to the top of the mast five minutes before each hour, and drops precisely on the hour.

3. **Smee battery of the type used to power Shepherd's electric clock.**
   Print of the 1851 Exhibition Building in Hyde Park, showing the large clock dial in the transept.

The magazine *Punch* was apparently unaware that the Shepherd electric clock had been replaced, and wrote:

"Lines to be recited on the closing of the Exhibition."

"At last the exhibition closes, —
But most things that open are obliged to shut;
Its knell is tolled by its electric clock,
Which strikes and everybody feels the shock.
'Happy' cries Colonel Sibthorpe 'The release!'
Well, well! — the exhibition ends in peace.
That end was gained, and Sibthorpe must confess
The whole affair has been a great success."

Punch 1851.

6. THE DISTRIBUTION OF TIME

Despite the manifest deficiencies of electric clocks the use of electricity in time-keeping had one overwhelming advantage, — it enabled time to be distributed over great distances as Alexander Bain had so strikingly demonstrated in 1846. Possibly as the result of the strictures of Sir Edmund Beckett (Lord Grimthorpe) the methods used in this country were initially limited to those which made provision for the possible failure of the electric current.

In 1843 Alexander Bain had suggested a method of forcibly correcting the hands of a mechanical clock at hourly intervals by means of electricity and this system was later used by Lund in London, and Ritchie in Edinburgh, during the 1870's. In 1858, R. L. Jones, the station master at Chester, had used another idea of Bain's, the use of electricity to keep the pendulums of mechanical clocks swinging together in sympathy. This method was later employed by Ritchie in his sympathetic pendulum.

On the Continent, Hipp adopted the bolder plan of using electrical impulses to directly advance the hands of secondary clocks (impulse dials) at intervals of one minute.

1. **Dial showing Lund's device for correcting the hands of a mechanical clock at hourly intervals by means of electricity.**

   Two arms close on the minute hand of the clock precisely on the hour and set it to the precise time.

2. **Two sympathetic pendulums demonstrating Ritchie's "Sympathetic" Pendulum of 1873.**

   The drive to the pendulum was electrical which also synchronized the sympathetic pendulum, dispensing with the mechanical drive. Both pendulums in the demonstration beat seconds, the shorter compound pendulum being used where insufficient space was available for a seconds pendulum of normal construction.

3. **Hipp's Impulse Dial of 1861.**

   In 1861 it was not possible to produce a single sharply defined pulse of current to advance secondary clocks. If the contacts in the master clock "chattered" and produced a series of impulses, the secondary clocks would respond to each one, and advance too rapidly, showing the incorrect time. Matthäus Hipp overcame this defect by using polarised dials which responded to impulses of current which were of alternate polarity and did not respond to a number of impulses in the same direction.

   Print illustrating Alexander Bain's method of forcibly correcting the hands of a mechanical clock.

   The V-shaped piece is raised by an electromagnet precisely on the hour and moves the minute hand to the correct position.

   Print showing public clocks in Milan operated by the Hipp System in 1875.

7. ELECTRICALLY WOUND CLOCKS

Despite the work of Matthäus Hipp, the reliability of electrically maintained clocks was by no means universally accepted. The alternative approach of using electricity to wind a conventional mechanical clock was often adopted, particularly in Germany and the United States of America.

1. **Electrically Wound Clock — Pond System.**

   This type of clock was invented by Chesters H. Pond of Brooklyn, New York, in 1881 and uses a small electric motor to wind the spring of a mechanical clock at hourly intervals.

2. **Synchronome Master Clock — 1895 Patent.**

   The clock is a high-grade regulator fitted with a dead-beat escapement which is wound electrically at half-minute intervals through a synchronome switch. The current which resets the clock also operates a series circuit of secondary dials.

3. **Synchronome Master Clock in its final form.**

   This is a later example of the design patented by Hope-Jones during the period 1905-7. The pendulum is impulsed directly by a gravity arm released at half-minute intervals by a count-wheel, which also closes contacts to impulse secondary clocks and reset the gravity arm.

   Print showing H. R. Kempe, Electrician to the Post Office, 1910.

   "I must assert, and I think with authority that by no man living or dead have electric clocks been brought to such perfection as they have by Mr. Hope-Jones" — quote by H. R. Kempe.

   Photograph of the Synchronome Company Stand at an exhibition in Earls Court in 1903.

   The Synchronome master clock operated a dozen dials connected by a one mile length of wire.

8. MAGNETA SYSTEM 1900

Fischer of Zurich introduced the Magneta contactless system for operating secondary clocks in 1900. The impulses of current are generated by a magneto type of electrical generator which is rapidly moved by a rocking train, first in one direction, and then in the opposite direction to provide reversing currents for the secondary clocks.

1. **Magneta Clock and Secondary Dial.**

9. DOMESTIC ELECTRIC CLOCKS

At the turn of the century, dry cells became available at much lower prices and with a more reliable performance and longer life. Interest in electric clocks for domestic use revived, resulting in many ingenious designs, none of which, however, met with lasting success. Their timekeeping was comparable with the average mechanical clock but appeared much worse as they did not receive periodical correction as is the case with the mechanical clock when being rewound. Nor was it possible to find a repairer to correct the various faults of the electric clock when necessary, as the horological trade would have nothing to do with electric clocks.

1. **Eureka Clock in four-glass wooden case.**

   Striking Eureka Clock.

   Invented by T. B. Powers, an American engineer, in 1906; patented by the Kutnow brothers in the same year. It was the first to make use of a balance wheel, proposed by Alexander Bain in 1840.

   The Kutnow Brothers were manufacturing chemists, aperient powder being one of their specialities reputed to have been used by Royalty.

2. **Bottle of Kutnow's Aperient Powder.**

Portrait of Hardy Parsons, co-inventor of the waiting train mechanism for electric turret clocks.

Photographs of the electric turret clock installed at the Liver Buildings at Liverpool.

Parsons and Ball of the firm of Gent, Leicester, patented the waiting-train for electric turret clocks in 1907, in which the Hipp toggle maintained pendulum is used as an electric motor to drive the train of an electric turret clock, making the minute hand arrive slightly early, upon which the pendulum swings idly until a synchronizing impulse allows the drive to recommence. It was fitted to the Liver Buildings in Liverpool, the firm of Gent was the only one which would guarantee that all the dials wou'd indicate the correct time under the severe conditions which obtain on the exposed site, the dials being larger than those of Big Ben. The Liver clock dials indicated the correct time in the severe gales of 1913 when Big Ben was half an hour slow due to the severity of the wind forces. An example of the waiting train movement can be seen in the Time Measurement Gallery.

10. TIME FROM THE ELECTRIC MAINS 1916

In 1895 Ferranti introduced the first alternating current generator in the world at Deptford. Frank Hope-Jones saw in this a means of distributing time if the frequency was controlled to fine limits, however there was not sufficient commercial interest to do this. H. E. Warren in the U.S.A. introduced methods of measuring the frequency with high precision in 1916 and also a new form of synchronous electric motor with shaded magnetic poles to provide a rotating magnetic field from a single phase supply. The power consumption was very low, and the motor was self-starting. Sales were low to begin with but by the end of the 1930's more than half of the clocks sold in the U.S.A. were of the synchronous type. The introduction of the "Grid" distribution of electricity in England led to frequency stabilised supply mains and a great increase in the popularity of the synchronous electric clock, the first of these clocks appeared in 1927.

1. **Telechron Synchronous Clock.** An example of the first type of mains synchronous clock, intended for use with a supply of 110 volts at 60 Hz, common in America.

2. **Synclock Synchronous Clock.**

One of the first type of synchronous electric clock marketed in Great Britain, appearing in 1931 and based on the Warren Telechron system but working on 230 volt 50 Hz mains supply.

3. **Smith Synchronous Clock.**

The American system of self-starting synchronous clocks was not popular in England where hand starting was preferred so that if the mains supply failed, the clock would come to a stop rather than restart and show an incorrect time.

4. **Synchronous Turret Clock Motor.**

Large synchronous electric motors have sufficient power to operate the hands of turret clocks through reduction gears, the example here was used to power the Guinness Floral Clock at Syon Park.

5. **Two Synchronous Clocks, one 50 Hz, the other 60 Hz.**

This exhibit shows that the time indication of the synchronous clock is entirely dependent on the frequency of the supply mains. Both clocks are fed from 50 Hz mains, the clock on the left is designed for use in Great Britain and shows the correct time, the clock on the right is designed for use in the U.S.A. and is therefore slow.

6. **Wheatstone Synchronous Clock.**

In 1840 Charles Wheatstone suggested the use of alternating currents to drive a system of secondary clocks. He did not make a practical system until the early 1870's and this was installed in the Royal Institute in 1873 but proved to be a failure, see page 46. Charles Wheatstone's synchronous clocks were the first of this type in the world.

Portrait of Henry Ellis Warren, inventor of the synchronous clock.

Copy of the Telechron Catalogue of 1927.

Photograph of Guinness Floral Clock at Syon Park.

Synchronous electric motor illuminated by strobe light to show advancement of rotor in small steps corresponding to the reversals of the supply current.

THE SUPREMACY OF THE ELECTRIC CLOCK 1921

The introduction of the Shortt Free Pendulum Clock in 1921 led to a new order of accuracy in timekeeping, and it became the standard timekeeper at Greenwich Observatory in 1925, continuing in this role until superseded by quartz crystal clocks in 1942.

1. **Shortt Free Pendulum Clock, and Slave Pendulum Clock.**
This prototype (SH.O) was made and erected by Shortt personally at the Royal Observatory at Edinburgh, it is on loan from the Royal Scottish Museum.

Portrait of William Hamilton Shortt.

11. TIMEKEEPING AT SEA

An electric clock system is of particular use at sea for it enables the "Ship's Time" to be altered to allow for the continual change in local time with change in longitude. As the ship sails westward the hands of the clock must be retarded, and conversely the hands of the clock must be advanced when the voyage is in an easterly direction.

1. **Mercer Marine Clock System — Chronometer, Control Unit and Impulse Dial.**

Introduced by Frank Mercer of the well known firm of marine chronometer makers. The chronometer is fitted with contacts which are closed every half-minute to energise a relay which then advances the impulse dials throughout the ship. An advancing mechanism is fitted to rapidly advance the secondary clocks when required, to retard the clocks they are not energised for a suitable period.

Loaned by Thomas Mercer Ltd.

Portrait of Frank Mercer (1882-1970).

Photograph of the Mercer electric clock system installed on board the liner Canberra.

12. THE QUARTZ CRYSTAL CLOCK 1927

The supremacy of the free pendulum clock was short-lived through the development of the vibrating quartz crystal as a frequency standard in the early 1920's which was applied in the form of the quartz crystal clock by W. A. Marrison of the Bell Telephone Laboratories during the period 1927-30. The quartz crystal clock was not only more accurate than the free pendulum but also much more convenient for comparison purposes. Since the supporting electronic circuits used thermionic valves, the reliability was low and three independent quartz crystal clocks were used in a single system to maintain a reliable time service.

Crystalline quartz possesses several properties which make it suitable for use as a vibrating element. It has a very low internal friction in the molecular arrangement and it is piezoelectric, these two properties making it possible to deform the crystalline structure by an electric charge with relatively little energy, and the development of an electrical charge with deformation which can be used to operate a counting circuit. By a suitable choice of frequency of operation of the quartz crystal and the ratio of division, a rate of pulses can be derived to drive the hands of a clock; for example one a second; one each half-minute for ordinary impulse dials, or an output of 50 Hz to drive synchronous electric clocks.

1. **Examples of Artificial and Natural Quartz Crystals.**

2. **Ring type of Quartz Crystal Oscillator designed by L. Essen in 1938,** later used in the quartz crystal clocks in use at the Greenwich Observatory.

3. **Quartz crystal clock system of the 1940's consisting of three independent quartz crystal oscillators.**

   Portrait of Warren Alvin Marrison.

   Print of first electric clock using quartz crystal control.

13. THE ATOMIC CLOCK AND ATOMIC TIME 1955

All the timekeepers considered to this point have depended on the oscillation of a solid body and calibrated in terms of the rotation of the earth about its axis, a motion which is subject to various irregularities. A more fundamental unit of time was desirable and in 1955 Essen and Parry of the National Physical Laboratory designed and built the first practical atomic clock making use of the hyperfine line of the caesium atom to control an accurate quartz crystal clock. The first prototype atomic clock is now on display in the Time Measurement Gallery of the Science Museum and was accurate to about one second in thirty years, or one-hundred-thousandth of a second a day, one hundred times more accurate than the Shortt free pendulum clock. In 1967 the use of the earth as a primary standard of time was abandoned, the vibration of the caesium atom being adopted to re-define the second, and in 1971 an International Atomic Time Scale was adopted.

1. **Rubidium Atomic Clock.**

   Rubidium atoms are used to control the timekeeping, and although it is less accurate than the caesium clock it is accurate to within one second in a thousand years. On loan from the National Physical Laboratory.

   Portrait of Dr. Louis Essen, F.R.S. Courtesy of the National Physical Laboratory.

   Film showing the atomic clock and principles of working. Produced by the National Physical Laboratory Film Unit.

   Photograph of the latest caesium standard at the National Physical Laboratory.

   This standard is expected to realise the second to within two parts in ten billion (2 in 10^{13}) or an error of one second in 100,000 years.

14. SOLAR POWERED CLOCK 1951

This is a prototype of a solar powered clock designed by Patek Philippe of Switzerland. Photocells convert light into electric power to drive an electric motor to wind the spring of a conventional mechanical clock.

1. **Solar Powered Clock and Demonstration.**

   Loaned by English Clock Systems.

   An Electric Clock without moving parts 1952.

   The output of a quartz crystal clock is displayed on a dial with a series of lamps.

   Photograph of Electronic Clock without moving parts.

   Shown by courtesy of English Clock Systems.

   Domestic Electronic Clocks 1956.

Mechanically operated electrical contacts have been a source of trouble since first incorporated into clocks, and although they could have been replaced by circuits incorporating valves when de Forrest placed the control grid into the thermionic valve, these circuits were too bulky and required too much power to be used in domestic clocks. The invention of the transistor in 1949 allowed electronic switching with small physical dimensions, low power consumption, and high reliability. The first domestic clock with electronic switching was the Kundo introduced in 1956.

2. **Kundo Transistorised Electric Clock Model 1101.**

Described on page 88 of this catalogue.

The Electric Watch 1957.

The French firm of Lipp announced the first electric watch in 1952 but the first to appear on the market was produced by the U.S.A. firm of Hamilton in 1957, see page 98. In essence it was a miniature version of the Eureka clock, having a coil mounted on the balance wheel. The Lipp and Ebauches electric watches reversed the arrangement and had a magnet on the balance wheel with a stationary coil. A mechanically operated contact system was used, hence reliability was not certain.

3. **Hamilton electric watch.**

4. **Ebauches electric watch.**

The first Electronic Watch 1960.

The first watch to employ electronic switching by means of a transistor circuit was marketed by Bulova in 1960. In place of the usual balance wheel it made use of an elinvar tuning fork, pioneered by Max Hetzel about 1950, see page 100.

5. **1950 prototype Tuning Fork Watch.**

6. **Bulova Accutron Tuning Fork Watch.**

7. **Demonstration model showing the action of the Bulova Accutron Tuning Fork watch.**

Loaned by Bulova (U.K. Ltd.).

Portrait of Max Hetzel.

15. DOMESTIC QUARTZ CRYSTAL CLOCKS 1967

Because the early quartz crystal clocks were bulky and expensive, Frank Hope-Jones was prompted to predict in 1948: "But I see no prospect of a popular domestic clock in a quartz crystal form—It would be an impertinence for a clockmaker to covet it and harness it to his mundane purpose. The following year the transistor was born and Hope-Jones' prophecy was short-lived. Junghans produced the first domestic quartz crystal clock marketed in 1967.

1. **Junghans Domestic Quartz Crystal Clock.**

The Quartz Crystal Watch 1969.

In the field of electronics miniaturisation proceeded so rapidly that Seiko were able to place a complete quartz crystal timekeeper in a watch case by 1969.

2. **Early Quartz Crystal Watch made by Seiko Time Ltd.**

Donated by Seiko Time Ltd.

Animated diagram illustrating the operation of a quartz crystal analogue watch.

Loaned by Louis Newmark Ltd.

Quartz Crystal Watches with no moving parts 1972.

In 1972 Hamilton introduced the first quartz crystal watch without any moving parts whatsoever, the time indication being in digital form from light emitting diodes (LEDs). Later in the same year the Swiss group Societe des Gardes-Temps produced a watch making use of a liquid crystal display.

3. **Sinclair Quartz Crystal Watch with LED display.**

Each digit is made up from seven light emitting diodes arranged in a figure of eight configuration. By illuminating an appropriate combination of diodes it is possible to display the digits 0-9.

Presented by Sinclair Radionics Ltd.

4. **Avia and Waltham Quartz Crystal Watches with LCD of the type made by the Societe des Gardes-Temps.**

Presented by Avia and Silvana SA and Waltham International SA.

Diagram explaining the operation of a Quartz Crystal Watch with LCD.
Loaned by Louis Newmark Ltd.

Model demonstrating the Liquid Crystal Display.

Normally the molecules in a liquid crystal display are oriented in an orderly fashion and lie parallel to each other and the liquid is transparent. The application of an electric field disorients the molecules and the liquid becomes opaque.

The display panel consists of two glass plates slightly separated, between which is a thin layer of liquid crystal. Transparent electrodes are secured to the surface of one plate to allow the formation of digits when a potential of about 15 volts is applied to a combination of electrodes, the digits 0-9 being presented in a stylised form. Loaned by Louis Newmark Ltd.

Solar Powered Watch.

The solar powered watch makes use of light falling upon solar cells to convert the light into electrical energy which is used to charge a small secondary cell. The stored power drives the watch during darkness, see page 102.

5. **Cristalonic Solar Powered Quartz Crystal Watch.**
Presented by Cristalonic GmbH.

16. ELECTRICALLY MAINTAINED PENDULUM AND BALANCE WHEEL CLOCKS

1. **The " Earth Driven " Electric Clock.**

P. A. Bentley of Leicester patented an electric clock in 1910, similar to Bain's electric clock of 1843, and also working from an earth battery. Bentley's electric clock had better electrical contacts and included an amplitude limiting device.

1. **Ornate longcase electric clock by P. A. Bentley.**

2. **Electrical clock made by Samuel Wadsworth, circa 1875.**
See page 54.

3. **Herbert Scott electric clock made by the British Ever-Ready Electrical Company Ltd., 1902.**
See page 60.

4. **T. J. Murday Electrically Driven Pendulum Clock** made by the Reason Manufacturing Company Ltd., Brighton, 1910.

5. **Electric clock by Brillié Frères, Paris, circa 1914.**
See page 72.

6. **Frank Holden Pendulum Clock, 1909.**
See page 64.

7. **Ato electric clock by Leon Hatot, Paris, circa 1925.**

8. **Estyma electric clock, Ato type** with mechanically operated contacts replaced by transistor circuit, 1970.
See page 92.

9. **G. B. Bowell master clock manufactured by the Silent Electric Clock Company, Circa 1913.**
See page 74.

10. **Group of ten Bulle Electric Clocks.**
    This display shows a small selection of the hundred or so designs of the Bulle clock available before the Second World War.
    See page 76.
11. **T. J. Murday Electrically Driven Balance Wheel Clock,** made by the Reason Manufacturing Company, Brighton, 1910.
    See page 70.
12. **Frank Holden Electrically Driven Balance Wheel Clock.**
13. **Sectronic balance wheel clock with Transistorised Control,** made by S. Smith & Sons Ltd., 1963.
14. **Two Electronic Balance Wheel Watch Movements by Ebauches S.A.**
    Page from the Daily Express of 26 September 1911 showing Sir Oliver Lodge arriving at P. A. Bentley's electric clock works and being greeted by P. A. Bentley.
    Portrait of Maurice Favre-Bulle inventor of the Bulle clock.
    Page 315 of Punch for 21 March 1934, with a reference to the electric clocks at the Ideal Home Exhibition.

18. GRAVITY ESCAPEMENT ELECTRIC CLOCKS

1. **Thornbridge transmitter master clock, circa 1909.**
   Loaned by Chloride Gent Ltd.
2. **Gillett and Johnston master clock and dial, circa 1923.**
   Loaned by Gillett and Johnston Ltd.
3. **Octo master clock and dial made by T. and F. Mercer, St. Albans, 1927.**
   Loaned by Thomas Mercer Ltd.
4. **Master Clock and Dial patented by R. J. Lowne, of Catford, 1901.**
5. **Turret Impulse Dial.**
   Portrait of Robert Mann Lowne.
   Print illustrating an employee of the Lowne Company with two clocks.
   Print showing page from Gent's 1909 catalogue.

19. GRAVITY ESCAPEMENT ELECTRIC CLOCKS

6. **Electric Clock by C. Detouche, Paris,** to the system devised by Robert Houdin, 1855.
   Loaned by the Museum of the History of Science, Oxford.
7. **Electric Clock by Hoeft-Möller, 1899.**
8. **Secticon Electric Clock, 1961.**
9. **Princeps master clock, circa 1922.**
10. **Regulator with Meath-Bowell electric gravity escapement, 1938.**
11. **Steuart continuous motion regulator,** made by T. and F. Mercer, St. Albans, 1921.
    Loaned by Thomas Mercer Ltd.

20. ELECTRICALLY WOUND CLOCKS

1. **Van der Plancke master clock and impulse dial** made by La Précision Cie., Brussels, patented 1885.
2. **Master clock and impulse dial by Vve. David Perret Fils,** Neuchâtel, circa 1900.
3. **Mantel electric clock by the Tiffany Neverwind Company,** U.S.A., circa 1904.
4. **Mantel electric clock with floating balance by Blech and Hettich,** circa 1965.
   See page 90.
5. **Skeleton Clock fitted with Pond's Rotary Rewind System,** circa 1881.

6. **Wall clock and mantel clock with movement invented by Dr. Hermann Aron** of Berlin in 1892-4.

7. **Marine Clock System operated by an electrically wound chronometer** made by Thomas Mercer Ltd.
Loaned by Thomas Mercer Ltd.

8. **Solar Powered Electric Clock made by Patek Philippe, 1955.**
Loaned by English Clock Systems.

9. **Memory Master Clock by English Clock Systems, 1962.**
Presented by English Clock Systems.

21. QUARTZ CRYSTAL WATCHES AND CLOCKS

WATCHES

1. **Omega Beta 21 watch claimed to be the first quartz crystal watch with integrated circuits, 1970.**

   Displayed with accompanying diagram of Omega watch.
   Presented by Omega and Centre Electronique Horloger, S.A.

2. **Longines Ultra Quartz Cybernetic Watch, 1969.**

   Displayed with accompanying diagram of Longines watch.
   Discrete components are used instead of integrated circuits. The small number of components required is achieved by the unusual system employed. A resonating vibrating motor drives the hands at about 170 Hz, the phase of its oscillation being compared with the oscillations of a 8,192 Hz quartz crystal, the difference in phase is used to derive a correcting signal to the vibrating motor.
   Presenetd by the Longines Watch Company Ltd.

3. **Omega Megaquartz Marine Chronometer, circa 1975.**
See page 102. Presented by SSIH (U.K.) Ltd.

4. **Ebauches Model 9180 movement.**
Presented by Ebauches S.A.

5. **Timex Quartz Crystal Watch with Analogue Indication, 1975.**
See page 102. Presented by the Timex Corporation.

6. **Zenith Quartz Crystal Watch with analogue and digital display.**
Presented by the Zenith Time Company Ltd.

Sircura " Superman " self-winding quartz crystal watch.

The motion of the wearer's wrist operates a small generator which charges the secondary cell which in turn powers the watch.
Presented by Time International (London) Ltd.

Working model of a Seiko Digital Quartz Chronograph.

To operate: Depress the crown, push button " B " to start the chronograph, push it again to stop it, and push button " A " to reset the display to zero. Depressing the crown again will change the display to show the date and time.
Loaned by Seiko Time Ltd.

CLOCKS

7. **Longines Desk Clock.**

   A mains-operated quartz crystal clock which has an independent power reserve for twenty-five minutes operation should there be an interruption in the supply. Cold cathode tubes are used to display the time.
   Presented by the Longines Watch Company Ltd.

8. **Longines Deck Chronometer 1966.**

The chronometer has outputs of 2 Hz and 100 Hz. which can be used to operate other devices requiring strict time control.
Presented by the Longines Watch Company Ltd.

9. **Chronolog International 3.**

By inserting a metal plug in the appropriate socket, the clock will indicate the time in any one of twelve different cities.
Presented by Lord Tanlaw.

10. **Quartz Crystal Master Clock by English Clock Systems.**

The master clock provides polarised minute impulses and can operate more than one hundred secondary clock dials. Should the mains supply fail, an electronic memory stores the lost pulses whilst the clock continues to function on its reserve power supply, the secondary clock not being impulsed during the power interruption. On resumption of the mains power, the stored pulses are fed into the secondary clock circuit at a rapid rate until the correct time is once more indicated. See page 94.

11. **English Clock Systems Telebox.**

The Telebox provides an impulse of current at one minute intervals to operate secondary clocks. It comprises a quartz crystal time-base and a radio receiver tuned to the transmissions from Prangins in Switzerland. The pulses are controlled by the radio signal but the quartz crystal time-base can take over the duty in the case of failure of the radio signal. When the radio signal is restored the error in the system (if any) is corrected.
Loaned by English Clock Systems.

22. UNUSUAL ELECTRIC CLOCKS

1. **Synchronous "Mystery" Clock made by Smiths English Clocks 1935.**
See page 84.

2. **Rolling Ball Clock, possibly designed by Charles Wheatsone, circa 1850.**

This is a very well made electric clock of great ingenuity. The time controlling element is a steel ball running in a tilted glass tube in a similar fashion to the well-known Congreve clock. The steel ball operates contacts which energise an electromagnet to tilt the glass tube in the reverse direction and also drive the clock movement.

3. **Derby "World Time" Clock.**
Presented by Ebauches S.A. See page 96.

4. **"Clipper" Synchronous Electric Clock, circa 1947.**

Manufactured by Vitascope Industries Ltd., Isle of Man, a clipper ship moves in an artificial sea with lighting effects to provide a continuously changing scene. The mechanism is driven from the same synchronous motor which drives the hands, the whole being intended as a novelty clock. See page 86.

5. **Junghans Electro-Pneumatic Clock, circa 1930.**
See page 78.

6. **Schatz Elexacta Electrically Wound Battery Clock.**

This clock is a compound pendulum incorporating the dial in the upper part, the movement is a mechanical one which is rewound by means of a 1·5 volt cell and electromagnet.

7. **Nuclear Powered Electrically Wound Watch.**

A radioactive source is used to provide the power. Beta rays (electrons) are used to charge an electrostatic motor which in turn winds the mainspring of the watch. This is an experimental watch model made by Patek Philippe in 1954 and it was never introduced as a commercial model.
Loaned by English Clock Systems.

Electrifying Time

ILLUSTRATED HISTORY OF ELECTRICAL TIMEKEEPING

1. FRANCIS RONALDS' ELECTROSTATIC CLOCK, 1814.

Francis Ronalds communicated the results of his work on an electric clock to the proprietor of the *Philosophical Magazine,* Mr. Tilloch, on 9th March 1815, In it he describes the working of his electrostatic clock as follows:

AA, &c. are six of Mr. Singer's columns in glass tubes, supported by two stems of glass covered with sealing-wax BB, and the flat pieces of brass CC, &c., which pieces serve also to render them continuous: the positive extremity P is connected by a brass wire with the dial plate D; and the negative extremity N, with the screw 6. The dial plate is supported by a stem of glass projecting from a piece of wood E behind it. The pendulum, which is a wire of steel of about one-fiftieth of an inch diameter and about 14 inches long, carries a ball of gilt cork about one inch diameter: this when unelectrified hangs at about four-tenths of an inch from the disk. No. 1 and 2 is a bow stretching a fine silver wire, and is attached to a spring so that it can be advanced towards or withdrawn from the pendulum by turning the screw 3. 4 is a flat piece of brass carrying the support of the disc &c. 5, and has a groove which allows the lower part of the screw 6 to pass through, so that the disc and bow may be placed and firmly secured at the required distance from the bob of the pendulum, which is ascertained by a great many trials. The whole is covered with a large glass shade. Fig. 1 is a front view of the mechanism attached to the dial plate, of the exact size of the original. No. 1 is the top of the pendulum, which is suspended from the peg 2 by a piece of fine watch pendulum wire. I have not drawn the lower part, because it would obstruct the view of the crutch 3. The crutch moves on the pivot 4, and carries at the upper end a small lever 5, which moves on the pivot 6, and is prevented by the screwhead 7 from moving beyond a certain point to the left, whilst a very delicate spring 8 causes it to regain that point after it has been removed from it. At the lower end of the crutch are two pins 9, which receive between them the pendulum. The wheel 10 has sixty teeth and is supported by the cock 11. When the pendulum moves to the right, the upper end of the crutch moving in the contrary direction, and the spring 8 yielding, allows the lever 5 to clear one tooth of the wheel; but when it moves to the left, the screw-head 7 stopping the lever, the wheel is caused to move through the space of that tooth, the elbow 12 dropping between the two teeth at the other part of it, and keeping it steady.

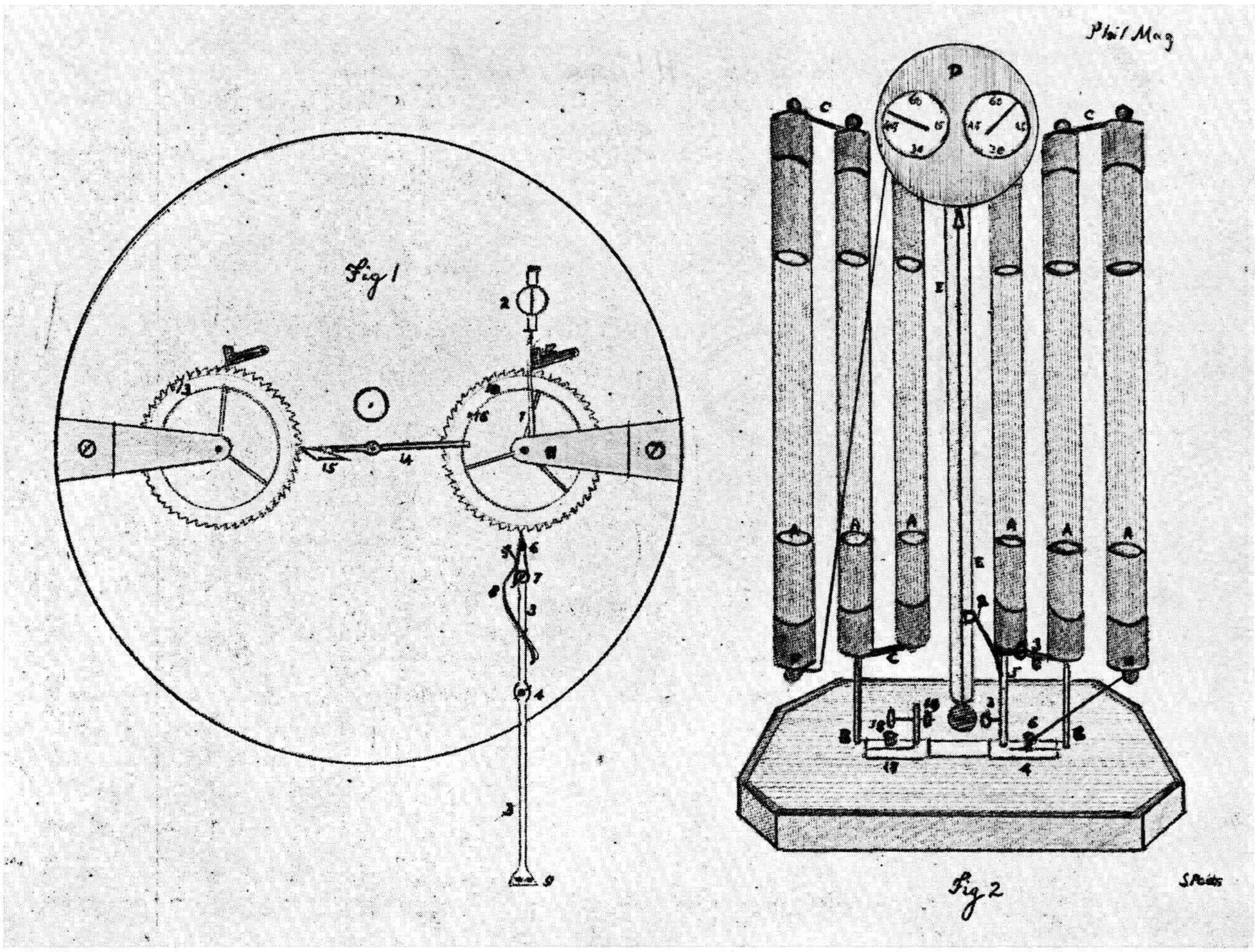
The wheel 13 has also sixty teeth, and is moved in a similar manner by the lever 14, which carries the small lever 15. 16 is a pin which acts upon the lever 14 at every sixtieth vibration; and consequently if the wheel 10 makes one revolution in a minute, the wheel 13 would make one revolution in an hour. Any number of wheels might be set in motion, if the maintaining power on the pendulum were sufficient to overcome the friction and the inertia. The indexes are fixed to the pivots on the other side of the dial plate. It will be easily understood by recurring to Fig. 2, that the vibrations of the pendulum are maintained by the successive charges of electricity which the cork ball receives from the positive end of the column, and it discharges at the cross wire No. 2, where a small spark is always perceptible.

It may be also easily conceived that the rapidity of the vibrations is influenced by the variations in the electromotive power of the column, which are occasioned by the circumstances stated by M. De Luc, Mr. Singer, and myself, viz. heat, moisture, and the electricity of the ambient air. Whilst engaged in the construction of this apparatus for the purpose above stated, it occurred to me, that if the power of the column were sufficient to make the pendulum vibrate *as fast* as seconds in all temperatures, and under all other circumstances, it would be possible to draw off the superabundant electricity which at higher temperatures, &c. made it vibrate *faster,* as quickly as it accumulated, and after several trials I adopted the following method, by which I succeeded better than I expected to have done in regulating the vibrations.

No. 17, Fig. 2, is a similar piece of brass to 4, it carries the support of the screw 18: this terminates in a fine point, and passes through the disc 19, which can be placed at any required distance from the point to be ascertained by experiment, and can also be advanced to or withdrawn from the cork ball *with* the point, by turning the screw. The point is placed at a very small distance from the cork ball when the latter is in the most distant part of its vibration from the disc 1, so that, in proportion as the electricity is more abundant and intense, the disc 19 causes it to make a longer vibration, and thus to bring it nearer the point, which discharges a portion proportionate to its proximity. The columns represented in the plate have kept the pendulum thus circumstanced in activity about three weeks. When the temperature of the room is above 53 degrees, it gains about two seconds in five minutes for every advance of one degree; but when it is below this degree it diminishes its velocity gradually, until it no longer vibrates so fast as seconds.

Reference: *A Conspectus of Electrical Timekeeping* by C. K. Aked.

PLATE 1



2. ALEXANDER BAIN ELECTRIC MANTEL CLOCK, CIRCA 1847.

Very few of Alexander Bain's electric clocks have survived, and of those designed for standing on a shelf or bracket there are only two known to exist, both in private collections. The one illustrated here is much more functional than the clocks shown in his book *A Short History of the Electric Clocks . . .* published in 1852, and would appear to have been specially made for there are contacts operated by the motion work at intervals of two hours, the precise use for these has yet to be discovered.

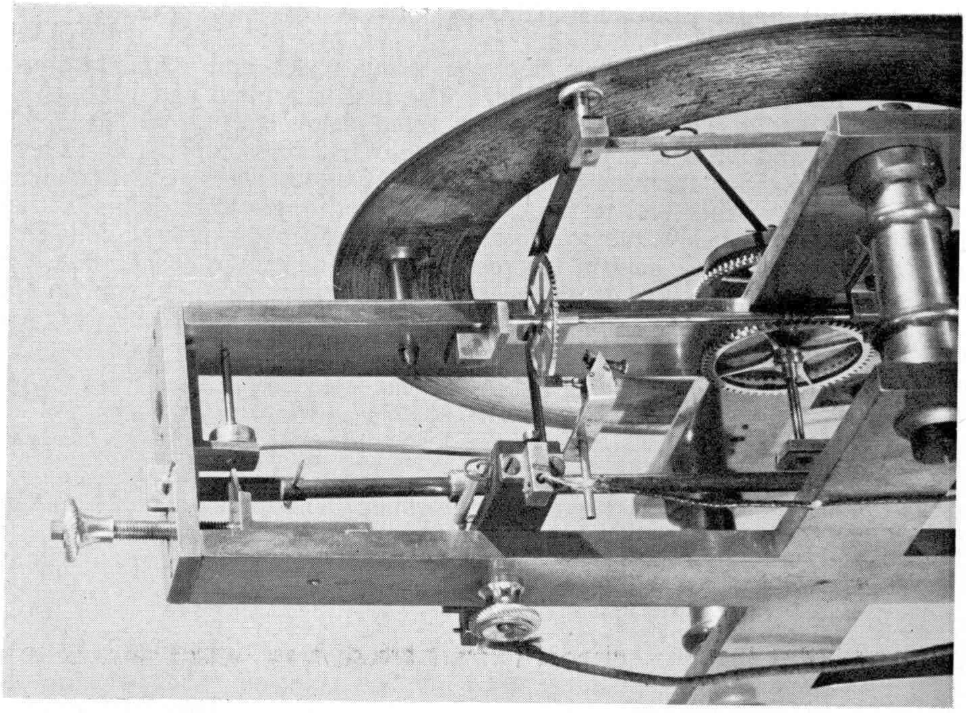
The detail in Plate 2 shows how a pivoted pawl mounted on the gravity arm extension to the side of the pendulum rod pushes the ratchet wheel forward tooth by tooth as it swings towards the viewer. A very light spring on the right prevents the reverse turning of the ratchet wheel. On the arbor of the ratchet wheel is mounted a worm-wheel which rotates the minute wheel arbor once in every hour.

Just above the gravity arm extension may be seen the contact system for controlling the flow of electricity through the two solenoids mounted on the base of the clock. The bars of the pendulum bob are small magnets with consequent poles, i.e., both ends are north poles and the middle is a south pole, when the contacts are closed electricity flows through the solenoids causing the left-hand coil to become a magnet with a south pole facing the pendulum bob, and the right-hand a north pole facing the pendulum bob. Thus the pendulum bob is repelled on the right-hand side and attracted on the left-hand side, since like poles repel and unlike poles attract. The pendulum is caused to swing to the left until a pin projecting from the pendulum rod pushes the slider bar off the electrical contacts, upon which gravity causes the pendulum to return to take up a similar position on the other side of its swing which closes the contacts once more, and the process continues as long as the supply of electricity is available.

The clock was covered by a glass dome to prevent dust from interfering with the proper operation of the electrical contacts, these being of gold with a sliding bar of silver or platinum.

See Alexander Bain's *A Short History of the Electric Clocks* or *A Conspectus of Electrical Timekeeping* for further explanations.

Science Museum Negative Nos. 1747/76 and 1748/76.



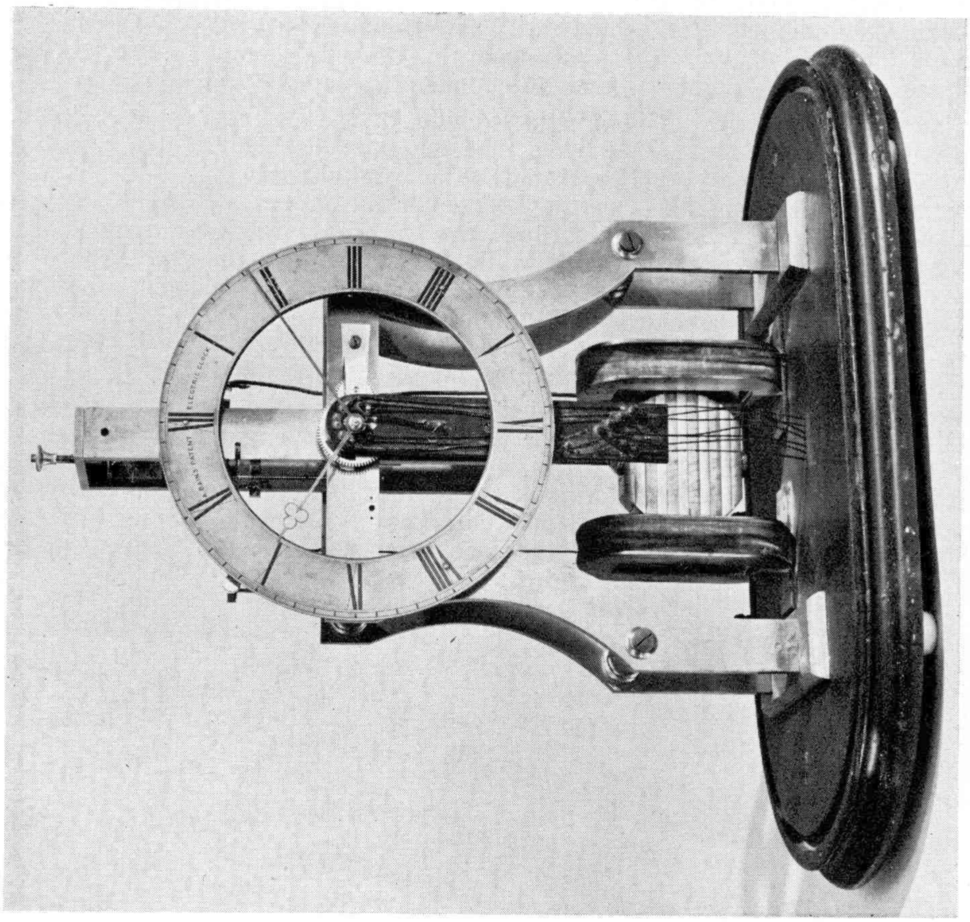


PLATE 2

3. ALEXANDER BAIN ELECTRIC CLOCK, CIRCA 1847.

Alexander Bain made his electric clocks in many styles and Plate 3a illustrates an example made for domestic use about 1847. The dial is painted and bears the signature BAIN'S ELECTRIC CLOCK, a seconds dial is fitted below the figure 12. A 1¼ seconds pendulum is fitted and has a solenoid bob swinging over a brass tube in which are enclosed a number of bar magnets, the tube being slightly curved to accommodate the arc of the pendulum, and fixed at each end to the clock base. To bring the pendulum to time a small subsidiary bob is fitted below the solenoid. This clock from a private collection is very similar to the longcase clock held in the reserve collection of the Science Museum, and it has been most skilfully restored from the results of an amateurish attempt to convert the pendulum to Hipp Toggle actuation. Glass panels in the case door and base enable the operation of the pendulum to be viewed.

Plate 3b illustrates the pendulum and movement from one of Alexander Bain's electric wall clocks, as illustrated in his book *A Short History of the Electric Clocks. . . .* The case and dial of the clock have unfortunately been lost, and some restoration has been carried out by the Science Museum workshop.

In the example shown here the magnets forming the pendulum bob have been nicely arranged and finished since they would be visible in operation. They are made with consequent poles so that one side of the magnet arrangement is repelled whilst the other side is attracted when an electric current flows in the two solenoids mounted one on each side of the magnet assembly.

It will be noted that the solenoid formers are of brass, and it is very strange that Alexander Bain never realised that the brass formers acted as a single turn coil of very low resistance. The magnetic field strength of the bar magnets is very low, so the generated voltage is low too, nevertheless the losses from this cause are roughly equal to moving the slider across the contacts. It was not until Favre-Bulle devised the Bulle electric clock that steps were taken to eliminate the losses from this cause by a complete saw-cut through the solenoid former at one point to break the conducting path.

It is essential that the magnetic field strength of the magnets is low, often restorers have the magnets recharged in the belief that they have lost their magnetic strength. If the magnets are too strong the emf generated as the pendulum swings through the solenoids may be too great and higher than the voltage of the properly applied source, hence no current can flow from the battery through the solenoid windings and no impulse can be given to the pendulum. After a short while the pendulum amplitude diminishes until it ceases to swing, only the application of a higher voltage can overcome the effect, however this leads to the destruction of the gold contacts, for the various parameters were very carefully devised by Bain to obtain reliable service over along period of use, and any departure from these soon causes deterioration.

The contacts of the example in Plate 3b are the inverted arrangement used by Bain where there is a groove on the underside of the sliding bar engaged by gold pins supported in boxwood discs. Dust could not settle in the groove as in the earlier contact arrangement, the slightest speck causing a disruption of the current path; and the gold pins were covered by the bar at all times, ensuring that dust could not settle on the acting surfaces. Protective dust cups were fitted to the early contact systems to alleviate the problem, the efficacy of the later inverted system is not known.

Science Museum Negative No. 8.

PLATE 3a

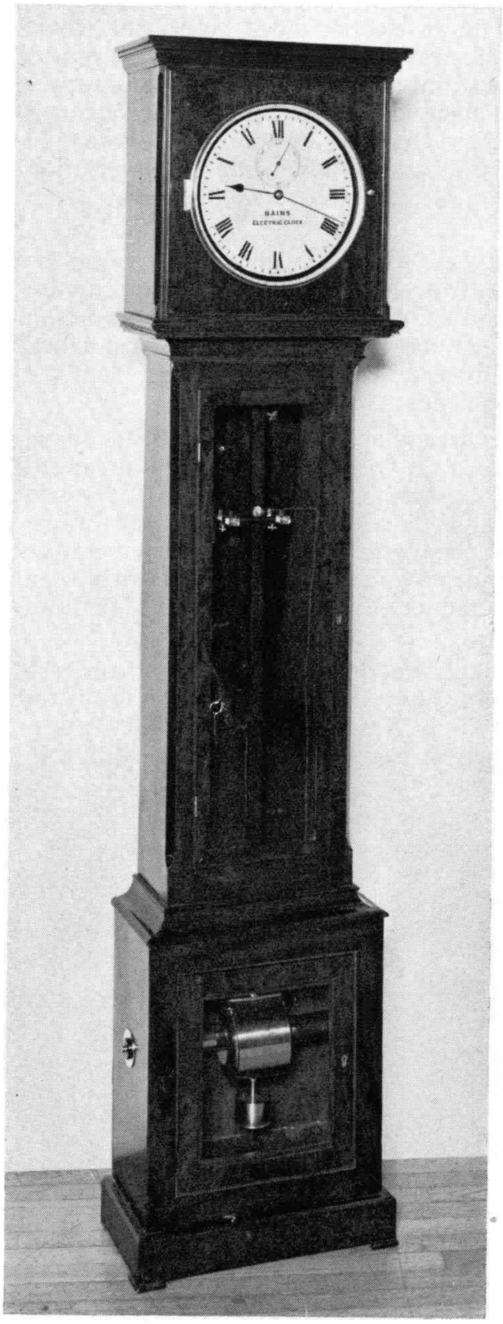
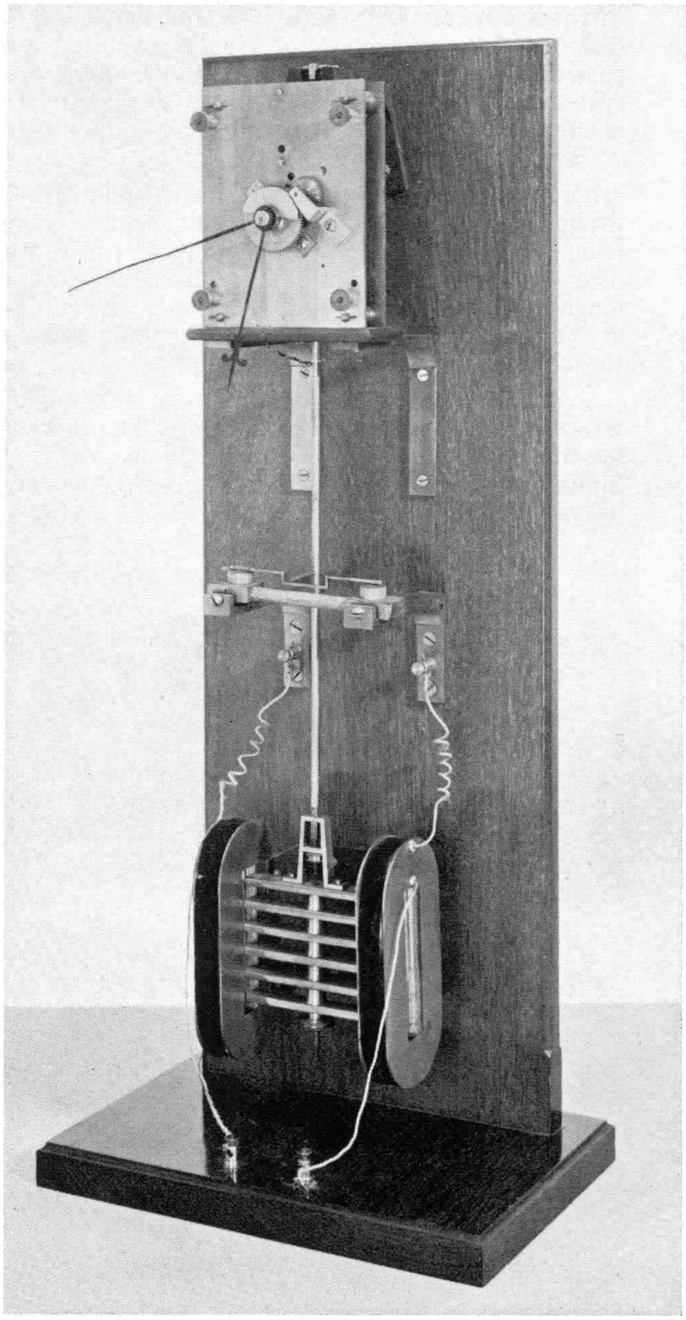


PLATE 3b



4. WHEATSTONE IMPULSE DIAL.

Charles Wheatstone is mainly remembered for his work in connection with telegraphy, however he was one of the first to publicly demonstrate an electric clock before the Royal Society of London on 26th November, 1840. This clock was not electrically driven, it was mechanically driven and closed electrical contacts, these interrupting and making a supply of electricity from a battery to an electro-magnet in a slave clock. Alexander Bain claimed that the electric clock shown by Wheatstone was based on the design which Bain had shown to Wheatstone in August, 1840. Alexander Bain had already made an application for the first electric clock patent in Great Britain on 10th October, 1840, almost seven weeks before Wheatstone's demonstration.

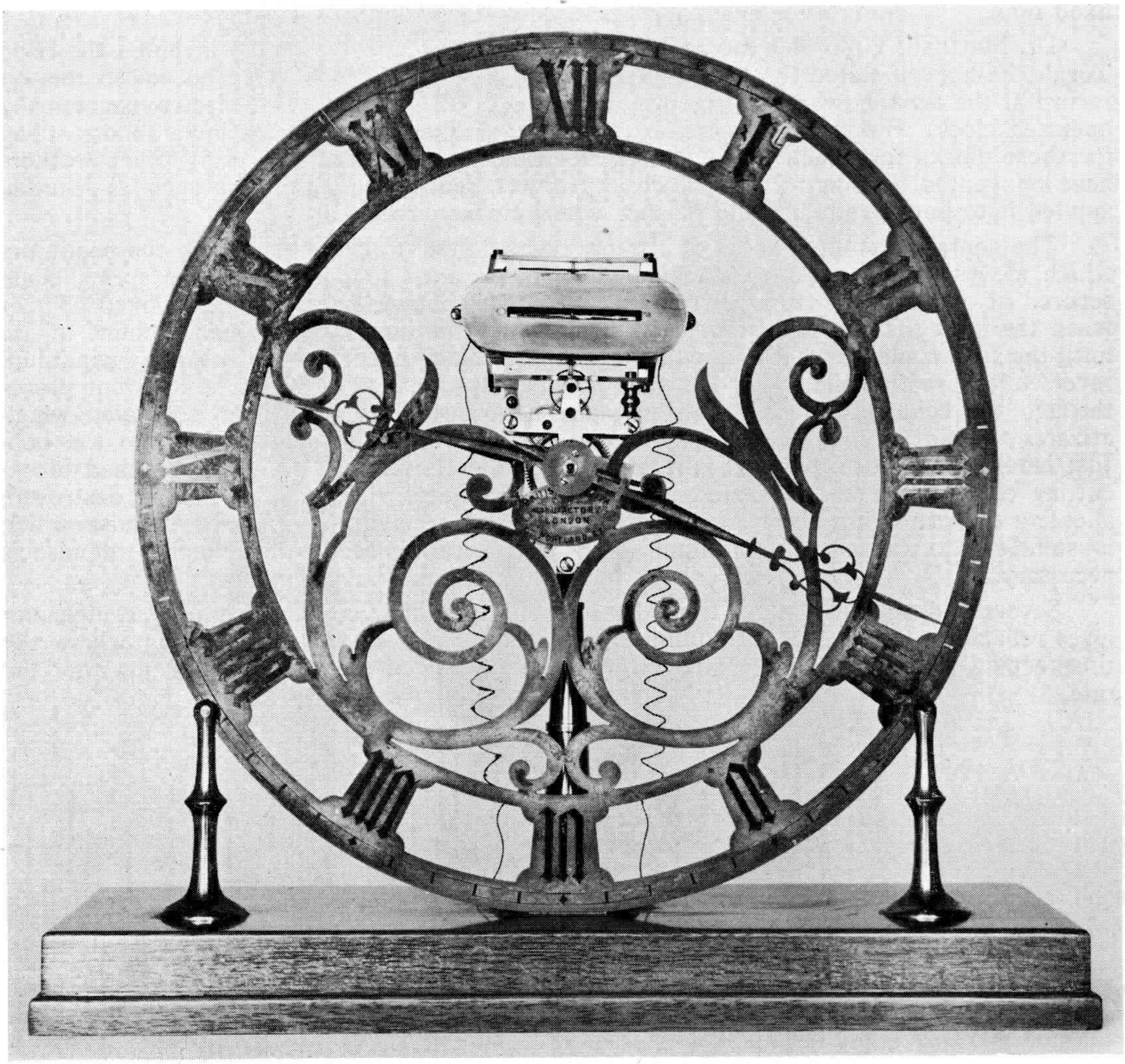
Wheatstone outlined his proposal to use the magneto-electric current discovered by Michael Faraday in a paper read to the Royal Society in 1840. The example of an impulse dial working on electrical currents generated by a coil of wire mounted on a pendulum passing over a magnet which is shown here, was made for use with the electrical clock system which Wheatstone installed in the Royal Institute in 1873, and was driven from the master clock on display in the Time Gallery of the Science Museum.

The driving mechanism of the clock consists of three magnets mounted on a single arbor, the centre one lying within the field of a coil, the whole magnet system is arranged to be astatic so that the magnetic field of the earth exerts no force on the composite magnet assembly whilst the coil exerts a field which acts on all the magnets in the same direction. When the coil is fed from an electrical supply which alternately reverses, the magnet assembly rotates in phase with the supply frequency. This assembly is clearly seen at the top of the movement, the remainder being the reduction train to turn the hands of the clock at the correct rate.

Wheatstone's impulse dial is, in fact, a synchronous electric motor driven from the alternating current generated by his master clock. As such it antedates the later synchronous electric clocks devised by W. E. Warren in America by about fifty years. Similar ideas had been put forward by Alexander Bain in the 1840's and are recorded in his patents, no examples of actual clocks are now known.

Science Museum Negative No. 90/55.

PLATE 4



5. HIPP ELECTRIC MANTEL CLOCK.

The electric clock shown in the illustration carries what is known as the "Hipp Toggle" at the lower extremity of the pendulum. The first clock working on this principle appeared in 1842 and was the first reliable electric clock since the contact operation was certain in action and only operated when the amplitude of the pendulum fell to a certain fixed limit.

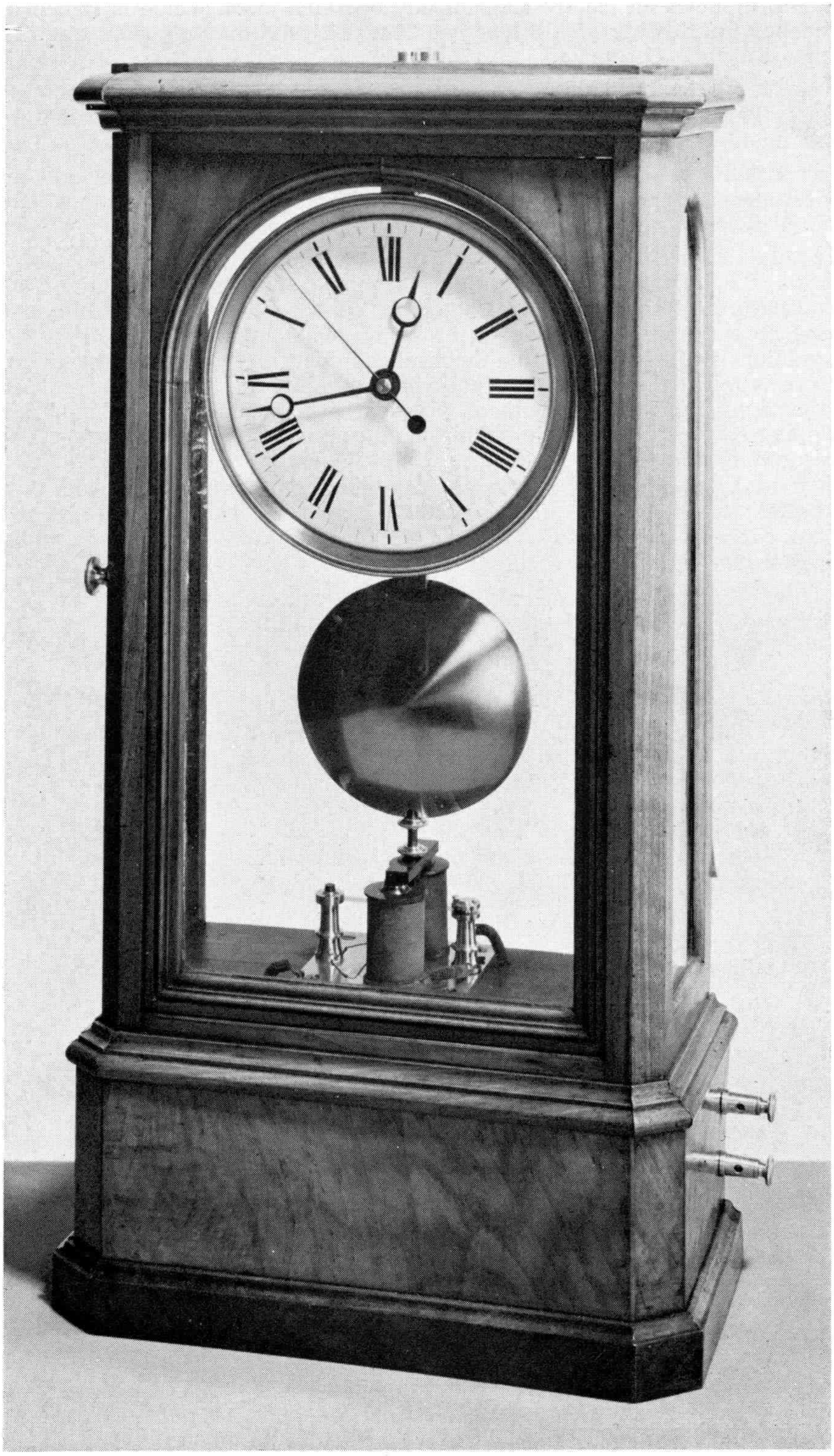
Dr. Matthäus Hipp of Neuchâtel was only a young student when he invented the Hipp Toggle, he himself stated that he first thought of the idea in 1834. Had he placed this on record at the time, he would be credited with the invention of the first electro-magnetically operated clock. Hipp's system is most ingenious and reliable and continues in use today for those clocks for which the highest performance is not required. Many other workers have reinvented the Hipp Toggle, such as Herbert Scott in 1902; others such as Murday applied it to both pendulum and balance wheel clocks circa 1910 - 12.

The contact system consists of a freely pivoted steel trailer mounted on the pendulum which moves over a notched triangular steel block fixed to the centre of a spring blade secured at one end, the other carrying an electrical contact which touches a fixed contact when the spring is depressed. At each swing the pendulum loses a small amount of arc until the steel trailer does not clear the notch in the block but falls into it. As the pendulum reverses its direction the trailer is forced downwards, closing the contacts. Current passes through the coils of the electro-magnet and a powerful magnetic field is created which attracts the soft iron armature fixed to the lower part of the pendulum under the bob. Just before the vertical position is reached the trailer is released from the notched block, cutting off the current by opening the electrical contacts, the magnetic field is destroyed, allowing the pendulum armature to pass freely after receiving a powerful impulse which is sufficient to cause the pendulum to swing several times before a further impulse is necessary.

Several advantages result from the Hipp Toggle, the contact pressure is high and gives reliable switching, the pendulum is impulsed at the centre of its swing where the timekeeping properties are not affected, and the voltage of the battery does not alter the rate.

Science Museum Negative No. 1598/76.

PLATE 5



6. DETOUCHE ELECTRIC CLOCK, CIRCA 1855.

Plate No. 6 shows an electro-magnetically operated clock which is signed on the dial "C. Detouche, Fournisseur de l'Empereur Rue St. Martin No's. 228 and 230 Paris", and on the rear "C. Detouche . . . 17643 Brevete S.G.D.G.".

The clock has an enamelled dial, gilt brass case and frame on an ebony base, the movement is of brass, steel and ivory, originally the clock was protected by a glass dome from dust.

Robert Houdin, 1805 - 1871, a French horologist and conjurer, devised the electro-magnetic escapement upon which the clock shown here operates; and took out a patent in the United Kingdom in 1856, No. 1751.

The pendulum carries a semi-circular bar at the top. When the left-hand arm touches a contact on the horizontal brass spring, the electro-magnet is energised, attracting a soft iron armature on the left. This motion is conveyed via a lever and rod to set the brass spring on the upper right, the spring being held in the raised position by a detent. As the pendulum swings to the right, the contacts open to de-energise the electro-magnet, the armature is released, leaving the right-hand spring in the set position. The right-hand part of the semi-circular bar contacts the set spring as the pendulum completes its movement to the right, raising it slightly and releasing the detent, thus allowing the spring freedom of movement once more. As the spring reverses the direction of the pendulum motion, an impulse is given to maintain the amplitude of swing at a constant value regardless of the voltage of the battery driving the clock so long as the value is sufficient to energise the electro-magnet and close the armature. The pendulum once more swings to the left and the cycle is repeated.

A portrait of Constantin Louis Detouche is shown on page 183 of *Dictionnaire des Horlogers Français* by Tardy. Tardy gives the following details:

Detouche, C. Paris. Rue Saint-Martin, 1825 - 90.
S'associa avec Houdin, 1850. Prit des brevets avec BRISBARD-GOBERT, pour une pendule électromagnetique, 1851. En 1866, une pendule magique et une transmission de mouvements sans l'emploi des roues d'angle et une disposition de reveil de poche à enveloppe spherique.

"Associated with Houdin, 1850. Took out patents with Brisbard-Gobert, for an electro-magnetic pendulum, 1851".

Museum of the History of Science, Oxford University Negative No. 71-32.35.S.

PLATE 6

7. DIAL MOVEMENT FOR RITCHIE'S SYMPATHETIC ELECTRIC PENDULUM, CIRCA 1873.

The mechanism shown in Plate 7 was patented by F. J. Ritchie in 1872, in which the motion of an electrically maintained pendulum is used to drive the motion work of a clock. Currents are sent from a master clock to the sympathetic pendulum to keep it in absolute synchronism, the pendulum lifts the two gravity arms in turn to allow an impulse to the ratchet wheel as they return to the lower level. The lowest arm serves to lock the ratchet wheel to prevent reverse rotation.

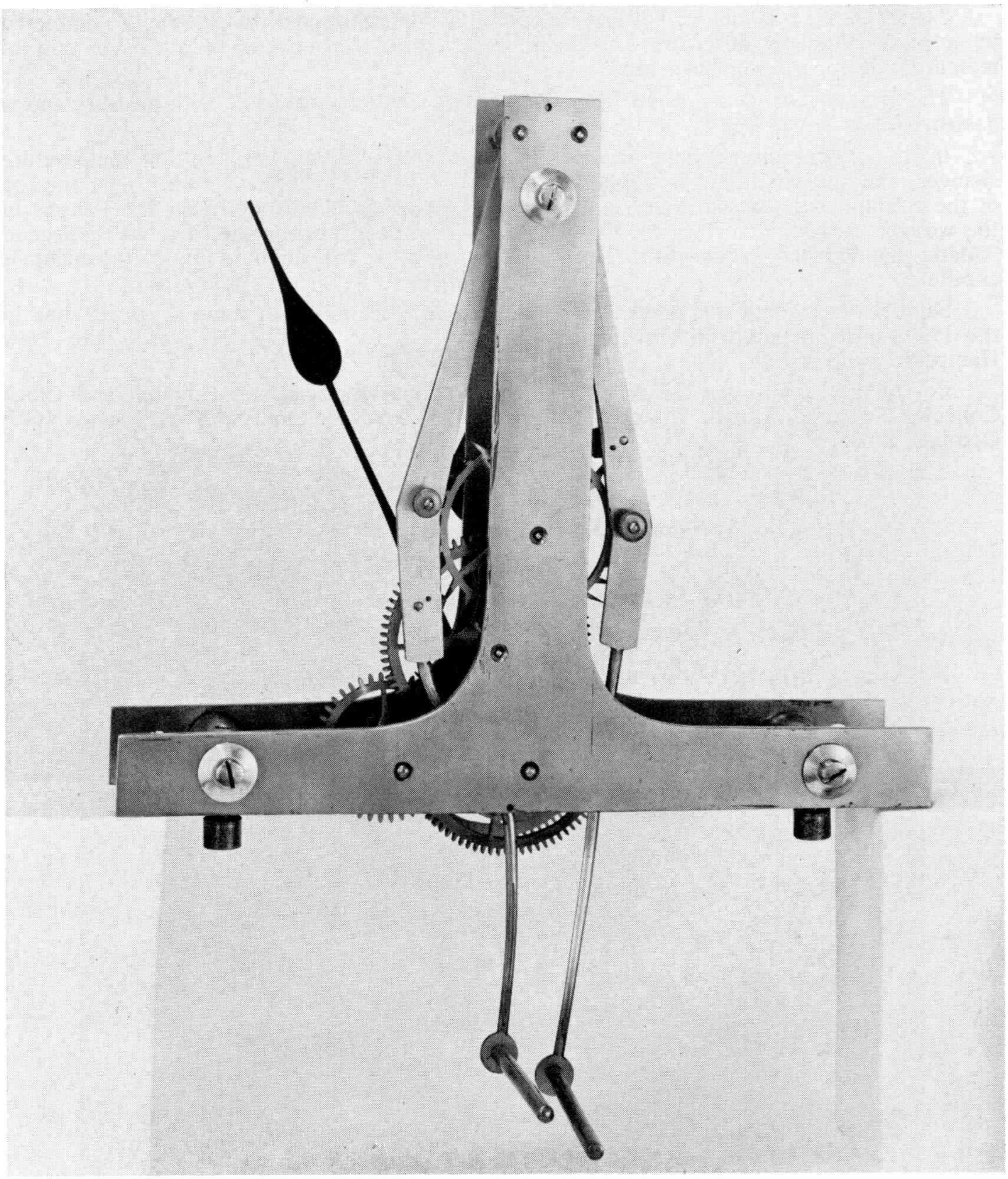
Sympathetic pendulums were first used by Alexander Bain, circa 1845, and were dramatically demonstrated by him working over a telegraph line he had constructed in 1845 - 46 from Glasgow to Edinburgh, a distance of about forty-six miles. R. L. Jones of Chester adopted Bain's system but employed spring-driven slave clocks with the pendulums synchonized by a master clock transmitting current pulses. The disadvantages were that each slave clock had to be wound by hand and should the master clock pulses fail for an interval, it was possible for the slave clock to have fallen out of step so that the synchonizing pulses stopped the pendulum. Ritchie's method avoided both of these disadvantages.

Ritchie carried out a great deal of work on the synchronization of clocks and read a paper on the subject before the Royal Scottish Society of Arts in 1878. He dealt with Bain's work on the hourly correction of clocks and paid great tribute to the work of the early pioneer. Ritchie's greatest achievement was the synchronizing of public clocks by electrical pulses at hourly intervals from a central station where an accurate master clock was maintained.

See British Patent Specification No. 2,078 of 1872 for further details of Ritchie's Sympathetic Electric Pendulum system.

Science Museum Negative No. 1712/76.

PLATE 7



8. WADSWORTH ELECTRICALLY DRIVEN PENDULUM CLOCK, CIRCA 1875.

The illustration shows a very fine electric mantel clock made by Samuel Wadsworth of Keene, New Hampshire, U.S.A. It is mentioned in Brooks Palmer's book *Treasury of American Clocks* and was once in the Terwilliger collection:

"Glass domed model of battery timepiece 22½ inches high with electricity conducted by a piece of silver at bottom of pendulum running through small alabaster cup of mercury. Of superb workmanship."

The contact wire must have been platinum as silver amalgamates with mercury and is destroyed.

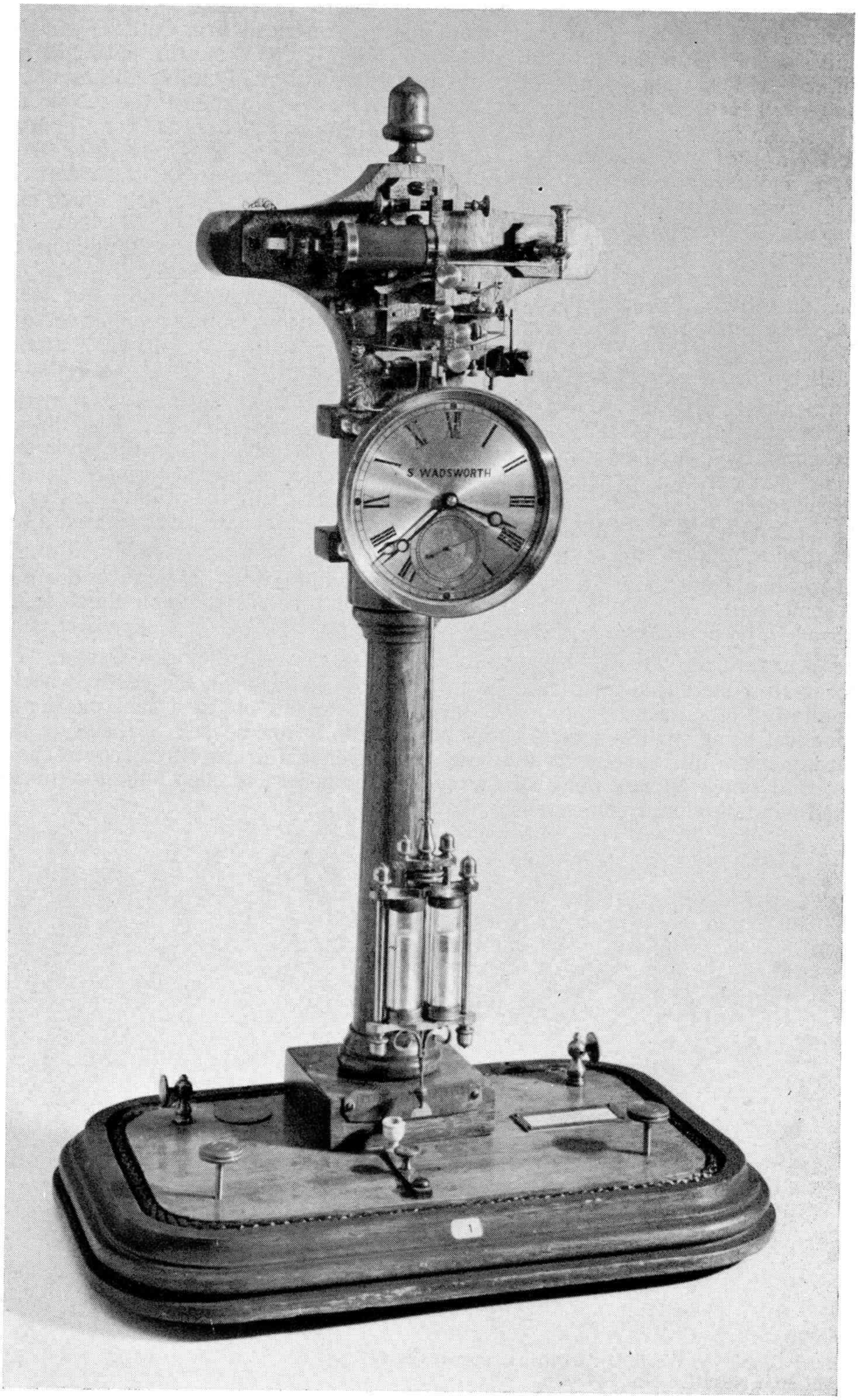
In the clock shown here the pendulum is mercury compensated for temperature changes, and the pendulum is not driven directly by the electro-magnet seen near the top of the column, but through a series of levers and springs. According to the ivory insert in the wooden base, the clock is the first of its type; another label on the base has the legend "Made by Samuel Wadsworth, Keene, N.H., 1875". The standard of workmanship is excellent.

Samuel Wadsworth was known as a jeweller and clockmaker of some skill. He died in the 1930's. He invented an electric time signal clock for the City Hall at Keene, New Hampshire, U.S.A.

For further details see the Bulletin of the National Association of Watch and Clock Collectors Volume X, No. 9, page 710, April, 1963, and Volume X, No. 12, page 1007, October, 1963.

Science Museum Negative No. 1661/76.

PLATE 8



9. POND'S SYSTEM ELECTRICALLY REWOUND CLOCK.

Although the dial of the clock shown in Plate 9 is signed "Jones Clock Maker —Greenwich Time", it bears the trade mark of the American firm Seth Thomas on the right-hand side of the movement and "Patented Nov. 17. 83" on the left-hand side. A serial number 193 is stamped on the plates in two positions. Possibly this is one of the clocks imported into England when an attempt was made to introduce the system into the United Kingdom in 1886. The system was the invention of Chesters H. Pond of Brooklyn, New York, in 1881. A small electric motor rewinds a spring hourly to drive the clock, being set in motion by a contact on the hour wheel. The armature of the electric motor consists of six soft iron bars set at 60° intervals, and three electro-magnets which move the bars round in 20° steps giving a driving force adequate for rewinding the clock. There is no means of synchronizing the clock and the phrase "Greenwich Time" might be thought to be somewhat optimistically applied to convince Mr. Jones' customers of the accuracy of the time indication. The phrase is, however, used to indicate that it is not local time which was in common use until the advent of the railways made it imperative to have a unified time, the so-called "Railway Time" of the railway companies, later legally superseded by Greenwich mean time for the whole country.

In America this type of clock was further developed and manufactured by the Self Winding Clock Company, by 1900 over 150,000 of these were in use, having the addition of a synchronizing device operated by a signal sent every hour over Western Union telegraph wires. The synchronizing signal initiated a forcible correction of the minute hand of the clock by means of a heart-shaped cam and a lever actuated by the armature of an electro-magnet. Each clock had its own local battery for operation. Later versions used a vibrating motor to give a cheaper and simpler construction for the clock.

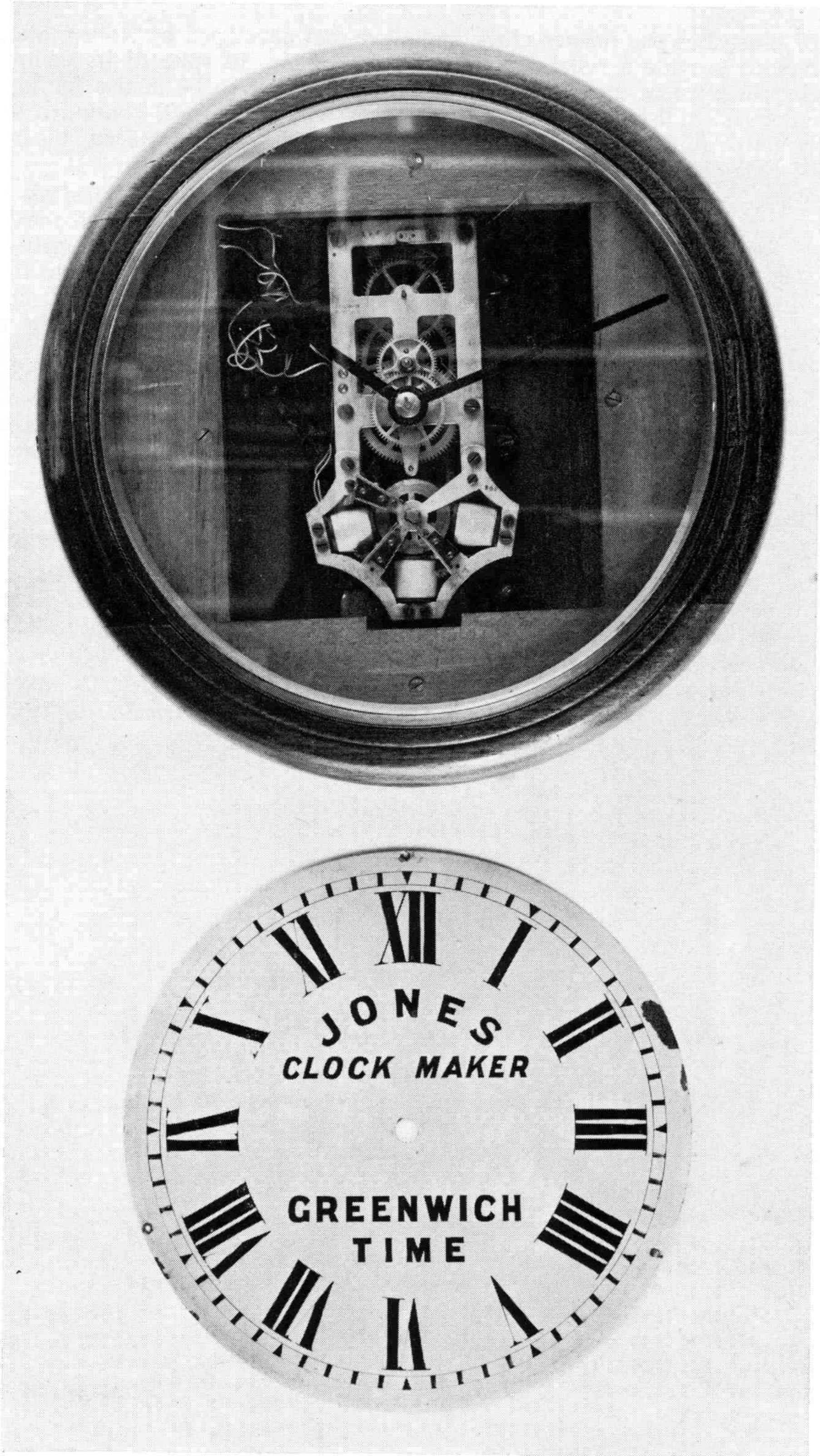
Self-winding clocks were later successfully introduced into England and are still in use on some parts of the Underground system, notably the Northern Line. In practise they proved to be one of the most reliable and successful systems developed for public use.

The master clock for synchronization of the self-winding clocks was a well-made regulator with a mercurial pendulum beating seconds. A cam on the centre wheel having a notch allowed a contact assembly with two leaves to fall on to a cam on the seconds arbor, one leaf being slightly shorter drops off the cam at one second to the hour, closing a pair of contacts, whilst exactly on the hour the longer leaf drops off to reopen the circuit. A one-second synchronizing pulse of current is thus generated each hour for transmission to the self-winding clocks connected to the system.

REFERENCE:

The Modern Clock by Ward L. Goodrich, pages 399-417.
Science Museum Negative No. 1647/76.

PLATE 9



10. LOWNE ELECTRIC MASTER PENDULUM TRANSMITTER AND DIAL, CIRCA 1901.

Plate 10 illustrates the master clock and slave dial developed by Robert Mann Lowne in his attempt to provide a reliable electric clock system. In spite of its complexity the master clock proved to be most reliable and they continued to be in use for many years, for example the system fitted in the Royal Arsenal, Woolwich, in 1903 continued to function satisfactorily until quite recently when the master clocks were replaced, the slave dials continue to be in use.

As with many other electric clocks, the electro-magnet does not impulse the pendulum directly. The grid-iron compensated pendulum rocks a pivoted pawl which then propels a count wheel tooth by tooth at a rate of one revolution a minute. At every half revolution the count wheel closes a pair of electrical contacts as the pendulum swings to the left, the electro-magnet is energised and bends a spring which is mechanically latched, upon which the contacts are opened to release the electro-magnet. On the return swing the pendulum releases the latch and receives an impulse as the bent spring returns to its original position. The pendulum continues to swing freely until the count-wheel closes the contacts once more, and the cycle repeats. The mechanism is arranged to draw only sufficient power from the electric battery to drive the clock, the duration of the current taken varying according to the terminal voltage.

Frank Hope-Jones in *Electrical Timekeeping* states:

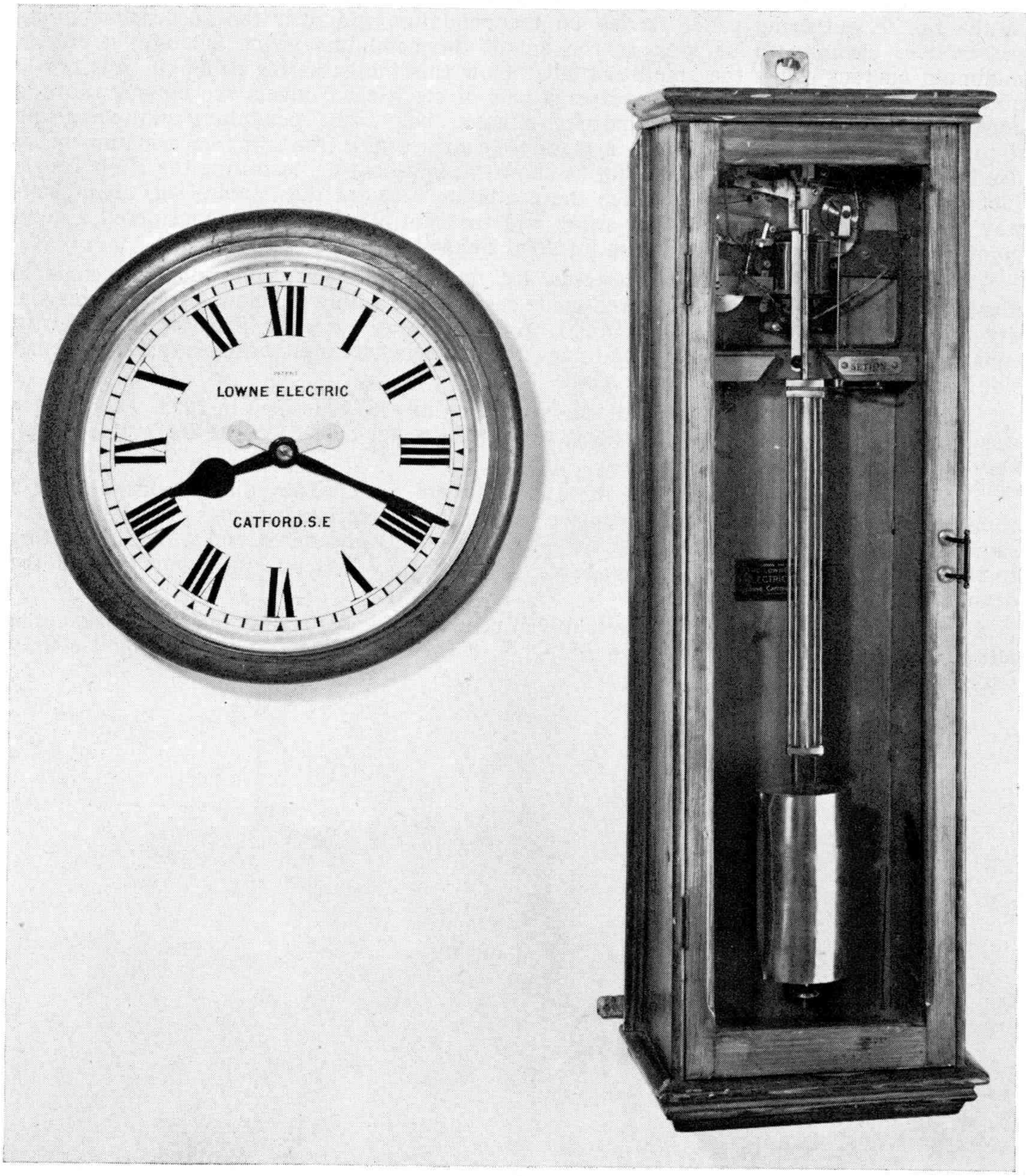
" The systems of Lowne, Campiche and Palmer were the pioneers of an idea which, when properly applied, ultimately became valuable and which therefore ranks as a definite contribution to the science of electrical timekeeping."

The career and inventions of Robert Lowne have been ably outlined in the article " Robert Lowne and his Electric Clock System ", Volume 9, No. 2, pages 209 to 214, March, 1975, issue of *Antiquarian Horology,* written by Mrs. Rita K. Shenton.

A more complete description of the operation of Lowne's Electric Master Clock, together with a diagram of the mechanism, may be found in *Electrical Horology,* by H. R. Langman and A. Ball.

Science Museum Negative No. 1809/76.

PLATE 10



11. SCOTT ELECTRICALLY DRIVEN PENDULUM CLOCK, CIRCA 1902.

Scott's electric clock represents an early British attempt to utilise the principle of the Hipp Toggle for impulsing a pendulum. He took out a patent in 1902, No. 10,271, in which the pendulum turned a count wheel having teeth of special shape, these having a notch cut in the tip. A gathering pallet carried on the pendulum rod near the suspension spring passes over each notch so long as the arc of the pendulum swing is above a certain minimum amount, when the amplitude falls below this the gathering pallet tip fa'ls into a notch. As the pendulum swing reverses a pair of electrical contacts are closed, allowing current to flow in an electro-magnet situated below the pendulum and energising it to give an impulse to a soft iron armature by attracting it, the soft iron armature being fixed to the free end of the pendulum as shown in Plate No. 5 illustrating the Hipp Toggle Electric Clock. The position at which the pendulum received the impulse was about half-way between the maximum arc of swing and the centre position, not considered a good point at which to impulse a pendulum for good timekeeping.

Scott's electric clock was marketed by the Ever Ready Company, the example illustrated in Plate 11, housed in a well-made case having a drawer below for containing the dry cells, was sold for £4 5s. 0d. (£4·25). A mirror was generally fitted at the rear to enhance the effect of the moving pendulum, this swinging to and fro instead of the normal side to side motion of the ordinary clock.

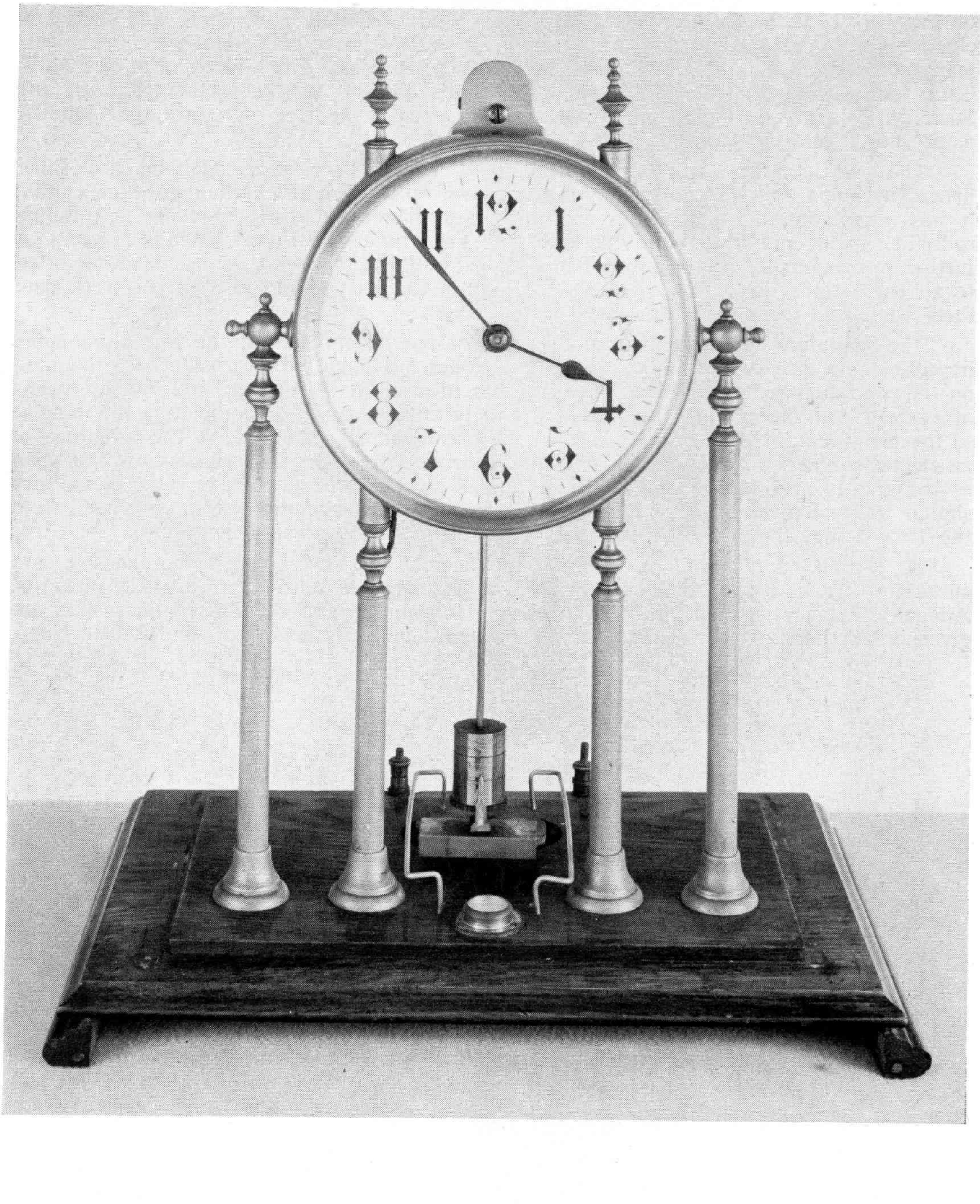
Herbert Scott was born in Bradford, Yorkshire, in 1865. He died in 1943. His brother was Alfred Scott who designed the Scott two-stroke water-cooled engine for motor-cycles, very famous in its day.

Possibly about five hundred of these clocks were made. They did not prove to be a commercial success, being more expensive than ordinary mechanical clocks and lacking the same standard of accuracy. Their appeal lay in the novel appearance, and whilst interesting to the horological collector of today, Scott's electric clock has no real significance in the development of electrical horology.

An account of the Scott electrically driven pendulum clock may be found in *Antiquarian Horology,* Volume 8, No. 5, pages 491 - 494, "The Scott Electric Clock" by Geoffrey Colbert Crabtree, F.B.H.I.

Science Museum Negative No. 522/72.

PLATE 11



12. GENT'S "THORNBRIDGE" TRANSMITTER AND DIAL, CIRCA 1905.

As the twentieth century opened there arose a great demand for clock systems which could provide simultaneous time indication on a large number of clocks installed in a building or factory. The most successful of these systems was the "Synchronome" based on the work of G. B. Bowell and F. Hope-Jones which resulted in the first reliable master clock generating half-minute electrical impulses to drive slave dials. However, there were many competitors in the field of electrical horology, amongst these was the firm of John T. Gent, founded in Leicester in 1872, later taken over in 1894 by the partners Parsons and Staveley. In 1904 A. J. Ball joined the company and designed the "Thornbridge" impulse clock shown here in Plate 12.

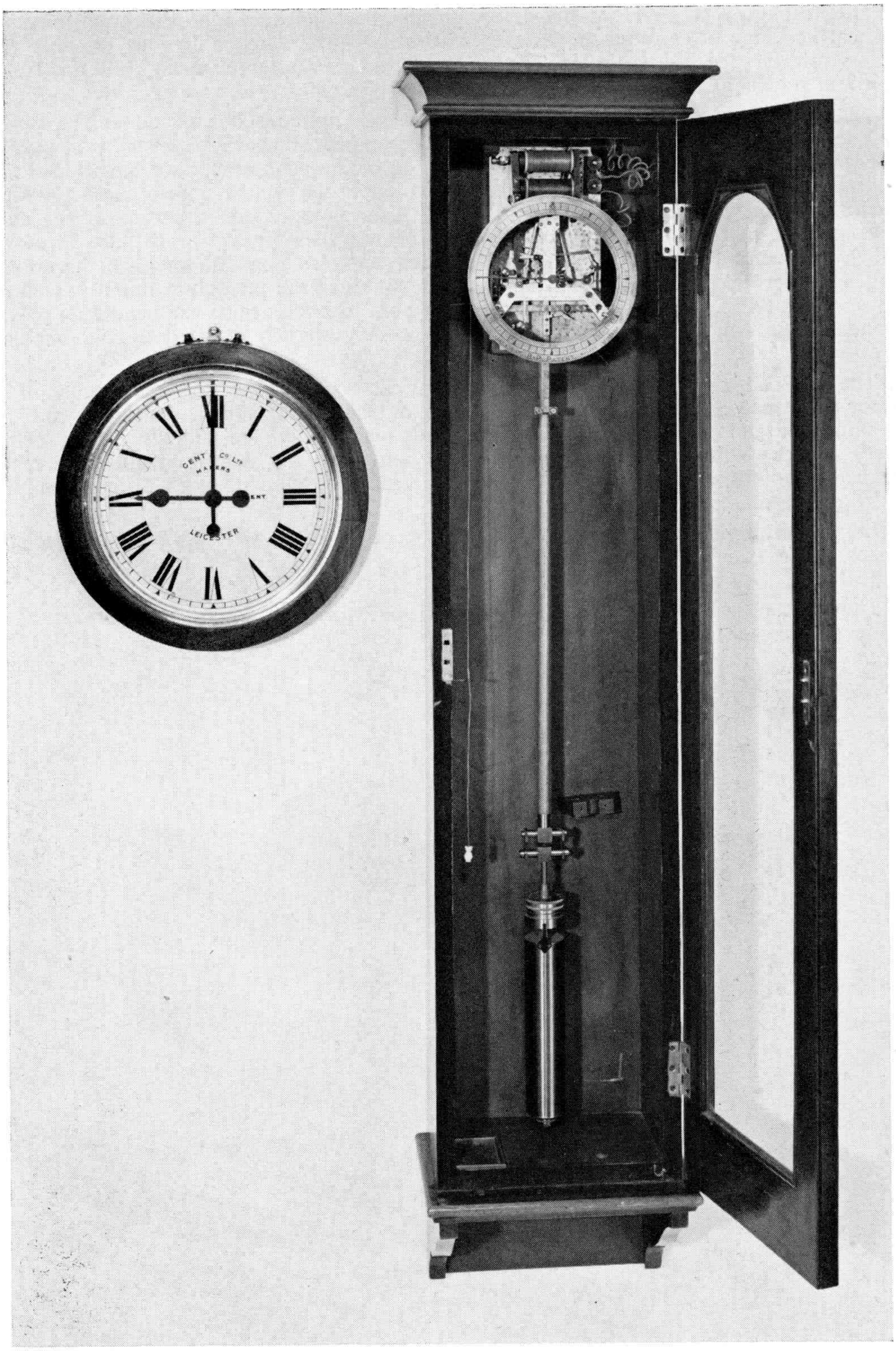
The electric clock was designed specially for use at Thornbridge Hall in Derbyshire, hence the name of "Thornbridge"; and it proved to be such an excellent timekeeper that it was manufactured in quantities and further developed by fitting "Sinevar" pendulum rods, i.e., Invar, and these were guaranteed to keep time within two seconds a week. A further refinement to the pendulum using a fixed bob, together with the use of jewels fitted to all the actions resulted in a regulator accurate to less than 0·5 second per week, and these were sold to many astronomical observatories.

The pendulum length in these models was of one second's beat, the pendulum being impulsed by a gravity arm set horizontally, a roller on which fell on a pallet arm mounted on the pendulum rod when the gravity arm was released at half-minute intervals by means of a release arm on a count wheel. As the gravity arm fell down on completing the impulse to the pendulum, it made contact with an electrical contact mounted on the armature of an electro-magnet, thus generating an impulse for working slave dials which ceased as soon as the gravity arm was reset and the electrical contact broken. The system is so very similar to the Synchronome that it would seem that the Pulsynetic system developed from the Thornbridge transmitter owes much to the prior Synchronome principle.

A. J. Ball, in conjunction with H. R. Langman, wrote a very comprehensive and successful work *Electrical Horology* which ran to three editions from 1923 onwards. Adequate explanations of the "Thornbridge" transmitter and the Pulsynetic system are given in this book, together with a great deal about the early history of electrical horology.

Science Museum Negative No. 1751/76.

PLATE 12



13. HOLDEN ELECTRIC PENDULUM CLOCK, CIRCA 1909.

The teachings of F. Hope-Jones led to the more advanced of the practitioners of electrical horology attempting to devise pendulums which were as free as possible from external interference, the so-called " Free " pendulum. An attempt made by Frank Holden in 1909 is shown in Plate 13.

The pendulum of half-seconds duration carries a high resistance coil at the bottom which moves freely over two horseshoe-shaped permanent magnets with soft iron poles to concentrate the magnetic field at the zero position of the pendulum. Two metal discs form the pendulum bob, the lower one carries a pivoted trailer which makes contact with an electrical contact projecting from an insulating pillar mounted on the base of the clock. The contacting of the electrical contact by the metal trailer gives a brief pulse of current through the pendulum coil as it passes through the zero position for each direction of swing, i.e., there is an impulse each half-second. Because the pendulum impulse occurs at the zero position of the pendulum, there is minimum interference to the pendulum motion, and hence the timekeeping of the pendulum is only slightly affected by the impulsing operation.

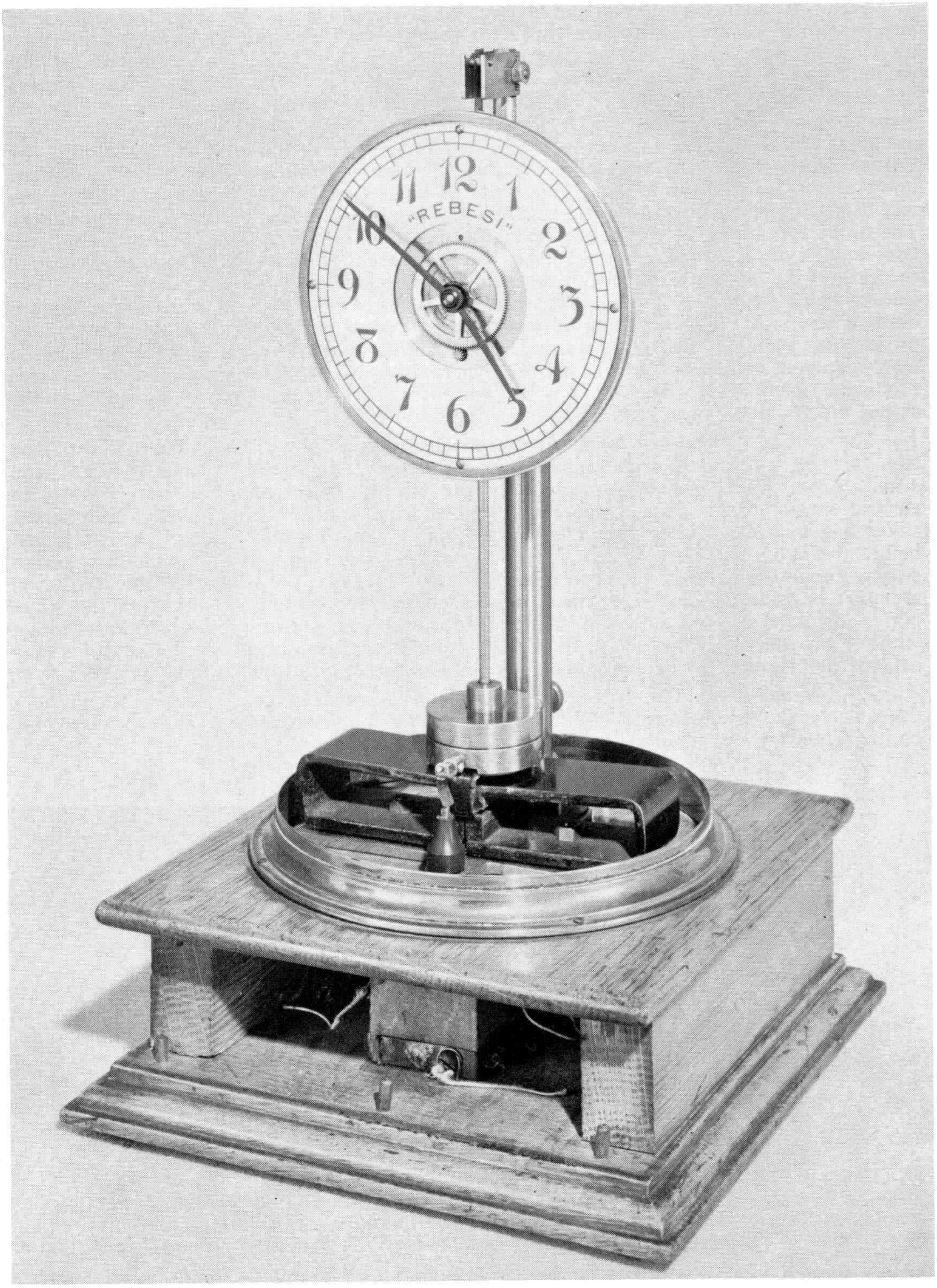
The main defect is the lightness of the electrical contact and the inconstancy of the contact resistance as a result, this is minimised by the use of a high resistance coil; also the amplitude of the pendulum swing depends on the applied voltage of the driving battery and there is no compensation fitted to neutralize the undesired effect. Precision timekeeping could not have been expected from a clock fitted with such a light pendulum bob in any case.

In the example shown, warping of the wooden base with atmospheric moisture changes causes the adjustment of the clock to be disturbed, it is therefore of no real practical use.

There is a brief reference to Frank Holden's work in *Electrical Timekeeping* by F. Hope-Jones.

Science Museum Negative No. 521/72.

PLATE 13



14. EUREKA ELECTRICALLY DRIVEN BALANCE WHEEL CLOCK, CIRCA 1910.

Plate 14 illustrates a late model of the Eureka electric clock, the first successful use of an electrically maintained balance wheel for timekeeping. The Eureka clock was invented by Timothy Bernard Powers, an electrical engineer in the U.S.A., and patented in 1906 conjointly with Sigismund, Herman and Gustav Kutnow, the latter being manufacturing chemists whose most profitable product was aperient powder. Many years of development were necessary to perfect the mechanism and it was not until 1909 that a manufactory was set up at 361 City Road, London, to commence production of the novel electric clock. The Eureka clock met with studied indifference or hostility from conventional clockmakers, however the Kutnows were early exponents of the art of advertising, even achieving the feat of getting King Edward VI to examine their new clock before putting it on the market. The novel appearance of the large rotating balance became the best selling feature and the later models always displayed the balance in a prominent position as in Plate 14. Many of the earliest models were in wooden cases and the balance wheel could not be seen. The Eureka clock was fitted into a great variety of styles of cases from glass domes to lantern clock cases, most of these being very attractive. Many of these clocks were bought by professional men for display in waiting rooms for there is a very soothing effect derived from watching a Eureka clock in action. Approximately ten thousand of these clocks were produced, manufacture ceasing in 1914 when the First World War broke out and the skilled electrical workers were drafted into the Services.

The arm of the balance is an iron cored electro-magnet with two external soft iron bars forming a magnetic circuit open at one end only. Below the balance is a soft iron armature which attracts the open end of the electro-magnet magnetic circuit when an electric current passes through the coil. A silver pin carried by the balance contacts a silver flag contact mounted on a light steel spring fixed to the frame of the clock just before the open end of the magnetic circuit reaches the fixed soft iron armature, and a strong impulse is given to the balance, ceasing just before the centre of the fixed iron armature is reached. On the return of the balance no contact is made because the silver pin is insulated on one side and passes over the reverse side of the silver flag contact without an electrical contact taking place. There are usually 45 swings of the heavy balance per minute, giving the unusual oscillation period of two and two-thirds seconds.

A "seconds" hand is fitted to the example shown but this is rarely found in a Eureka clock. The timekeeping can be excellent for long periods and then become erratic, often for no accountable reason.

FURTHER REFERENCES:

Electrical Engineering, page 563, 17th June, 1909, "New Electric Clock".
Horological Journal, pages 172-3, July, 1909, "The Eureka Electric Clock".
Model Engineer, pages 364-366 and 390, 12th September, 1957, "The Clock that was years ahead of its time" by B. S. T. Wallace.
Science Museum Negative No. 1666/76.


Nº
7825
PATENT
Nº 14614
1906
FAST

15. MURDAY ELECTRICALLY DRIVEN PENDULUM CLOCK, CIRCA 1910.

The Murday electrically driven pendulum is basically little different from the original Hipp Toggle electric clock and has the same features of a trailing pivoted lever which clears a notched block if the pendulum amplitude is above a minimum amount, and depresses it to make an electrical contact when the minimum arc of swing is reached. Murday incorporated a nickel steel pendulum rod to compensate for temperature changes. His reverse escapement for allowing the pendulum to drive the clock train consists of two wire arms which alternately push and pull the teeth of a ratchet wheel, each swing of the pendulum resulting in the ratchet wheel moving forward the space of half a tooth. His system has less merit than that employed by earlier workers, for although Murday's aim was to reduce the number of parts in the clock, he did not make a very successful attempt or result.

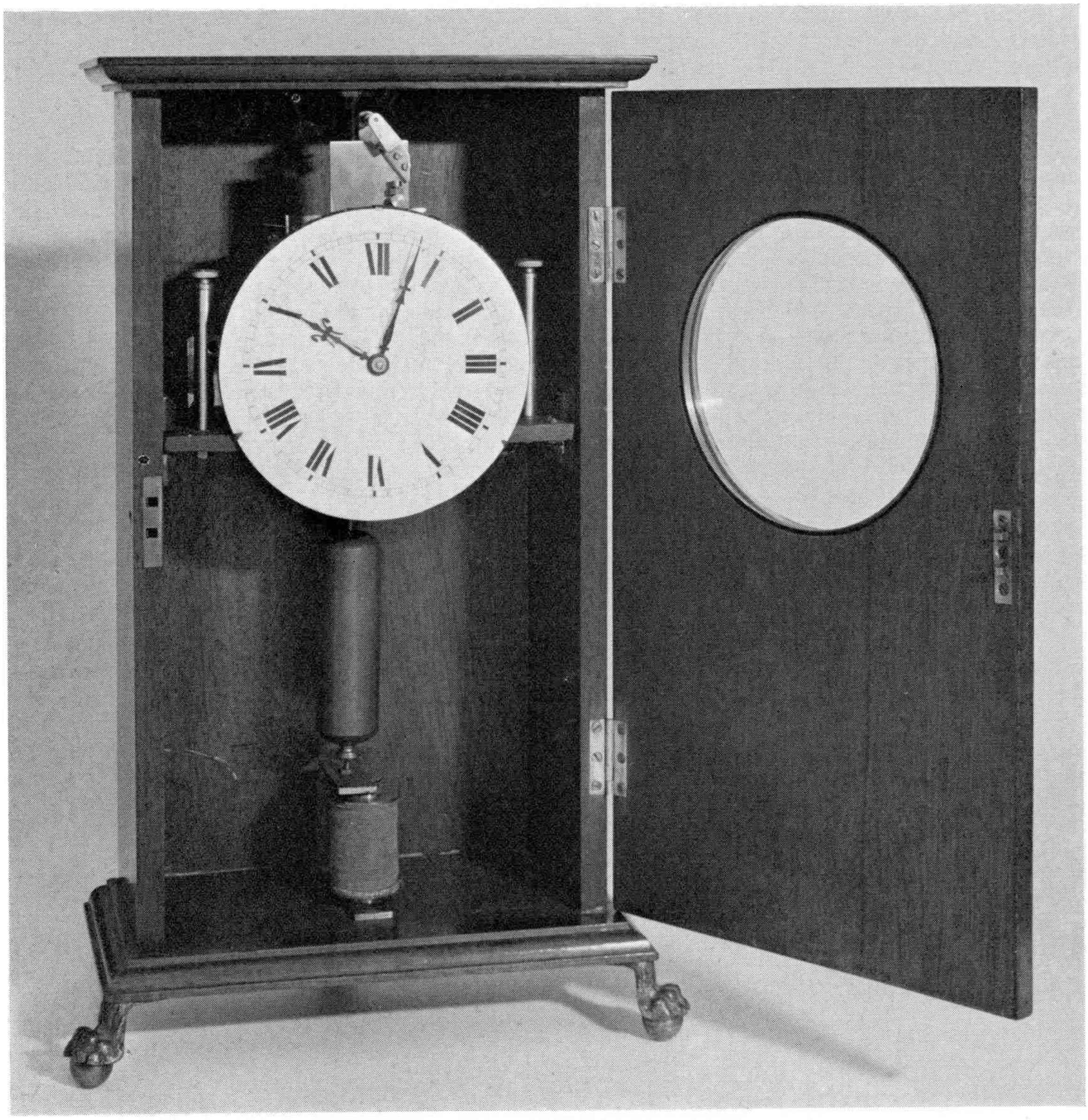
This particular clock was presented by the Reason Manufacturing Company of Brighton (who made the clocks for Murday) in 1912 to the works foreman, Mr. Goldring, in appreciation of the services he rendered to the Company. It seems unlikely that many clocks of this type were manufactured although Murday had spent many years of his time in experiment and hard work to produce the clock.

It would appear that many workers such as Murday did not bother to first ascertain what other workers had done in the same field of endeavour, he was basically an electrical engineer and his research did not add anything to the progress of electrical horology.

REFERENCES:

Scientific American, page 146, 20th August, 1910, and December 1910.
Horological Journal, pages 56-58, December, 1910, "The New Electric Pendulum and Balance-Wheel Clocks" by the Reason Manufacturing Company, Ltd. (Murday's Patents).
Patents Nos. 22819 of 1908, and 1326 of 1910.
Science Museum Negative No. 1665/76.

PLATE 15



16. MURDAY ELECTRICALLY DRIVEN BALANCE WHEEL CLOCK, CIRCA 1912.

There have been few applications of the Hipp Toggle principle to the balance wheel control of clocks. Plate 15 shows the most famous of these, Murday's Electrically Driven Balance Wheel Clock, for which Murday took out Patent No. 1326 of 1910. He utilized the propulsion mechanism, originally designed for his earlier pendulum clock, with some modifications for his balance wheel clock. Murday's electrically driven balance wheel clock is by far the most imposing of all the electrical balance wheel clocks made, for the nickel plated balance is five inches in diameter and turns at a majestic fifteen oscillations per minute.

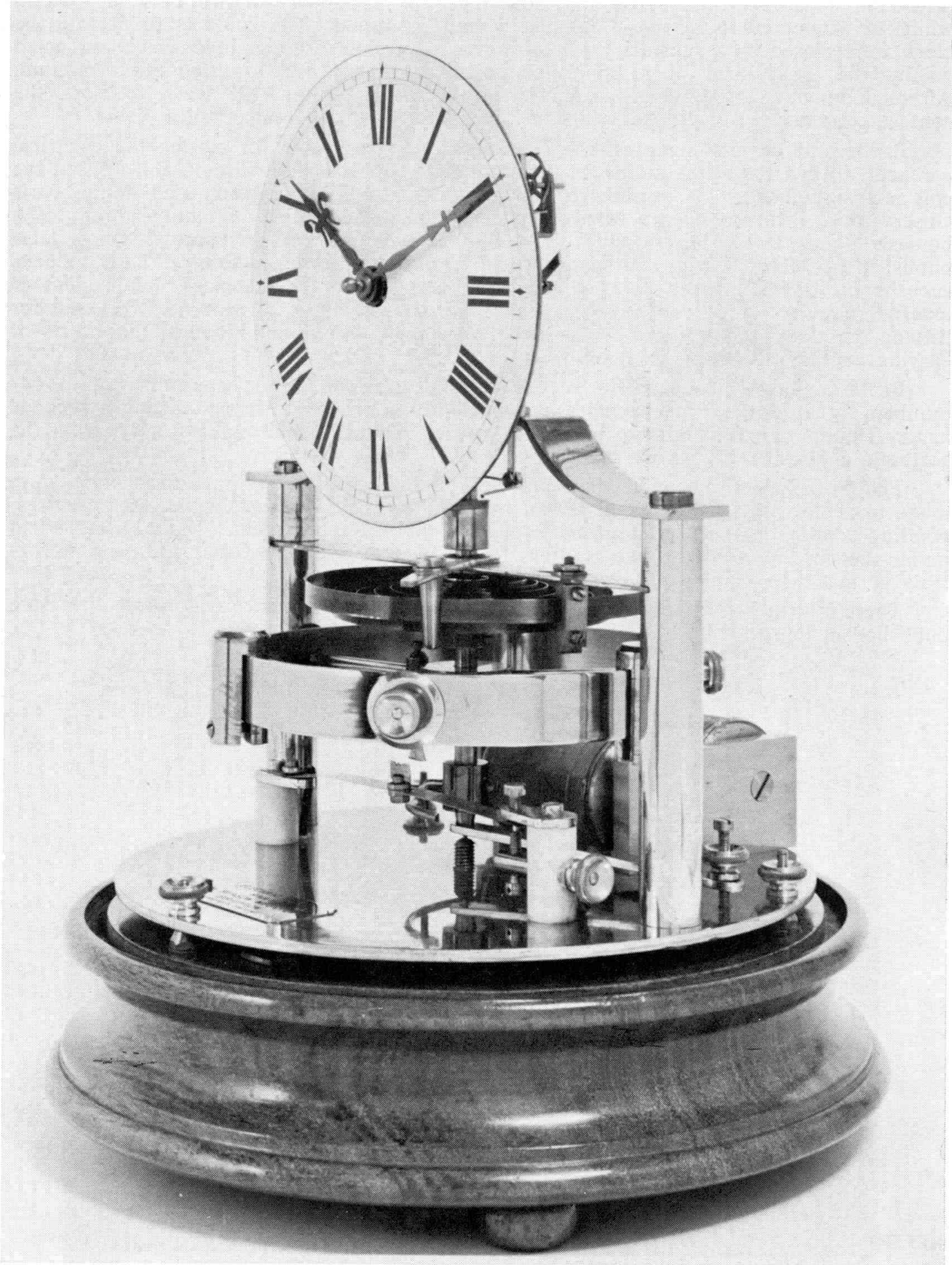
A small pivoted lever is carried on the arm of the balance and passes over a two-notched steel projection mounted on a flexible metal strip fixed at one end under the balance quite freely as long as the balance amplitude is above a minimum arc. When this minimum arc is reached, the lever fails to clear the notches in the steel projection and forces it down on the reversal of the balance swing, causing a contact on the end of the flexible spring to meet a fixed contact mounted on an insulated pillar. A current of electricity from the cells housed in the wooden base of the clock passes through the two-pole electro-magnet at the rear, energising it and attracting towards it a soft iron armature free to turn on one end. The other end carries a curved projecting arm which presses upon a pin mounted on the balance arbor, impulsing the balance and then returning as the toggle is released, cutting off the flow of electricity. The increase in amplitude of the balance is sufficient to allow the balance to swing freely for up to twenty times before the toggle is acted on again. The impulse to the balance is given at the extremity of the swing, an incorrect point for good timekeeping. A pin on the upper part of the balance arbor engages in a fork which actuates the drive to the clock train and motion work of the dial.

Murday did not appreciate that the change in elasticity of the balance spring is responsible for the change in rate with change in temperature, for he fitted a balance wheel of invar but used a carbon steel balance spring, as a result there is no temperature compensation whatever. A glass chapter ring was generally fitted to allow the operating mechanism to be seen clearly.

Murday showed great ingenuity in achieving an imperfect timekeeper, and it is the incidental fascinating appearance which has ensured that examples of his clocks have survived. About three hundred were made.

REFERENCE:
A Conspectus of Electrical Timekeeping, C. K. Aked.
Science Museum Negative No. 1832/76.

PLATE 16



17. BRILLIÉ ELECTRO-MAGNETIC PENDULUM CLOCK, CIRCA 1914.

The handsome electric clock in the gilt brass four-glass case shown in Plate 17 is a direct descendant of the electric clock developed by Professor Charles Féry in 1908 in which he attempted to achieve a completely free pendulum. The contacts to operate the clock were closed by a subsidiary pendulum having a closed copper loop which was acted on by the upper arm of a horseshoe-shaped magnet carried on the free pendulum. Although no physical contact was made by the free pendulum, the work to close the contacts was abstracted from it, thus the arrangement had no real practical value.

Brillié and Le Roy removed the subsidiary pendulum used for closing the electrical contacts, altered the shape of the magnet to improve the magnetic circuit, and utilised the coil and pendulum in " la pendulette " for a synchronized time system used in the Paris Observatory. Professor Cornu carried out a mathematical analysis of the reactions of a horseshoe magnet passing through a solenoid carrying an electric current, it was later published by Marius Lavet, another electrical horologist working in France. Later models, such as the one illustrated here, have contacts fitted to make the clock independent of external circuits. A special silver chloride cell, shown in the foreground, was used for driving the clock, the solenoid coil having a very high resistance to reduce the effects of varying contact resistance to a minimum.

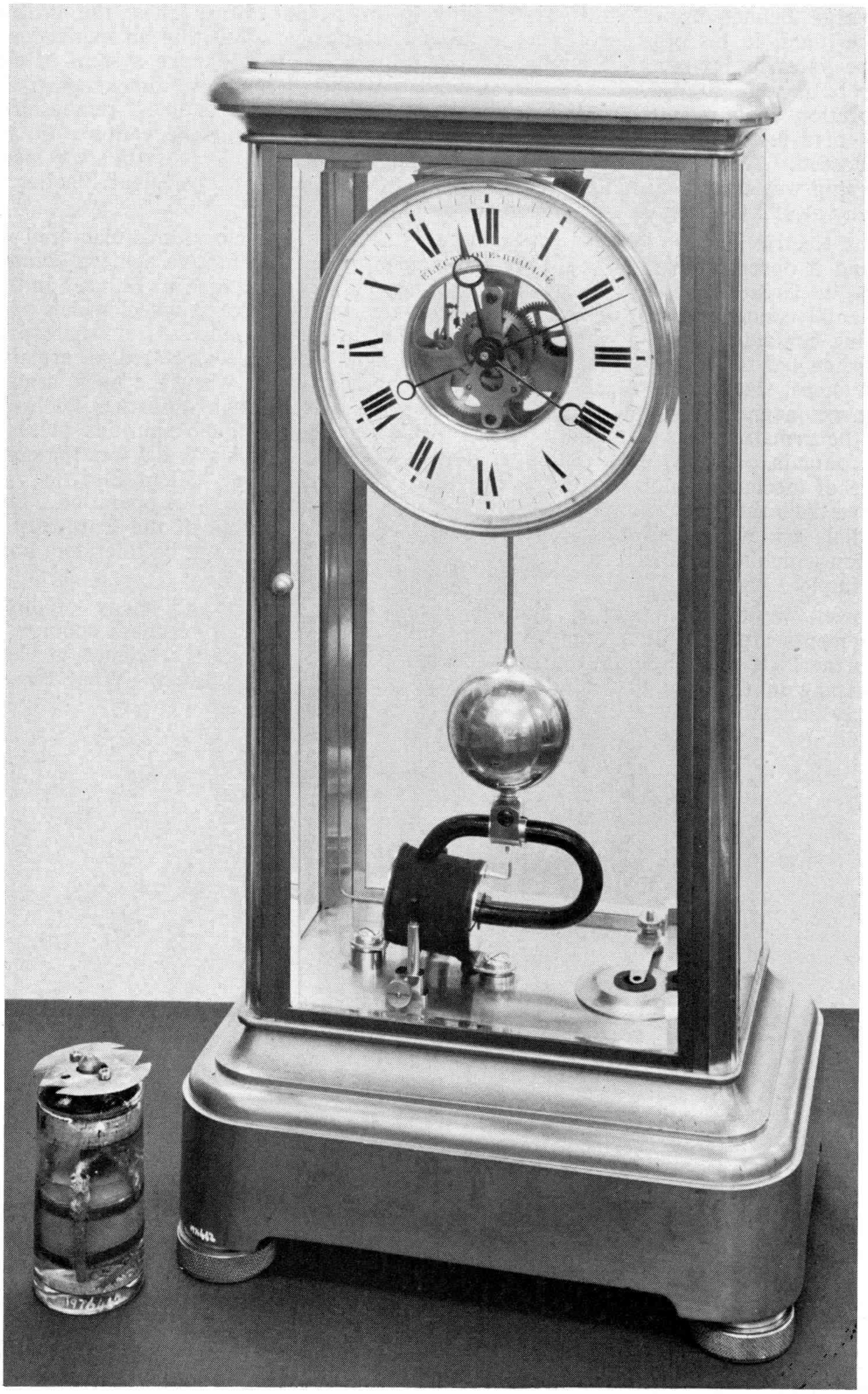
Brillié's electric clocks were very successful in France and have survived in fair numbers because the timekeeping was sufficiently accurate to warrant fitting a seconds hand. The spheroidal pendulum bob was favoured by the French makers, apart from the aesthetic appearance it has no significance.

The Brillié electro-magnet pendulum clock needs accurate levelling, arrangements are made to achieve this in the clock shown by a pointer fixed to the solenoid, with a corresponding pointer on the pendulum under the top limb of the magnet. The adjustable feet under the base allowed the two pointers to be lined up to ensure that the pendulum is truly vertical when at rest.

There is little information on these clocks to be found in electrical horology literature published in England.

REFERENCE:
Electrical Timekeeping. F. Hope-Jones.
Science Museum Negative No. 1410/76.

PLATE 17



18. SILENT ELECTRIC MASTER CLOCK AND SECONDARY DIAL, CIRCA 1913.

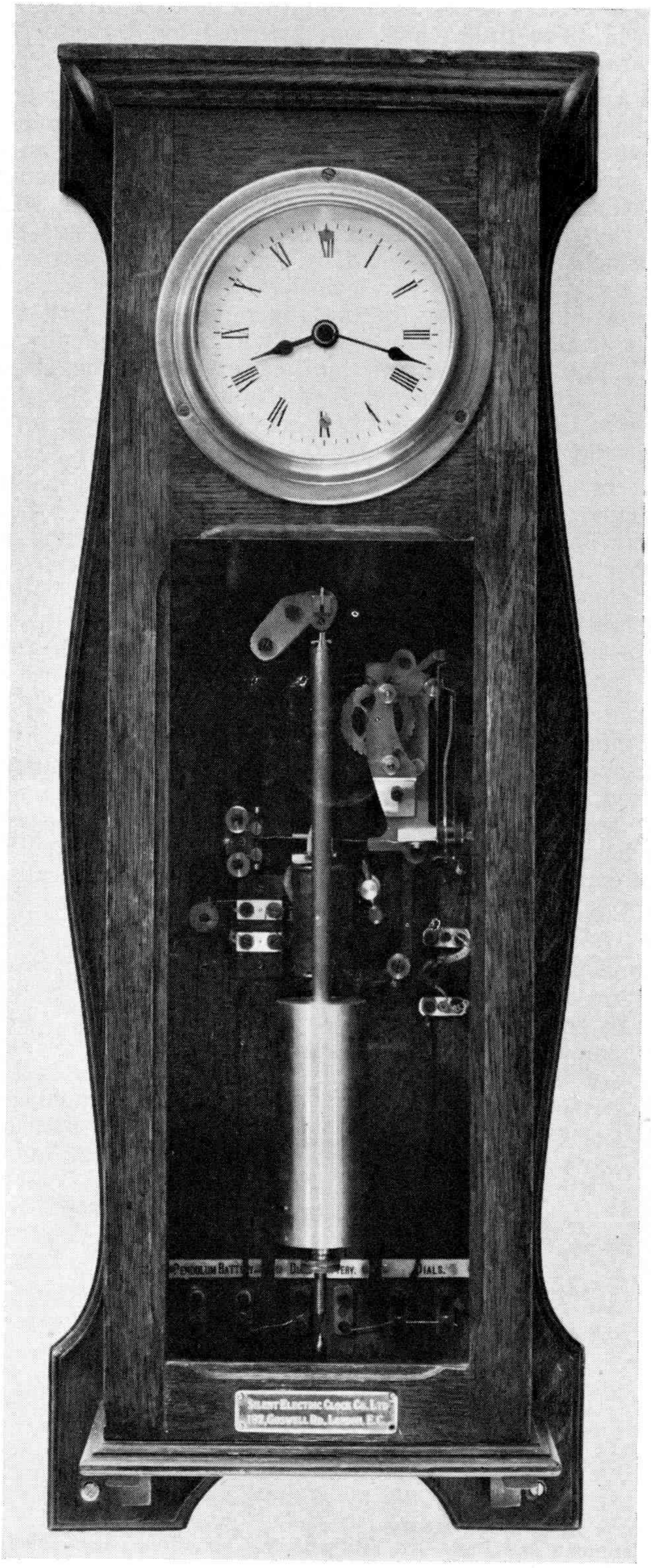
George Bennet Bowell (1875-1942) worked for Robert Hope-Jones, the brother of F. Hope-Jones, in his organ works as an electrical engineer. Visiting an exhibition with F. Hope-Jones in 1884, to see an installation of the Van der Plancke system of electric clocks; both were fired with enthusiasm for applying electricity to timekeeping. Their collaboration soon resulted in the development of the "Synchronome" remontoire, the subject of a lecture to the British Horological Institute in 1895; the venture did not at first succeed. As a result of some difference in the personalities of the two men, the partnership was dissolved and Bowell formed his own company, The Silent Electric Clock Company at 192 Goswell Road, London.

The electric master clock shown in Plate 18 is one of the clocks manufactured by the firm, and it operates on the Hipp Toggle principle, one of the first to achieve commercial success in Great Britain although it had long enjoyed success in France and other Continental countries. In this clock the pendulum rotated a count wheel which operated switching contacts at half-minute intervals to provide current pulses of alternate polarity, these being fed to slave dials of Bowell's own design. The pulses rotated an armature of special shape, the current turning the armature by 90°, whilst when the pulse ceased the permanent magnet surrounding the armature rotated it through a further 90°. At all times the armature was securely held against malfunction through spurious pulses from faulty contacts, or multiple pulses. The great merit of Bowell's slave dial was the complete absence of mechanical noise in operation, hence the trade name "Silent Electric", for all the slave dials then in use for timekeeping systems were quite noisy in operation . Bowell's slave dials achieved a fair degree of commercial success because of the feature of silent operation which allowed their use in situations where noise could not be tolerated, hospitals for example.

Bowell went on to design many unique electric clocks and many of his later developments are very interesting, however he did not have the business acumen of his late partner. It must be admitted that Bowell did not advance the science of electrical timekeeping in the way that his first promise would have suggested. What remains is not truly indicative of Bowell's genius.

Science Museum Negative No. 1660/76.

PLATE 18



19. BULLE ELECTRIC CLOCKS

Basically the Bulle electric clock is an improved version of the original Bain electric clock invented in 1843. The Bulle clock was invented by Professor Marcel Moulin and M. Favre Bulle of Paris in 1920.

A solenoid with a high resistance winding is carried at the lower end of the pendulum, as can be seen in the left-hand clock of Plate 19, and passes over a curved bar magnet with consequent magnetic poles. Near the top of the pendulum is an insulated silver pin which engages in a forked lever, one side of which carries a silver contact, the other has an insulating piece attached. The silver pin just contacts the fork with the pendulum at rest, thus when a battery is connected to the clock, a current passes through the solenoid to create a magnetic field which is repelled by one side of the bar magnet and attracted to the other side in the direction to give a positive pressure on the silver pin against the fork contact. There is sufficient play of the silver pin in the fork to allow the contact to be broken as the pendulum swing reverses, cutting off the flow of electric current through the solenoid until the pendulum motion returns to the original position. The clock is therefore self-starting, unusual for a pendulum clock. Once the amplitude builds up the silver pin leaves the fork completely to cut off the current without contact being made on the reverse swing.

Once the pendulum is swinging at the normal amplitude, the operating current is very low since the coil moving over the magnet acts as a generator whose voltage opposes that of the battery. The amplitude of swing of the pendulum is proportional to the applied battery voltage and would cause circular error, to avoid this an isochronal spring is fitted to the pendulum rod. A pecking pawl is turned by the fork lever and pushes a crown wheel round tooth by tooth, on the same arbor is a worm drive which propels the clock train. It is essential that the battery be connected with the positive terminal connected to the silver pin, as the clock will not function if the battery connections are reversed.

In the group of clocks shown in Plate 19, the left-hand example is the earliest type of Bulle electric clock, appearing for sale in 1921, the large brass column to the rear holds the single cell required. The centre example is an improved version with a folded magnet system to save space and improve the magnetic circuit, and has the spring clip fitted which allows the clock to be moved safely without damaging the fragile silk suspension ribbons on which the pendulum swings, these are easily snapped if the clock is roughly handled. On the extreme right is the Tempex clock, a cheaper version of the original Bulle electric clock, it has a bakelite base and is of a much lower quality of workmanship.

The Bulle Company stated their clocks would run for 800 days on a single cell. Examples of the cells sold by the Bulle Company are shown in the foreground, the black cells being provided by the parent French company, the lighter cells being of British make sold after the Bulle company ceased operation.

Many thousands of Bulle clocks were made, they were housed in a wide variety of cases, and proved to be very popular as they were usually good timekeepers when correctly adjusted. These clocks were marketed in Great Britain by The British Horo-Electric Ltd. The Bulle electric clock was the first where the losses in the metal bobbin for the solenoid were eliminated by splitting the bobbin lengthways and have a saw-cut in each cheek to prevent the eddy currents generated from abstracting energy from the swinging pendulum, a point completely overlooked by previous electric clock makers.

REFERENCES:

La Bulle-Clock Horlogerie Electrique. Henry L. Belmont, Besancon, 1975.
Electrical Horology. Langman and Ball. 3rd Edition, 1946, London, pages 159-161.

PLATE 19


PILE
BULLE-CLOCK
Nº 23
LA PILE
RÉGULATRICE
DE L'HEURE
REMPLACEMENT DE LA PILE
PILE
BULLE-CLOCK
Nº 24
REMPLACEMENT DE LA PILE
IMPORTANT
BULLE
BATTERY
TEMPEX

20. ELEKTRONOM ELECTRO-PNEUMATIC CLOCK, CIRCA 1930.

In the example shown in Plate 20, a slave dial driven by compressed air is illustrated. It was a development of a clock originally designed for the use of clockmakers as a special clock for the workshop which would not magnetise tools or pocket watches, nor require electrical knowledge either to make or service the clock.

The master clock worked on the following principle:

An electrical contact operated by the master clock closes an electrical circuit which allows current to pass through a filament contained in a glass lamp bulb, thus warming the air in the envelope. This rise in temperature expands the contained air and the increase in pressure is communicated to a cylinder containing a piston by means of a rubber tube, the motion of the piston winding a mainspring which drives a pendulum clock, giving a reserve of about eighteen hours when fully wound.

As the compressor lamp has a large amount of surplus power, slave clocks, up to six in number, could be served providing the connecting tube did not exceed 60 metres. One disadvantage was that the alternating pressure changes forced air in and out of the slave cylinders and a condenser was found to be necessary to prevent the entry of moisture which caused corrosion, seen here at the top of the case.

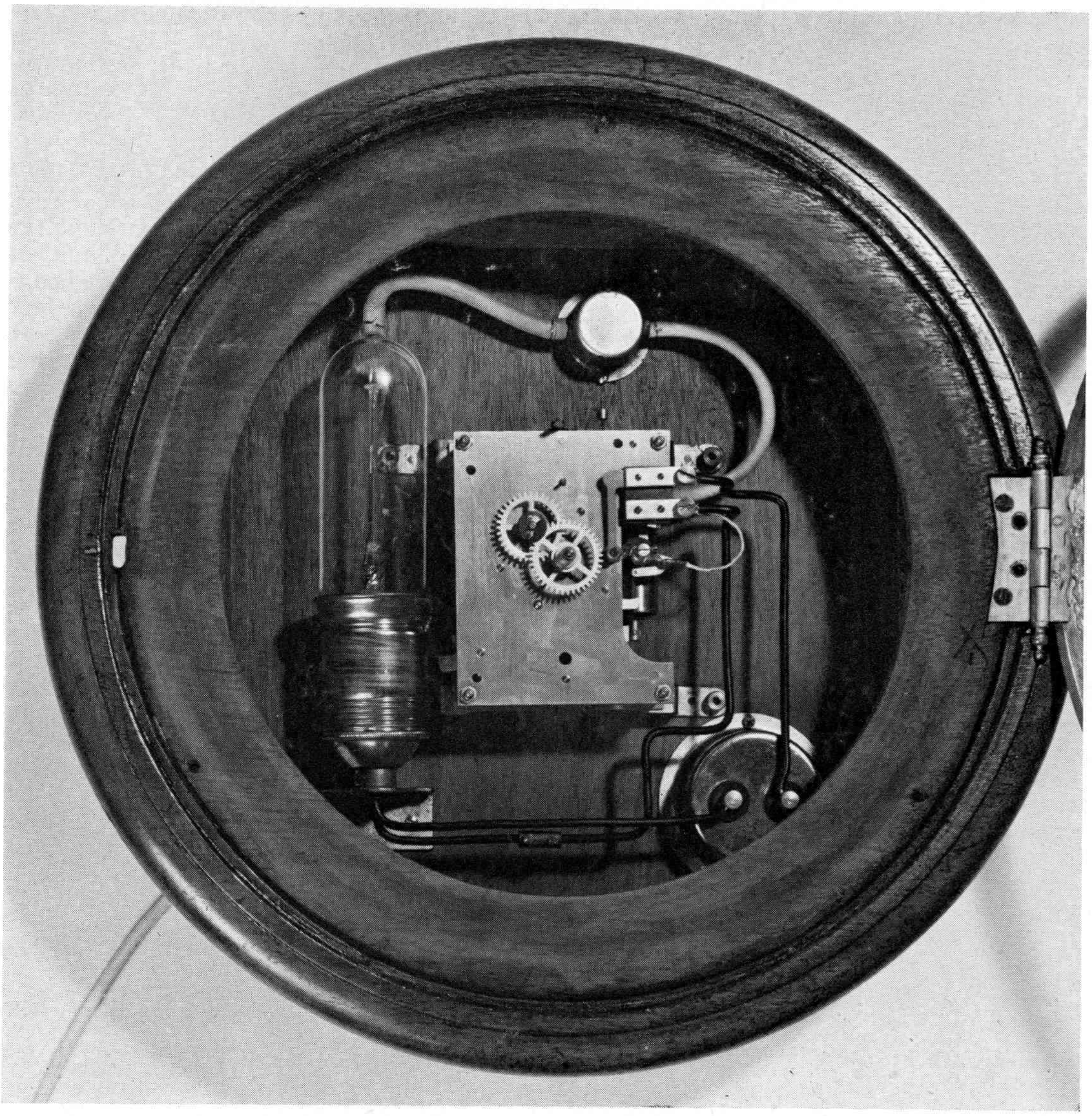
An alternative arrangement was devised whereby the contacts of the master clock also energised compressor lamps in slave clocks such as the one illustrated here. The rubber tubing was replaced by electric wires in these cases. The slave clock of this type had no power reserve and stopped in the case of power failure.

The heating of the compressor lamp worked equally well with alternating or direct current supplies, a good selling point at a time when domestic electricity supplies were very varied and changing from direct to alternating current. It was usual to run no more than six slave clocks from the master clock contacts, another six could be connected to the pneumatic circuit, making a total of twelve slave clocks.

These clocks were produced by the firm Gebr. Junghans A.G. of Schramberg and marketed as the "Elektronom" system for standard time distribution, or for a home clock installation (Heim-Uhrenanlage). Production ceased with the advent of the Second World War.

Science Museum Negative No. 1759/76.

PLATE 20



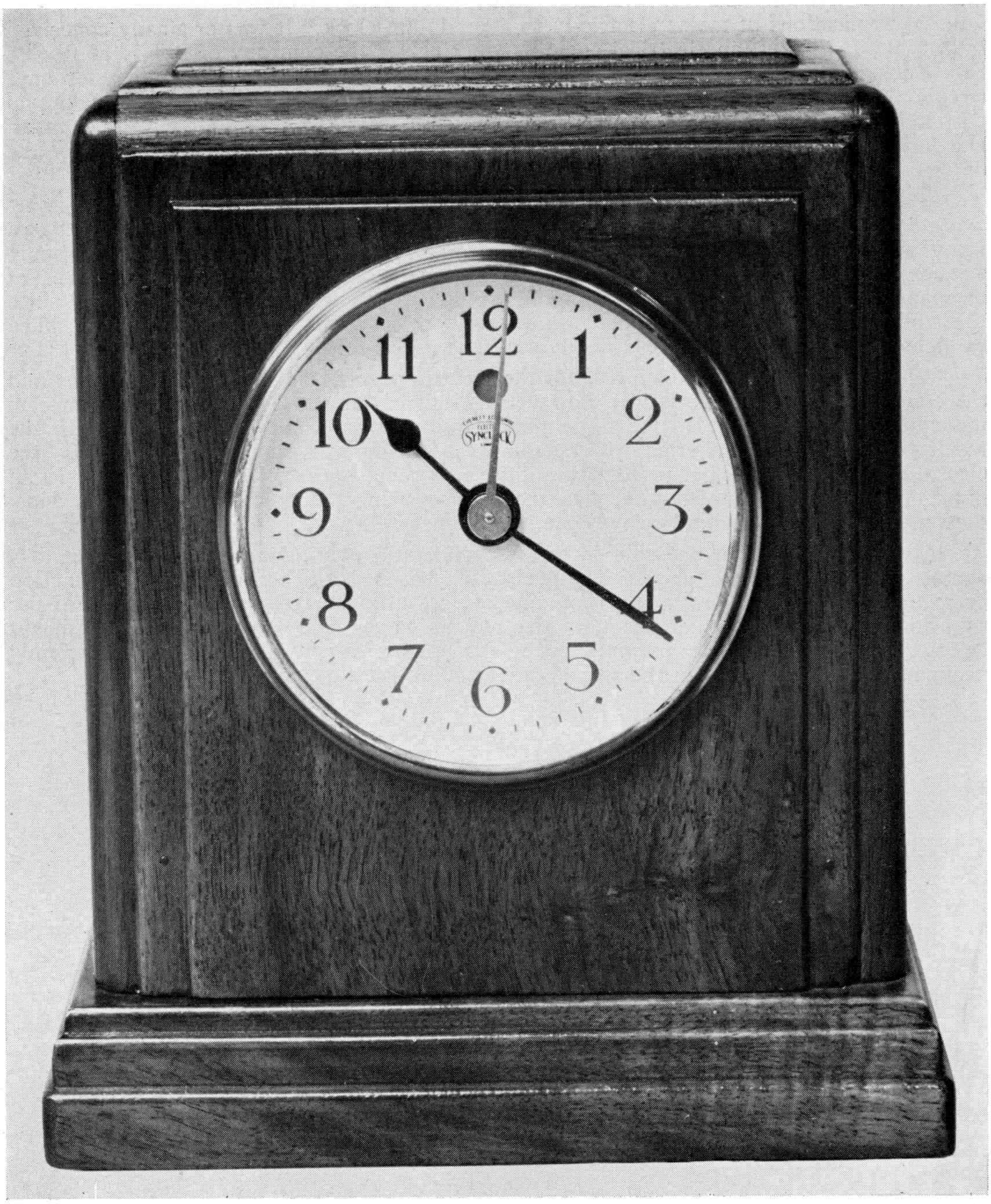
21. EVERETT EDGCUMBE SYNCLOCK SYNCHRONOUS ELECTRIC CLOCK, CIRCA 1931.

Everett, Edgcumbe and Company Ltd. was one of the first to introduce the synchronous electric clock to the United Kingdom in 1931, and one of these early models is shown in Plate 21, being sold under the trade name of "Synclock". The synchronous motor is of the "Warren" type having a laminated field magnet with four poles, one pair of opposite poles having thick copper rings which modify the alternating field produced by the alternating current passing through the winding on the field magnet in such a way that a rotating magnetic field is set up in the gap between the field magnet and the enclosed steel rotor. The field drags the rotor round at the rate of one revolution for each double alternation of current, giving a speed of 1,500 revolutions per minute for a 50 Hz supply frequency. An oil-filled bath held the reduction gearing to bring the speed of rotation down to one revolution per minute as in the clock shown, for driving the seconds hand, or, more usually, down to one revolution per hour and omitting the seconds indication.

The synchronous clock shown was self-starting, hence if the supply failed and then was restored, there would be an error in the indication equal to the period of failure of the supply. To show that a supply interruption had occurred, a red indicator moved into the aperture just below the figure 12 on the dial, warning that the indicated time was not correct. There was considerable controversy at the time as to whether self-starting or manual starting synchronous electric clocks were the most suitable, some users preferring a completely stopped clock to one that had restarted and thus indicated the incorrect time.

In the text accompanying Plate 4, mention is made of the synchronous electric clock designed by Charles Wheatstone, probably the first in the world. The true development of the synchronous electric clock rests with H. E. Warren of America who first took out a patent for this type of clock in 1918 and formed the Warren Telechron Company at Ashland, Massachusetts, U.S.A., his clocks were designed for the standard supply of 110 volts and 60 Hz frequency, consuming about two watts in operation. As with the later British developments, Warren had great trouble in getting the supply companies to maintain the correct frequency so necessary for accurate timekeeping. In England the creation of the "Grid System" for supply mains overcame all the previous disadvantages of varying frequency on the accuracy of indication, and the synchronous electric clock became widely used. Difficulties in maintaining power supplies since the last war have caused a loss of popularity in these clocks, firstly the inability of the Central Electricity Generating Board to maintain the correct frequency of 50Hz when the Grid system is heavily loaded, secondly the advent of the accurate and reliable battery clocks, notably quartz crystal types. The need for a supply outlet and connecting lead is a very great disadvantage.

PLATE 21



22. "CLINKER" MAINS-DRIVEN NON-SYNCHRONOUS ELECTRIC CLOCK, CIRCA 1932.

The non-synchronous electric clock illustrated in Plate 21 represents one of the most unusual applications of mains electricity to a pendulum clock. It was originally conceived by Mr. R. C. Clinker, an electrical engineer working for the company of B T-H of Rugby, and it depends for its operation on the finite time taken for changes to occur in a resonant circuit. If an a.c. voltage be applied to a resonant circuit the envelope of the maximum current rises with successive cycles according to the formula $e=E(1-e^{-Rt/2L})$, i.e. in an exponential manner. In a similar manner, a lag occurs if a change occurs on one of the parameters of the circuit, e.g. in the inductance.

A small laminated iron armature is attached to the lower end of the pendulum, passing over an open iron core upon which is wound a coil of wire forming the inductive part of a resonant circuit, tuned by a parallel capacitor to resonance with the mains supply frequency when the pendulum armature is remote from the core. The condition of resonance can be obtained with a series or parallel capacitor, the latter is preferred since the voltages across the components are lower than with the series capacitor. The combination is fed from the mains supply with a series capacitor.

When the iron armature approaches the electro-magnet, the inductance increases and the condition for resonance is lost, however the fall in current lags behind the change in inductance causing it due to the finite time required for the changes to occur, with the result that the pendulum armature experiences a greater attraction as it approaches the electro-magnet than when it recedes, the difference being imparted to the pendulum as an impulse to maintain it in motion. On the reverse swing the preceding conditions apply once more, i.e. the pendulum receives one impulse per swing.

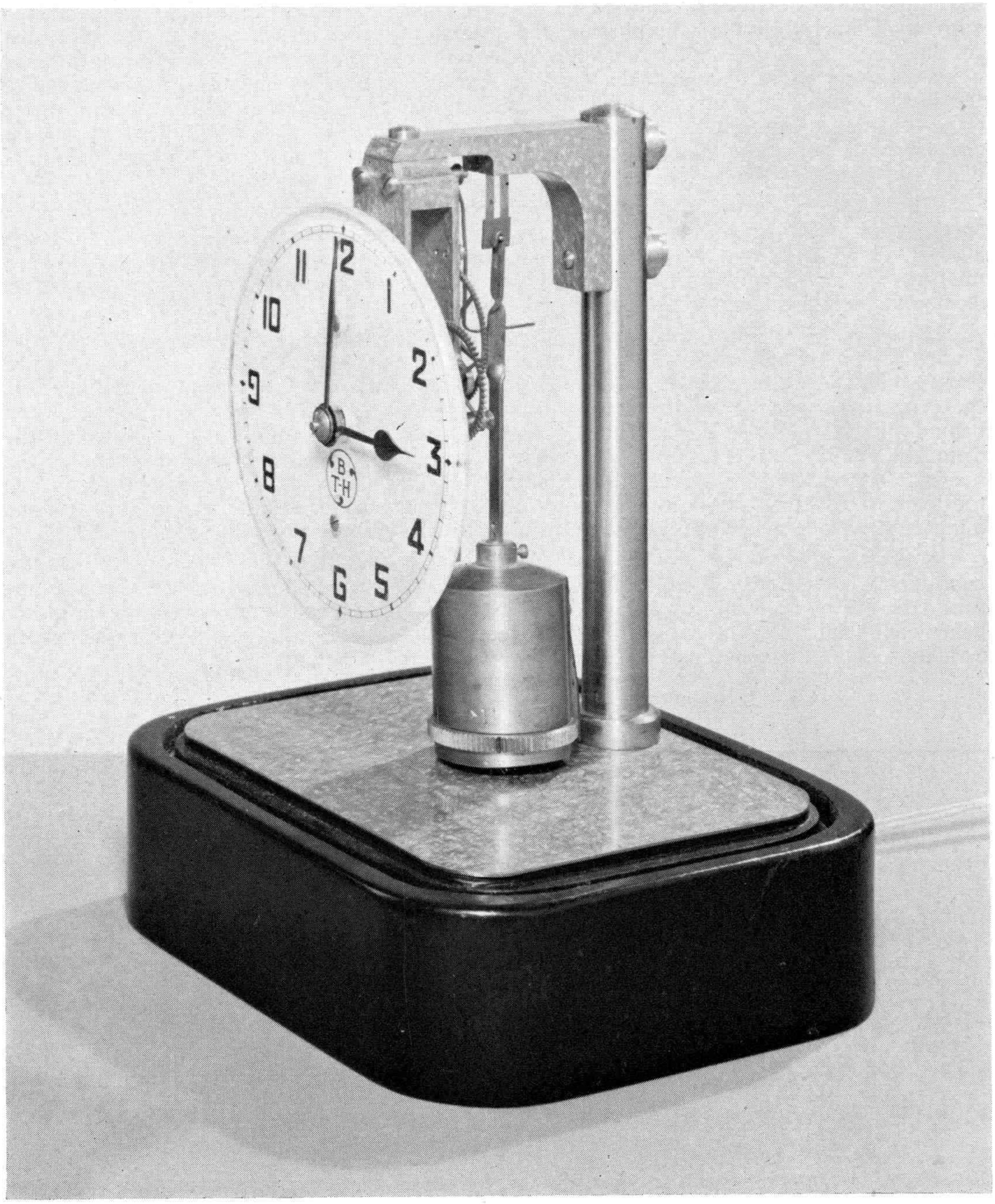
A crutch bearing on one side of the pendulum rod only, communicates motion to a simple pawl and ratchet drive. The pendulum has a large arc of swing to function correctly, it is therefore not a precision timekeeper, although completely adequate for use as a domestic clock for which the attractive motion makes it ideally suited. The resonant circuit absorbs very little power, making the mains supply consumption completely negligible, and much less than the normal synchronous electric clock.

REFERENCE:

The Clinker Non-Synchronous Electric Clock. C. A. Mason. Institution of Electrical Engineers Students Quarterly Journal, Volume 4, No. 16, pages 163-6, June, 1934.

Science Museum Negative No. 1599/76.

PLATE 22



23. SMITH SYNCHRONOUS ELECTRIC MYSTERY CLOCK, CIRCA 1935.

Mystery clocks have a fascination of their own and were extremely popular at the beginning of the nineteenth century, the makers' aim being the indication of time combined with the impossibility of discovering the means of achieving it even under the most careful scrutiny. In the 1930's the clock trade went to great lengths to provide eye-catching novelties in an effort to boost sales, and the example illustrated in Plate 23 is a revival of the mystery clock in a contemporary design. As can be seen from the illustration, there is no visible connection to the hands of the clock, and no possibility of using a glass circular plate with outer teeth such as was used in certain mystery clocks having circular dials and bezels in which the teeth of the glass wheel could be readily concealed.

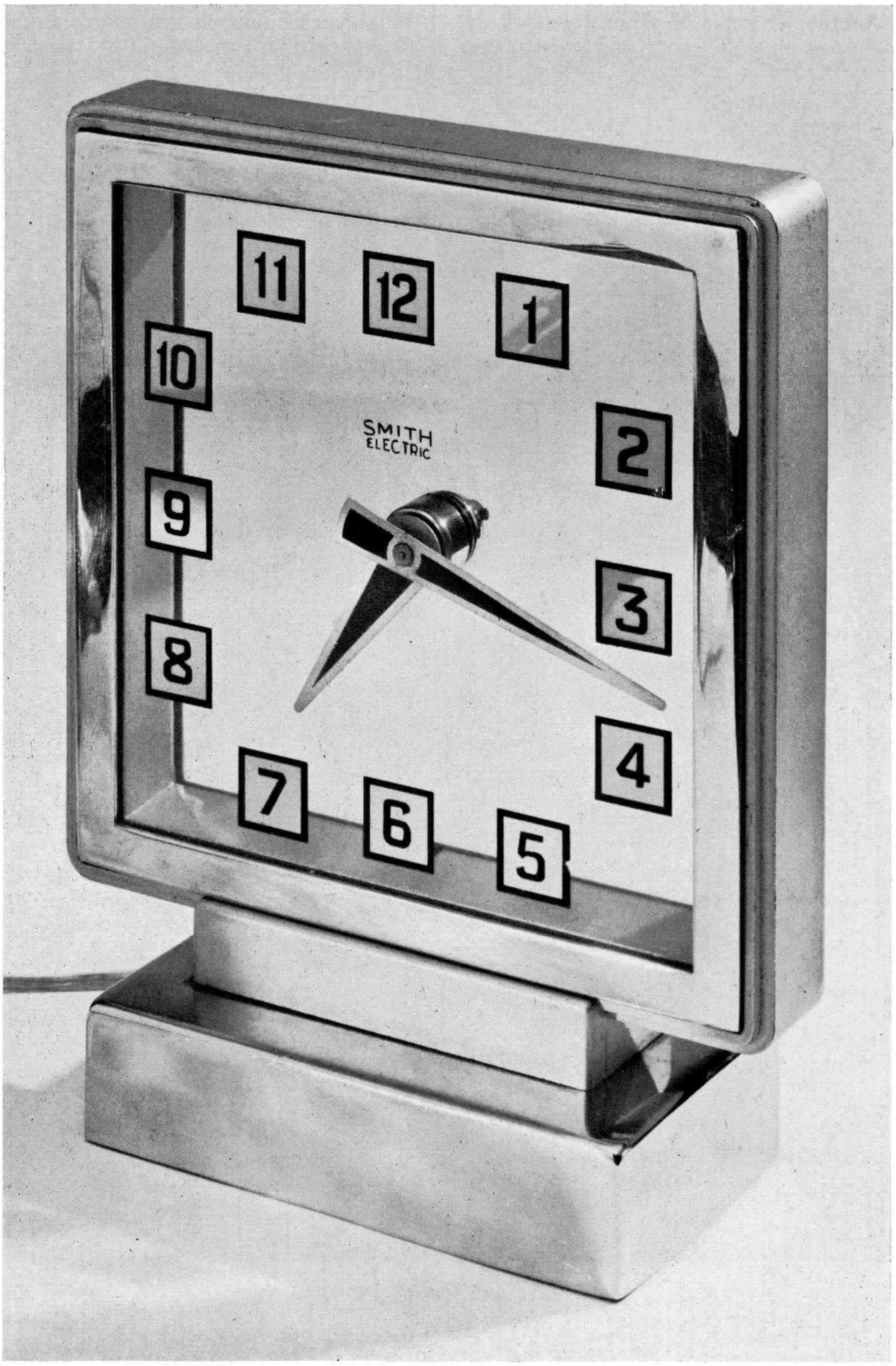
The metal base of the example shown contains a synchronous motor running at a speed of 200 rpm from a 50 cycle main supply. The motor spindle is mounted vertically and drives through two worm reduction gears of 10:1 and 20:1 respectively to give a final drive of one revolution per minute which turns a cranked arm conveying reciprocating motion via a rocking arm to the time indicating mechanism.

Three plates of glass are contained in the square framed metal surround, the front carries the painted figures, the rear is plain, both being fixed. Between the two is a third plate which can move up and down through a total distance of approximately half an inch, the centre having a hole whose edge is concealed in a groove of the small drum located behind the hands. The necessary 12:1 motion work for the hour hand is housed in the drum in addition to a ratchet and click required to prevent reverse rotation of the hands. Movement of the centre glass plate in one direction moves the ratchet back one tooth of the driving wheel in the drum, as it returns the hands are driven forward one minute; the plate receiving its motion from the rocking lever previously mentioned.

Several patents cover the design, 374713, 366710 and 10068 of 1934. The clock was manufactured by Smith English Clocks Ltd., of Cricklewood, London, in 1935 and some time later, to work from 200-250 volts, 50 cycle ac main supplies, the synchronous motor being, self-starting. The model illustrated has the dimensions: height 8 inches, width 6¾ inches, depth 2¾ inches, and is housed in a chromium-plated case.

REFERENCE:
Practical Watch and Clock Maker, page 42-3, April, 1935.
Science Museum Negative No. 1662/76.

PLATE 23



24. CLIPPER SYNCHRONOUS ELECTRIC CLOCK, CIRCA 1947.

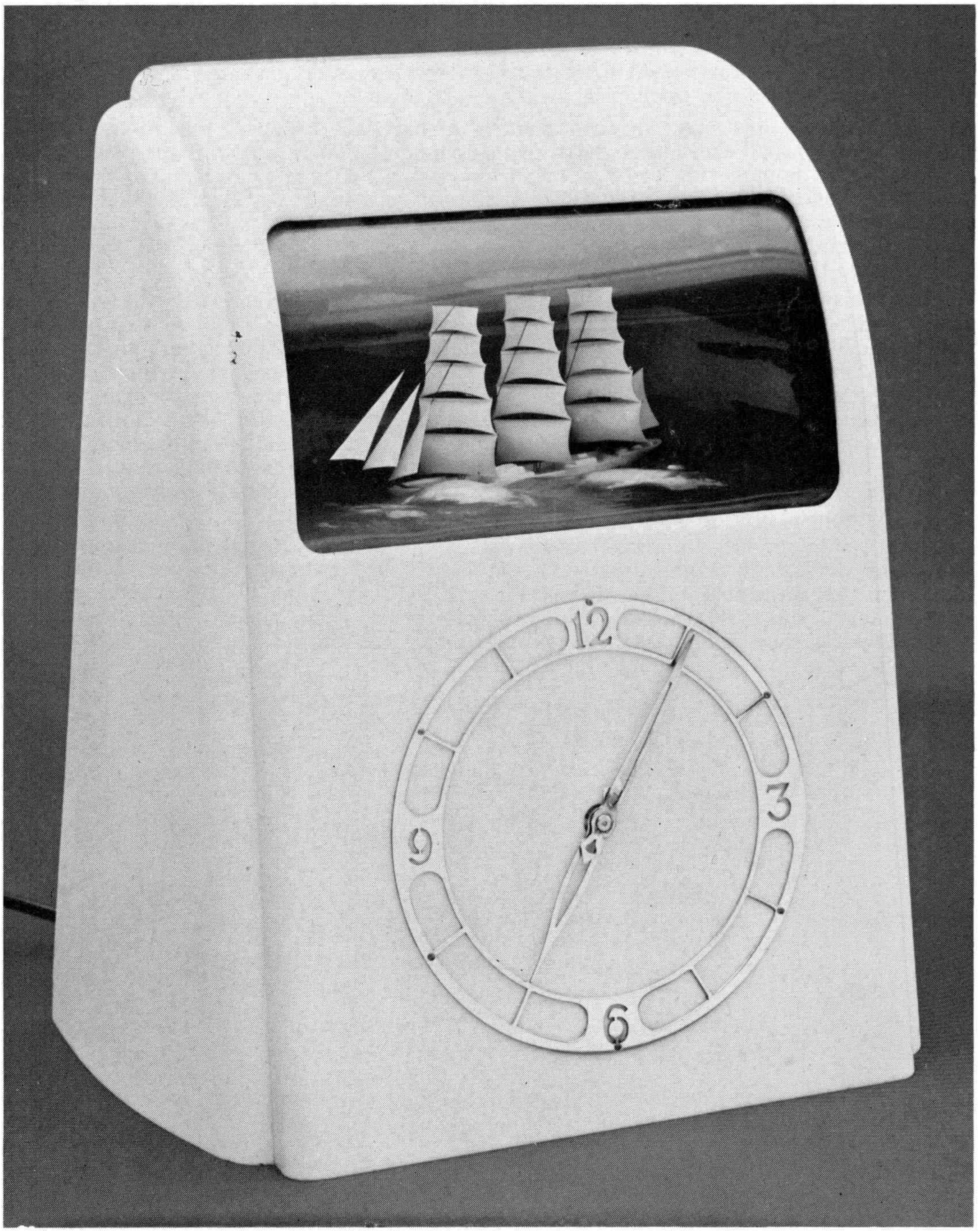
Another example of a novelty clock driven by a synchronous electric motor from the ac mains supply. The ample power reserve of the synchronous motor allows the driving of subsidiary mechanisms without interfering with the timekeeping function.

Plate 24 illustrates the "Clipper Ship Clock" manufactured by Vitascope Industries Ltd. of the Isle of Man, Great Britain, in the late 1940's. A manual start synchronous motor rated at 230 volts 50 cycles drives the clock hands in the usual way, and in addition drives an oval drum through a worm reduction gearing. The oval drum moves the "clipper ship" in the "sea", simulating the pitching and tossing in a realistic manner, whilst a second drum with a dyed gelatine cover over an internal lamp, rotates also to provide a constantly changing lighting to the background. The effect is sufficiently realistic to make those subject to "mal de mer" feel somewhat squeamish. The clock shown here has a serial number of 06239.

Overall dimensions for the clock illustrated are: height 12¾ inches, width 10¾ inches, depth 6½ inches. Many patents for the clock design were taken out, 550361 (1941), 580886 (1944), 632500 (1947) in the United Kingdom, 2488483 in the United States; and others in Switzerland and France.

J. S. Thatcher was the original patentee, followed by J. F. Summersgill, both in the United Kingdom. The clock has no serious horological content, for it was intended mainly as a novelty. It may be noted there is no provision for protecting the hands by a glass and bezel in the example shown. The case is of cream bakelite, the present modern plastics were not then available for commercial use, and the comparative fragility of the case has resulted in most of these clocks being damaged by accidents through ordinary usage.

Science Museum Negative No. 1668/76.



25. KUNDO TRANSISTORISED ELECTRIC CLOCK MODEL 1101, CIRCA 1957.

The electric clock shown here in Plate 25 is the Kundo transistorised electric clock manufactured by the firm of Keininger and Obergfell in Western Germany, and marketed by B. H. Ries Ltd., 19-21 Hatton Garden, London, EC1. Powered by a single Mignon Cell type R6, it was claimed to run for a year (some sources state 5-6 years). It is one of the first commercial electric clocks to make use of the transistor, invented only about eight years previously, as a non-mechanical switch.

In the clock illustrated, the pendulum is λ-shaped and holds a curved bar magnet which passes through the hollow metal cylinder mounted on the base of the clock. This metal cylinder houses two coils, a transistor, and a 5,000 ohm resistor. One coil is used as a drive coil and has the 5,000 ohm resistor connected in parallel with it, the other coil is used as a trigger coil and is mounted to the right of the metal cylinder, one side of this coil is connected to the base of the transistor; the collector of the transistor is connected to the drive coil.

As the pendulum reverses its swing after reaching the extreme left, the magnet is accelerated until there is sufficient current generated in the trigger coil to switch on the transistor, allowing current to flow through the transistor from the battery to the drive coil. The magnetic field created in the drive coil repels the magnet on the pendulum, impulsing the pendulum until the pendulum approaches the extreme right, the velocity of the magnet is less than that required to switch the transistor, hence the transistor switches off and the impulse ceases. The impulse to the pendulum is therefore in one direction only. To reduce the back emf generated when the transistor is switched off, the resistor of 5,000 ohms is connected across the power coil to dissipate the energy stored in the magnetic field, otherwise damage to the transistor might result.

The pendulum has an invar rod to reduce the effect of temperature changes, and drives the clock train in the usual way, the train being jewelled to reduce friction to a minimum. An adjustable nut on the pendulum is used for rating the pendulum and gives an adjustment of $\pm$ 40 seconds in twenty-four hours. The model shown here has a height of nine inches, and a base diameter of six and a half inches.

REFERENCES:

American Horologist and Jeweler. June, 1957, pages 40 - 41.
Horological Journal. October, 1961, page 652. B. H. Ries advertisement.

PLATE 25

26. HETTICH ELECTRIC CLOCK WITH FLOATING BALANCE, CIRCA 1965.

The floating balance clock was introduced about 1957 by the West German firm of Blech and Hettich to replace domestic clocks having short pendulums. Small domestic clocks have to contend with the moving imposed by the proud housewife in search of dust, and pendulum clocks do not take kindly to the constant handling. The model shown here is one of the later models and is very attractive in appearance.

A 1·5 volt cell provides the motive power and is used to raise a weighted arm when it reaches a lower position and makes contact with a contact on an arm attached to an armature, the resulting current energising an electro-magnet, throwing the weighted arm upwards sharply until the electrical contacts separate*. As the weighted arm falls it drives the clock mechanism for about fifty second before resetting occurs. A maintaining spring is fitted to drive the clock whilst the resetting takes place, this has a reserve of about forty seconds. The floating balance his a double helical balance spring of 28 turns, allowing it to turn without moving up or down although there are no pivots to support the balance. The large screws in the balance rim are for timing the balance since there is no regulator fitted, the time of oscillation is two seconds. and the seconds hand moves forward at every swing.

The escapement is a modified pin pallet with a double impulse pin, and there are only three wheels in the driving train. The weighted arm drives the train via a toothless ratchet wheel, giving a longer working life than the customary ratchet wheel and click.

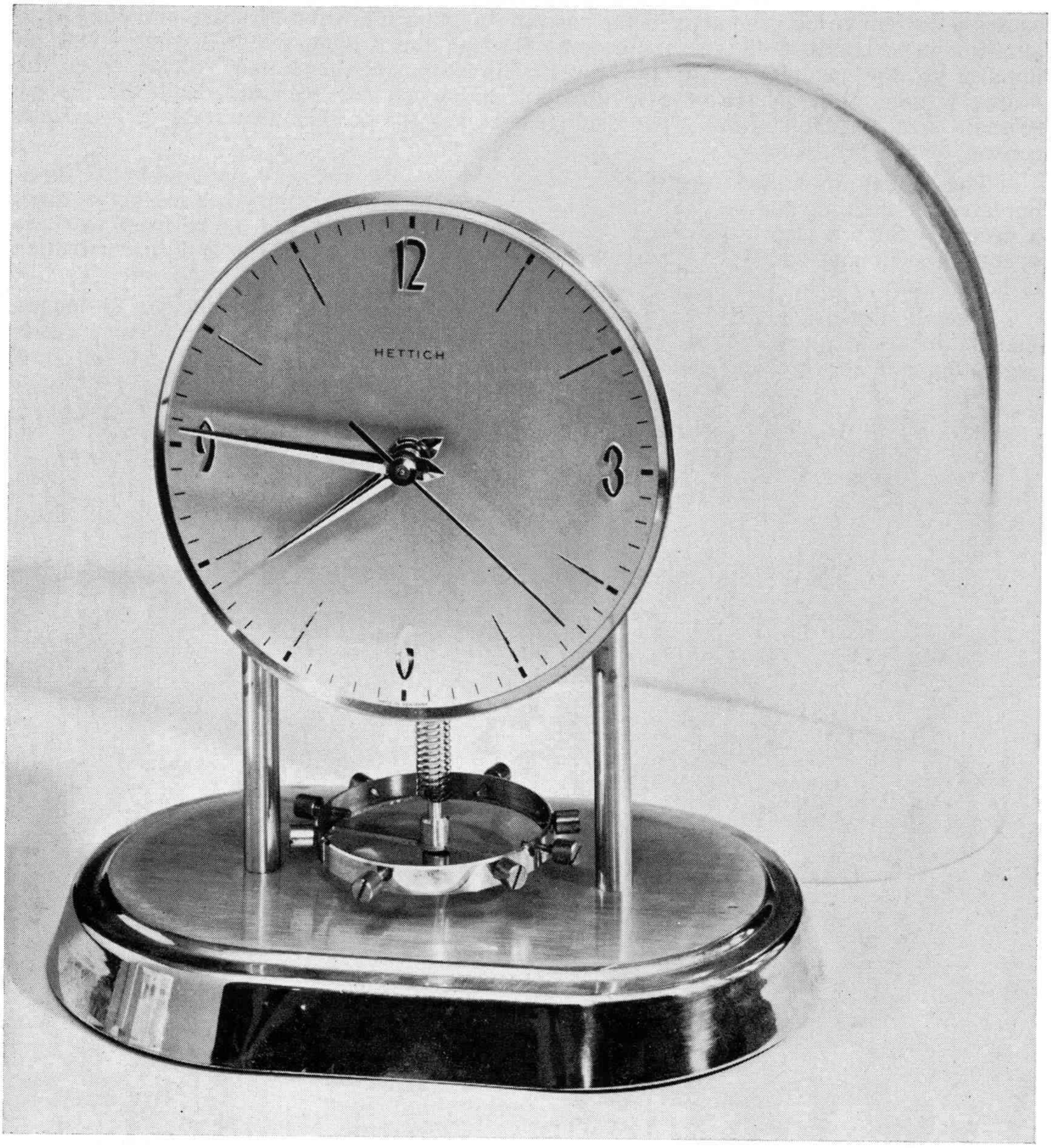
In normal running conditions the balance has an amplitude of just over $1\frac{1}{2}$ turns and it takes some little time to settle to a constant value on restarting the clock. If the clock is dismantled at any time it is necessary to ensure that the maintaining power be set up again or the clock may not function correctly.

The accuracy of the clock was about 30 seconds a week or so and it was of use only where the noise of resetting was of no consequence, it was quite unsuitable for use in bedrooms for example.

*F. Hope-Jones was the first to use such a system in England, the so-called Synchronome Remontoire which appeared in 1895 for driving a pendulum clock.

Science Museum Negative No. 1670/76.

PLATE 26



27. ESTYMA TRANSISTORISED ELECTRIC CLOCK, CIRCA 1972.

Many battery electric clock manufacturers took advantage of the development of the transistor to provide circuit switching without using metallic contacts, these having been a fruitful source of trouble in clocks which have to run continuously for years on end.

In the Estyma transistorised Ato type EL-30 electric clock of German manufacture illustrated in Plate 27, the bar magnet in traversing the switching solenoid in one direction causes a current to be generated in the correct direction to switch the base of a transistor, allowing it to conduct and pass a current through the driving solenoid, thus giving an impulse to the pendulum. In the reverse direction the generated voltage from the switching solnoid is in the reverse direction to switch the transistor and the driving solenoid remains unenergised. The arrangement has the further advantage of amplitude control of the pendulum.

The model illustrated here works from a single 1·5 volt cell on which the clock operates for at least one year, the pendulum is five inches in length, beating three times a second. Such a short pendulum would be inaccurate if it had to perform work in operating switching contacts. The power required to drive the transistor into conduction is insignificant.

Overall dimensions of the clock are: Base 6 inches in diameter, height 8½ inches, dial 3½ inches diameter; dome 5 inches in diameter, 7 inches in height. The circular regulating nut above the pendulum bob alters the rate by 60 seconds for one full turn.

Science Museum Negative No. 1667/76.

PLATE 27

28. ENGLISH CLOCK SYSTEMS QUARTZ CRYSTAL MASTER CLOCK AND SLAVE DIAL, CIRCA 1962.

The Electronic Master Clock Type Quartz-M-11 and associated slave dial type School-3-d illustrated in Plate 28, represents a pioneer application of the quartz crystal controlled master clock for driving a system of slave dials. Patek Philippe of Switzerland were responsible for the design and manufacture of the quartz crystal master clock shown in the lower half of the illustration, the slave dial in the upper half being designed and made by English Clock Systems Ltd., a subsidiary of Smiths Industries Limited, Clock and Watch Division.

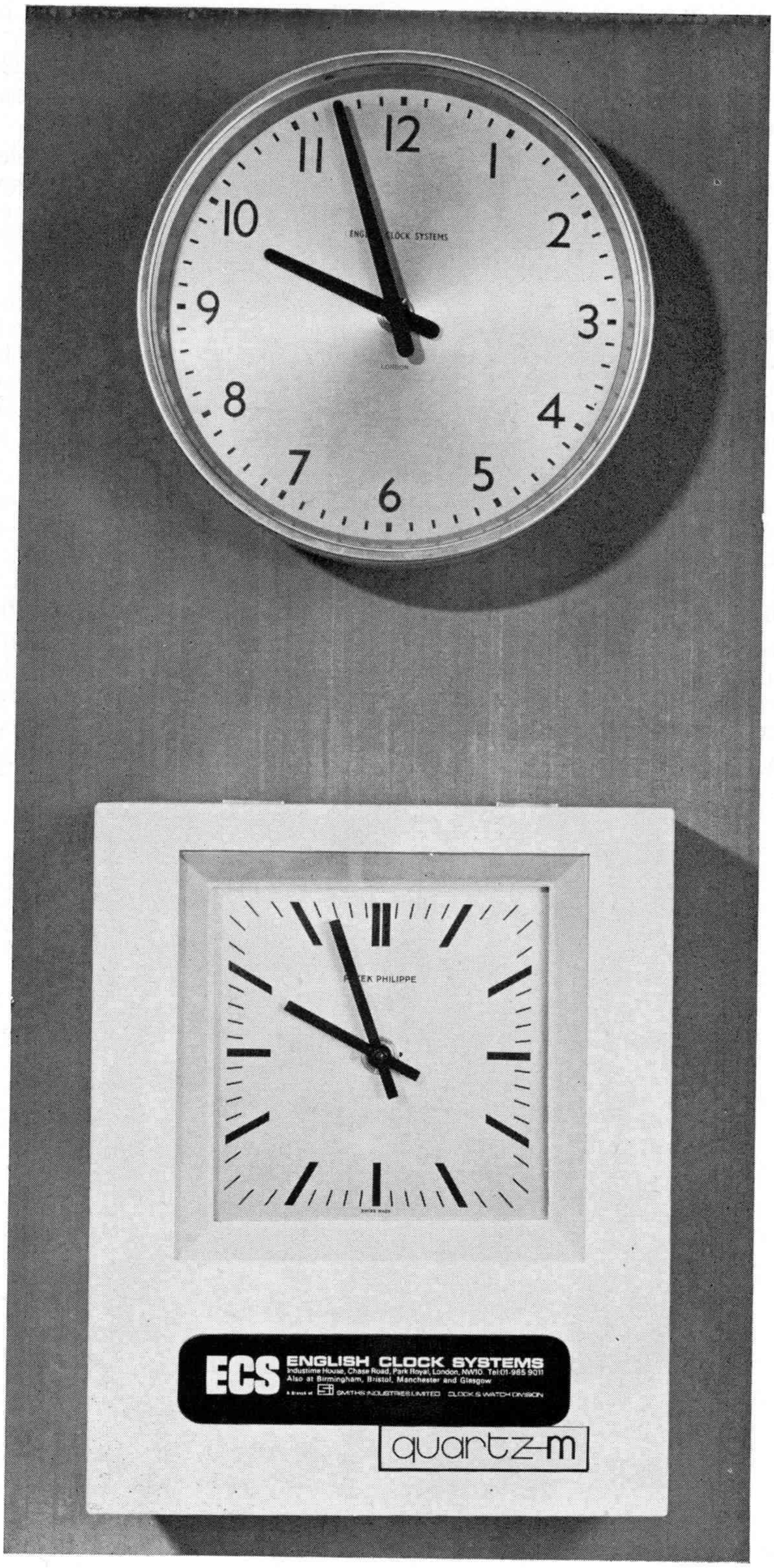
A nickel-cadmium battery powers the quartz crystal master clock and is trickle charged from the ac mains. The master clock generates pulses of current with a duration of one second at one minute intervals, the maximum current being limited to one ampere, sufficient to drive up to a maximum of 125 slave dials directly. Should the mains supply fail, the master clock continues to function from the battery but does not drive the slave dials in order to conserve the battery power; an electronic memory stores up the number of pulses in the period of supply failure. On restoration of the mains supply, the slave dials are advanced at a rapid rate until the correct time is indicated once more.

Push button controls are fitted to enable the slave dials to be stopped when required, e.g. for putting the clocks back at the end of British Summer Time, or advanced rapidly, e.g. at the beginning of British Summer Time; and then synchonized absolutely to a time signal. When the master clock is correctly adjusted and rated, the clock will not lose or gain more than one-tenth of a second per *diem,* i.e. a continuous loss or gain would take almost two years to give an error of one minute on the slave dials if no corrective action was applied.

The clocks illustrated were presented to the Science Museum by English Clock Systems.

Science Museum Negative No. 1723/76.

PLATE 28


12
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8
9
10
11
ENGLISH CLOCK SYSTEMS
ECS
ENGLISH CLOCK SYSTEMS
Industime House, Chase Road, Park Royal, London, NW10. Tel:01-965 9011
Also at Birmingham, Bristol, Manchester and Glasgow
SMITHS INDUSTRIES LIMITED CLOCK & WATCH DIVISION
quartz-m

29. DERBY ELECTRONIC WORLD TIME CLOCK, CIRCA 1970.

Although this electric clock (model type 2969) is an imposing creation, being intended for the executive's desk, it is no more than a modern development of the "picture" type of clock. As such it is aethetically satisfying, but the advertisement which heralded its entry into the commercial world is typical of the play on words by horologists to enhance the seeming superiority of the product.

Basically the "Electronic Time Clock" is an Ebauche type of electric balance movement, i.e. a mechanical "high frequency" balance of higher than the normal beat rate of 18,000, five beats per second, maintained by a transistorised circuit controlling the current from a battery of 1·4 volts. It is euphemistically described as "Electronic High Frequency" in the advertisement.

A mechanical drive from the electric clock movement is used to transport the tape showing the hours from 1-24 across the base of the world map from right to left, the hours being duplicated on the half of the tape not visible and lying within the clock panel, i.e. there are two 1-24 hour indications forming a single loop of tape. The position of the tape can be adjusted to indicate local time at the particular longitude desired. In Plate 29 it is set for Greenwich mean time, and the time for any other place on the world map can be ascertained almost at a glance.

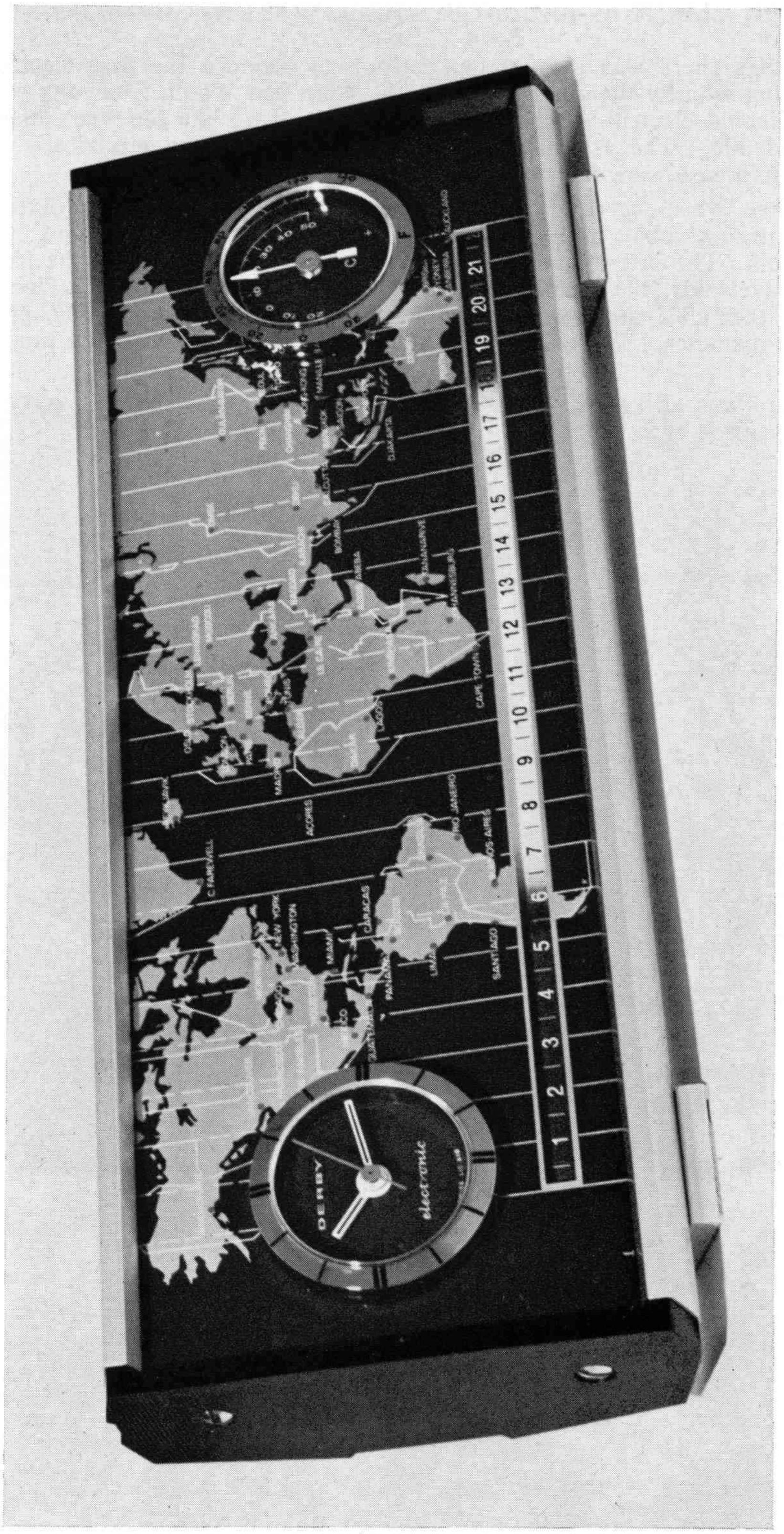
The day and night indication shown is the civil division of day and night, and not the sunlit and dark portions of the world as the appearance of the strip might lead an observer to believe. Such an indication of night and day can be very useful to the business man who wishes to contact people in other parts of the world, it is difficult to visualise this easily in one's mind, especially if concentrating on a specific problem.

Complementary to the clock dial indicating seconds, minutes, and hours, is a thermometer dial on the right-hand side of the world map. The world map is enamelled in several colours and his time zone lines clearly indicated, a useful feature since the time zones are often distorted through geographical necessity.

These electric clocks were made by Ebauches Electroniques S.A., Neuchatel, Switzerland.

Science Museum Negative No. 1807/76.

PLATE 29



30. HAMILTON ELECTRIC BALANCE WHEEL WATCH, CIRCA 1957.

In the 1950's there was a great competition to produce the first electrically driven watch, this being won by the American firm the Hamilton Watch Company who marketed the first commercial electric watch in 1957 after something like ten years of research, see Plates 30a and 30b. The associated problems of producing an electrically driven time-keeper in a watch case were then very great indeed.

The balance wheel carries a minute coil which passes over two fixed permanent magnets of platinum cobalt alloy at the time two contacts are closed and current passes through the coil. The interaction of the two magnetic fields impulses the balance in one direction of travel only, the contacts not closing as the balance returns. One contact was of silver, the other gold, and the coil was wound with about 200 feet of copper wire only 0·0006 inch in diameter. The contacts make and break about 80 million times in a year's operation.

The battery was also specially designed to power the watch for a period of one year, it was of zinc-carbon type.

REFERENCE:

Horological Journal, Volume XCIX, No. 1186, pages 406-412. July, 1957. " An Analysis of the Electric Watch " by R. Good.

Science Museum Negative No. 1640/76.

PLATE 30a

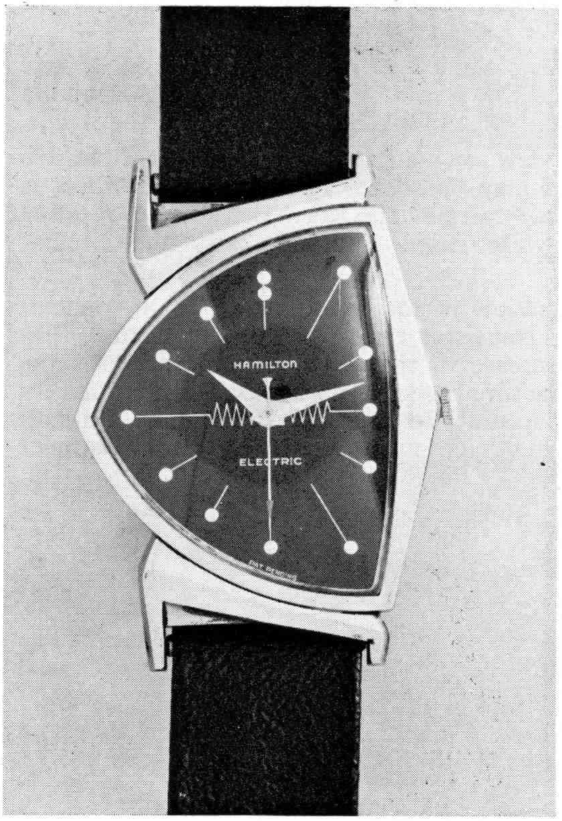
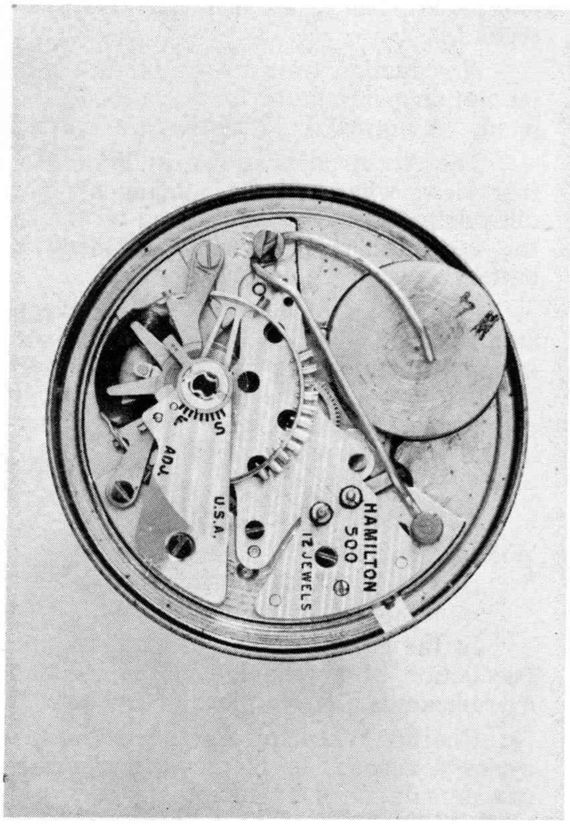


PLATE 30b



31. ACCUTRON WATCH AND PROTOTYPE MOVEMENT, CIRCA 1960.

First appearing about 1960, the revolutionary " Accutron " watch made by the Bulova company was described as the " first " electronic watch. A more realistic description would be electronically maintained, for the heart of the system is a miniature tuning fork of an elinvar alloy 25mm in length, vibrating 360 times a second. Each tine of the tuning fork carries a soft iron cup with a conical magnet located centrally within it. Two fixed windings occupy the space thus formed, one coil carried 8,000 turns, the other 6,000 turns, both drive coils, the latter having a secondary winding of 2,000 turns known as the phase sensing winding which is used to control the current pulses through the drive coils by means of a switching transistor. A miniature mercury cell of 1·3 volts is used to power the mechanism, consumption being of the order of 10 microwatts.

The oscillating motion of the tuning fork is converted to rotary motion by a click on one of the tines acting on a fine-toothed wheel having 300 teeth, the travel being only one-thousandth of an inch per oscillation, the resulting speed being 1·2 revolutions per second.

A reduction train to the minute hand converts the 1·2 revolutions per second to one revolution per minute for the seconds hand and one revolution per hour for the minute hand. A normal 1:12 motion work drives the hour hand and allows setting of the hands.

The Accutron is shown in Plate 31a front view, and a prototype model in Plate 31b rear view; where all the components mentioned may be seen. The 36 toothed wheel is difficult to see but it is mounted on the small arbor carrying the worm drive wheel rotating the seconds hand arbor. Prominent is the white cased transistor, also the circular battery.

An important part of the timekeeping function is the maintenance of a constant amplitude of vibration of the tuning fork by the transistor circuit. An increase of +10% in amplitude reduces the impulse to zero, a decrease of the same amount increases the impulse to double the normal value, restoring the amplitude to its correct value in a very short time. The timekeeping was claimed to be accurate to within ± one minute a month in use when correctly adjusted. To rate the watch each cup is fitted with an adjustment piece.

The period of oscillation of a fork at *low* amplitudes is given by: $T = \frac{L^2.e}{t}$

Where L = length of tines
t = thickness of tines
e = coefficient of elasticity

In the course of one day the tines move back and forth over 31 million times. The production of a reliable mechanism to withstand the prodigious number of mechanical movements is a masterpiece of precision engineering in miniature.

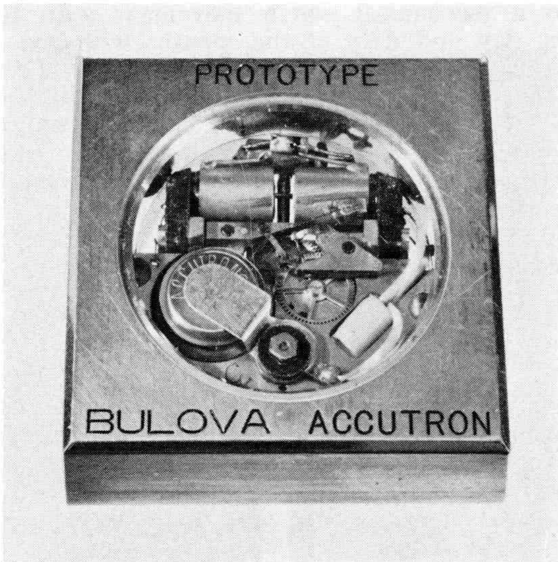
Charles Wheatstone was one of the first to use a vibrating reed, of one thousand cycles a second, to measure brief periods of time with his chronograph of the 1850's, it was maintained by compressed air at low pressure.

REFERENCE:

The " Accutron ", Bulova's Electronic Watch. L. Defossez. *Swiss Watch and Jewellery Journal,* No. 1, February, 1961.
Science Museum Negative Nos. 1639/76 and 1909/76.

PLATE 31a

PLATE 31b



32. SEIKO QUARTZ CRYSTAL WATCH, CIRCA 1969.

By 1967 complex integrated circuits were developed of sufficient sophistication to allow the housing of all the electronic circuits for a quartz crystal timekeeper in a watch case. In Switzerland a consortium of Swiss firms under the title of *Centre Electronique Horloger* produced prototype models of the Beta-21 quartz crystal watch which set new standards of timekeeping accuracy in the chronometer trials at Neuchâtel and Geneva observatories.

The first commercially available quartz crystal watch was, however, produced by Seiko in 1969. A quartz crystal oscillating at 16,384 Hz was used as the controlling element, the high frequency output being divided by a chain of counters to produce current pulses at intervals of one second to drive a stepping motor, which in turn drives the watch hands *via* a reduction train.

Science Museum Negative No. 1635/76.

33. CRISTALONIC SOLAR POWERED QUARTZ CRYSTAL WATCH.

The limited space available for a cell in the quartz crystal watch results in cells that have a life of only one year or so, even though the power consumption is very small. The resulting inconvenience and expense of changing the cell at yearly intervals is avoided in the Cristalonic Solar Quartz watch illustrated in Plate 33. In the dial may be seen a row of solar cells which convert incident light falling on them into electrical energy to be stored in a chargeable cell, thus eliminating the need for periodic changes of the driving cell.

Science Museum Negative No. 1644/76.

34. TIMEX QUARTZ CRYSTAL WATCH WITH ANALOGUE INDICATION.

In 1975 the firm of Timex produced the interesting watch illustrated in Plate 34. Basically it consists of a mechanical watch movement with the usual indication of seconds, minutes, hours, day and date of the month; with the unusual feature of the balance driving as a stepping motor of 21,600 beats an hour. The accuracy of the watch would be lower than the conventional mechanical watch but it is synchronized by a quartz crystal oscillator of frequency 49,152 divided down by an integrated circuit to 6 Hz, these low frequency pulses are then fed to the drive coil for the balance and it is held to a guaranteed error rate of less than 15 seconds a month. The balance wheel drives the train *via* pin pallets. The combination of a quartz crystal and conventional watch movement to provide an analogue indication of the time allows a very cheap and reliable watch to be made.

Science Museum Negative No. 1714/76.

35. OMEGA MEGAQUARTZ MARINE CHRONOMETER.

The frequency of the quartz crystal employed in a timekeeper depends on a number of factors, the higher the frequency the more circuits are required to divide down to the final frequency for driving the time display. In the early days of the bipolar transistor the power consumption restraints meant that quartz crystals of low frequency had to be used, these are not satisfactory from a view of timekeeping accuracy, especially for stability of frequency with temperature changes. Advances in integrated circuit technology leading to the complementary metal-oxide semiconductor technology have allowed many more circuits to be used with a lower power consumption, in turn it is now possible to use the higher frequency quartz crystals with a zero temperature coefficient at the normal working temperature.

The Omega Megahertz Marine Chronometer shown in Plate 35 employs a quartz crystal vibrating at a frequency of 2,359,296 Hz, the highest yet used in a watch. Its accuracy is far better than any of the conventional mechanical marine chronometers over short periods and it can be adjusted to have almost zero rate quite easily when adjustment is necessary.

Science Museum Negative No. 1643/76.

PLATE 32

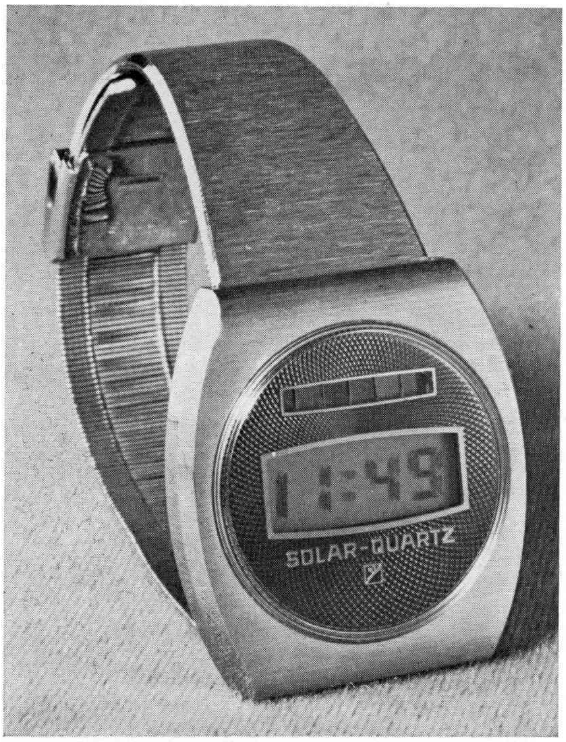


PLATE 33

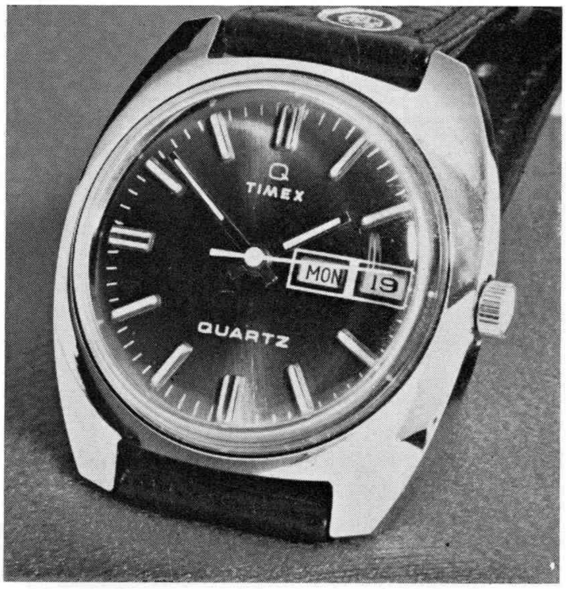
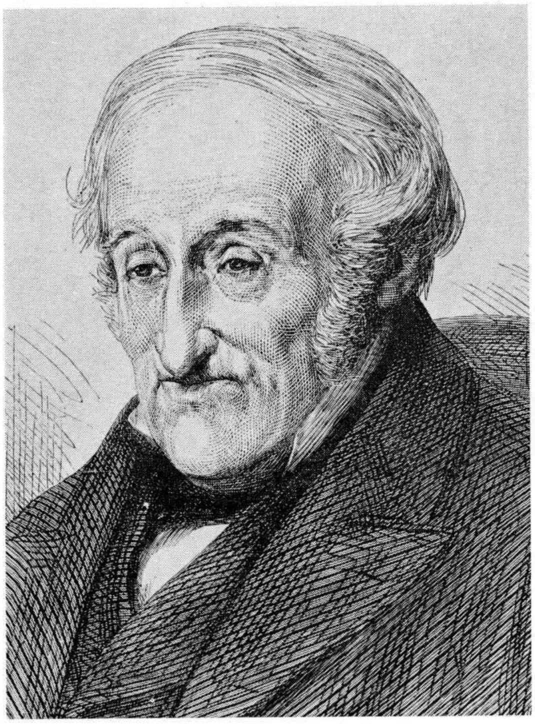


PLATE 34

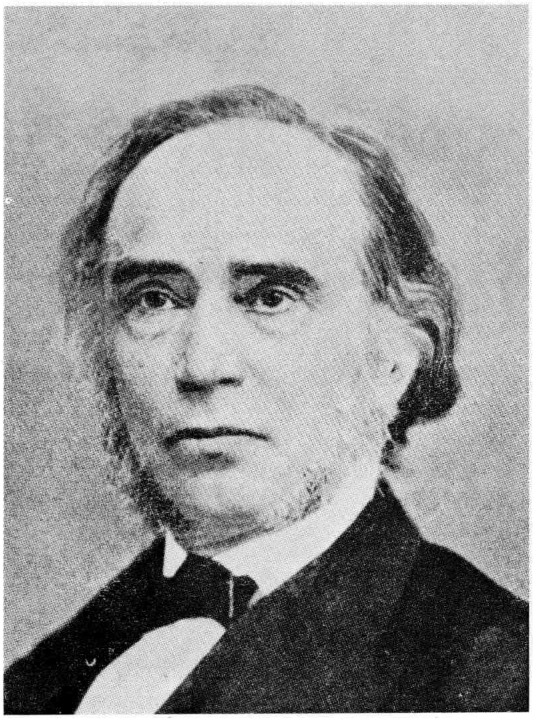
PLATE 35

THE PIONEERS OF
1814 -

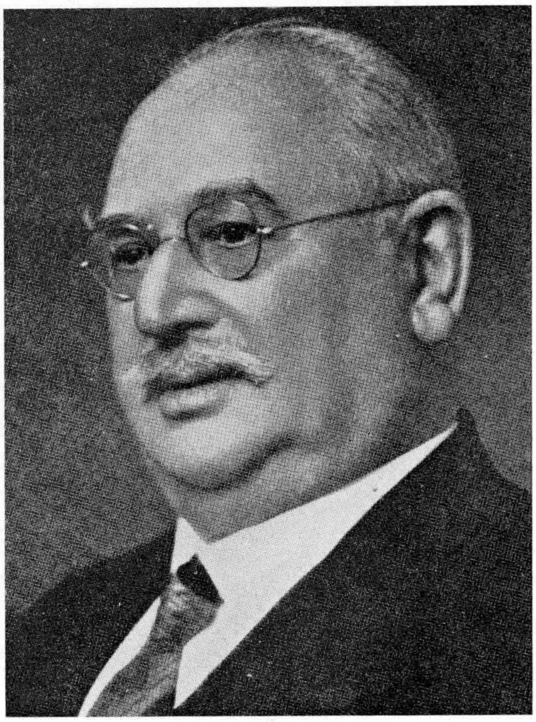


SIR FRANCIS RONALDS
Electrostatic Clock — 1814

ALEXANDER BAIN
Electromagnetic Clock — 1840

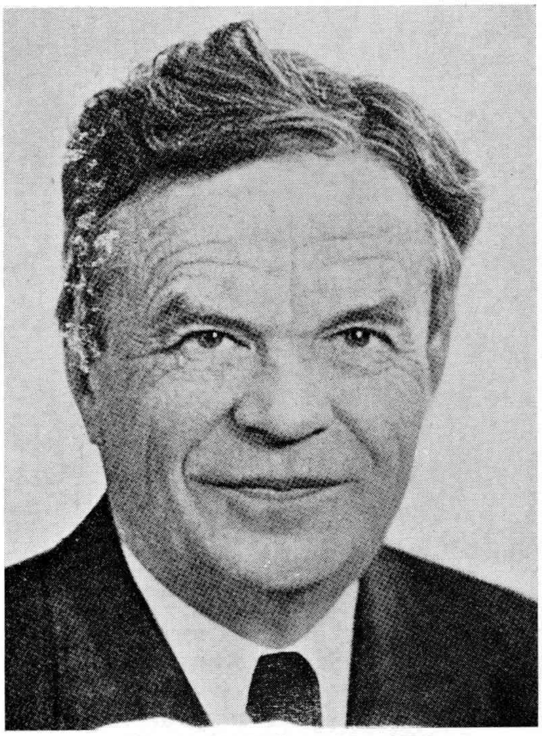


MATTHAUS HIPP
Hipp Toggle — 1842



FRANK HOPE-JONES
Synchronome Switch — 1895

ELECTRICAL TIMEKEEPING
1955



HENRY ELLIS WARREN
Synchronous Electric Clock — 1918

WILLIAM HAMILTON SHORTT
Free Pendulum — 1921

WARREN A. MARRISON
Quartz Crystal Clock — 1927

LOUIS ESSEN, F.R.S.
Caesium Atomic Clock — 1955

THE ANTIQUARIAN HOROLOGICAL SOCIETY

The Society was formed in 1953 and has a world-wide membership. The primary aim is to further the study of the history of time measurement in all its forms. To help achieve these aims the Society holds regular meetings in the Science Museum and visits in the summer to horological collections. A journal *Antiquarian Horology* is sent to members quarterly, and there are other publications published at intervals from the results of research by members.

Details of membership may be obtained from the Secretary, Antiquarian Horological Society, New House, High Street, Ticehurst, Wadhurst, Sussex, TN5 7AL. Telephone enquiries (0580) 200155.

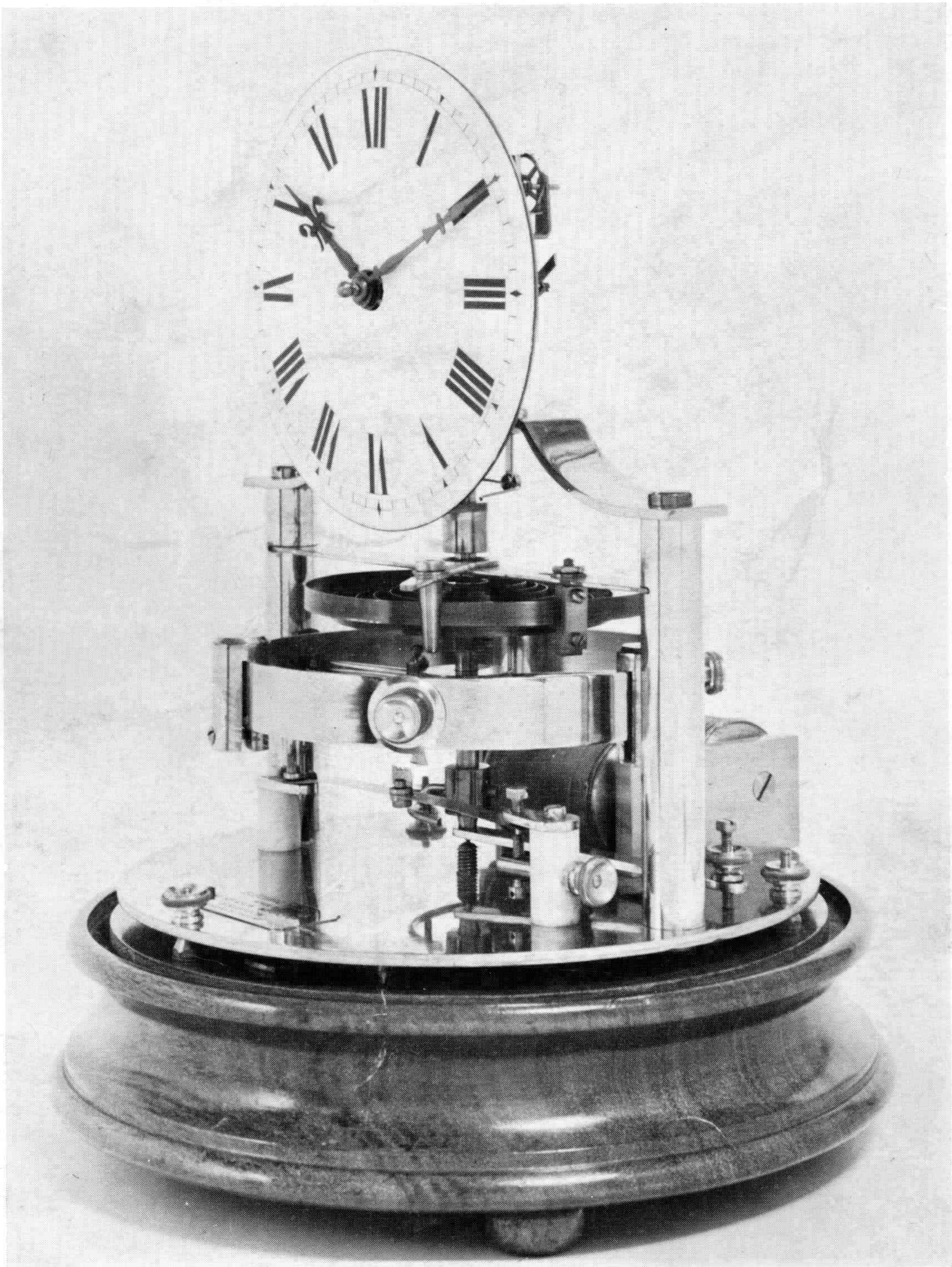


PLATE 16

Murday Electrically Driven Balance Wheel Clock, c. 1912.