THE EARTH DRIVEN CLOCK

by Dr. F. G. Alan Shenton

THE fascination and thrill of exploring the unusual is inherent in most of us. It certainly is in the clock collector. Who ever heard of an Earth Driven Clock ? The name on the plate was intriguing, but helpful as well.

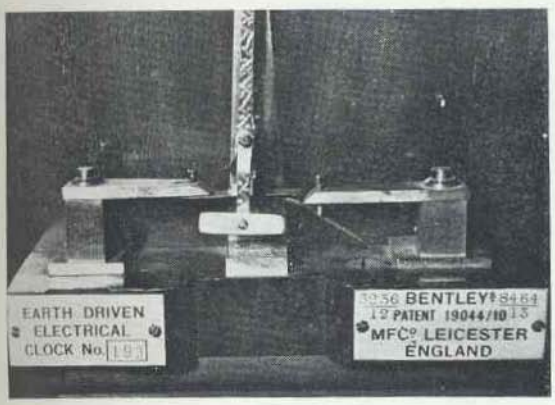

Fig. 1. Contact mechanism — the pendulum removed. Earth Driven Electrical Clock No. 193. Note tapper bar below cam and spring contacts.

Inspection of the Patent (Number 19,044, date of application 13th August, 1910) reveals that the specification was declared by Percival Arthur Bentley, 161 Waterloo Street, Burton-on-Trent, who was described as a Clock and Watchmaker.

Some qualification of this title seems necessary as P. A. Bentley had in fact had an extremely interesting career which had provided the necessary experience for the subsequent development and production of his clock.

P. A. Bentley, known to all his friends and fellow workers in later life as "Pa" Bentley, commenced as an apprentice Precision Engineer at A. E. Slater and Oakes, Electrical Engineers. This firm produced electrical and telephone equipment for the Great Western Railway. Slater was on very friendly terms with Smiths of Derby, who made clocks for the Midland Railway. A considerable degree of co-operation existed between the two firms to the extent that workers found experience coming from both firms. The firm of Slater subsequently went into liquidation and for a short period P. A. Bentley worked for the Rickneal Motor Company.

P. A. Bentley was successful in winning a Lord Derby Scholarship, value £5, to the Liverpool Technical School and commenced work at Beehive, Liverpool, makers of waters meters and instrument suppliers to the Great Western Railway. This firm became absorbed into the Automatic Telephone Company, where he eventually became foreman. During this period he studied under Sir Oliver Lodge, who was lecturing at University College, Liverpool. Here he was introduced to Lord Kelvin (1824-1907) and was asked to undertake some work for him as a precision engineer.

It is interesting to record here that P. A. Bentley had made a self-winding electric skeleton clock in recognition of which he was awarded on 15th August, 1902, the Gold Medal of Merit, given and presented by Lord Derby.

P. A. Bentley decided to establish himself on his own and opened a small Watch-

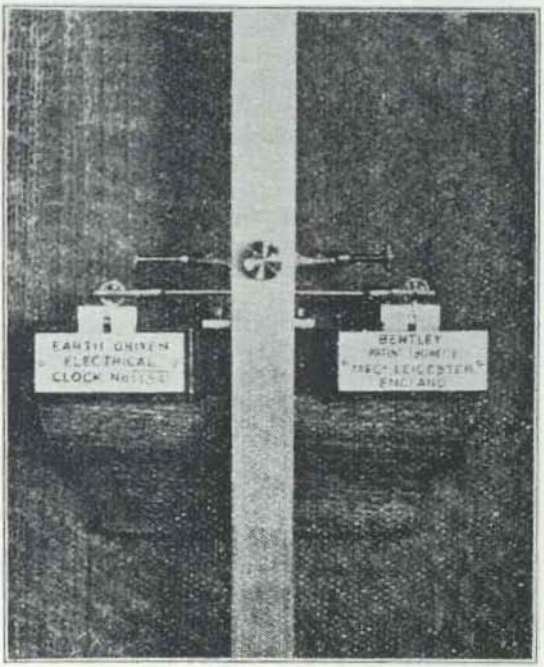

Fig. 2. Photograph of Fig. 2 *Horological Journal*, February, 1912, showing detail of wheel carriage early form — Model No. 134.

maker and Jewellers at 161 Waterloo Street, Burton-on-Trent, Staffordshire. Here he was able to develop his ideas for the design and production of his Earth Driven Clock.

A mutual interest existed between Professor J. H. Gurney, late physics master at Repton School, and P. A. Bentley. A sixth form pupil at that time remembers clearly an incident which I record in his own words: "J. H. Gurney had been physics master at Repton and by the time I got there in 1909 he had retired. But my parents knew him and so I was asked to tea. In his study he had a forty-inch length contraption, made, he told me, one wet Saturday afternoon with a metre rule, plus a bit stuck on as a pendulum, three discs of sheet aluminium cut out with a pair of scissors for seconds, minutes and hours; the seconds face with sixty vanes being engaged by a pawl on the pendulum. Once a revolution it clicked a tooth in the minute face — anyway the thing worked. It was going. Horizontal solenoid floating over two permanent magnets, North Poles opposite as in Bentley's prototype. This tea party must have been in the late 1909 or early 1910 . . . Gurney had his two clocks recording one minute impulses on a converted baragraph drum for comparison".

P. A. Bentley's first Patent, Number 19,044 application date 13th August, 1910 (accepted 13th April, 1911), was aimed at providing a means whereby the amplitudes of the pendulum swing could be kept constant and also to provide an improved arrangement and construction of fixed and moveable contacts. It is interesting to note that Mr. T. D. Wright lecturing on electric clocks at the Northampton Polytechnic Institute's Annual Conversatione is recorded as saying "History repeats itself in clockwork as in other things. During the last year or two Mr. Bentley, who has never seen or heard of Bain's clock, designed one on similar principles, but with some important differences, including a method of short circuting, ensuring constancy of arc, and with a slide having a much lighter action; so that the friction is reduced to a minimum, and is, I understand, practically negligible". On the occasion of T. D. Wright's lecture on electric clocks two Bentley clocks were exhibited driven by a single Earth Battery.

Whereas Alexander Bain had used a make-and-break slide, Bentley in his clock initially used a bar with a little wheel at each end in tandem fashion. This carriage was maintained upright by a pendant weight, reciprocation from side to side being by an adjustable pair of tappers attached to the pendulum. The wheels, insulated from the carriage by their jewelled bearings, acted as a moving contact between two pairs of contact "rails".

The aim in view was to keep the arc of vibration under closer control. This type of electric clock was easily affected by fluctuations in the electric current. In order to achieve a more constant amplitude Bentley devised a mechanism to give reversal of current as the arc of the pendulum increased beyond a certain point. When the arc was excessive the carriage wheels over-ran to reach contacts which maintained the original direction of the current and thereby retarded the downward acceleration due to gravity. Reference

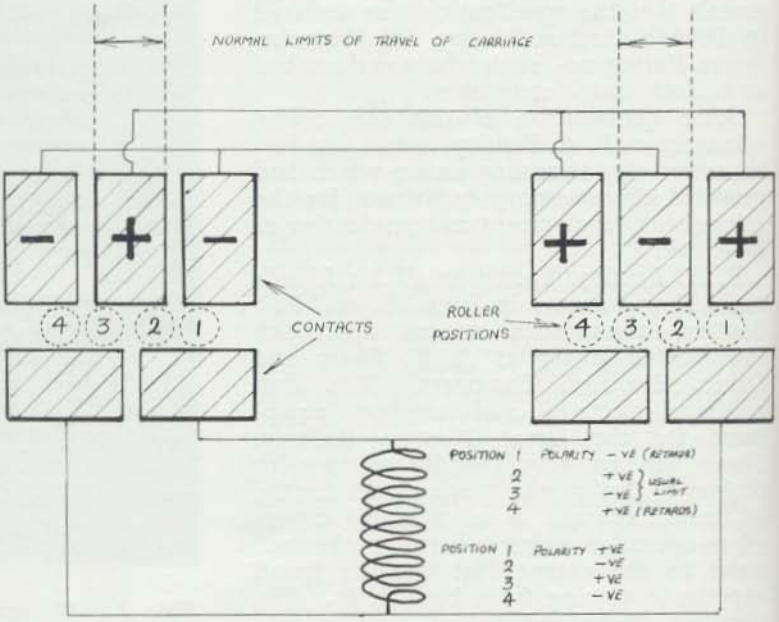

Fig. 3 SCHEMATIC DIAGRAM OF CONTACTS

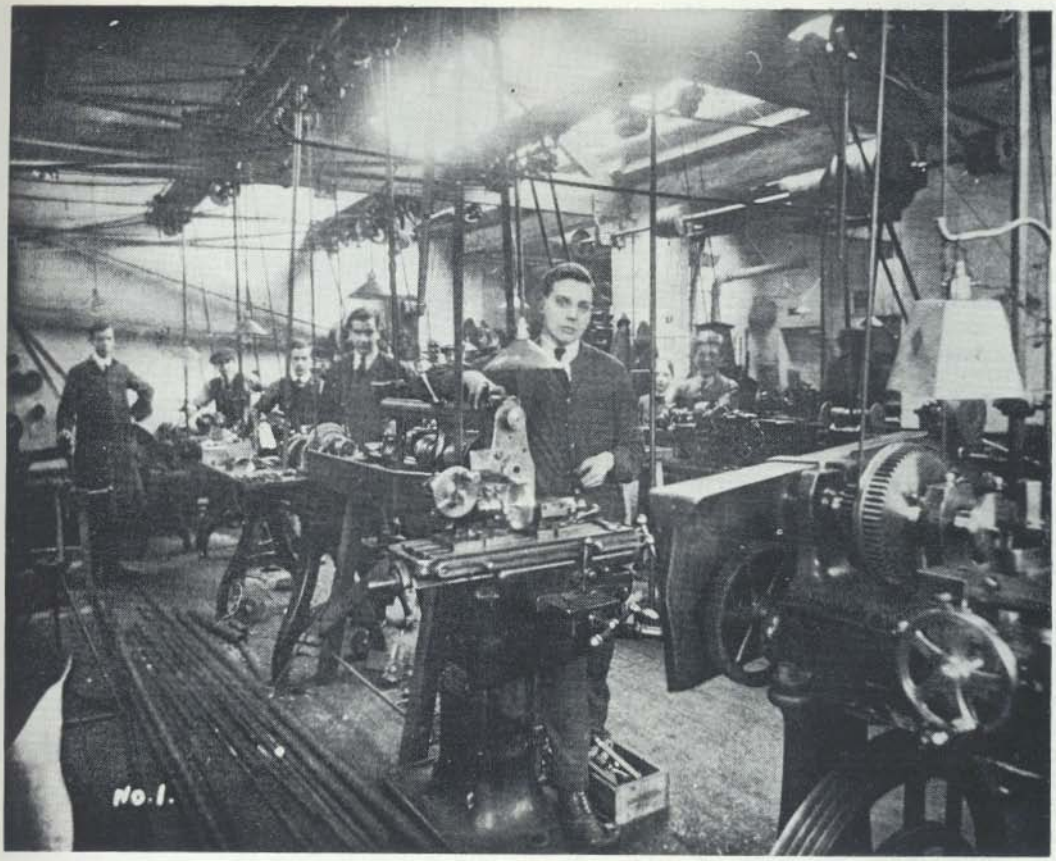

Fig. 4. Photograph of Workshop of Bentley Engineering where the Earth Driven Clock was produced. Note lathe, in right foreground, of Bernard Prince, foreman. Photograph taken Autumn, 1916. From left to right: Mr. Ashwell, Percy Evatt, John Brown, Leonard Broughton, Frank Moore, William Bentley and Charlie Stevenson.

to schematic diagram will indicate the sequence of action. It should be noted that the carriage is not directly connected to the pendulum, but moved through the medium of tappers.

From July, 1910, the Earth Driven Electrical Clock was widely acclaimed, being extensively reported in the daily press of Canada and the United States as well as in the electrical and horological journals of this country. The Clock was exhibited on Stand No. 307 at the Electrical Exhibition at Olympia and was awarded the only Medal and Diploma for Earth Driven Electric Clocks at the Festival of Empire Imperial Exhibition and Pageant of London in the Coronation Year 1911.

By 1911 P. A. Bentley was operating from 11 Bowling Green Street, Leicester — his accounting address — and opened his factory at Forest Gate, Clarendon Park Road, Leicester. Here he remained until the Autumn of 1916, when the firm moved to the Queens Road Factory to undertake precision work on behalf of Woolwich Arsenal for the war effort.

The factory opened in 1912 with P. A. Bentley, A. E. Slater (skilled instrument maker and electrical engineer who had provided the first electric tramcars and telephones for Derby as a rival of Edison), Bernard Prince (nephew of A. E. Slater), and four apprentices. A. E. Slater assumed the role of mentor and guide to P. A. Bentley, whilst Bernard Prince was workshop foreman. The four apprentices were Frank Moore, who subsequently became a Board Room Director of Bentley Engineering, Leonard Broughton and Jack Brown. The latter married P. A. Bentley's daughter. The firm continued manufacturing clocks until September, 1914, at which time there were approximately twelve employees before expanding considerably to

help the war effort.

P. A. Bentley travelled with his son, William Bentley, fitting clocks, as also did Bernard Prince (Foreman) accompanied by his apprentice Frank Moore.

The clocks were normally sold through Harrods London Store, therefore, the majority of the clocks were installed in the Surrey area. In Leicester, however, they were sold by a furnisher at the junction of Charles Street and Granby Street near the present Harris Furniture Store and were also exhibited at the Temperance Hall Exhibition, Leicester, in late 1912 to 1913. Orders were received from many foreign countries including the United States of America, Canada and Russia. Unfortunately on 15th April, 1912, among the victims of the Titanic Disaster, was Mr. D. J. Jarvis, representative of the Earth Driven Clock Company, who was on his way to America on behalf of the firm.

On the 8th February, 1912, Percival A. Bentley described as Watch and Clockmaker of Forest Gate, Clarendon Park Road, Leicester, applied for Patent Number 3236 (accepted 20th June, 1912) in which he made further provision for the control of secondary dials. The Earth Driven Clock Company catalogue states that these could be of any size or design as required. In the stock book of December, 1912, there are listed 8″, 12″, 24″ diameter old pattern and 6″, 9″, 12″, 15″ diameter new pattern; silent subdials and turret clocks. Mention is made of a 3ft. metal cased subdial by Standard Time Co.

It is recalled by an apprentice at that time that he well remembers having to take a large dial on a hand cart down to the case makers to have the bezel fitted. This dial was subsequently fitted to the corner of the Arcade, Lewis's, Manchester. It may be mentioned also that the installation of an Earth Driven Clock in the Manager's Office in Lewis's Store, Manchester, provided time throughout the shop on subsidiary dials and was also one of the first occasions when automatic shop window lighting was operated by a master clock. A simple electro-magnetic catch was used, releasing a heavy weight which knocked on the master switch to the shop window lights. The switch and weight were restored manually to their original position the following morning.

Cases for Bentley Clocks were made by Thomas Jones, Cabinet Maker and Pattern Maker, 61 Bardolph Street, Leicester, known as Leicester Cabinet Company after

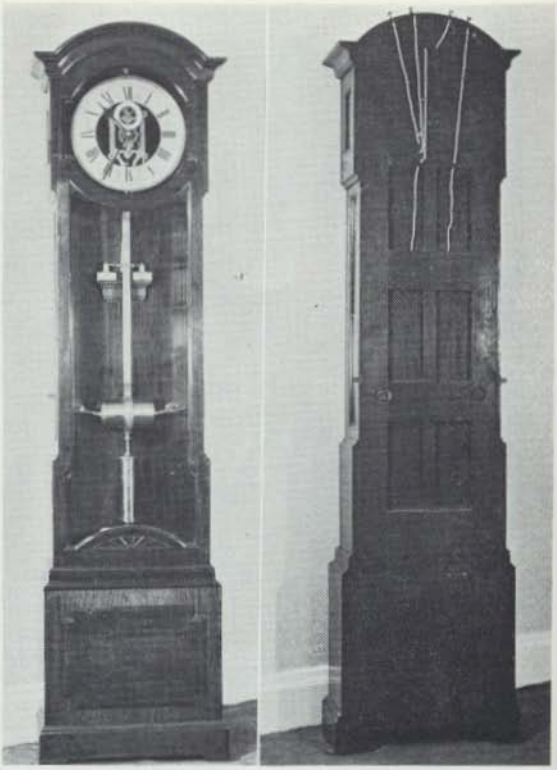

Fig. 5 (left). Earth driven clock Model V No. 193, mahogany case. Front view.

Fig. 6 (right). Back view, showing wiring from clock contacts and slave contacts to terminals for slaves and earth battery.

1909. Cotton covered bell wire was used for wiring the clock and stapled into grooves in the back of the clock case.

To special order a slate back to the clock was used, especially if it was anticipated that the clock was being sent to intemperate climates. In particular a clock of this type was sent to St. Petersburg Museum, although others still exist in this country.

The energy driving the Electric Clock is obtained from a zinc carbon couple buried three to four feet deep and one foot apart in moist soil. A soil with some drainage is preferred, but not too sandy as it is necessary to keep it moist. Peat and clay soils were to be avoided. This Earth Battery provides a potential of approximately 1 volt at the clock terminals. Carbon was used for one electrode, this was customarily obtained from the local Gas Works in the form of a lump of retort coke. A hole was drilled and a carbon rod with terminal attached was screwed into

the coke and the joint seal with pitch to prevent entry of moisture. From this the positive lead was taken. The source of the carbon rods was from old arc light carbons which were in use at that time on the Midland Railways stations. The zinc plate treminals were similarly sealed with pitch to prevent corrosion.

According to a former apprentice, performance was always much more reliable if a properly constructed earth battery was used. The fluctuating voltage of Leclanché cells adversely affected the time-keeping. The *Electrical Review,* 13th October, 1911, stated that with 1 volt p.d. at the clock terminal from an earth battery, the Bentley Clock kept time to within one minute a year. This time-keeping was also confirmed by an employee. "The work-shop regulator never needed adjusting". He recalls that it was his duty to visit Leicester Station with the chronometer to check with railway time, thence to New Walk to check the clock at Leicester Museum and on to the factory to check their regulator.

Originally the Earth Driven Clock was stated to work for fifty years without attention. In fact, the one in Leicester Museum ran for forty years without attention on its original installation before servicing in 1950.

Further testimony of its time-keeping is made by Professor J. H. Gurney on 8th July, 1912. "The point in which no other electric clock on the market can compete with it is its accuracy of time-keeping. This depends in the first place on the constancy of current from a properly laid earth battery (no ordinary battery, even if its temperature could be maintained constant, can give so constant an E.M.F. without constant attention) and secondly on the excellence of workmanship in every detail. It is a luxury to have a clock which requires no attention whatever, and may be depended upon never to fail and which, when once regulated, will not have a rate variation from day to day of more than a fraction of a second".

It is worthy of noting that the earth battery for an electric clock had also been the subject of a patent in the United States. Daniel Drawbaugh, Eberly's Mills, Pennsylvania (1847-1911) took out letters patent on the 14th January, 1879, Number 211,332, assigning three-quarter interest to T. and J. H. Grissenger and J. E. Shettel, these being exhibited at the World's Exposition in Paris, London and Berlin.

The next major development in the Earth Driven Clock is recorded in Patent Number 8464. Application date 10th April, 1913, accepted 29th January, 1914, and submitted by P. A. Bentley, Forest Gate, Clarendon Park, Leicester.

This Patent describes a new type of contact mechanism to ensure constant amplitude of the pendulum. It states that this was an alternative method of contact mechanism to provide a retarding effect and with the aim of simplifying the construction of the contacts.

The impulse was once in each complete swing and not at every half-swing, with energising of the coil before completion of the swing to keep the amplitude of the swing constant. Retardation is effected without any reversal of current, only one contact being necessary.

The pendulum operates a pivoted arm carrying a specially shaped cam surface at its lower end. This cam surface depresses a contact spring, to complete the circuit to the solenoid carried by the pendulum, the current exercising a retarding force upon the pendulum in the latter part of one half swing.

The adjustment is such that as the pendulum swings the cam surface is not

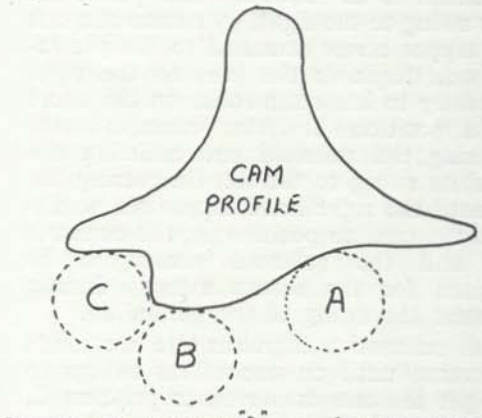

Fig. 7. Diagram of cam profile and alternative positions of roller.

carried right over the roller in each direction, but is moved from one side onto the roller to depress it and make contact between the springs and then to remain in that position until the proper point in the return swing of the pendulum, when it is moved again in the same direction from which it started.

The battery is connected with polarity arranged such that a stationary pendulum would be fractionally moved towards the left. The solenoid is of low resistance, 80 ohms to 200 ohms, wound with enamel covered wire. It is covered by one layer of lead wire to give extra weight to the solenoid bob. The consumption is approximately 10mA with each contact, but with careful adjustment will give Current Pulses 7½mA and Mean Current 2½mA. Both ½″ and ⅜″ diameter magnets were used. Polarity was arranged S-N-N-S, i.e. inner ends North Poles towards each other with a ⅞″ air gap between. Patent Number 8464 makes further provision for a similar arrangement to that described, except that the motion of the pendulum is retarded during the latter portion of each half-swing. A double contacting mechanism is described, but there is no evidence to date that this arrangement was ever required or used in practice.

The mode of operation of contact mechanism is as follows. The pendulum on its swing to the right, by means of a left hand tapper screw attached to the pendulum rod, displaces the cam to the right sufficiently to leave the roller on the short flat in position B. The contacts close energising the solenoid and assisting the pendulum swing to the left (increasing the rac) until the right hahd tapper screw displaces the cam to position A, the contacts open and the solenoid ceases to be energised for the return swing. Inertia continues the swing of the pendulum.

With successive impulses the arc tends to increase until on one of its swings to the right the cam is moved to position C, where the solenoid is not energised, the coil being energised only very briefly during its passage through B.

On the return swing to the left, the right hand tapper restores the cam to A, the coil once again being given a brief impulse.

These brief impulses through position B are insufficient to maintain pendulum arc which thus reduces to enable the high energy mode of operation of pendulum to

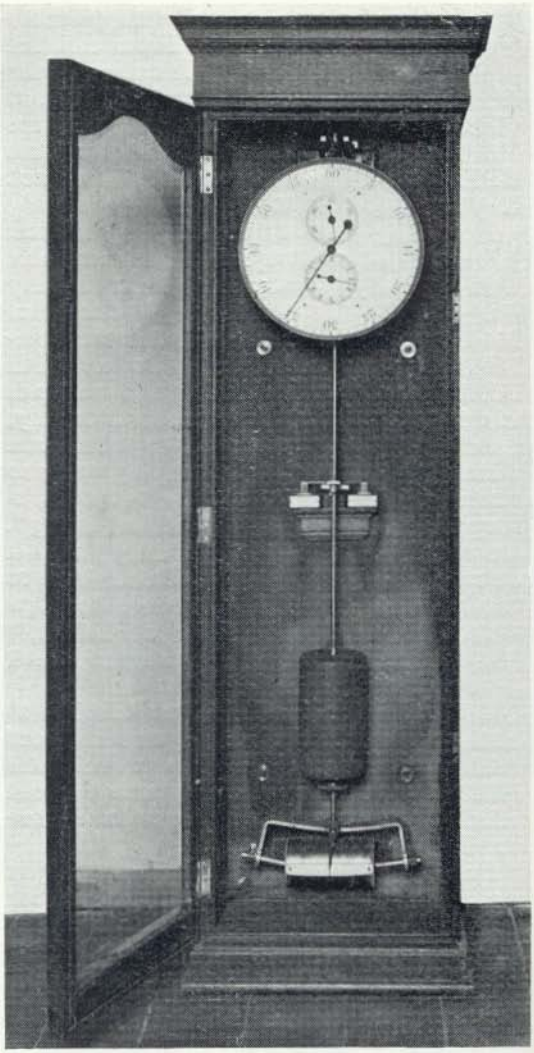

Fig. 8. Bentley Regulator with slate back — Serial No. 203. Fixed solenoid moving magnet.

Acknowledgements to H. J. Fenn and Studio Wreford

recommence. If the swing to the right is insufficient to position the roller on to the flat of B, position A will be resumed as soon as the pendulum commences to swing to the left and as a result of insufficient energy to the pendulum the arc will diminish to zero.

The pendulum assembly consists of a flat invar strip suspended from an ebony block by two adjustable suspension springs; the solenoid bob being weighted by a single layer of lead wire as mentioned previously and with a further cylindrical bob consisting of a lead weight in brass casing placed below the solenoid. On regulator clocks

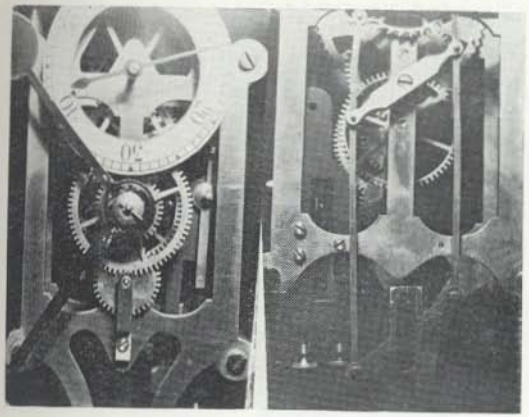

Fig. 9 (left). Front view of skeletonised movement, Model V No. 193, showing general arrangement.

Fig. 10 (right). Rear view, showing parallel movement of "crutch" mechanism and slave contacts.

a round pendulum rod was used and the pendulum bob was even heavier, as can be seen from the accompanying photograph.

The movement of the Earth Driven Electrical Clock was usually with a dead beat escapement of which No. 193 is a typical example. Detail differences in lay-out of the escapement do occur, and the provision of slave contact mechanism was an optional feature depending on the requirements of individual customers. Patent Specification Number 3236 describes an impulsing mechanism arranged above the scape wheel, whereas on the model described is shown a later improvement with a parallel pivoted link mechanism from the "crutch" arranged below the scape wheel.

Movement No. 193 consists of a sturdy skeletonised plate screwed to a heavy brass bezel which houses a silvered chapter ring. This is engraved with Roman numerals, at hour positions, and Arabic numerals at five minute intervals. A smaller seconds dial is supported by the chapter ring at the twelve o'clock position. The standard finish for these hands was a jet black enamel.

A parallel pivoted link mechanism connects the crutch pin on the pendulum to two "D" shaped pallets, which operate a thirty tooth scape wheel whose action is dead beat. It is driven round through a distance of one tooth for each complete oscillation of the pendulum, i.e. half a tooth each swing. On the same arbor is a sixty tooth wheel with "V" shaped teeth and with two pins at 180° apart, giving an

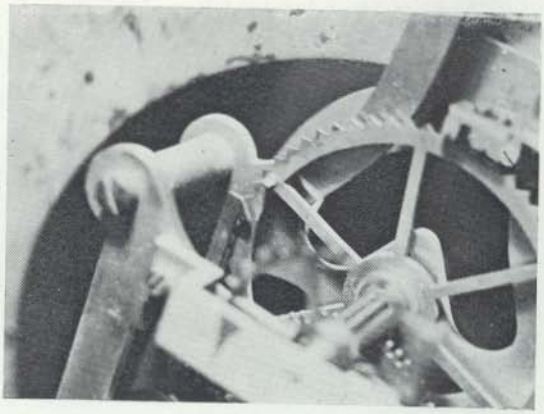

Fig. 11. Detail of slave impulsing mechanism. Model V No. 193.

impulse every half minute to slave clocks. The second hand is also screwed to this arbor. A small roller detent under a light spring and gravity loading prevents free movement of the wheel or its arbor unless acted on by the escape mechanism. Third wheel pinion of eight leaves, third wheel of sixty teeth (six crossings), centre pinion eight leaves, centre wheel sixty-four teeth (six crossings), minute pinion six leaves, minute wheel thirty-six teeth (not crossed out), cannon wheel thirty-six teeth (not crossed out), hour wheel seventy-two teeth (four crossings) completes the train.

The slave contacts are mounted to the frame in an ebonite block. The frame of the clock mechanism is secured firmly by two knurled screws to two cast brass brackets on the back of the case. On all the clocks inspected there was evidence that the majority of the movement was stamped by an assembly number. Brass castings were normally supplied by Messrs. Haycock of Ashbourne.

To the electrical horologist the Earth Driven Electrical Clock appears to be a serious contribution by P. A. Bentley to control the arc of vibration of the pendulum in electro-magnetically impulsed clocks, which was so susceptible to any fluctuations in the electric current. This was the first time this was satisfactorily accomplished.

I wish to acknowledge the help of all those who have assisted me in the piecing together of the above information and members who have kindly advised me of details of clocks in their collections. Special thanks for the help of Mr. William Bentley, Miss Dorothy Taylor, Mr. Frank

Fig. 12. P. A. Bentley greeting Sir Oliver Lodge on a visit to Leicester.

Moore, the Right Rev. Bishop Anthony Otter, Mr. H. J. Fenn, Mr. Allan Rodway and Mr. T. A. Walden, Director of Leicester Museum.

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Correspondence from the Right Rev. Bishop Anthony Otter.

Stolen

On 7th November an early Dutch clock by Johannes Van Ceulen in a black ebonised case was stolen from a house in Chelsea. The clock has recently been overhauled and is in fine condition.

Will any member who comes across information that might lead to the recovery of this clock, please get into touch with Dr. D. G. Jamison, 22 Old Church Street, Chelsea, London, S.W.3 (Tel.: 01-352 5188 or 9465).