Electrical Engineers.

ELECTRICAL TIME-SERVICE.

BY

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The subject of this paper has, I believe, never before appeared in the Proceedings of the Institution of Electrical Engineers, presumably because electric clocks have until quite recently been considered little more than interesting toys, or at any rate have not achieved that measure of success which alone makes the wholesale distribution of time possible; the Electrical Engineering Profession as such has consequently had no occasion to deal with it.

In the first place, let there be no mistake as to the importance of the subject. The advantages of an organised service of uniform and accurate time make an apology for giving it an evening at the Institution quite unnecessary, provided it is not a mere dream, but, as I maintain, within our reach. Time-keeping is essentially one of those things that can be done much better by a Municipality or a Company than by the individual. What is every one's business is nobody's. There is not an argument in favour of the public supply of such commodities as electricity, gas, or water, which does not apply with equal or even greater force to the distribution of time. Anything like correct measurement of time is a delicate operation, so difficult indeed that absolute accuracy is impossible even with the aid of carefully compensated seconds pendulums

in our observatories. How then can we expect to do it for ourselves in every room and in every office, with clocks in which the length of the pendulum and the quality of the works are sacrificed to the ornaments of the cases? Yet we grumble at them unjustly, and go on using them—so true is it all the world over, but particularly, I fear, in England, that in the trivial and common things of daily life we are content with inefficiency, and submit to many of "life's little worries" through thoughtlessness or the want of energy and concerted action.

We have not made much progress in obtaining uniformity since Charles V. of Spain went mad in the attempt, and it seems strange that electricians have not accomplished it before, when we recollect that they have been at it since the beginning of the present reign, since the earliest days of telegraphy.

ALEXANDER BAIN began to think about it in 1837. In 1846 his system was in use between Glasgow and Edinburgh, and he had an attractive showroom of electrically-driven synchronous clocks in Old Bond Street at a date when it was necessary to devote a chapter in his description of them to an "Explanation of the electro-magnet."

Sir CHAS. WHEATSTONE and R. L. JONES's systems were almost as early as BAIN'S, and C. SHEPHERD, some of whose work may yet be seen in Greenwich Observatory, installed a time-circuit of eight dials in the offices of Messrs. J. F. Pawson & Co., in St. Paul's Churchyard, in 1849. On the Continent we find that M. PAUL GARNIER (a veteran in the service of "Time," whom I had the pleasure of meeting in Paris last year) devised a system in 1850 which was applied to eighteen clocks in the Lille railway station in 1855; and again M. BREGUET, whose ingenuity provided seventy-two synchronous clocks in the streets of Lyons in 1856.

With such early and creditable pioneering work before us in the middle of the century, I think we should have made more progress before its close. Of that, however, you will be a better judge than an avowed champion of the cause, and it is only for me, in this short paper, to summarise and dispassionately review the various systems forming the steps in that advance, to point out carefully the conclusions which a study of their theory, and a practical acquaintance

with their working, leads me to form, and finally to describe my contribution to the subject and the system which I advocate.

In substantial agreement with Drs. TOBLER and SCHELLEN, M. FAVARGER, and other authors on the subject, I adopt the following general classification of electric clocks :—

(1) Independent, self-contained, self-wound clocks.

(2) Systems of clocks connected together by a line.

In such systems a "regulator," "controller," or "master" clock (whether self-wound or key-wound) is invariably used to send out electrical impulses (*a*) correcting or synchronising ordinary clocks, or (*b*), directly propelling the hands of "subsidiary," "secondary," "receiver," or "indicator" dials.

In Class 1 the main object is to save us the trouble of winding our clocks up once a week. When properly applied, electricity performs this operation better than we can do it, for a clock is an organism which likes its feed of power in small and equal instalments meted out to it with perfect regularity.

The first self-wound clocks were by BAIN and JONES, who applied electro-magnetic attachments to the bob of the pendulum, which, in obedience to contacts connected to the pendulum itself, attracted it to and fro. The wheel-work of the ordinary clock was retained, but the escapement modified to enable the pendulum to drive it, instead of the wheel-work driving the pendulum. In addition to the theoretical objection that the free action of gravity is interfered with when the impulses are applied to the lower end of the pendulum, there is the practical difficulty of obtaining a satisfactory working contact off the moving pendulum, and the fact that fluctuations of battery necessarily varied the impulse.

In 1856, M. FOUCAULT devised a most ingenious method of obtaining a firm contact from each vibration of the pendulum, which device was improved upon and adapted to a self-wound clock by Dr. HIPP in the same year, and has since become well known as HIPP'S "Electric escapement." It consists of a little pallet pivoted upon the pendulum and swinging freely over a pair of contact springs. The upper spring is provided with a notched block which catches the pallet and is depressed by the pendulum when the arc of its

vibration has fallen too low. An armature is fixed to the lower end of the pendulum, and the contact momentarily completes the circuit of a magnet placed immediately underneath it. I show you an example of this in one of the earliest instruments made by Dr. HIPP, and in the latest improved form devised by Mr. T. J. MURDAY for the self-winding integrating meter of Messrs. Johnson and Phillips. The same device has doubtless had many other applications since. I last saw it in use as a gas-engine regulator. HIPP'S electrical escapement satisfactorily disposes of the first difficulty I mentioned—that of obtaining a good contact off the pendulum, and almost meets the second objection by increasing the frequency of the impulses automatically and in exact proportion to their lack of strength. It is so successful that many Continental observatories use it in preference to key-wound regulators for accuracy of time-keeping.

A more common form of self-wound clock is that in which an ordinary 8-day timepiece has electro-magnetic power periodically applied to its wheel-work in place of a spring or weight, the electro-magnet or motor being controlled by a contact operated by one of the wheels of the clock-train. I show you the works of an American self-wound clock invented by H. CHESTERS POND as typical of this class. It is driven by a toy electro-motor which winds up a spring every hour. One naturally doubts the stability of its contact made off the going train when the spring power is at its weakest, the efficiency of such a small motor and its silence after running for a few months, and perhaps faults of this nature were contributory causes to the failure of the English Company which was formed to put it on the market in this country in 1885-6. Sir William Preece presented one of them to the Institution in 1888, and we may safely assume that the reason it is no longer in use is that the replenishing of the battery and the attention to the contacts has been found in practice to be more troublesome than weekly winding.

Other self-wound clocks which should be mentioned are those of SHEPHERD, BREGUET, VICTOR RECLUS of Paris, VAN DER PLANCKE of Brussels, WARNER of Waterbury, U.S.A., Lord KELVIN, Dr. LIPPMANN and Dr. AARON of Berlin, but we shall have occasion to refer to them later on under

Class 2 *b*. To these I could add the names of many other inventors, the evidence of whose ingenuity is only to be found in Patent specifications. With my notes before me of some two hundred British patents on the subject applied for during the last thirty years, it would seem that the idea of self-wound clocks was fatally alluring to the dreamer in search of perpetual motion who has done so much to swell the revenue of the Patent Office.

These inventions, however, do little more than save us the trouble of winding up our clocks, and, except in the case of electric meters, I should not be surprised were you to class them all—even the best of them—as misapplied ingenuity. It is true that in the case of HIPP and one or two others greater accuracy of time-keeping incidentally results, but if that cannot be communicated to and represented upon a number of dials its benefit is very limited. Inasmuch as it is impossible to make an absolutely accurate timekeeper whatever expense and care may be lavished upon it—and its error is necessarily cumulative—it will not suffice merely to improve the standard and quality of our ordinary clocks; we must strike at the root of the evil—*their independence.*

We therefore turn to Class 2, which sinks the individuality of a group of clocks by making them subservient to one master. Let us take first those methods in which the Controller sends out an impulse on a line to (*a*) correct or synchronise existing clocks. R. L. JONES accomplished this in 1858 by making contact every second in the master clock to control the vibration of subsidiary pendulums by means of electro-magnetic attachments to their bobs; and this method, improved upon and made by Messrs. JAS. RITCHIE & SON of Edinburgh, is in regular use in many of our observatories. It is, however, found incapable of application to a number of clocks in one circuit, though well adapted for keeping a small group of high-class regulators in sympathy, beat for beat. In this system it is necessary that the pendulums which are to be synchronised be regulated in the first place to considerable accuracy; as, of course, the more they are out of sympathy, the more will the electro-magnet be required to interfere with the free action of gravity. A temporary cessation of the seconds synchronising currents often allows a pendulum to get so far out of

phase that, when re-established, the electrical impulses directly oppose its swing and bring it to a standstill. After several years' trial with a clock at London Bridge, controlled from Greenwich in this way, the late Mr. C. V. Walker gave it up as impracticable.

Another class of synchronisers, far more suitable for wholesale application, is that in which a standard clock sends out impulses at longer intervals, usually every hour, to forcibly pull the hands of independent clocks into synchronisation by the armature of an electro-magnet fitted to each.

BAIN employed the stabbing action of a V-shaped notch (operating upon a pin on the minute-hand at each hour) for this purpose in 1843, and it is fully described in a pamphlet of that date, "On the Application of the Electric Fluid to the Useful Arts." RITCHIE revived this method in 1876, but renounced it in favour of giving the clocks to be synchronised a permanent going rate and stopping their hands or their scape-wheels by armatures interposed thirty seconds before the hour and liberated exactly at the hour. In the meantime, however, LUND was patenting a variety of devices for correcting the hands, and his name will always be associated with the Electro-magnetic Clip, which, in response to an impulse transmitted every hour, grips the minute hands of a number of clocks, pulling them forward if slow and backward if fast. An exhaustive paper on this subject was read by him before the Society of Telegraph Engineers in 1881, and we have to thank the Standard Time Co., Ltd., for the survival of this, the fittest system. Their central station at 19 and 21, Queen Victoria Street, E.C., is equipped with two steel and mercury regulators of the highest quality, which are kept very close to time by daily comparison with a special Greenwich time signal. Both of these regulators make a contact of one second duration every hour, but only one of them takes the load, the other being held in reserve and automatically switched in by a sentinel clock in the event of the working regulator stopping. The hourly contacts operate relays, which send out impulses in all directions over London correcting a large number of clocks, deflecting galvanometer needles or ringing single-stroke bells. If it were not for this service we should have nothing but the Greenwich-time signals supplied to a few of the leading clockmakers and disseminated to the principal provincial post-offices over the telegraph lines from St. Martin's-le-Grand at 10 a.m. or 1 p.m. Since the inauguration of the Company in 1886, I understand that their rentals have been steadily increasing in spite of the difficulties incidental to overhead lines. As I shall have something to say later on in criticism of synchronisation in general, it is fitting that I should express the obligation we are under to this, the only system of Public Time Distribution in London.

It will be observed that in all synchronisers the complete key-wound clock is retained, the sole use of the line being to correct its errors periodically. The one advantage in such systems is that each dial has a life of its own and will continue to go if the line breaks down. But this argument in their favour only applies in these degenerate days when we value truth so little that we prefer a clock which goes even inaccurately to a stopped one. The greatest objecton to synchronisation is the small use to which the lines are put. In telegraphy our energies have for years been almost exclusively concentrated upon increasing the transmitting capacity and the load factor of the line. Of course no such problem occurs in the electrical distribution of time, for we are not likely under any circumstances to require signals of greater frequency than 15 seconds, but the commercial argument is the same. Why use the line only once an hour to correct key-wound clocks, instead of using it every minute, half-minute, or quarter-minute to directly propel the hands, thereby dispensing with clock-works and the necessity of winding them up?

It is this consideration which forces us to the conclusion that for practical and wholesale distribution of time we must look to that class of electric clocks referred to as 2 *b*, in which a controller sends out frequent impulses to directly propel the hands of large numbers of indicator dials. Let us now consider the work that has been done on these lines.

One would think that no mechanical problem could be more easy than that of rotating pointers synchronously in response to periodic contacts. Surely a simple step-by-step movement consisting of a magnet pulling a lever against a spring and a click on the lever engaging a ratchet wheel so as to pick up one tooth at each vibration, would suffice. Yet it is not so. This has been the most difficult problem

in the whole subject; in fact, it is one of the principal rocks upon which so many systems have split, leaving the shores strewn with the wreckage of fruitless inventions and failures, resulting in a deep-rooted prejudice against this use of electricity.

The simplest form of electro-magnetic time counter or "Dial movement" is shown in Fig. 1, in which A is the ratchet wheel to be propelled, carrying the minute-hand, B the rocking armature lever, C the propulsion click, and D the backstop. This movement fails because there is nothing to prevent the wheel A shooting forward more than one tooth. The momentum of a minute-hand is considerable, and its velocity is greatest at the end of its journey; it is therefore necessary to provide a "stabbing"

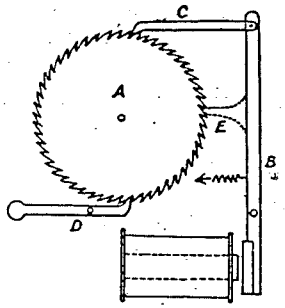

FIG. 1.

click to prevent it overshooting, which is shown in dotted lines at E.

The time counters of Messrs. ALEX. BAIN, PAUL GARNIER, RECLÛS, FROMENT, ROBERT-HOUDIN, DETOUCHE, MILDÉ, COLIN, LIAIS, WARNER, JOYCE, POTTS, STOCKALL, GENT, and others, are, with slight variations, identical in principle with Fig. 1. Theoretically this method is correct, but it has met with so little practical success that we must conclude it is a form ill-adapted for wholesale manufacture. I believe the difficulty lies in the mechanical accuracy necessary to make three pallets exactly in phase with the teeth of a ratchet-wheel when they are placed widely apart on the circumference. That there are difficulties which, rightly or wrongly, were considered insurmountable, seems clear from the number of less simple devices that have since been

invented to obtain the same result. If it were not for this surely the intricate and costly hydro-pneumatic system of CHARLES A. MAYRHOFER would never have been devised, nor even the POPP pneumatic system of Paris, for we cannot seriously admit the rivalry of pneumatics for transmitting small impulses to long distances. And again, innumerable complicated electrical step-by-step movements have since been devised, such as those containing the double impulsion clicks with reversed motions of MM. NOLLET, BREGUET, and DETOUCHE, and the weighted fly-wheel of VAN DER PLANCKE. In the latter system, the property of La Precision Cie., of Brussels, and in this country from 1893 to 1898 of the Electrical Time Recording Co., Limited, a sample of whose instruments is shown, the armature of an electro-magnet hits with a percussive blow an unevenly weighted balance-wheel, causing it to make one complete revolution, which is geared down through a train of wheels to produce a half-minute movement of the minute-hand.

Assuming that simplicity is commonly revered for its own sake, we must suppose also that the difficulties of making a step-by-step movement of this simple form that would neither trip nor overshoot, yet would be safely operated by a periodic current sent in one direction, drove some inventors to use polarised or rotary armatures and currents alternately reversed. Sir CHARLES WHEATSTONE in 1840, recognising also the difficulty of making reliable periodic contacts, generated alternate currents by means of the pendulum bob of his controlling clock, which was, in fact, a magneto-electric machine driven by an enormously heavy weight wound up by hand. The armatures in his dials revolved once for every complete vibration of the pendulum of the master-clock, and were geared to the minute-hand through a train of wheels. Truly this was an ideal system. Absolute uniformity of fifty clocks, only one of which requires winding up, and no battery is needed! But it was built upon a foundation of sand. It required that a time-keeping pendulum should serve also as a magneto-electric generator, and unfortunately that was impossible.

BAIN operated subsidiary dials from his self-wound clocks on similar lines. but with this important difference, that he recognised the necessity of a battery as the source of power; and RITCHIE also, in 1873, used alternate currents

to propel subsidiary pendulums, which revolved the hands upon their dials.

The rotary armature has, however, survived in the system of Grau, commercialised by C. THEOD. WAGNER, of Wiesbaden, which has received considerable support on the Continent, and is now represented in this country by the GENERAL ELECTRIC CO., LTD., to whom I am indebted for the models which I show you. Another alternate system which has had its share of success is that of Dr. HIPP (whose self-wound pendulum has already been noticed), commercialised by PEYER, FAVARGER & CIE., of Neuchatel. In this system the dials are provided with a polarised armature, which rocks an ordinary pallet staff engaging with a crown wheel as in a verge escapement.

Advocates of systems in which the direction of the current is alternately reversed will perhaps demur at my suggestion that their method had its origin in the difficulty of designing a satisfactory single-acting step-by-step motion. Two arguments in their favour can be advanced—(1) that the receiver dials are not readily susceptible to intermittent contacts, should any such occur in the controlling clocks; and (2) that no special care is required to make the action silent, owing to the movement of the armature being slow and not suddenly arrested by a fixed stop. I admit these advantages, but they constitute no argument against the more simple form of counter, provided a reliable one can be designed and a safe and non-intermittent contact can be obtained to operate it.

The production of such a contact has been another great stumbling-block, and innumerable methods have been devised whereby the wheel-work of a master-clock shall perform the duty. The difficulty of course lies in the fact that at the scape-wheel end of the clock train there is very little power available for such a purpose, and what there is can ill be spared from the primary and all-important duty of imparting equal impulses to the pendulum. In some cases, notably in this regulator movement of WAGNER, a separate train of wheels supplies the power required to send out the contacts, this train being let off by the going train at its side much in the same way as a striking gear is operated in an ordinary clock. The best method of obtaining a contact at regular periods off a pendulum clock that I have ever met

with is an unpublished invention of Mr. T. J. MURDAY, and I have his permission to describe it. In Fig. 2, A is a pendulum, whose vibrations are maintained by any means, whether electrical or mechanical does not now concern us, and B is a gravity arm bearing against it and carrying a pawl C, which rotates the disc D one step at each vibration. The free arm E is normally supported by the disc D, on which it rides backwards and forwards with each swing of the pendulum, until the notch in the disc allows it to fall,

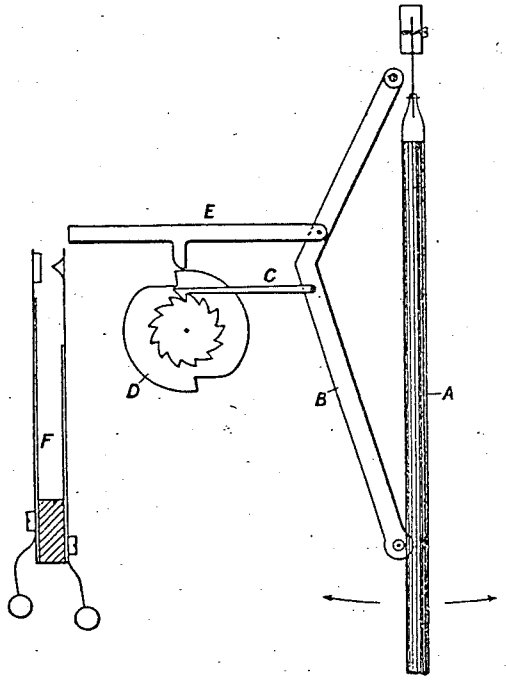

FIG. 2.

then it charges full tilt into the contact springs F with the whole weight of the pendulum behind it.

Having now reviewed the work of others and given, I hope, a clear idea of the progress achieved and the difficulties that still have to be overcome, I must here express my opinion as to which of the many suggested methods is destined, perhaps after further patient improvement, to give us House to House Time Service.

I consider that the case for "one-wheel" step-by-step

of wholesale manufacture than any of its predecessors. By driving at an angle of 135° to the radius and adopting rectangular teeth, we can with safety apply a fixed stop above the propulsion click which will effectually arrest the momentum of the hands after their forward movement, thus accomplishing the object of the third click. The position of the propulsion click and this upper stop is of the greatest importance. If we drive at a tangent the slightest eccentricity of the wheel will, by varying the dimension between the circumference and the fixed stop, allow the click either too much space, so that it locks the wheel inefficiently, or too little space, in which case it will jam. The propulsion click in this movement is carried up against the fixed stop whether the wheel is eccentric or not, and runs no risk of becoming jammed, but remains perfectly free to slide out on the dead surface of the next tooth in response to an electrical impulse of any duration, provided it is not less than 1ooth of a second. Another point to be noted is that when only two clicks are used, and these are placed near one another on the circumference of the wheel, there is no difficulty in adjusting them nor any necessity for accuracy of workmanship.

This movement is particularly suitable for operating turret-clocks in which the hands are exposed to the weather. The usual turret-clock consists of an ordinary eight-day time-piece built upon a scale proportionate to the increased diameter of its dial. It is a difficult thing to build an accurate time-measurer of such a large size, and in spite of Lord Grimthorpe's invention, which prevents the wind pressure on the hands affecting the escapement, it is seldom accurate and always costly. Inasmuch as the only requirement is to revolve the hands at a given rate, it is obviously economical to accomplish this by so much brute force supplied on the spot and controlled by a time circuit or a self-wound electrical pendulum of reasonable size if no such circuit is available. It is of course necessary to provide a very large margin of power to overcome exceptional resistance, such as a gale of wind or the accumulation of snow up the minute-hand. Consequently a much larger size of our electrical step-by-step movement is required, and as the inertia of its parts is necessarily much greater, the duration of the contact of an ordinary time-circuit would

be insufficient to operate it. We therefore drive it by a separate battery in a local circuit controlled by a relay in the time-circuit. This relay is electrically interlocked with the large dial movement so that the latter can take its own time to complete its cycle of operations, the last of which is the breaking of its own local circuit. This arrangement is, I think, clearly expressed in the accompanying diagram (Fig. 5), and does not require further description. It will be noticed that the primary electro-magnet of the relay is in the time-circuit, and that a contact of the shortest duration

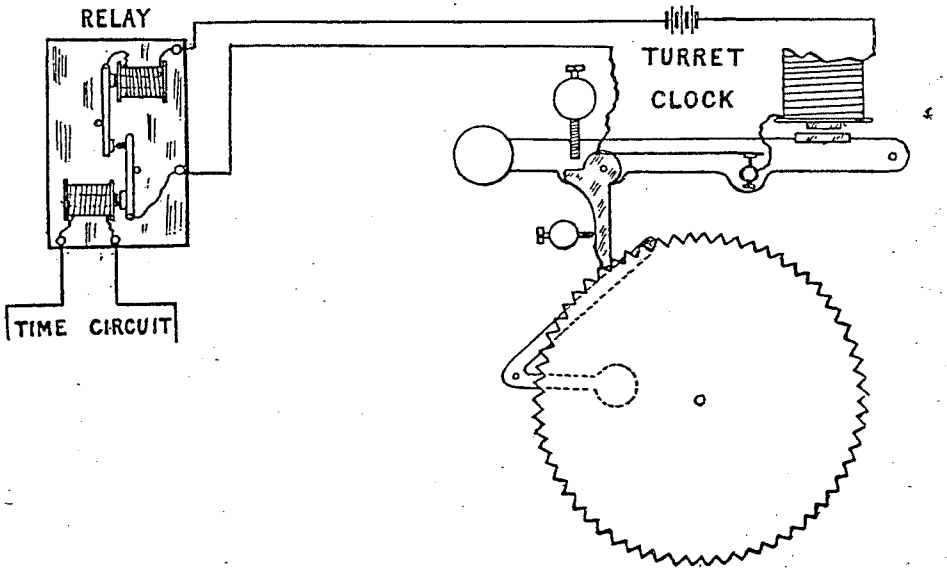

FIG. 5.

will suffice to start the secondary mechanism upon its work, which it will then perform in its own time. Even where a time-circuit is not available the great expense of the customary turret-clock movement may be saved by using an ordinary self-wound pendulum and escapement in mechanical combination with a large step-by-step dial movement; but the available space in this short paper prevents a description of it here. I, however, exhibit a model, which will serve to show that for this particular purpose an individual and independent self-wound clock is justified by its efficiency and economy.

Referring again to the small edition of the step-by-step

movement illustrated in Fig. 3, let us apply a rough-and-ready means of ascertaining the minimum duration of contact to which they will respond by putting a few of them in series with a vibratory interrupter. I take an ordinary electric bell for this purpose, and, removing the bell, adjust the hammer to a periodicity of about 25 per second. You will observe that the dials in circuit with it duly revolve at the rate of 12 hours per minute, and that whenever I break the circuit they stop at exactly the same half-minute, having kept perfectly in step. This test is of course unnecessarily severe, and it leads me to ask in all seriousness whether, when such step-by-step dials which have not been specially designed for rapidity will work synchronously in response to such rapid and imperfect electrical impulses, they will not serve to distribute time in a wholesale manner from house to house when controlled by a properly equipped central time station.

In such an undertaking we must, before all things, realise the enormous responsibility that public time-service carries with it. With our present method there is at any rate some security in numbers, and knowing that no two of our ordinary household clocks ever agree we only expect approximate time, and refer to our watches when greater accuracy is required. In an electric light service a breakdown betrays itself immediately, but in a time-service the stopping of one or more dials is an unannounced and insidious evil. Perfect synchronisation and immunity from breakdown is therefore necessary in any system of Electric Time Distribution. There is, however, no need to starve it. A hundred pounds or so would equip a central station lavishly, and, as the earning power of the lines is great (enormous when compared with systems of synchronisation or correction), they should be laid as carefully as electric light cables.

Lest we be tempted to allow considerations of economy to outweigh those of security, let me quote Antwerp as an object lesson. For about fifteen years endeavours have been made in that city to work a hundred street-corner dials on overhead lines radiating in all directions from a central time station, and earthed at their extremities. It is true that their step-by-step movements and the switches to control them were partly at fault, but no circuit could be

considered safe which a storm might interrupt and a falling telephone line might short-circuit. The Antwerp installation has now been abandoned.

Several suggestions have been made for utilising existing electric light networks for time service, but though interesting they are impracticable, and I must therefore deny myself the pleasure of dealing with them here. In the equipment of a central time station, it would be wise to provide two automatic timed-switches (such as those described in Fig. 3) and a sentinel switch of a simple form, of which I show you a drawing, to transfer the load in the event of the one in operation stopping from any cause. They would carry all the current required in an area of several square miles, the spark being of course shunted through a non-inductive resistance. It would be convenient to use low resistance magnets, and to put any number from, say, 50 to 100 receivers in series. The switch operates several such circuits in parallel. I think it would be unwise to risk the safety of time mains by allowing them to circulate in any building. I would, therefore, confine them to street clocks and relays placed in similar positions to meters, from which sub-circuits in each building could be operated. An ordinary relay, however, would be quite unsuitable to such a purpose; instead, we should use the pattern I show you, in which the duration of the contact is dependent upon the electrical inertia of the circuit it serves, and so designed that it refuses to work at all unless the battery power in the sub-circuit is sufficient to run its dials with safety. Thus responsibility for failure in local circuits would be decentralised, and a glance at the relay would show whether the fault was insufficiency of the local battery or a break in the local line.

Once a reliable time-service is established we shall recognise its utility for many other things besides turning the hands of our clocks. It will be required for operating tally clocks and watchman's watchers in factories, for ringing bells at pre-arranged times in schools, for speed-recorders in engine rooms, for automatic cut-in and cut-out switches for arc lamps, and last, but by no means least, to enable us to supply the most simple and efficient form of electricity meter imaginable.

Is it possible that such a simple method of electrical

distribution of time will suffice? I maintain that it is, provided the principles upon which the dial movements are designed and the electrical impulses are produced and distributed are correct. You will tell me that key-wound clocks are reasonably serviceable, and that, thanks to the accumulated force of centuries of industry and millions of capital, independent timekeepers can now be bought for 1s. 6½d. each. You will say that the vested interests of the clock-making trade are too powerful to admit of such rivalry. But to this I reply that the best is bound to win in the long run, and that one wheel giving uniformity and accuracy without weekly winding is better than the five or six wheels, the escapement, and the pendulum of an ordinary clock which requires weekly attention.

With a capital outlay of only a few pounds, and without organisation, already several large blocks of offices in the City have this time-service installed, the tenants gladly paying £1 1s. per dial for the first year and 10s. 6d. per dial per annum afterwards, and even at these low figures the business offers tempting prospects to the financier. At such a popular price it would not be unreasonable to expect that electrically propelled dials will be required in 50 per cent. of the offices in a busy district of the City, Greenwich Mean Time being guaranteed, and no charge being made for erection in addition to the rental. Further, the tenants would be spared the inconvenience of the weekly visits of the clock-winder. We must not wait for the municipal authorities to establish a public time-service in the streets, for they never yet in this country took the *rôle* of pioneers. It is not sufficient for them that the majority of the more important towns of the Continent have for years considered street-timing as much their duty as street-lighting and street-cleaning, particularly as existing systems have not been uniformly successful. Private enterprise must lead the way. The commercial considerations have been carefully looked into, and the existence of a demand for such a service has been proved. I believe I have demonstrated by theory and practice that these instruments are capable of supplying it, and that it now only requires the Electrical Engineering profession to take it in hand to establish public time-service on the same firm footing as electrical light supply.

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Mr. A. J. LUND: It would ill become me to say anything derogatory to the very interesting paper to which we have listened to-night, and after the kindly terms in which the author has spoken of me and of the system with which my name has been so long associated, if I make any remarks, they will rather be touching upon points in which Mr. Hope-Jones and myself would be equally interested, than depreciatory of the author's system. Mr. Lund.

First of all, I demur to the way in which he divides up the kinds of electric clocks. I doubt if the division he makes is one which will be readily apprehended by the public generally. I think it would be better understood if they were divided into "Impelled Clocks," "Controlled Clocks," and "Synchronised Clocks." Those are three descriptions which are readily understood. The Impelled Clock is one which, as in Mr. Hope-Jones' system and others, is driven by the current itself. The Controlled Clock is one which is controlled by the pendulum. When the clock goes the pendulum is not allowed to go wrong; it is made to go right; and therefore, by controlling the vibrations of the pendulum, you control accurately the time of the clock. The other kinds of clocks are those with which I have myself been associated for nearly twenty years, namely, Synchronised Clocks. The object of these clocks is to have an independent timekeeper which, whatever happens, would never be worse than an ordinary clock, which certainly ought not to vary by more than a very small part of a minute in a day. The object is this: As the clock goes round, the time current is made to clip the minute hand and set it exactly right every hour. Two of the advantages of the system are these: First, you are not without the time if the line breaks down, and if the clock is fairly well regulated you certainly, even then, ought not to be half a minute out after twenty-four hours. Another advantage is that, supposing that there be a break-down, and that for three or four hours the time-signal fails, when at last it does arrive fifteen out of, say, twenty or thirty clocks on the circuit would probably be put right by it, and then the circuit goes on as usual. In impelled clocks there is the corresponding disadvantage that, supposing your line breaks down, the hands are most likely at different parts of the dials, according as you are at one side of the break-down or the other. If that break-down were on your line, the clocks on this side of the earth would continue to act, whereas those on the other side of the earth would break down, and you would be obliged, in spite of not liking the services of the clock-winder, to send somebody round to set the whole of them right to some particular minute, in order that they might all start off again.

With regard to impelled and controlled clocks, some years ago my firm had the control of the whole of the Post Office clocks in London. About the time that our contract was expiring there was an electrical step-by-step system of clocks put up (I do not know by whom) at Mount Pleasant. I was, however, soon telegraphed for to wind up the ordinary clock in one of the rooms, and to disconnect the clock which was going step-by-step, as the continued click of the latter was too disturbing to the occupant of the room. Even after this, for three months, I continued to receive telegrams to wind the ordinary clocks, because the step-by-

Mr. Lund. step clocks had broken down. This was necessary in order that the office might not be without time.

The question of battery power is one of which perhaps Mr. Hope-Jones has not had the experience which I have had. To find a battery which will admit of constant use is a very difficult matter, and even if we use it only once an hour we find that it soon breaks down. But when you come to take current from batteries every half-minute, and have only half a minute to allow them to recuperate, you will want something better than a Leclanché battery before you will be able to keep the clocks going and be quite sure that your battery will not break down.

One word about Mr. Pond's system, which was introduced here some years ago. The author remarks that all synchronised clocks are supposed to be key-wound, independent clocks; but Mr. Pond's intention was to break away from that: he had a distinct system of synchronisation. His idea was to have self-wound clocks which would wind themselves by means of a local battery, so that each clock was an electrical clock; but, not being all electrically connected, if one broke down the others did not necessarily break down also. Then he connected all those clocks upon a synchronising system in order to correct any errors in the going of the clock.

Then, as to the duration of those clocks, which has also been touched upon in the paper. I have had one of them going in Fitzjohn's Avenue for seven or eight years at least, and the battery, instead of having broken down, I am glad to say, has been in the habit of lasting from two to three years before it required to be renewed. I should like to point out that, in my experience, local batteries should not be put in cellars or cupboards. You cannot put them in a better place than in a corner under the brickwork of the window, out in the open air, exposed to all the variations of temperature. A battery placed there will last six times as long as it would anywhere else.

The Silvertown Company, at the time I was floating Mr. Pond's patent in this country, took much trouble to get a battery which would be suitable for my purpose, and succeeded in producing a very small contact battery which would go inside any ordinary dial case, and I have known them last three years, winding the clock hourly, before they broke down; although in other cases, of course, they have not lasted so long. My assistant has one in his house which has been going ever since it was started, seven years ago. Some of you will know of an interesting attempt made by the late Mr. De La Rue to have a clock going in his works controlled from Greenwich. I think it was put in the same circuit as Mr. Walker's clock, referred to by the author, at London Bridge. The idea was to have a pendulum electrically controlled every second, or at each swing of the pendulum, by a current sent from Greenwich. But Mr. De La Rue got so tired of the break-down of the impelled clock that he had the impelling process taken away and a synchroniser put on the clock. I am not sure if the synchroniser is there to-day, but anyway the impelled clock had to give place to the synchroniser.

Having touched upon this question, I must refer to Mr. Hope-Jones' statement that one great objection to synchronisation is the

small use to which you put your lines. He forgets that if you put your Mr. Lund. lines to small use, you put your battery to small use; and if you put your lines to great use, you put your batteries to great use; and therefore, while you cannot break your lines down by sending a battery current through them, you can break your batteries down by using the battery power through the lines. I think that will be found a very serious matter. The author says that we prefer a clock which goes inaccurately to a stopped clock. That is so. We prefer a clock that shall go and show us the time within reasonable limits *to no clock at all*, because *if the clock stops it ceases to be a clock.* A remark was made in the paper about the wrecks strewn upon the shore wherever persons had tried to operate these step-by-step clocks. They are everywhere, and I can present the lecturer with not a few. I have worked at the subject, and I have known what it is to be disappointed. I can only say that I hope his system will not suffer with the rest. But these wreckages have produced a serious prejudice in the minds of the British public against step-by-step clocks, or rather I should say that, as these things produce so many wrecks, I fear the public will decline to undertake the use of a system which most likely would only add another wreck to the many that already exist.

Mr. HAYDN T. HARRISON: Mr. Hope-Jones' paper has interested me Mr. Harrison. particularly, because I was connected as electrical adviser with the company which is synchronising clocks all over London on Mr. Lund's system, and during that time I had a chance of finding out exactly what the faults were and to what the failures were due in electrically synchronised clocks. As Mr. Hope-Jones says, the lines we employed were only used once an hour to correct the time, but they were overhead lines, and we found that it was as much as we could do to keep them in order, the intervals between the hours of synchronisation giving an opportunity for repairing them. It would be hopeless to talk about using clocks in which the impetus is sent out every half-minute, if you intend to employ overhead lines. I am sure that in London, at any rate, it would prove a failure. Then the question comes as to whether it would be possible to use underground lines. I have thought seriously over that question. Of course there are all the difficulties and troubles—which are not to be despised in London now—of getting permission to put down underground lines; but granted the permission, would it pay you to lay down a line which has perhaps a potential difference of 200 volts on it impressed by the battery, and the large self-induction which, with all the magnetic relays proposed, would cause the potential to be very high at the break on every occasion? Would it pay you to lay a line which requires all that amount of insulation for the simple purpose of actuating clocks? That, I think, is the question to be put on a financial basis before any one attempts to propose a universal system of electrically actuated clocks. I am seriously doubtful of it, at the prices named in this paper. Moreover, I do not think you would find it would be universally taken up on those particular terms, and if you reduce the terms you have still less chance of paying the interest necessary on the monetary outlay on the underground wires and other plant necessary for that class of work. For

Mr. Harrison.

these reasons I do not think that on this basis it could ever be made a financial success, although it would be very pleasant to know that our clocks are keeping somewhat near standard Greenwich time. I think the system of hourly synchronisation, which at present prevails, and which is very successful, is one that will always continue, and for which I believe there will always be a demand; and if it can only be worked, as I fancy it is now being worked, with a little more expenditure on the lines, subscribers would come on very rapidly, because they would know that whether their clock is working correctly or not they can be sure of a signal every hour correcting the clock and giving them the absolute Greenwich time, which is obviously particularly useful to scientific people or clock-makers, or people who have to go by Greenwich time.

The ingenuity which Mr. Hope-Jones has displayed in some of the mechanisms he has put before us has struck me as being marvellous, and particularly his standard clock for sending out the half-second impulses, but I am afraid that the actual dial movements would suffer in the course of time from a good deal of wear and tear, because, as everybody knows, water dropping continually will wear away a stone, and so that continuous series of strokes on the wheels will no doubt, unless those wheels are made of steel, in course of time wear the dials; but, perhaps, as dials are cheap that would not matter much.

Mr. Raworth.

Mr. J. S. RAWORTH: When we get rival inventors of clock systems together we discover that each of them would rather that we went on using the old-fashioned clocks than that we should use the modern system of the other inventors. I should like to look at this matter from not quite so pessimistic a point of view as Mr. Harrison. He is of opinion that this system cannot be made to pay on account of the great difficulties of distributing the current. There is no doubt, however, that it does pay already in some places. Take the case of large hotels with 400 or 500 rooms: it is not until you have lived in one of them for a week and found how very inconveniently the clock-winder times his visits that you really begin to appreciate the advantage of an electrically-propelled clock. I have had some experience of these clocks in Paris. There is one thing about which I wish Mr. Hope-Jones to assure us before the discussion is finished, and that is as to the noise. When you go to bed in Paris you are worried by the intermittent "tick" of the electric clock. You start and wonder what it is. Time after time you are disturbed by it just as you are dropping off to sleep, and finally you get out of bed and shut off the switch and you have done with it. I think that will be one of the difficulties which Mr. Hope-Jones will have to surmount.

When I came into this room I thought I had nothing to say on clocks, but when I saw the diagrams I remembered that I went through all this experience some years ago in trying to make ship signals synchronise by electricity. If I had only had Mr. Hope-Jones' paper at hand at that time, I have no doubt that my experiments would have come to a successful issue instead of being a total and complete failure. I hope that the gentlemen who are working on these lines will study

that action very carefully, because it is very ingenious, and so far as I can see it ought to be perfectly reliable.

Mr. Raworth.

Mr. Bateman.

Mr. A. H. BATEMAN: I should like to say a word or two, not so much from the scientific as from the practical side. I started making an electrical clock in my earlier days, and have watched clocks of this type with much interest ever since, and nearly two years ago that interest culminated in my finding accidentally one of the early pamphlets of Mr. Hope-Jones. I did not then know the gentleman at all, but as I was inquiring about a good clock for a parish hall at Lewisham, I instructed my own mind as to this new system, and it ended in my buying a clock, and then two more, and then a fourth; and I have been watching with scientific, horological, and electrical interest the performances of these clocks, which have now been going for nearly two years—an 18-inch dial in the parish hall; a 12-inch dial in the club room attached, some 300 feet away; a 10-inch dial in the artists' room; and a 4-inch dial in the kitchen. They have gone on one set of batteries—Siemens' Obach batteries—absolutely well. They have kept most admirable time, and on only one occasion to my knowledge was there anything disagreeable about them. That was when the "click" which the last speaker described occurred in the clocks on the occasion of some private theatricals, and the hall-keeper had to stop the pendulum. I circumvented the difficulty by fastening two pieces of old felt carpet on the wall behind the clock-case, that is between the clock-case and the brick wall. Since that there has been no more trouble, for the clock is quite inaudible. When I went to report to Mr. Hope-Jones about this he showed me a clock that he had recently brought out, which is absolutely silent. Therefore that difficulty can be overcome. I ought to mention that in one instance somebody knocked the kitchen clock off the nail, but the other three clocks continued to keep perfectly good time, while even the clock itself, although hanging from its wires, was also going true to time. Its being out of level did not matter at all. I venture to think there are very few ordinary clocks which would have stood that ordeal.

Mr. Stockall.

Mr. W. H. STOCKALL: There is, without doubt, a very big future for electric clocks, but much depends upon getting the right and proper system. With regard to Mr. Hope-Jones' clocks, I put my hand, before the meeting began, on the minute hand of one of the turret clocks exhibited, just by way of putting a little wind pressure on, and away went the hands for a quarter of an hour at one "click." That does not look as though the step-by-step motion were secured there. But there is a clock at Liverpool Street Station with four six-foot dials fitted with a new one-wheel, step-by-step, movement that has as yet only reached the stage of provisional protection at the Patent Office, and I will defy anybody, by putting a ton weight on to the hands, to move that more than one tooth at a time, although exposed freely to wind and to the dirt and corrosion inseparable from a railway station.

Mr. Lund referred to the system of electrical clocks installed at the West Central Post Office. These were made by a Belgian firm, *The Electrical Time Recording Company*, and my firm installed the clocks for hem. That system, from the time it was inaugura ted, has gone to

Mr. Stockall.

perfection, and is still in existence, and at the present moment the Tothill Fields Post Office has not a mechanical clock in the place, nor has it ever had one since it was built. He then spoke about a gentleman being worried at one of the offices, and his having to wind the ordinary clock in his office because he could not bear the click of the electrical clock. I remember the incident very well. It was also in connection with the Belgian system, the clocks of which do make a nasty click, like those of Mr. Hope-Jones' system and many other systems. The gentleman who occupied the office was very irritable, and the clock was done away with. But the electrical clocks in all the other departments still go on and give perfect satisfaction, and remain under our control. Much stress has been placed upon the silencing of electrical clocks. I have them in my own home in every room, and they are as silent as can be. With a little rubber attachment they can be made so silent that you would not know there was a clock in the room at all. With regard to the magnitude of the system, when properly carried out, and by a definite step-by-step movement, I may say that at Liverpool Street Station and at Wolferton Station we have at the present time the whole of the station, signal-boxes, telegraph-offices, and booking-halls, all controlled perfectly and positively, and doing their work accurately and well; and the Post Office authorities are so far satisfied with our new system, that they have ordered their new premises at Mount Pleasant, where they have some 2,000 or 3,000 sorters, to be entirely fitted up with the same electrical clocks.

The most serious question for the whole system is the battery power required. I notice that the clock exhibited, which has 5-ft. hands, has seven dry cells to drive it. Fortunately we are driving ours with one; but at the same time, whether you have one or whether you have seven, they must in time give out. We clockmakers are doing our very utmost to introduce into the market a reliable, sound, commercial system, and we rely upon you electrical engineers to find us some sort of constant battery that really won't fail us in the time of need. I have read and re-read Mr. Hope-Jones' paper very carefully indeed, but can only say that, while thanking him exceedingly for it, it does not appear to have advanced beyond what he told me three years ago at the Horological Institution.

The President.

The PRESIDENT: Some time ago I had occasion to go over the new building of the Institution of Mechanical Engineers, and I found that the whole of the buildings were fitted with Mr. Hope-Jones' clocks. I also, not long ago, was invited to pay a visit to the new building of the Surveyors' Institute, and there also I found Mr. Hope-Jones' clocks installed all over the building. Is there any one here who knows whether clocks in those two places have been giving satisfaction?

Mr Worthington.

Mr. EDGAR WORTHINGTON, in response, said: At the Institution of Mechanical Engineers, where we put in these clocks about twelve months ago, although at first we had a great deal of trouble, due to an unfortunate bit of wire-laying, which had nothing to do with the clocks, I cannot say that they have gone absolutely perfectly, but they have given almost perfect satisfaction, and I believe Mr. Hope-Jones, who pays us occasional visits, is finding out and putting right the two

Mr. Worthington.

or three little defects, where one clock dropped behind, for instance. We have a master-clock situated in the cool cellar and about a dozen other dials, all driven from the 200 volt lighting mains. The question of noise has troubled us a little, but the clock which gave the most trouble in this direction is now silent, and during the last few weeks they have been going well. The Secretary of the Surveyors' Institute, Mr. Rogers, told me that he is satisfied with the installation in their building.

Professor Ayrton.

Professor AYRTON: I should like to ask the author whether the rate of going of the master-clock is found to be at all affected by the time-constant of the circuit to which he alluded. Is there any intentional interval between the lifting of the weight and when it begins to depress the wheel? The weight falls and makes a contact with the armature when it has fallen by a definite amount. Then how long it takes to be raised depends on the battery and the time-constant of the circuit. Supposing I were to put, say, self-induction in the circuit and rather prolong the time the weight takes to rise, would not that tend to make the master-clock go a little slowly? Or is there in this arrangement an intentional interval of time after the raising before the weight begins to introduce a driving force? Some fifteen or sixteen years ago I had to test an electric clock in which there was a very similar contrivance. In that clock, if I remember rightly, there was an intentional interval of time between the falling of the weight, that is to say before the weight began to exert the driving force and its being lifted; so that although the lifting was commenced at a given point, the pendulum went on alone driving the clock for a short interval of time. Consequently, whether the weight was lifted rather quickly because of the battery being strong, or rather slowly because the battery was weak, or because there was a good deal of self-induction in the circuit, the time when the weight began to exert the driving force was always exactly the same. I think probably, however, the very ingenious arrangement which Mr. Hope-Jones has employed to make contacts was not employed, and that there was a more old-fashioned method of making the contact. I am interested in the point I have mentioned because I had to make a report to the Council of this Institution on that particular clock, and it struck me as being very interesting from possessing the ingenious device to which I have referred.

Mr. Frodsham.

Mr. G. W. FRODSHAM: I have not had the paper long enough in my hands to study all the details, and therefore am not competent to pass remarks upon some of the minute points which are very important. The author made some apology for going into the subject minutely, but it is necessary to do so. The history of electric time-keeping during the last thirty or forty years may be briefly summed up. For many years it had been considered that an electrically-driven clock was not to be countenanced, and that an electrically-controlled clock was the best, that is to say, some clock which had in itself the power of going independent of the current. At the present time, when so many Institutions are using electricity in their buildings and there is a staff of electricians accessible, these views have been modified. Still, as a clock-maker and electrician, I hold that every clock should have in it some internal force independent of the current. Of course in Mr. Hope-

Mr. Frodsham.

Jones' system the current may be always perfect and reliable, but we know in practice how things sometimes fail. If we take that view, it is necessary to have some power within the clock such as that in use in the Belgian system, which is employed in many places with great success, I believe—although in Glasgow some were put up which gave trouble for a time.

The author mentions one system which is used in connection with his clock. It is that of sending the current to the houses and not allowing it to go through the wiring of the house, to avoid interruption of or tampering with the circuit. In that case the difficulty of attending to the local batteries, or to the batteries locally used in each house, or to the current turned on by the relays would still have to be overcome and still be a source of expense.

Of course, as has been pointed out, there is a certain amount of waste in not having the current always at work, but it can easily be made to do more duty by arranging that in a series of, say, fifty clocks, six different clocks should be brought under the influence of the current every ten minutes of the hour; by this means a current of lower power would effectually do the work required. By a mechanical arrangement the clocks would themselves invite the visit of the current during a period which would range from a little before to a little after the time at which the contact should be made.

With regard to the necessity of going into questions very minutely, I may refer to a matter within my own horological experience. Some years ago I thought it would be useful to devise an instrument for observatory use which would give astronomers the opportunity of recording half-seconds upon a slip of paper such as is used in many of their instruments. With that object I determined to break a current every half-second by passing it through the escapement of the chronometer. I then visited Hamburg, Bremen, Dresden, Berlin, Vienna, and Geneva, in order to ascertain what was being done in this direction on the Continent. I found in one or two places that my idea had been partially anticipated, and eventually found it had been thought of by Professor Plantamour of Geneva. He had worked at the observatory and had discovered that the difficulty was, that the current passing through the escapement of the chronometer, which was a small spring lifted from a stationary screw, created an attraction between the spring and the fixed screw which altered the rate of the chronometer. He was therefore compelled to make two trains of wheels, one to keep time and the other to make and break.

Captain Acland.

Captain F. E. D. ACLAND: I think it must be a source of great satisfaction to Mr. Hope-Jones to have had so little real criticism on the points raised by him in his paper. Mr. Stockall, I notice, was particularly strong on the step-by-step movement, which is the main point of Mr. Hope-Jones' paper. I personally have been interested, as an amateur, in the measurement of time. I do not agree in the slightest with Mr. Lund. I think Mr. Hope-Jones has the power behind him to do away with the old-fashioned methods. I have in my own house, I purchased it from Mr. Hope-Jones over three years ago, quite the worst sample of installation that he can produce. There were

no two-dial movements the same. The controlling pendulum was very rough, and I put it up in an old case in my front hall, which is perpetually open to the garden. When I had controlled it, it went so accurately that after three months I could not detect any variation in the half-minute beat at all. There was no variation. From that day I never regulated it for nearly three years, and I will undertake to say that it is running to-day within the half-minute beat. It has stopped once, I admit, owing to my own fault. I went away for my summer holiday, and on my return found the clock case inhabited by a family of earwigs and spiders. I could, literally, have brushed off the controlling instrument a fair handful of dirt and dust. Owing to that the clock stopped. Captain Acland.

I have had a similar clock in my office for three and a half years, and was much troubled by the periodical "click" until I got accustomed to it. But within the last year I have purchased a movement which is so silent that when I put my ear to the case containing it I cannot hear it. My experience, which has been chiefly in gunnery work, has taught me that, in attacking a problem, when you come to a difficulty, the best way is not to invent new things to get round your difficulty, but to remove the source of the difficulty itself. If the noise is great, Mr. Hope-Jones and Mr. Stockall, and those interested in this class of electrical work, have got to remove the noise, and I am quite certain it can be done if the cause is discovered. I believe that Mr. Hope-Jones by his long and patient work is getttng down to the bed-rock of the matter, and I think the reason why in the early experiments electrical time-service was impossible, was that the knowledge of electricity twenty years ago was relatively so small. If electrical engineers do not overcome these electrical difficulties there is very poor hope for the future. I must congratulate Mr. Hope-Jones on the care which he has given to this paper.

Mr. W. ELLIS, F.R.S. [*communicated*]: My experience in regard to the application of electricity to horological purposes was confined to the period from 1855 to 1874, when I had charge of the Time Department at Greenwich Observatory, after which I became occupied with other duties. A system of sympathetic clocks on Shepherd's principle had been set up in 1852; worked from a central pendulum clock, the pendulum impulse was given at alternate beats by the discharge of a small weight raised by action from a one-cell battery, the several other clock trains being driven, second by second, on Shepherd's plan, from a larger battery; the system was thus wholly maintained by electric action. In early times there seemed to be an idea that electricity should do everything, instead of using it as an auxiliary. I should have preferred, for the central clock of the above-mentioned system, an ordinary weight clock, making the necessary contacts for the sympathetic clocks, for as it gave the hourly time signals to the Post Office it was desirable to guard it from the consequences of any temporary accidental electrical failure. The system of sympathetic clocks, with some modification, still, I believe, exists. Mr. Ellis.

In regard to the two systems of electrical control that Mr. Hope-Jones discusses, (*a*) the correcting or synchronising of ordinary clocks,

Mr. Ellis. and (*b*) the directly propelling the hands of secondary clocks, I may say that, as respects the controlling of ordinary clocks, I had experience at the Observatory and otherwise of Mr. R. L. Jones' system of electrically controlling other clocks by action on their pendulums, and found the system very satisfactory. In one case in which we controlled a half-seconds pendulum on this system, the arrangement of magnet and coil was reversed, a small bar magnet being attached to the pendulum below it, the coil being fixed to the clock-case. The system was also applied to a chronometer beating half-seconds fixed to the eye-piece of one of the equatorials; here a small magnet was fixed centrally on the balance staff of the chronometer, being encircled on one side by a coil fixed to the chronometer plate. Mr. Hope-Jones seems to me to give an impression that clocks controlled on R. L. Jones' system require to be regulated to a greater nicety than is, I think, the case. The clock that Mr. Hope-Jones speaks of as thus controlled at London Bridge from Greenwich was not so worked; it had no pendulum, and its train was driven, second by second, from the central clock of the Greenwich system, as were the clocks within the Observatory walls. Its performance at this distance from Greenwich was not satisfactory, and it was after some years removed. Had it been a pendulum controlled on R. L. Jones' system, it would have had a better chance.

With respect to Mr. Hope-Jones' method (*b*) in which the distant clock depends entirely on the transmitted current, I sympathise very much with him in what he says as to the difficulty of contriving an efficient step-by-step movement, an obstacle that has no doubt retarded the introduction of such clocks. If he has overcome this practical difficulty he will have done a good thing, and I trust that it may be so. And even admitting that perfect clocks of this kind are possible, so far as their internal mechanism is concerned, they are still subject to derangement from two external causes—(1) failure of current, and (2) interruption in, or rupture of, the communicating wire. In either case the clocks would stop, which, in a large system, even if it seldom occurred, would, when it did occur, be serious. A clock that continues to go as an independent clock, even with some little error, appears to me to be preferable to one that from the causes mentioned may come to a stand, though Mr. Hope-Jones seems to think otherwise. It is for the reason mentioned that I rather cling to the principle either of continuous control, or of the synchronising at short intervals, of self-contained clocks, although there is, no doubt, the trouble of periodically winding such clocks. It is more or less a question of degree. If Mr. Hope-Jones can ensure uninterrupted wire communication and constancy of current, and if his step-by-step movement be as reliable as he appears to say, we may then congratulate him on having developed a system that may be of great benefit. But there must be no failures, or next to no failures. For it is when there is any possibility of such occurring that the superiority of the principle of control over that of driving comes in.

With reference to Mr. Hope-Jones' remark on the little progress made in the application of electricity for the promotion of more accurate timekeeping, I may mention, as a matter of history, that in

the year 1866 I accompanied a deputation from the British Horological Institute to a committee of the Court of Common Council of the City of London urging the establishment of public controlled clocks showing seconds, and placed near the leading thoroughfares, with dials a little above a man's head. Controlled on R. L. Jones' system from a central clock in the City brought daily to time, as is the central Greenwich clock, the plan was quite practicable; but nothing was done. The opposition to it was believed to come from those who might have been expected to approve of it. Mr. Ellis.

Mr. F. HOPE-JONES, in reply, said: In reply to Mr. Lund I regret that I am unable to adopt his classification of electrical clocks under the headings Impelled, Controlled, and Synchronised. I thought it was good at the time he devised it, and I read it again with interest only a few weeks ago in his paper before your predecessors, the Society of Telegraph Engineers. In adopting the classification which I put in my paper I have only followed a very good lead, viz., those authors in France and Germany who have gone into this matter far more thoroughly even than I have. We have no standard works on the subject here in England, and must go abroad for them. Dr. Tobler, M. Kareis, and M. Favarger, of Neuchatel, do not ignore self-contained, self-wound clocks, and they consider that what Mr. Lund calls "controlling" is only a form of synchronisation. In that I agree with them. Mr. Lund made a very strong point of the battery, and that has also been touched upon by several speakers, Mr. Harrison among others. The question is not so serious, I believe, as has been made out. Mr. Lund spoke particularly of the fact that a contact in the case of synchronised or correcting methods was only required once an hour, whereas in the method I advocate it is required once every half-minute. I would point that although that is so, the demand we make upon the battery is absolutely less than that made by synchronisation. The reason is this: The amount of electrical energy required to move the hands (which are necessarily mounted spring-tight upon their arbors) is considerable, and a contact of at least one second duration is required for the purpose. But with the light aluminium balanced hands used in our clocks we require a contact of less than $\frac{1}{120}$ second duration. Consequently even if the amount of electrical energy were the same in each case, we use less than is required in the synchronising method. As a matter of fact we use a great deal less, because less energy is required at each stroke. Mr. Hope-Jones.

In reply to Mr. Raworth, I have myself experienced the annoying "click" of the dials in the Gare de Lazare Grand Terminus Hotel in Paris, and eventually I had to do as he did,—get up and turn off the switch. Could there be anything more ridiculous than a time circuit in which a switch is provided, to enable you to turn one of the dials off? It is infinitely better to have a key-wound clock than one which requires attention irregularly and not at stated periods. Silence has been spoken of by some of my supporters, and some whom I did not expect would speak for me. I thank them for replying in advance to many points which have been raised. The silence of the dial in the glass shade on the table has been obtained

Mr. Hope-Jones.

mainly by insulating the movement itself (which must necessarily emit a slight click) from anything in the nature of a sound-board by suspending it from spiral springs instead of supporting it in rigid connection with the case. The result is that although the click is still there, it is not communicated to any sound-board and therefore is not heard. It is not a difficult matter to silence clocks. I think I may safely say that had the gentleman in the Post Office, who was referred to by Mr. Lund and Mr. Stockall, been provided with one of these clocks which has a very light movement, made of thin metal, cemented on to the back of the dial by rubber pads, and consequently mainly insulated from the dial which would otherwise act as a sound-board, he would not have complained. This clock is so quiet that it does not cause annoyance in any ordinary room, although I admit it is not good enough for a bedroom. The one with the movement supported by spiral springs is suitable for this purpose and cannot be heard when lying awake at night.

In reply to Professor Ayrton's question, I would point out that in the pendulum movement exhibited there is a maintaining spring which perhaps has not been noticed. The click which supports the weighted lever communicates its thrust to a ratchet disc, but the ratchet disc is not in rigid connection with the wheel. On the contrary, it is loose upon its arbor and is connected with the wheel through the medium of a spring. There is also a back-stop click engaging the wheel which comes into operation just before the winding action takes place. The result is that the going pressure is never off the escapement. Even at that minute instant of time when the action is taking place, when the weight is being lifted up, there is no diminution of the pressure upon the escape wheel.

Mr. Stockall referred to the absence of lock on one of the dial clock movements. He has, however, merely mistaken an interior pattern dial for a turret clock. The lock in this case is amply sufficient for light aluminium hands protected by a sheet of glass. In turret clocks, where the hands are exposed to the weather, they would be locked not only in the position of rest, but at every point in the cycle of operations.

With regard to the slight irregularity of the time circuit at the Institution of Mechanical Engineers mentioned by Mr. Worthington, the principal source of the trouble was the flooding of a conduit box which caused the main fuse to blow and cut off their supply, consequently stopping the clocks too. An earth developed on our clock wiring about that time also. The only other unsatisfactory point that I am aware of in that installation was the use of a large mirror as a dial; this clock had to be taken out on account of the noise it made, being rigidly attached to the mirror.

In reply to Mr. Harrison, I admit that to use overhead lines extensively and indiscriminately for public time-service would be to court failure, but a very large number of dials would be served by comparatively few and short lengths which would be duplicated for safety. It would be easy to shut down any section of the time-service in business districts for testing and repairs for twelve hours between, say, 8 or 9 p.m. and 8 or 9 a.m. After installing nearly a thousand of these propelled

dials, and in view of the extensive use of more complicated systems on the Continent, I cannot agree with his pessimistic view of the commercial prospects of time-service. I admit that "10s. 6d. per annum is the interest on a very good clock indeed," but at present this half-guinea is absorbed in its weekly winding, regulation, and setting it to time, to say nothing of its repairs. Mr. Hope-Jones.

In conclusion, I would express my thanks to Mr. Harrison for dealing with the question of distribution. I could wish that more of the discussion had been devoted to it, for if there are any difficulties still to be encountered they will be met with here.

The PRESIDENT: It is now our pleasing duty to return thanks to Mr. Hope-Jones for his paper which has given rise to this most interesting discussion. I think those numerous gentlemen who have come here, not being members of the Institution, and have taken such an interesting part in this debate, should also be included in the vote. Will you give your thanks to Mr. Hope-Jones and to those gentlemen who have taken part in the debate? The President

The vote was carried by acclamation.

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