ELECTRIC METERS.

BY GEO. W. WALKER.

The time has come for the central station companies to realize that they must supply the electric current in a more thoroughly commercial manner—that is, it must be sold as other commodities are sold, by measure, weight or its equivalent. To convince, however, an already skeptical public that the electric current can be measured with as great if not a greater degree of accuracy than the established and accepted methods of measuring gas, water and steam, is no small undertaking. The fact remains, however, that we have to-day a number of electric meters which will measure the electric current more accurately and thoroughly than instruments adopted for similar purposes in other branches of business.

We have, it is true, one great question which we cannot answer, and that is what the electric current really is. We explain this, however, by saying we can measure its effects, which are reflected either in light, heat or power. Fortunately for us, we have adopted units which are universal; the coulomb, ampere and ohm represent values practically the same throughout the entire world. Therefore we start out with fixed rules which must be recognized as well by the old world as the new. Compare this fact with the different weights and measures adopted by various nations and countries, and see what universal dissimilarity exists. Imagine for a moment what consternation would exist among the great dry goods houses if it were possible to instantly transfer all our yard sticks to France and their metre sticks to this country; the result would be to momentarily paralyze their business. We can, however, place our measuring instruments on

any circuit, and the result remains the same and is read with the same degree of certainty and accuracy by all nations.

As gas was the follower of the tallow dip, so is electricity the successor to gas, and one of the legacies inherited by us is the much-abused and anathematized gas meter. The peculiarities of this somewhat venerable object are numerous, sometimes amusing, many times annoying and expensive, as our personal experience will prove. The original gas meter was a very crude affair, indeed, and would insist on freezing or drying up at the wrong time. Probably many of us could tell amusing experiences which have befallen us in our endeavor to make it work. Its progress to its present state of perfection was very slow ; in fact, for almost if not quite twenty years after it was first introduced, no improvements were made upon it. Much as we blame and question its arithmetic, it is undoubtedly a very reliable instrument. It has, however, by comparison, caused the ever suspecting public to look with suspicion upon the electric meter, even though they "see the wheels go 'round."

In presenting this subject to you, it may be interesting to know that although there are but a very limited variety of electric meters now on the market, this number does not in any sense represent the thought and time that has been given to this particular branch of the electric field. A perusal of the United States Patent Office reports show that up to date about 185 patents have been granted on electric meters alone. The first patent granted by our government on electric meters was No. 132,569, dated October 29th, 1872, and issued to S. Gardiner, Jr., of New York City. The mechanism of this meter consists of an electro-magnet, having its armature connected to a releasing device of a clock movement, the dials of said movement indicating the time during which an electrical current is in action.

No further patents were issued until the year 1878, during which year a patent was granted to W. E. Sawyer, also of New York City. The same month, November 26th, a patent was issued to J. Billings Fuller, of Brooklyn, N. Y., on what was perhaps the first alternating meter invented. His invention is embodied in one claim which reads as follows: "An electric lighting system in which the light is produced by alternating currents, an electro-magnet placed in the main or induced current circuit, or in a shunt therewith connected, and having a polarized armature, the vibrations of which actuate a train of registering wheels, substantially as and for the purpose specified."

The patents granted to Sawyer and Fuller were the only ones issued in 1878. One patent was granted in 1879; three in 1880; seven in 1881; seven in 1882; eight in 1883; nine in 1884; five in 1885; twelve in 1886; thirteen in 1887; twenty-two in 1888; thirty-six in 1889; and about sixty during the year 1890 and up to the present time. You see, therefore, that considerable time, brains and money have been expended in the direction of perfecting the electric meter. A careful examination of the 185 patents issued, reveal many ingenious devices for the measurement of the electric current. But in most cases the expense of manufacture, the likelihood to derangement and the cost of operation kept these meters out of the race, from a practical standpoint. It would be impossible in the time allowed for this paper to describe a great many meters. I presume you will be interested only in those which have been placed prominently and in a commercial manner before the American public. I will take them up according to their seniority and describe them as briefly as possible.

The first to consider is the

EDISON ELECTROLYTIC METER.

The fundamental patent taken out by Mr. Edison on his chemical meter is No. 251,545, dated December 27th, 1881. In the patent, an electro-magnet is claimed as part of the meter, the principal claim, however, is in the use of an electrolytic cell placed in a shunt circuit, the resistance being so proportioned that a definite fraction of the current passes through the cell. The chemical action of this meter when in use, consists in depositing metal from one electrode to another, the rate of deposit being regulated by the amount of current passing through the meter. The electrical energy consumed is measured by ascertaining the increase of weight of the electrode which receives the deposit. Subsequent to the issue of this patent, he devised various modifications of this meter, introducing recording devices, as in Patent No. 304,082, which provides for the use of two electrolytic cells, one plate of each being suspended from the beam of a sensitive balance, the circuit being so arranged that one cell is in circuit at a time. The direction of current in that cell is such that the electrolytic action in the same will throw the balance out of equilibrium, causing the beam to kick and by that action throw the current to the other cell and register one on the counter. Various other devices were patented and experimented upon by Mr.

Edison to accomplish similar results. He also devised a meter upon the motor principle, a patent for which was allowed him June 14th, 1881, No. 242,901. However, he finally adopted the electrolytic cell meter pure and simple as the one to offer to the public in a commercial sense.

The meter as used to-day by the Edison Company, is but a slight modification of the original plan. Mr. A. E. Kennelly, in a paper which was read before the Association of Edison Illuminating Companies, at Minneapolis, is my authority for stating that the bottles, plates and resistance in the present three-wire Edison meter are of a uniform size without regard to the size of the meter. For example, it is so arranged in the smallest meter that each milligramme of weight transferred represents one ampere hour of supply, the rate of transfer being ten milligrammes per hour at a full load. In a No. 8 meter, each milligramme of deposit would represent 8 ampere hours, a No. 4 meter 4 ampere hours etc. The meter number being the index of the supply in each case. It is claimed that making all bottles, plates and resistances uniform in size has simplified in some degree the handling of this meter. Whilst this may be the case, we must not lose sight of the fact that another constant has been introduced which is governed by the size of the meter. This, together with the fact that only $\frac{1}{975}$ part of the current supply passes through the meter, allows a possibility of quite a large error. I will not weary you with a dissertation on bottle resistance, oxidation, the correctness of the german silver shunt, etc. I will merely add that although the Edison electrolytic meter has been criticized very severely by many prominent electricians, and much has been said pro and con about it, we must all acknowledge that it has been introduced quite extensively by the Edison Company, and has, in a commercial sense at least, proved a success.

THE SHALLENBERGER METER.

This meter is of the motor type and devised for the alternating current only. The first patent allowed to Mr. Shallenberger was No. 388,003, dated August 14th, 1888.

The elements employed in the construction of this meter are : First, an armature of metal capable of rotation ; second, an electric circuit which is so arranged that when it is traversed by alternating electric currents, a field of force is induced having a given polar line or axis with reference to the armature ; and, third, a

circuit so regulated as to the first circuit, that currents are produced in such second circuit by the action of those in the first, the phases of which succeed those of the currents in the first circuit and set up for the armature a second field of force, the axis of which intersects that of the first. To the armature is attached a shaft which by a worm gear operates a suitable dial train, representing the number of revolutions made by the armature. Means have been provided to retard the speed of the armature, by introducing a set of fans or vanes, which are also attached to the shaft. It is claimed by the inventor that the retarding effect produced by the fans or vanes should increase as the square of the speed, inasmuch as the tendency of rotation increases as the square of the current. Whether this has proven to be a fact, those who have used this meter can best decide. Like all other motor meters, the difficult points to solve are to produce proper speed on very light loads and have the retarding action correct as the load increases and your motor commences to move itself along. Mr. Shallenberger has recently taken out a number of patents consisting of improvements and modifications of his original claims. One of his recent devices provides for cutting the meter out of circuit when all the lamps have been turned off. It has been found that even though all lamps are out, there is still a leakage occasioned by the transformer, and the inventor concludes it to be unwise to ask the consumer to pay for such leakage. The patents of Mr. Shallenberger are now owned and controlled by the Westinghouse Electric Company, and this meter has been introduced by them quite extensively both in this country and abroad.

THE ARON METER.

This meter, invented by Dr. Aron, of Berlin, Prussia, has as its underlying principle, the ascertaining of current consumed, by noting the difference in the rate of movement of two clocks, one of which is affected by the electric current passing. The apparatus consists substantially of two pendulums, regulated so as to have synchronous oscillations. The left hand pendulum is of usual construction; the right hand pendulum carries at its extremity as weight, a steel magnet. Each pendulum is kept swinging by a clock movement actuated by spring power. Both pendulums act jointly upon one dial train, which counts the difference of their oscillations. As long as no current passes through the counter coil fixed below the magnetic pendulum, both pendulums

oscillate synchronously and the dial train is at rest. As soon, however, as the current passes through the large coil, the time of oscillation of the magnetic pendulum is affected, so that it swings faster as the current passing through the coil increases, the dial train registering the oscillation of the magnetic pendulum. In order to take a reading of the current consumed, it is necessary to multiply the degrees marked on the dial by the constant, which is determined for each meter individually. The clocks are supposed to run thirty days with one winding. This meter has been introduced quite extensively in Berlin. Judging from its general construction, it should give very accurate results, if operated under favorable conditions. Its size and cost, however, have prevented any general adoption of it in this country. I understand its representative in America has concluded to give up the fight and return to Berlin. This, I am told, was hastened somewhat by the passage of the McKinley bill, which imposed such heavy duties on their importation as to make it impossible to compete successfully with the other meters in the market.

THE THOMSON WATT-METER.

Prof. Elihu Thomson has probably been the most prolific inventor of electric meters, as the Patent Office reports will prove. Previous to bringing out his watt-meter, Prof. Thomson's efforts were largely directed to perfecting what might be termed vapor meters. The general principle of this character of meter is the evaporation by heating effect of fluids, such as alcohol, ether and water, such fluids being confined in sealed vessels or chambers. Each meter provides for the use of two or more glass chambers, such chambers being connected by a suitable glass tube, and then delicately poised. By the heating effect of the passing electric current a change in the weight of one or the other of the vessels is produced, which disturbs their equilibrium, and by a suitable arrangement counts their oscillations upon a dial train. Prof. Thomson has devised many interesting meters operating on this principle, but, unfortunately, they did not appeal to the commercial public in a favorable manner. His most recent invention, and the one which has been adopted by the Thomson-Houston company, is what is known as the Thomson watt-meter. This meter is of the motor type and consists of a set of coils wound on a hollow frame, forming what might be termed a Siemens armature of polygonal outline, without any iron core.

Passing through this armature is a vertical shaft which rests in jewelled bearings at the top and bottom. The coils of the armature are connected to a commutator carried on the shaft near its upper bearing; two light springs bear upon this commutator and constitute the brushes. The coils of the armature are wound with fine wire and have in circuit with same, resistance which is wound according to the voltage required. The armature and resistance are usually connected in shunt across the mains. The armature has, surrounding it, a set of fixed coils, forming the field magnets, through which the current to be measured passes. Attached to the shaft which passes through the armature, is a gear which engages with a train of dials or counters for the purpose of recording the revolutions of the armature and, consequently, the amount of current consumed. The means provided to regulate the speed of the armature consists of a copper disc, which is also attached to the armature shaft. This disc rotates between the poles of a number of permanent magnets and is retarded by their influence. In this case, as in other meters of this type, the difficulty of securing proper speed for light load and regulation on heavy load, is the great question to overcome.

The claim that this is an absolute watt-meter, I fail to see the justice of, inasmuch as the armature and resistance must be specially wound for any given voltage. For example, a meter wound for the 110 volt circuit will not operate correctly on a 60 or 75 volt circuit, and vice versa. In fact, it is absolutely necessary to correctly wind the armature and resistance for the given voltage of the circuit upon which the meter is to be used.

The tendency of this meter to continue to operate after all lamps have been turned off has, it is claimed, been in a measure overcome by the use of brass instead of iron in the frame of the meter. However, the permanent magnets surrounding the copper disc seem to give out lines of force creating a field for the armature, which is usually in shunt across the mains, and in case the armature and resistance are not adapted to the voltage of the circuit, the meter will continue to operate for or against the consumer.

The principle embodied in this meter is not new, and it is only fair to add that as far back as the years 1883 and 1884 patents Nos. 233,547 and 304,881 were taken out by Mr. Edward Weston, on a meter of similar construction. The claims of Mr. Weston's patent provide for the use of a motor in which the armature

is connected across the mains and a suitable device for regulating the speed of same, also a dial train to record the number of revolutions made by the armature, representing the amount of current consumed. Mr. Weston's method of controlling the speed of the armature provided for the moving of one of the field magnets to and from the armature. The principles embodied in these two meters seem very similar.

The meters which have thus far been described, all provide for measuring the amount of current consumed in a culminate manner, either by a series of dials or by ascertaining the amount of metal deposited on an electrode. Therefore, any question as to the correctness of the result attained cannot be explained in detail. As I stated before, the gas meter is our legacy, and strange to say, the efforts thus far made by inventors have been to produce a meter resembling the gas meter as much as possible, both in its appearance and operation. The meter which I will next describe is one with which I am the most familiar, and which differs in its operation from any thus far brought to your attention.

THE WALKER METER.

It has been usual, in testing any electric meter, to place in the circuit with same, an ammeter for the purpose of proving the correctness of the meter's operation. Assuming this hypothesis to be correct, we have in the Walker meter the element of a test instrument, inasmuch as the meter consists principally of an ammeter which measures all the current passing, and records by photography the various positions occupied by the ammeter needle. The use of photography in this case is to eliminate the element of friction in the meter. When I use the word photography, I do not wish to imply that there are lenses or any of the necessary devices pertaining to the photographic art, to contend with. The apparatus is simply so arranged that the ammeter needle point is represented by a speck of light, and as the needle moves its position, this point of light traces an image on the sensitive paper which is immediately behind the same. In other words, we are practically photographing the position of the ammeter needle during such time as it is being affected by the passing current, and the result is a continuous line marked upon the sensitized paper, representing the fluctuations of the ammeter needle.

In detail, the meter consists of an ammeter coil or solenoid, in which an iron wire in the shape of a nearly complete circle, is

placed as a core. The same shaft to which the circle or core of the ammeter is attached, has also fixed thereto a light aluminium sector provided with a fine vertical slot; this slot representing the needle or pointer of the ammeter. Immediately behind this sector is a box which encloses a roll of sensitized photographic paper. The screen placed between the sector and the box has a horizontal slot before which the sensitized roll is made to pass. The vertical slot in the sector is so arranged as to come at right angles with the slot in the screen, so that in whatever position it may be it will always allow a point of light to pass from the lamp which is enclosed in the meter, onto the roll of sensitized paper.

Perforations in the screen, representing the calibration of the instrument, cause continuous horizontal lines to be printed on the sensitized paper. Another horizontal slot below these perforations is covered by a shutter which is opened every hour by the clock movement, and causes vertical lines to be printed across the sensitized paper, representing hours of service. The number of the meter is also printed every hour just above this hour line. Means have been provided for causing a continuous movement of the paper roll at a given speed, and this is effected by the use of a small clock movement which is wound automatically by the electro-magnet, placed in shunt circuit with the lamp in the meter. The clock movement remains stationary and the lamp goes out when no current is on the circuit, but both start up immediately upon the lighting of a single lamp. In this way there is impressed upon the moving paper roll a complete record in a detailed manner, of the current consumed in the circuit for a given time.

The roll of paper after a certain time, say one month, is taken from the box and developed in the usual manner, so as to fix the light impressions. It can then be measured up in the same way as an indicator card, by the use of the planimeter. The consumer is, therefore, at any time able to check the charges made, and the records being permanent can be used for future reference. It is evident that a large number of rolls can be developed in the same time required to handle a single one; in fact, the number is restricted only by the size of the vessel used. In the meter, as at present manufactured, each square inch on the diagram represents 16 ampere hours, therefore the total number of square inches measured by the planimeter need only be multiplied by sixteen to arrive at the sum total of the energy consumed. The loss in

operating this meter is confined to the energy required to burn one lamp in the meter which, at the candle power used, takes one-sixteenth of an ampere. This is the maximum loss, whether the current of one or a thousand lamps is being measured, the ratio of loss decreasing as the load increases.

The only care required in operating this meter is in placing the sensitized paper in the holder. In order to do this satisfactorily, a dark room should be built in a convenient portion of the station. A window of dark yellow glass in this room will provide plenty of light for the operator, but if more light is required this window can be covered with yellow post office paper and an incandescent lamp suspended before it. The sensitized paper in rolls of sufficient length for one month's use comes in sealed packages, and must only be opened and placed in the holder in the dark room. A boy can be instructed to collect the boxes, as skill is not required. As stated before, the meter number is printed on the diagram every hour, therefore it is not necessary to keep any record of the box itself.

It is evident that a meter which provides means to compute the current consumed in a detailed manner, has advantages which other meters do not possess, inasmuch as any question as to the correctness of bills rendered, can be satisfactorily explained by referring to the diagram or chart made by the meter which is in dispute.

The Patent Office reports show numerous devices for securing the record of the ammeter needle on a moving strip of paper, by the use of a siphon pen or pencil. In all such cases, however, the element of friction is so apparent as to make their use prohibitive. The patent granted to W. C. Patterson, No. 333,777, issued January 5th, 1886, and another to myself, No. 406,678, dated July 9th, 1889, are the only ones which cover the use of paper which is sensitive to light in combination with electrical measuring devices. I regret that my time will not allow me to describe several other meters which have been presented to the American public, as well as meters of recent foreign production. The subject matter is too extensive to include in one paper, and probably may be taken up at some future day and more fully presented.

DISCUSSION.¹

PROF. THOMSON:—I am a little at a loss to know just exactly what we have under discussion, whether it is the meter which is before us, or the various meters that are mentioned in the paper. If I look upon the matter in the broadest way I might perhaps be able to say something as to each type of meter mentioned. But that would be rather a lengthy procedure and as one form of meter which I have designed is mentioned, perhaps I had better confine my remarks principally to that.

In the first place, Prof. Forbes made a very apt remark in connection with this meter, and that is, that it ought not to be called a watt-meter, which is perfectly true. Watt simply indicates a rate. But it is not called a watt-meter. It is called a recording watt-meter; that saves it, that is, it records the rate and integrates the rate for the time. In that sense, of course, it would be proper to call it an integrating watt-meter, recording the rate and multiplying it by the time.

The paper before us speaks of this form of the meter, which, by the way, has of course been designed for certain purposes, to fit certain conditions. One of those conditions was to give the customer an opportunity to read for himself (just as he does with the gas meter) a record and to understand it. Now, we found this in a good many cases an important matter, and our efforts were spent largely to secure that end, to get as it were, an instrument that would represent the gas meter recording on a dial the use of current energy.

The instrument, of course, has its limits; that we must fully recognize, but that it does good service inside those limits, perhaps is also perfectly true. It will, of course, not readily respond to one volt or to 10 volts, perhaps, but it will respond to conditions of considerable variation in the voltage as well as to enormous variation in the current. Such meters have been constructed which will range from one to 200 amperes. This, of course, is quite a wide range, the error being only a few per cent. on the lighter loads. The accuracy for the heavier loads is almost exact, as exact as such mechanism could be expected to be. The accuracy of the smaller load meters is all that could be desired, those taking from 10 to 30 amperes for the heavy loads are practically accurate, and the sensitiveness is, of course to a fraction of one ampere. It sometimes goes lower than a quarter of an ampere.

Now, this matter of the range which a meter can work under is, of course, an important one; and I know of no type of meter which has given that much range with the same accuracy, at least so far as my information goes. It is true that the principle of the meter is not new. I claim nothing especially for the principle. I simply claim the working of that principle into a

1. By Messrs. E. Thomson, Birdsall, Van Trump, Weston, Rice and Mailloux.

device which is useful in the industrial applications. There are features about the meter which did not appear in any former arrangements and these features I think are features which have made it a success. The same criticism might be made on the meter before us—that the principle of it is not new. The new feature perhaps is the recording by a photographic method as distinguished from recording by other methods. I remember distinctly. I think it was in 1886 or 1887, making a meter which was substantially the same in principle, only the record was made on a sheet of paper by punching little pin holes at intervals. There was no friction during the setting of the ammeter portion of the apparatus. The friction was as little as it is in the meter before us and the little point that passed over the paper was clear of the paper until an electro-magnet struck it a blow and made a little indentation, the point jumping up again and being ready to take a different position. That eliminated the element of friction, and I had in that meter an arrangement for doing away with clockwork which worked very satisfactorily in the meter constructed. It is nothing more nor less than a pendulum which is self starting. There was an electromagnet which pulled upon an armature and a pendulum self starting. This depending lever or the pendulum worked a pawl [illustrating] which gave us the motion or winding of the paper. The pendulum at rest was always stopped in a position ready to start and it broke its own magnet circuit, or worked a set of contacts for the magnet which kept the pendulum in motion so that the rate of going was perfectly regular. The little recording point was mounted on a spring connected with the ammeter which latter was merely a little piece of iron on a vertical shaft inside a coil, and the coil and the iron shaft so arranged as to get substantial uniformity of movement throughout the range of current. The little recording point was over the strip of paper and the electromagnetic hammer was above it, and at every revolution of this ratchet wheel worked by the pendulum which constituted practically the whole of the clockwork, the magnet armature was drawn and struck a blow which brought the point down to the paper. The paper as it came off would have a series of dots the position of which would change according to the load, and the same process of integrating this curve would be used as in the meter before us. For the purpose of recording, we did not waste any energy as is here done in working an incandescent lamp for photographic action in the meter. No doubt the lamp used could be diminished in size. But if it should give out from any cause, it is not replaced at once or until some one discovers the difficulty. Until then the record fails. I do not care to go into any further criticism in relation to this matter; but I think when we look at these things we should be prepared to look at them from all sides.

MR. WALKER:—The remarks of Prof. Thomson are undoubtedly very explicit, and very true. We do not claim for this

meter that it is a new principle, beyond the manner of securing the record of the action of the ammeter needle. I am aware that devices such as Prof. Thomson has explained in which a slip of paper has been marked by the aid of the ammeter needle, have been tried very frequently as well as the use of a siphon pen on the needle point, I remember in looking over this question to have discovered one which was proposed by Mr. Edison. Mr Edison provided a siphon pen which was carried on the ammeter needle and a strip of paper which was kept moving by a clock movement or suitable device and a magnet which at intervals of half a minute or half a second would bring the paper against this siphon pen and get a dot. However, in case of an interruption of an hour or two it is very likely that the siphon would clog up and there would be no further dots. The meter described by Prof. Thomson, would have the same difficulty inasmuch as the pointer might pierce through the paper and fail to act thereafter. The major criticism that has been made on the Walker meter is the possibility of the breaking of the lamp in the meter. In the exhibit you see a lamp burning very brightly, the candle power used there however is not at all necessary. In fact, a lamp burning at one candle power or a sixteen candle power lamp of very high voltage will be ample. Say you are supplying a meter on a 110 volt circuit; place in the meter a 150, 160 or 175 volt lamp and you have ample light to photograph the action of the needle, and it is then quite likely that the lamp will not break. In other words lamps burning under their voltage are very apt to have considerable life. If, however, this question should prove to be a serious objection, it is very readily overcome by putting in a double filament lamp or a contrivance for operating two small lamps. The power required to operate the clock mechanism depends entirely upon the size of wire used in the winding magnet, and as said before the candle power of the lamp is of very slight consequence, inasmuch as the burning of a match would be ample to give us all the record necessary.

MR. VAN TRUMP:—The distinguishing feature of this instrument is that it is a recording ampere-meter, and I should like to ask Mr. Walker what he has to offer us in the way of a recording voltmeter. The use of such an instrument would immediately suggest itself to those who have to do with central station management. Such an instrument placed on lines in a station and a duplicate instrument used at different points on the mains would give us cards which would give us very valuable data in the distribution of our copper on the mains. And besides that a recording ampere-meter to automatically register the load on a central station is a very nice feature. It does away with the unreliability of having an attendant mark up on a load chart the load on the station at different times; so that we can at any time tell exactly what we have done and what our proportion of fuel to output has been.

MR. WALKER:—I would state that we have in contemplation a system based on the principle referred to by the gentleman who has just spoken. For example, we propose to devise instruments sufficiently large to measure the amount of current produced at the central station and smaller sizes for distribution service and any difference between the products of the station instruments and those on the line would naturally be the loss on the line in ampere current. We are also at present at work and have very nearly ready for placing before the public a recording voltmeter operating on precisely the same plan. Such an instrument was suggested to us by the usefulness which the recording ammeter has shown. By having the recording voltmeter at your station and at various points on the line it is absolutely certain of securing the exact drop of potential on the line, and will besides be practically a detective on your engineer and electrician at your stations, showing whether they are keeping up the proper electromotive force all the time. In other words, the superintendent will at the end of the month have a perfect check against his engineer and electrician.

MR. BIRDSALL:—The subject of recording meters at stations has, I think, come to every station manager, and they have all felt the need of them, and in the course of my trips among the various stations of the country I saw the great need; as in a great many of the stations they made a curve of the load every day by hand. Recognizing such a want, about four years ago I started out to design a recording volt and ampere-meter for such uses. The great object with all these instruments is to avoid friction. The use of a pen or pencil is not feasible; and after talking with a good many station managers I gave up the idea that is used in this meter—that of photographing the record. The station managers or the superintendent would not bother to develop the slip. They want something that is in ink or pencil like the steam engine indicators, something that they do not have to bother with afterwards. And after working on this matter sometime I hit upon the plan of running the paper over the face of a magnet. The pencil or pricking point has a small mass of iron on it. By clockwork the circuit of this magnet under the paper was closed at every five seconds, I think, and the pencil was in that way brought down on the paper. The magnet was of a sufficient size, so that the field was practically uniform within the range of the movements of the small armature. I attempted to get a patent on it, but I found that Mr. Cuttriss had patented almost the identical thing for a siphon recorder. That of course, produces a series of dots. By making the intervals of striking sufficiently close together you practically get a line. So far as I know there is nothing of a practical nature of this sort in the market at present, although the need is felt by station managers. The question of friction is the great item, especially on the voltmeters. Of course, the paper in the meter need not be wider than a ticker tape on a zero instrument.

MR. VAN TRUMP :—I would say in connection with the matter of friction that some years ago in looking around for just such an instrument—a recording voltmeter—and not being able to find such an instrument for our station in Wilmington, we thought that the best plan was to have one made, and we have done so on the Cardew plan having three wires. In that way you have plenty of power to drive your pencil and we have three wires, one for each side on the Edison system and one for the zero. Of course, such an instrument does not give absolute values, but it points out fluctuations in electrical pressure and may suggest a remedy.

MR. EDWARD WESTON :—I was particularly struck by one remark in regard to the Thomson watt-meter, which I think gives rise to some misunderstanding of the operation of the device. It seems to me impossible for a Thomson watt-meter to run unless current is passing through the main coil spring. It seems to be utterly impossible that any action of the retarding mechanism would take place on the armature to produce motion of the armature by simply the shunt coil and if such a thing did arise I should attribute it to something totally different and not to the permanent magnets in that instrument. It would indicate that insulation of the spring in which that armature was placed should be looked after. If the current was flowing through the meter which should not flow there, there was some very bad work somewhere in that installation. The form of meter having the dial seems to me to have a great many very marked advantages over any other type of meter known. In the first place, the public are more or less acquainted with the gas meter. A great many of them understand reading it. It is there; a fixed thing from month to month. You can make note of the changes on the dial and have a check upon the gas company, assuming, of course, that the meter is moderately correct. On the other hand a system of metering which does not enable the consumer to check the results, to check the consumption, seems to me to be open at least to some objection, and possibly considerable objection and suspicion on the part of the consumer. Hence you can readily understand why so much time has been spent in endeavoring to bring that type of meter closely approaching the gas meter, to the state of perfection to which it has been brought to-day. The type of meter before us to-day has certain excellent features and is certainly a very ingenious piece of mechanism and I have no doubt will record quite accurately. It is free from a great many difficulties and defects where recording is accomplished by mechanical means. The recording mechanism does not induce any friction. But it has, of course, the disadvantage that the record has to be taken back to the station house and developed. It is true that that record can be produced at any time for inspection of the consumer in case of dispute; so it might be said to be proof positive of the correctness of the bill rendered.

But it seems to me that it would never be accepted with the same degree of confidence that it would if the consumer could make these calculations and did make them himself and thus kept a real check on the meter. It has to go out of his hands to be developed and unless he has a person to see that it is developed he might readily charge fraud on the part of the supplying company. The public are somewhat tender on this question of meters anyhow. They unjustly, I think, blame meters for things that do not exist, or only exist in their own imagination. In the gas business that is exactly the same. The gas meter is not an instrument of absolute precision, but it is a good practical instrument. Any one who has investigated it will admit that it is a very reliable thing indeed, if kept in repair. It does not need very much time to keep it in repair, or very much attention. And if electric meters could be brought to about the same state of efficiency that gas meters are—and I think they have already reached that stage, and even excelled that—it is sufficient for the requirements of the art. I have entirely forgotten the patent to which Mr. Walker referred a little while ago, as bearing upon the same form of meter that Prof. Thomson has invented and therefore I cannot speak with any confidence about the nature of the device I used there. But I have had occasion to examine the Thomson meter, and I will say this, that I never got such results as Thomson did, and I am inclined to give him the most credit for working out the details of the appliances and getting it to the state of perfection that he has brought it to. It means a great deal of close study to bring appliances of that kind to a condition where they can be used practically and trusted perfectly, and while someone else may have got an idea too, let us give the man who has brought the thing to a state of perfection, credit for that. The objection to the clockwork meter is, of course, its first cost. The most accurate meter I have ever seen in my life was the Aron meter, but it requires a little more skill than we generally meet with to set it up, and it requires considerable skill to adjust it so as to get it to yield good results. It will yield admirable results if handled right—better than any I have ever seen.

There has been some discussion about voltmeters, and that introduces a subject which is somewhat interesting to the members here. It is generally supposed that in recording voltmeters friction would be the principal source of error. Now that is not so. I think that you can get the recording measurement so perfect and so simple in character that you may say that you can practically eliminate friction from that part of the apparatus. The temperature changes are very frequently overlooked and they usually amount to a very large sum indeed. They can be compensated for to a certain extent, and possibly as we gain more experience, perfectly so. But there is a good deal of misconception about that question of compensation of instruments.

A short time ago I devised a little apparatus for compensating for change in temperature, which consisted substantially in a little thermometer, the bulb of which extended over on to the coil of the instrument so as to indicate the temperature of the coil. The thermometer bulb is supposed to be small and the instrument as actually made was not as small as it should be, and it responded very readily to slight changes in the temperature of the coil. You could read the thermometer from the outside of the instrument and to avoid any computations I put on a little device by which you could turn an index around to a point corresponding with the temperature indicated on the thermometer; that is to say if the thermometer showed 75 degrees, then you would turn the indicator around to a point indicating 75, and you compensated without any calculation whatever. I was somewhat surprised, however, by the publication of the thing—it got into the journals before I was ready to have it appear. An article was printed in one of the English journals, I think it was the London *Electrician*, saying that such a thing as that was of no use; it was easy to compensate an instrument without any such thing as that. Now the writer of that article had not given as much thought to it as he ought to have done. If he had he would not have expressed such things as he did in the article. I did not take any notice of it. Well, it overlooked one important thing—that you might compensate for air changes quite readily and yet not compensate for changes produced by the heating effect. Now to get an instrument properly compensated you must compensate for both things—changes in the instrument itself due to the changes in the atmosphere, and changes in the temperature due to the actual passage of the current. When you have got a device that will accomplish that, then, of course, you do not need any mechanical device to switch into a certain fixed point. It just happened that at that time I did not have a device of a character which I could put in a satisfactory form. I think now I can do it. It frequently happens that criticisms and remarks are made about the operation of an apparatus which are wholly unjustified and untenable upon a close study and examination of the things themselves. I think this same is true of the Thomson watt-meter. I have had occasion to listen to a good deal of talk about the Thomson watt-meter. Some of it has been of pretty severe character too, and the instrument has been severely criticised. Now I do not think the instrument was so much to blame as the parties who were using it. I am frank to say the examination indicates that no such errors as they speak of come into that instrument unless they abuse it. In the Thomson instrument I do not think the proportions are the best imaginable, to get the very best results. But I think it is only a question of time when they will make quite important changes in detail which will make it far better than it is to-day. One criticism I should make of it is, that the moving parts are some-

what heavy and they should be reduced in weight as much as possible. That can be done by the substitution of aluminium for copper in the retarding device, that is on the disc. The form of retarding device might be changed. Instead of adopting a disc, a cylinder might be used running between the poles of a powerful magnet and you might get exactly the same retarding effect by bringing the poles very close together, having a central core, and there reduce the weight very much. I should be very much afraid of errors creeping in from the mass of matter to be acted on there by the current, especially with low loads. I should not think much of it with heavy loads; I think there you would have power enough to overcome it. But with small loads and but three or four lamps, I should be afraid that the friction on the pivot would not be a constant element but would be quite variable in use. I do not think that is anything against the instrument, because I think it can be entirely overcome.

The Thomson instrument, of course, has the advantage that it can be used for either alternating or direct currents. Now, so far as I remember it, no instrument that I had anything to do with in my earlier work on meters was capable of those applications. They could only be used for a direct purpose. I do not remember doing anything in that line where the meter produced would be available for both purposes.

PROF. THOMSON:—It seems perhaps that I should make a few remarks. I think Mr. Weston has shown by his remarks that he has spent a good deal of thought on this very problem and understands the conditions most fully. It is not an easy thing, and I can say it after considerable experience, to get commercial results such as we may get in laboratory testing. You may make a laboratory apparatus and produce it as perfectly as possible and put it out into commercial use and you will find difficulties. I have frequently had that experience, and that experience has come to me more forcibly perhaps on the meter question than on any other. It is not until you have had commercial experience that you can make those little refinements which are then shown to be absolutely necessary.

Mr. Weston has said very truly that the weight of the parts in the meter as constructed by us has been rather excessive. We are using every effort to reduce it. We are using much lighter discs and getting as strong as possible a field for it to move in, that is, the retarding disc.

There are a good many points which cannot be brought up in this discussion; but I do not know that they are important to discuss at this present time. Experience, of course, will tell the story in the end. There is just one point I wish to make before closing my remarks, and it is, that it is not the case of getting a meter that will meter, but it is the case of making such a thing that you can put in for the price. It is the case of making a thing that

we can put on the market which will not cost too much. You may have a very fine mechanism; you may have an excellent device for the purpose, but if it costs \$50 nobody will take it. You must be able to make it for \$7 or \$8. I hope to be able some day to make a good meter for three or four dollars. [Applause.] I do not know that I shall succeed—do not applaud yet. But when we have done that, I shall consider that the meter question is probably laid aside. But it is one of those questions that has been with me for a long time, and I have had no problem that has demanded more time, care and attention than that very problem. I would much prefer to design a thousand horse power dynamo and see it through than to see a meter through any day, where you are obliged to have a sensitiveness to extremely small currents and also a sensitiveness to large currents. The effects of those currents tending to increase as the squares or in some such proportion, our elements of friction of course become excessive when we get down to the small currents and are practically eliminated with the larger currents. Our object then was to get proportionality between the various currents in their effects and secure for the meter as great sensitiveness as possible for the lighter loads. Having secured that, the rest is not so difficult. Of course, we are still working at the problem. We have gone through thousands of experiments and thousands of tests on this very question and we never know just exactly when we are out of the woods.

MR. MAILLOUX:—I want to add a little bit of experience in relation to meters, which goes to show that while a dial meter may be very easy to read, it is not always satisfactory to the producer. Rather an anomalous case came under my observation. I put in a plant up town, in an apartment house, where the tenants wanted to pay for their light by meter. They did not care to pay for it in their rent. It was a large apartment house, consisting of twenty odd suites of apartments. Some of the tenants maintained that as they were in Europe or elsewhere half the time, they did not care to pay for electricity that they were not using. Consequently, the only recourse was to put in meters. These were put into the air shaft usually, or the nearest place to the various suites of apartments so as to have them as much out of sight as possible. They were clockwork meters, differential clockwork meters of the type which has been described here and referred to in connection with this paper. There is much building going on in that up-town district, and after a time they began to excavate and blast in the immediate neighborhood. When the engineer called around to take the meter he found that he was owing the customers for electricity instead of their owing him. In other words, the meter was going backwards and he found that not only had the previous record been obliterated, but that he was actually owing more than he had ever had. Upon an investigation of the strange

phenomena we found that one of the two clocks had stopped and it happened to be the wrong clock. If it had been the other the customer would have owed the company several times more than he had used. As it was, the company was literally owing the tenant for electricity. The experience was repeated several times and it was found that we had practically to abandon the meter, because it was so unreliable. In some other instances it did actually happen that the other clock stopped and it would charge more in a month than could be consumed in a year. So we had to go by average and guess work, and it was almost as easy to guess without the meter as with it. I have recently put in a Thomson meter, which, as far as I can see, gives perfect satisfaction. Of course, I can see that since the meter is really a motor which has got a sort of Prony brake to it, the coefficient of friction is likely to vary a little and that it may not be so accurate on light loads; but I consider that when it approximates anywhere near 60 or 75 per cent. of its capacity it would be practically correct under all circumstances. I do not see why it should not be correct.

PROF. THOMSON:—There is just one remark I intended to make when I was up before, and that is in explanation of the statement that the meter has been known to turn without load. That is true. The meter was originally developed for alternating currents and was used for alternating currents for a long while, the demand being in that direction; and when it was put upon continuous currents it did turn and keep turning sometimes in one direction, sometimes in the other direction, when there was no load. The side frames were made of cast-iron and while under load with continuous currents, they would get permanently magnetized with two poles opposite the armature. Of course the field is exceedingly weak, must have been exceedingly weak, but it was sufficient to cause rotation of the armature. It shows how little force was needed to rotate the armature, the armature being $2\frac{1}{2}$ inches in diameter and the frames about 8 inches apart. That however, is eliminated by making the frames of brass instead of cast-iron.

PROF. ANTHONY:—I would like to inquire of Prof. Thomson if the meter would not run in the earth's magnetic field.

PROF. THOMSON:—We have got certain indications of that. We have thought sometimes that it had a tendency to turn, but the coefficient of friction is fortunately generally large enough to prevent that.

PROF. ANTHONY:—I had a little experience with one of the meters, and I never tested it for that, but I know that the two main coils were connected in the armature circuit so that there was a little tendency to run any way. Of course the idea was to overcome the friction and I set it up in such a position that the earth's horizontal lines of force were in the same direction as the lines of force developed by the main coils and the meter continued to run

when there was no current in the main wires, except the small current that went through the armature. I had always in mind to take the meter and turn it around the other way, so that the earth's magnetic field would go in the opposite direction and see what effect it had,

PROF. THOMSON:—If the meter was set east and west it would obviate the difficulty. By the way, it is true that with the very largest capacity meters, the shunt is beyond the main coils so that the shunt current through the armature goes through the main coil, and the purpose of that is, of course, to make the co-efficient of friction disappear, as far as possible. This in the instances in which the meter works at very high loads, and also (is to) be sensitive to the lowest load.

MR. WALKER:—I would like to say, in reply to Mr. Weston's remarks, that although I fully realize the desirability of having a satisfactory dial meter I fail to see how the customer is to be convinced of the correctness of its operation. I do not see, for example, how the customer will very readily understand what 25,000 watt hours mean, or what we would understand by a certain number of milligrammes of deposit on the electrode. On the contrary, he can quite readily understand a diagram chart such as is made by the meter before us. If you will place the Walker meter on a 110 volt circuit each 16 candle power lamp will take in the neighborhood of half an ampere; consequently, if the record should show that 10 amperes, for example, were consumed, say for five or ten hours, why it could be very readily explained to the consumer that he had been burning 20 lamps for five or ten hours. As I stated in my paper the manner in which the result is attained is so readily explained to the customer that I do not see why he should not understand it.

Now, as to my remarks on the Thomson watt-meter, I merely wish to add that I have endeavored to state facts concerning this meter, based upon personal experience in operating the same. I will be frank to say that I have one of their early meters in use, and probably the results obtained therefrom are not as satisfactory as from those now manufactured. In looking at some meters in operation at the Providence convention, which were of the most approved pattern having brass frame instead of iron, I found the tendency to operate after the load had been turned off, was still prevalent.

MR. BIRDSALL:—Mr. Walker says that he thinks the customer would not care much what the record was, as long as it was explained to him, or that he would not know what watts meant, etc. That is all very true. But I have had experience with the "dear public," so to speak, in connection with a chemical meter and the great cry always was when there was a dispute about the bill, that the thing had no dial on it—no figures—that those little bottles did not show them anything and when you branched out into the number of milligrammes of zinc deposit per ampere,

why you generally talked alone. I do not think it matters what the dial registers, so long as you have a dial. [Laughter.] The customer does not care whether it is lamp hours or watts or horse power. The mere fact that he has a number—that he has 75 of something, is all that is necessary. He knows he pays so many dollars for so many things, and he is willing to pay the money as long as he is pretty positive that he gets them. The accuracy of the meter I do not think is such an awful thing to strive after, because if the dial says 75 and the man burns 60 he will pay for the 75.

MR. E. W. RICE, JR.:—Before this discussion is closed I think it is proper to remark that even in cases where the Thomson meter has been found to register current passing through the meter the rate of such registry is exceedingly small. I do not think it exceeds (1-18) one-eighteenth of one lamp per hour so it would take a long time to run up a large bill against the customer.

In regard to Mr. Walker's remarks in reference to the dial, the last speaker has stated what I had in mind so fully that I do not know that I could add anything to it. I have one of the Thomson meters in my house and it is quite a convenience to be able to read the dial and find out how many watt hours I have burned in one week, and caution people in the house not to leave the lamps burning in the garret and cellar.

In reference to the fact that a customer would not know what a watt hour is, I think it is also equally true that the average customer has no idea what a cubic foot of gas means, that is, I do not think that the average customer knows that a gas burner consumes say five or six cubic feet of gas per hour. He knows that he pays one dollar and a half or two dollars per thousand cubic feet. Now that is exactly the case with the Thomson watt-meter. The register reads watt hours. The price is so much a thousand watt hours. Now it curiously happens, as first noticed I believe by the speaker, that one thousand watt hours in a lamp of the usual efficiency will give about one-tenth the amount of light given by one thousand cubic feet of gas, so that the customer, to be on an equal basis, can be charged one-tenth the amount for one thousand watt hours as is charged for gas per thousand cubic feet. That is, a thousand watt hours is roughly equivalent to one hundred cubic feet of gas. So we say twenty cents a thousand for electricity is the same as gas at \$2.00 a thousand.

The customer likes it because it seems more natural to pay by the thousand, and electricity at eighteen or twenty cents, appears cheaper even if it is the same, as gas is one dollar eighty, or two dollars.

MR. WESTON:—I would like to explain a remark I made some time ago. I questioned the fact of the Thomson meter running under low current through the main coil. I had had no experience with the iron frame meter. I did not know they had an iron frame. If I had known it I should not have made the re-

mark. As to the question of the meter revolving in the earth's field, I think it would be a nice thing to get the meter to run in the earth's field.

Prof. Thomson made some remarks about the cost. Now, I think he is wrong. I should take issue with him on that. I think that the best thing electrical engineers can do in this state of the business is to produce the very best thing that they know how, and trust to the future for returns. It is true that one company starts in and puts a meter on the market at say \$20 or \$18. That meter may be good or it may not be very good; but I think that it is not very good; that the man who follows along and tries to get up a meter should make a very much better meter and get a price appropriate to the superiority of the instrument. I think that question of low cost plants and apparatus in electric lighting means in the end very high cost. Many people have paid a good deal of money for that kind of experience. Cheap engines, cheap boilers, cheap wiring—everything cheap, means in the end everything very dear. Now, you see what the effect of it is. All through this country stations are being remodelled to get in the very best appliances—triple-expansion engines—the maximum economy in every direction consistent with good work; and the meter I think should be given just as much consideration as the rest of the plant. Do not make the cost so that you can not make the meter really fine and good. I would of course increase the cost of the meter and put better work in it, and make the best I could.

PROF. THOMSON:—I would say that I agree most fully with Mr. Weston in regard to this matter. Those are the sentiments under which I have worked, but when I make that argument to the Boston office of our company, the answer is, yes, and so and so sells a meter for so and so, and by the way his has a dial on it. [Laughter.] We must do something about as well, even if we have to sacrifice something in the perfection of the meter. I hold just as Mr. Weston does that you cannot do the thing too well. It is a nice problem anyhow. It is a delicate affair at the best and you cannot get the meter too good. You must look to cheapening afterward. But that is an argument which the business managers fail to see, and particularly I am afraid that those in charge of stations who have to buy meters perhaps fail to see it still more. That is they have not that high sense of justice in regard to the meter. They want something that they can put out to satisfy the customer that it has got a dial, and then bring in a bill, and if it costs seven or eight dollars and they put that kind in and it can be read every now and then and a bill calculated it is all right so far as they are concerned. Just as in the case of engines and other appliances which are now being remodelled, if they do have these imperfect things the day will come when they will have to buy them over again and pay a good price.

There is one other point. I would say here that, of course, in an electric meter we measure electricity, or at least we measure the volts and the amperes. In the gas meter it is different. We measure whatever comes through, whether it is air or gas. But we cannot adulterate our electricity. [Applause.]

THE CHAIRMAN:—As the time is limited, and the programme still quite extensive, we had better pass to the next paper which was left over from this morning's session. It is upon a subject of great importance, but which has never been touched upon before to-day, and a matter which is interesting in being unique and deculiar, and that is "A Study of the Fluctuations of Electromotive Force in the Open Coil Armature of a Constant Current Machine," by Mr. M. E. Thompson of Cornell University.

Mr. Thompson then read the following :